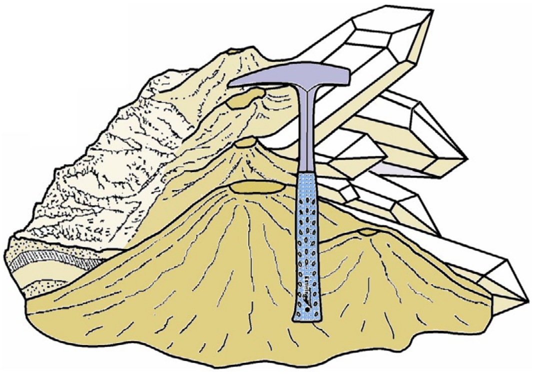

Geocene

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CONTENTS

Instructions on use of hyperlinks	*last page*	35
A WALK THROUGH THE FLOOR OF THE PALEO-PACIFIC OCEAN (PANTHALASSA) NORTH OF LONG BEACH, RUSSELL, BAY OF ISLANDS	Bernhard Spörli	2 – 7
IS NEOGENE UPLIFT AND EASTWARD TILT OF GREAT BARRIER AND COROMANDEL RANGE RELATED TO THE ORIGIN OF THE HAURAKI RIFT?	Bruce W. Hayward	8 – 16
DENDRITIC BARYTE CRYSTALS FROM WAIWERA	Tim Saunderson	17 – 18
A LATE MIOCENE PALEOVALLEY AT HIHI: INSIGHTS INTO THE HISTORY OF THE ANTECEDENT ORUAITI RIVER, DOUBTLESS BAY	Bruce W. Hayward	19 – 22
ORBICULAR GRANITE: AN UPDATE ON THE MURCHISON BOULDER AND ANOTHER SITE, LITTLE HOHONU RIVER, KUMARA, WESTLAND	Glenys Stace	23 – 25
THE RUSSELL COLLECTION	Hugh R. Grenfell	26 – 30
MEMORIES OF MALCOLM SIMPSON (1936-2022), GEOCLUB'S GENTLEMAN-STATESMAN	Bruce W. Hayward, Hugh R. Grenfell	31 – 34
Corresponding authors' contact information		35

Geocene is a periodic publication of Auckland Geology Club, a section of the Geoscience Society of New Zealand's Auckland Branch.

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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A WALK THROUGH THE FLOOR OF THE PALEO-PACIFIC OCEAN (PANTHALASSA) NORTH OF LONG BEACH, RUSSELL, BAY OF ISLANDS

Bernhard Spörli

This is the first of a group of articles planned to provide insights into the Waipapa Terrane (Spörli 1978, Black 1994), our main basement (or undermass) unit in the northern North Island, at easily accessible locations. These articles are also intended as repositories of outcrop information for further work, and as an opportunity to familiarise uninitiated geology enthusiasts with the basic concepts of structural geology and tectonics. The general framework of the Waipapa Terrane and its accretion at the edge of Gondwana through the late Palaeozoic and Mesozoic (300–70 million years ago) have already been laid out in the article on the 'Landing' exposure, in Geocene 30 (Spörli *et al*. 2022), so I will only dwell on the most important points. During the accretion, the voluminous sediments from the Gondwana continent and the underlying seafloor deposits were crunched up, sliced and folded, so that the Waipapa Terrane now consists of large tracts of the continental sediments interspersed with thin slices of ocean floor deposits, marking the base of thrust slices (Fig. 1).

The Waipapa Terrane is part of the 'Eastern Province' of New Zealand (Fig. 2A), which lies outboard of the 'Western Province'. The latter is a sliver of older Gondwana terranes that travelled with Zealandia after it split away from the supercontinent (e.g. Hayward 2017). The Eastern Province is mainly represented in Northland by the Waipapa Terrane, with only small tracts of the Caples Terrane (e.g. Hayward 2017 p. 23) exposed to the west of it (Fig. 2B). These two terranes are examples of the early stages of continental crust formation from oceanic material.

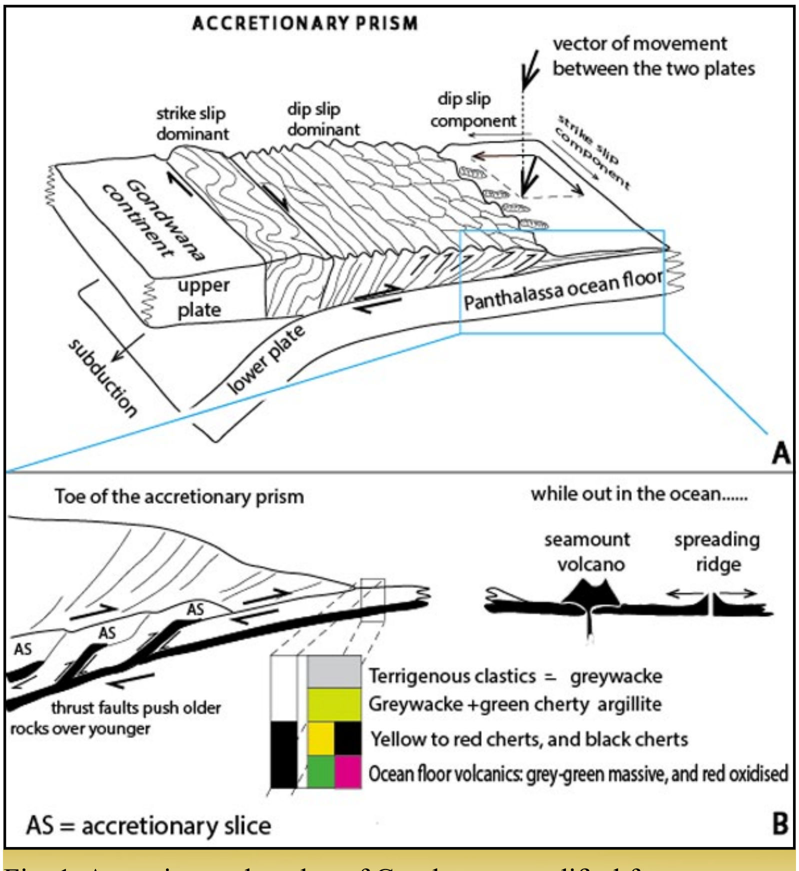

Fig. 1. Accretion at the edge of Gondwana, modified from Spörli *et al*. (2022). A: Formation and subsequent progressive deformation of accretionary slices by oblique subduction. B: Incorporation of ocean floor material (lavas and cherty sediments, summarised in black) into the accretionary prism. Colours in the accompanying rock unit column correspond to those in the geological map of Figure 3.

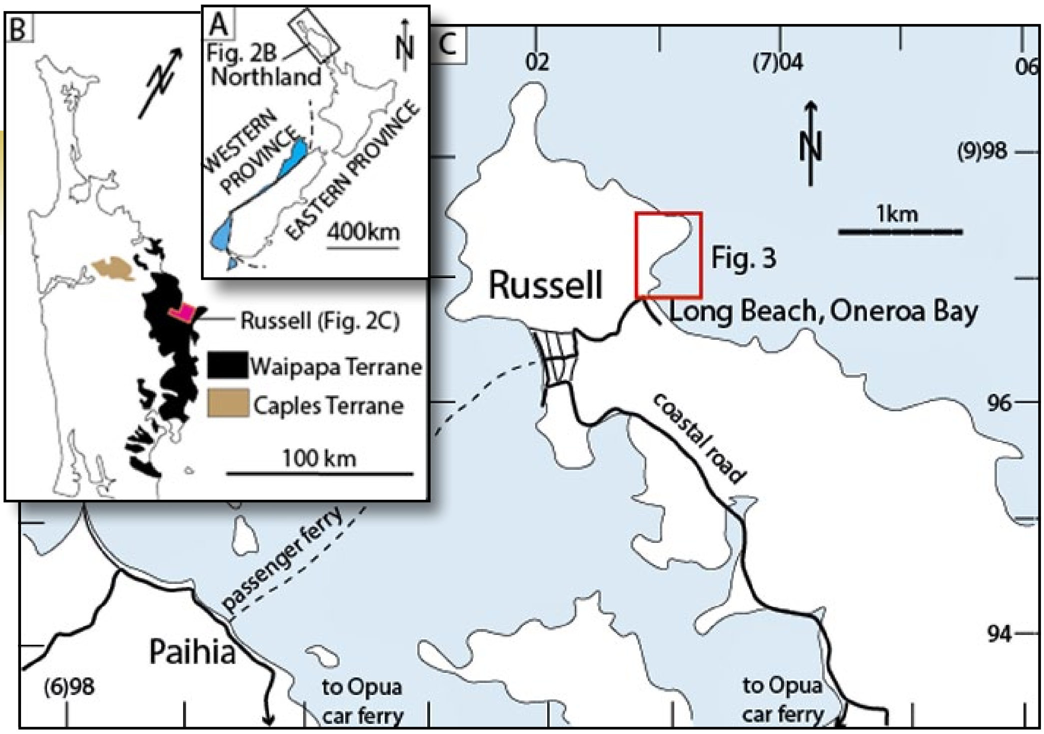

Fig. 2. Index maps.
A: Location of Northland and subdivision of basement domains within New Zealand.
B: Exposures of Waipapa and Caples terranes within Northland.
C: Study area (red rectangle) and road and ferry accesses to Long Beach, Russell. Numbers at the edge of the map are New Zealand Topographic Map grid references.

Because of the intense accretionary slicing, it is a fortunate coincidence when there is an easily accessible and somewhat less disturbed exposure of these ocean floor rocks. That is the case at Long Beach in Oneroa Bay to the east of Russell (Figs 2 & 3). Long Beach can be most easily reached by car using the Opua Car Ferry (Fig. 2C). Taking the passenger ferry from Paihia is a walking or cycling alternative. Driving the coastal road is a more time-consuming option. Oneroa Bay is of historical significance because in 1845, Hone Heke's warriors started their tactical diversion from there for the fourth cutting of the Kororāreka (Russell) flagpole (Cowan 1922).

The rocks we are concerned with are at the north end of the beach and extend through Waiata Bay to the next prominent headland (Fig. 3).

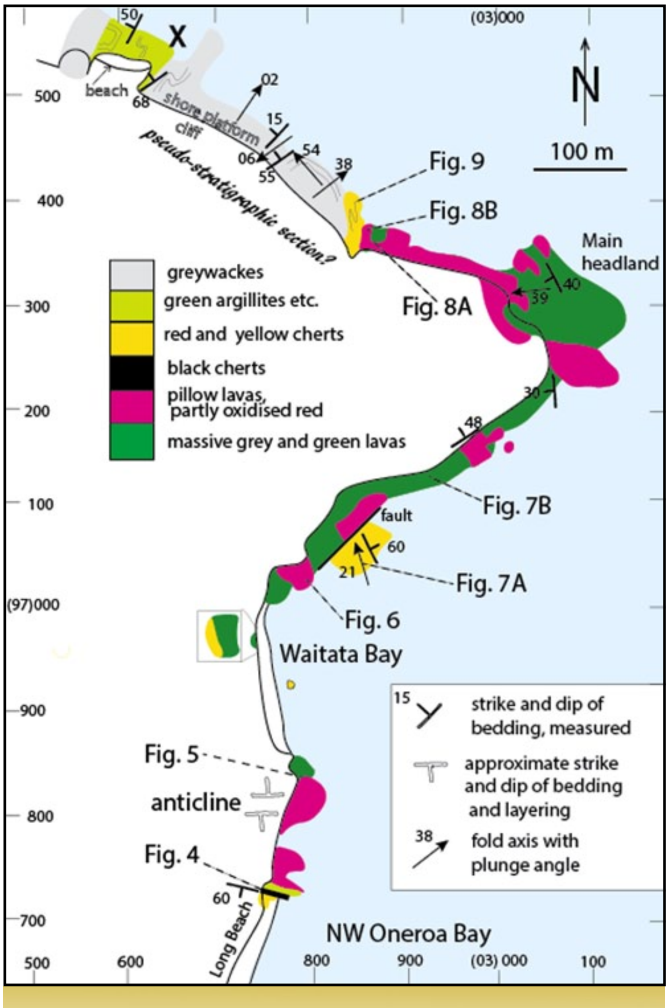

Fig. 3. Geological sketch map of the coastline north of Long Beach (northwest Oneroa Bay) with location of outcrop photographs. The thinnest black lines on the shore platforms trace bedding patterns. A small exposure in Waitata Bay is enlarged in the adjoining box. Numbers at the edge of the map are New Zealand Topographic Map grid references. For an explanation of "pseudo-stratigraphic section?", refer to 'Structural geology' discussion.

Some useful terms for this article

Bedding

Geologists use the term "**bedding"** for the layers deposited in sedimentary rocks.

Strike and dip

On geological maps, the orientation of planar features such as bedding, faults, etc. **is shown with a "T"-shaped symbol** (Fig. 3). The cross bar at the top of the 'T' represents the **strike** (a horizontal line) on the plane. This can be directly plotted on the map and illustrates the map trends of the layered features studied. The stem of the 'T' shows the downward inclination (**dip**) direction of the plane. Since it is not in the plane of the map, the dip angle has to be added. This angle is measured down from horizontal and ranges from 0° to 90°.

Bearing and plunge of a fold axis

A fold axis can be visualised as a line around which the layers in a fold have been folded (like the spine of a book, see Spörli *et al*. 2022). The **plunge** is the angle of inclination of this line, measured downward in a vertical plane through the line, ranging from 0° to 90°. The **bearing** is the strike of that plane and indicates the map direction of the fold axis. On a map, a fold axis measurement is shown as an arrow with its head in the down-plunge direction, and labelled with the plunge angle (Fig. 3).

Vergence of folds

If the sides of a fold (the limbs, see Spörli *et al*. 2022) are not of equal length, the fold is said to be asymmetric. This gives the structure a **'sense of lean', which is called the vergence**, emphasised by its inclined axial plane. For folds with sub-horizontal axes, we say that the fold verges in the up-dip direction of the inclined axial plane. For folds with a steeply plunging axis, we use an implied sense of shear: **dextral if the fold is Z-shaped** and **sinistral if it is S-shaped**.

Upright and recumbent folds

The simplest folds are **upright**: their sides (limbs) dip by similar angles in opposite directions and are of similar lengths. If the dips and lengths are seriously different, we then have an **inclined fold**. If one or both limbs are near horizontal, we talk of a **recumbent fold**.

What we see along the coast

We start our traverse at the north end of Long Beach (Fig. 3). The first notable rock units that we encounter are **cherts**. These are silica-rich rocks deposited in the deep ocean with a major component of siliceous radiolarian micro-fossils. Regular bedding in the yellowish cherts in the cliffs dips to the south. A distinctive reef that juts out onto the shore platform consists of black cherts (Fig. 4). Large angular boulders from higher up in the back slope of the shore platform are shed by these lithologies. As we move north, there is a small embayment with badly exposed green argillites and cherty sandstones. Then harder rock reappears underfoot; we are now in highly faulted and veined pillow lavas, mostly of green colour but with some red oxidation. The layers in the pillow lavas still dip to the south, but further north the dip changes to the north (Fig. 3). Some of the pillows are well preserved

Fig. 4. The foreground shows ~2 m thick black cherts dipping steeply to the left (southwest), with yellow cherts and greywackes dipping similarly in the background cliff.

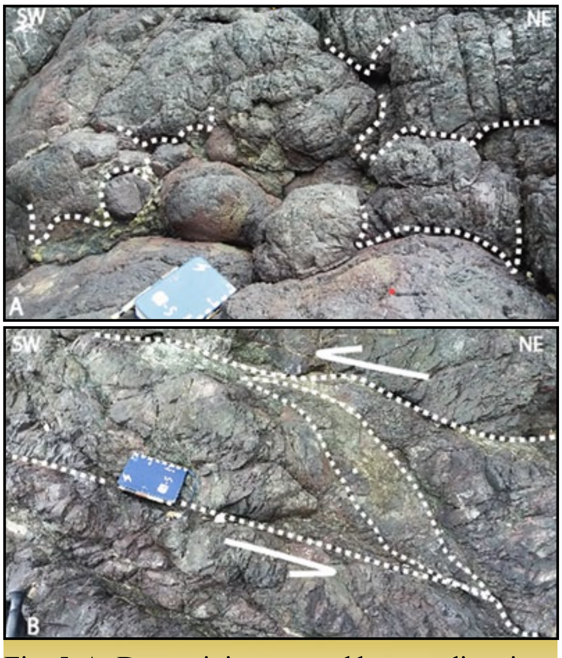

Fig. 5. A: Determining top and bottom directions (younging direction) in a pillow lava. During extrusion of the pillows, upper, hotter, softer pillows moulded themselves around lower, more cooled, harder pillows (white broken lines).
B: Pillow lava sheared into sigmoidal shapes. Asymmetric arrows indicate top to the south sense of shear.

(Fig. 5A) and indicate that the sequence is right way up, so the dip change represents an anticline. In other portions of the outcrops the pillows have been modified into sigmoidal shapes by top to the south ductile shearing (Fig. 5B).

After we cross Waitata Bay, the northeast-trending coast north to the main headland is dominated by more such volcanic ocean floor rocks (Fig. 3). The first outcrops are massive, relatively coarse, veined basalts, green grey in fresh exposures (Fig. 6A). There is some slight, swirly red oxidation. Further north, these pass into spectacular piles of red oxidised pillow lavas (Fig. 6B). The boundary between the massive lavas and the pillow units is diffuse and complex, and is highly simplified in the map of Figure 3. A large unit of well bedded, mostly red chert is faulted against the southern part of the coastal strip (Fig. 3). Although generally dipping in a northeasterly direction, these rocks are highly folded (Fig. 7A). Lenses of intensely folded chert and red argillite are also locally included in pillow lavas (Fig. 7B). At both chert localities shown, the tight folds verge to the southwest.

At the main headland (Fig. 3), grey-green lavas are overlain by red oxidised pillow lavas on a complex contact that rises up into the high cliff at the back of the shore platform, suggesting an anticlinal structure.

The coast now turns into a northwesterly direction. Pillow lavas and some grey-green igneous rocks occupy its southeastern third. Near the western end of this rock assemblage, massive green lavas and oxidised pillow lavas can be very distinctly seen interfingering in a primary (non-tectonic) contact (Fig. 8A). It is not clear whether this is due to intrusion of the massive lava into a pile of pillows or (more likely) the massive lava changing

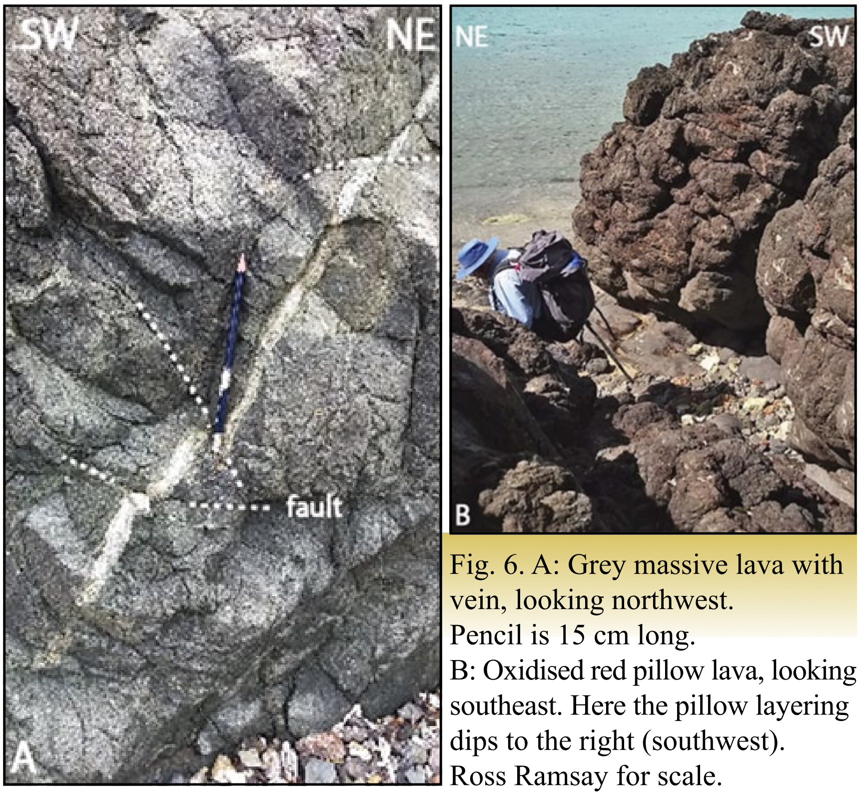

Fig. 6. A: Grey massive lava with vein, looking northwest.
Pencil is 15 cm long.
B: Oxidised red pillow lava, looking southeast. Here the pillow layering dips to the right (southwest).
Ross Ramsay for scale.

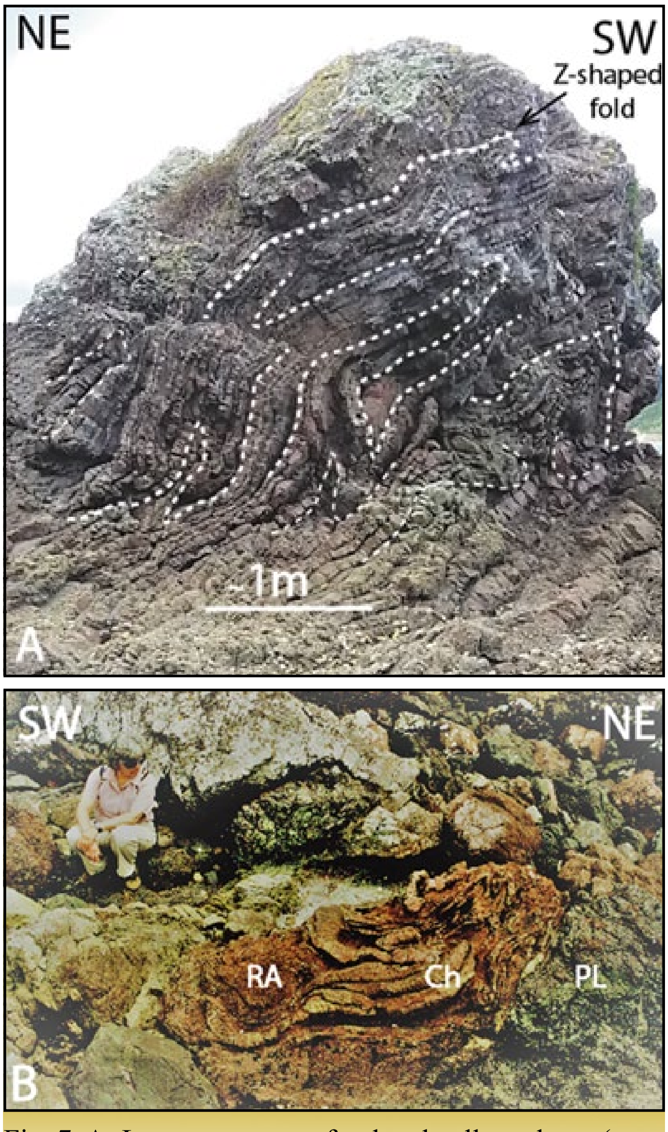

Fig. 7. A: Large exposure of red and yellow cherts (see Fig.3 for location). White broken lines trace prominent bedding markers around tight folds. Many of the folds are asymmetric, with alternating long and short limbs forming Z-shapes, i.e. they verge to the south.
B: Inclusion of tight, south verging folds in chert beds (Ch) and red argillites (RA) contained within pillow lavas (PL). Hanni Spörli for scale.

into pillows due to sea water chilling. A bit further on, there is a block of green lavas strongly striped by white carbonate layers (Fig. 8B). In our case it appears to be a signal of lava intruding into a limestone.

Going further, we now pass a fundamental boundary: a band of yellow and red cherts cuts off the igneous rocks. It contains folds, one of which is recumbent (Fig. 9). From here onwards, greywackes, the most common lithology of the Waipapa Terrane, dominate. They consist of alternating meta-sandstone and argillite beds. Some sections are thin-bedded (5–10 cm thick), in others the sandstone beds are decimetre to metre thick. Folding and disruption of bedding is common. In the few fresh outcrops, the rocks are grey to dark grey, but most commonly they are weathered to a buff colour. At the northern end of our traverse there is a slice of folded green argillites between the greywackes (X in Fig. 3).

Some interpretation

This article is the product of an initial visit in 2003, a GPS traverse in 2004, and a further visit in 2021. Given the marvellous exposures, much research remains to be done, including further analysis of structures and, particularly, petrographic and geochemical work. There are also long coastal exposures of greywacke to the north and south that need to be investigated. Nevertheless, some interpretation of our observations seems justified.

The rock types

Proceeding from oldest to youngest: **the two types of igneous rocks** (massive lavas and pillow lavas) are similar to those encountered in other basement exposures of Northland (Jennings 1991, Sakakibara & Black 2007). Figure 1B shows two possible sources of such ocean floor rocks: 1) those formed at a spreading ridge, and 2) those building up intra-oceanic seamount volcanoes like Hawaii. The latter can be sitting on and be younger than the spreading-ridge-sourced volcanic crust underlying them. There are also geochemical differences. These were examined for the Waipapa Terrane by Jennings (1991). He found that the volcanics in the southern regions around Auckland to Whangarei tended to be of the spreading ridge kind, whereas the northern group were of the seamount type. Since the oldest rocks in the north are lavas containing lenses of upper Middle

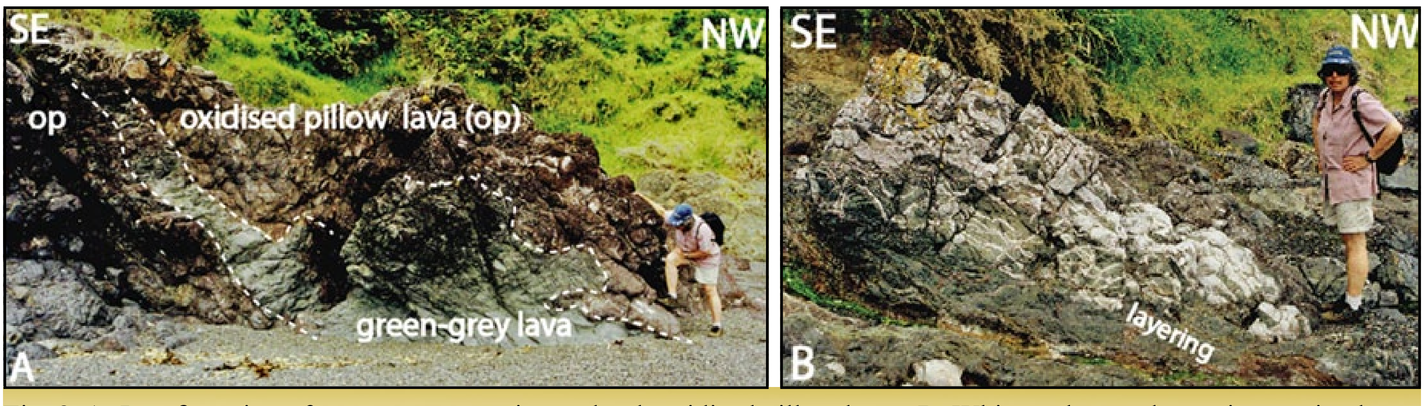

Fig. 8. A: Interfingering of green-grey, massive and red, oxidised pillow lavas. B: White carbonate layers in massive lava.

Permian (~265 million years old) marbles at Tauranga Bay (e.g. Spörli *et al*. 2007), there is the intriguing possibility that somewhere in Northland there might be spreading-ridge-derived ocean floor rocks that are older than that.

The occurrence of sediment lenses in the volcanics north of Long Beach (Fig. 7B) and intimate intercalation of carbonate layers in massive lavas (Fig. 8B) might indicate lava intrusion into ocean floor sediments accompanied by contact metamorphism, as has been documented for Arrow Rocks near Tauranga Bay by Sakakibara & Black (2007). The interfingering of massive grey-green lavas with pillow lavas (Fig. 8A) might also record intrusion (massive lava into pillow lavas), but alternatively could be explained as an outer pillow rind created by chilling of a lava flow at the lava-water contact.

Of the **three types of chert**, the red cherts, although metamorphosed during the accretion, are the closest to the normal occurrence of such ocean floor sediments. The black cherts are very much less common, and might give a hint about their age. Elsewhere in the Waipapa Terrane such cherts have been recorded from the Early Triassic and have been shown to be rich in organic material due to widespread ocean euxinia (oxygen depletion, sulphur enrichment) after the end-Permian extinction event (Suzuki *et al*. 2007, Hori *et al*. 2011, Takahashi *et al*. 2013). Yellow cherts are recrystallised alteration products of the red cherts, in part due to contact metamorphism associated with lava intrusion (Hori *et al*. 2007, Sakakibara & Black 2007, Spörli *et al*. 2007).

Green argillites mark the gradual contamination of the ocean floor sediments by terrigenous material, with iron changing from an oxidising to a reducing state, as the oceanic plate approached the Gondwana continent, eventually terminating in the deposition of greywackes. We do not know the age of the **greywackes** at Long Beach, but detrital zircon crystals deposited in such rocks of the region indicate Late Triassic or Triassic-Jurassic (around 200 million years) ages (Adams & Maas 2004). Because the terrigenous sediments are the youngest in our general stratigraphic sequence (Figs 1B and 3), this age range would give some support to our guess of an Early Triassic age (~ 250 million years) for the black cherts in the oceanic sediments. Such age considerations may also be supported by the report of Permian fusulinids in an imprecisely located historical museum specimen from the Russell area (Hornibrook 1951). A bit further afield, on Okahu Island, approximately 10 km northeast of the Long Beach locality, red mudstones contain possible Palaeozoic corals (Moore 1981) that with further study might eventually also contribute to defining the age patterns in the Waipapa rocks of this region.

Structural geology

Considering the distribution of rock types and the dip of layering in the map of Figure 3, we recognise that there is a central zone of igneous rocks, flanked in the north and south by (probably younger) sedimentary successions. This suggests an overall anticlinal structure with the older rocks in the middle and the younger ones at the flanks.

The rocks at the north end of our traverse (the north flank of this anticline) represent a stratigraphic section from ocean floor volcanics via cherts into the overlying terrigenous clastics (greywackes) that has been disturbed by internal shearing (Fig. 3: "pseudo-stratigraphic section?"). The green argillites have been removed from the main chert/greywacke contact but appear 'out of sequence' within the greywackes at X in Figure 3.

Recording of fold axes and bedding plane orientations (Fig. 3) reveals at least two directions of folding, one on fold axes trending northeast and the other on axes trending northwest. Northwest-striking folds have also been detected on Urupukapuka Island to the northeast of Russell (Moore 1981). The accretion model of Figure 1 can be imagined as a system active over a long time, instead of just an instantaneous snapshot. It then becomes clear that most of the slices detached from the down-going slab (and that is what we are seeing here), while gradually being transferred towards the back of the accretionary prism, go through at least three stages of deformation (Fig. 1):

1. Initial detachment and formation of folds oblique to the margin but perpendicular to the subduction vector.
2. Steepening, and further folding with dip-slip deformation dominant.

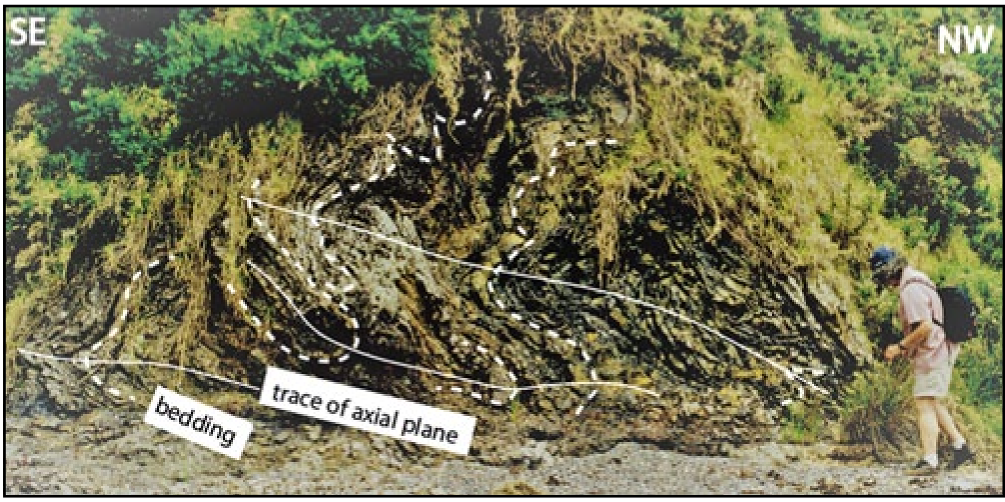

Fig. 9. South verging folds in the northern cherts, looking southwest. The low dips of the axial planes mark these as recumbent folds (distinct from an upright fold where the axial plane is subvertical).

3. Under oblique subduction, strike slip deformation takes over at the back of the accretionary prism, superposing another, differently oriented set of folds in the now steeply dipping layers.

It is therefore not surprising that we find two-fold axis orientations. Much more detailed structural work is necessary to determine how these folding directions relate to our very generalised model. For instance, the southward shearing in the pillow lavas of Figure 5B might be due to the same stage of deformation as the tight southwest-verging folds in the cherts of Figure 7A. These structures would fit with stages 1 or 2 of the accretion model, while the more open folds like the large regional anticline mentioned at the beginning of this section would have formed later. With further studies it will be possible to find additional stages and local variations of the accretion process, and test whether there is evidence that the model has to be modified.

Accretion of these rocks terminated about 70 million years ago, but the tectonic development of Zealandia continued. Some of the fracturing, faulting and veining in these rocks might be inherited from these later stages of development.

Acknowledgements
Many thanks to Yoshiaki Aita (Utsunomiya University, Japan), Ross Ramsay and Hanni Spörli for company and discussions in the field. I am grateful to Bruce Hayward and Jill Kenny for pointing out relevant reports of fossils from the Waipapa basement rocks of the region.

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Return to contents page

IS NEOGENE UPLIFT AND EASTWARD TILT OF GREAT BARRIER AND COROMANDEL RANGE RELATED TO THE ORIGIN OF THE HAURAKI RIFT?

Bruce W. Hayward

Summary
Answer: Possibly, in part.

Eastward tilt of Great Barrier Island

In 2018, while touring around Great Barrier Island with an Auckland Geology Club trip, I noticed that the majority of bedded volcaniclastic strata appeared to be tilted eastwards. When I was on the Barrier next, in 2023, I spent a day driving the roads and making actual readings of the strike and dip wherever I could see it in road cuttings, bluffs or sea cliffs. The result is the accompanying map (Fig. 1), on which I have also added a few strikes and dips obtained from the literature (see caption).

From the map it can be clearly seen, with three exceptions in the Windy Canyon area), that the predominant dip within the andesitic and rhyolitic sequences is towards an easterly quarter. Most of these deposits are probably terrestrial and may have had a primary dip on the slopes of the volcano(es) of up to ~10°, meaning that only dips greater than this can be used to infer later tilting. In two exposures (Whangaparapara Road and Medlands Stream) the strata are clearly water-laid (freshwater ponds or lakes) and would have been originally horizontal and their current dips are entirely a result of later deformation. These have dips of 30° northeast (Fig. 2) and 10° east respectively (Fig. 2).

The majority of the dips on Great Barrier Island are 10–30° east in the northern and central parts of the island and 20–40° in the southern part, and I infer these are proof of significant uplift of the western side of Great Barrier, along the Hauraki Fault, and tilting down to the east. The northern Great Barrier block, of outcropping greywacke, has obviously been uplifted even more (>500 m) and the younger rocks stripped off it to expose the basement rocks. The outcrop of basement greywacke around Harataonga in the east (Fig. 1), is contrary to the eastward downtilt and is best explained as a separate uplifted block with greywacke up to 150 m above MSL.

This uplift and tilting has occurred since eruption of the andesitic Coromandel Group sequence (post 12 myrs ago). The congruence of dip on the silicified rhyolitic deposits of Te Ahumata (Fig. 3) with the older andesitic strata beneath them indicates that most of the tilting occurred after eruption of the rhyolitic Whitianga Group as well (post 8–10 myrs ago). What drove this uplift and tilting? Could it have been related to the formation of the adjacent Hauraki Rift?

Origin of the Hauraki Rift

The origin, age and drivers of the Hauraki Rift (Fig. 4) in the northern North Island of New Zealand are poorly understood (Hochstein & Ballance 1993). These two authors provide a summary of the known structure of the rift and discuss its possible timing of onset and tectonic origins.

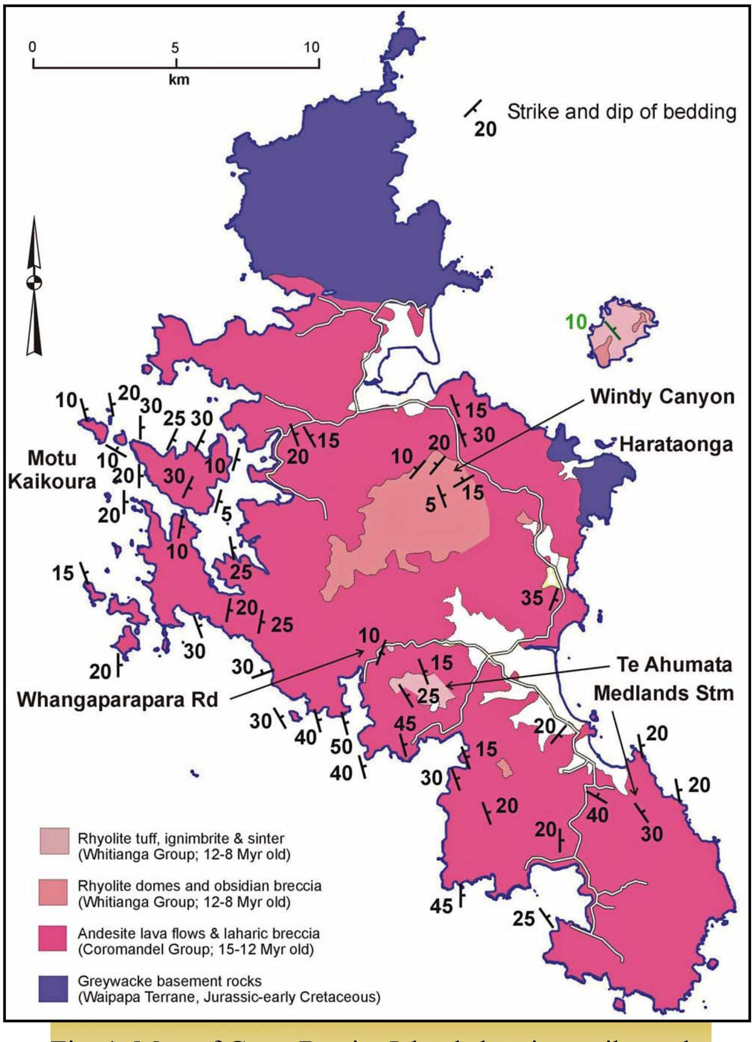

Fig. 1. Map of Great Barrier Island showing strike and dip on bedded volcanic sedimentary rocks and the outcrop distribution of the major rock units and their ages. From observations of Hayward (1973, 2023a, b), Ramsay & Kobe (1974), Hayward & Moore (1985), Moore (2001) and Edbrooke (2001).

Fig. 2. East-tilted, water-deposited, freshwater, sedimentary rocks exposed in a Whangaparapara Road cutting, Great Barrier Island.

They conclude that it is "*an active, young continental rift which developed in a plate segment behind and parallel to an extinct volcanic arc segment, the Coromandel Volcanic Zone. Rifting was preceded by crustal arching.*" … "*Although arguments for the geological age of the Rift are circumstantial, sediment accommodation is probably older than 5 myr.*" (Hochstein & Ballance 1993, p. 303). In their discussion they infer that "*Arching of the crust was induced prior to rifting by upward-moving asthenosphere rocks which heated the whole lithosphere beneath the Rift.*" These rocks are still at elevated temperatures today (Pandey 1981, Hochstein & Ballance 1993). They also state (p. 302) that "*arching of the Northland crust must have occurred, as indicated by the uplifted Jurassic basement rocks now exposed over the rift shoulders; a similar uplift occurred in Northland along the extrapolated axis of the rift.*"

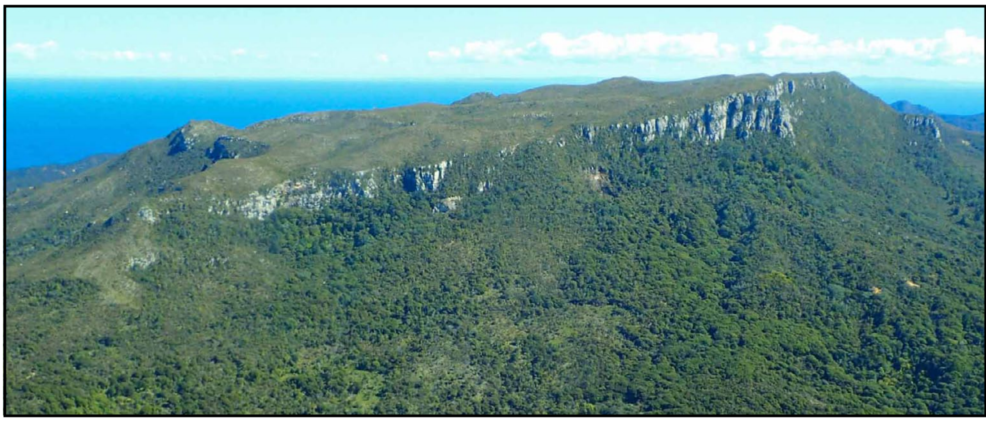

Fig. 3. East-dipping "flat" top of Te Ahumata Plateau, Great Barrier Island. This plateau is composed of erosion-resistant, silicified ignimbrite and rhyolite sediment and is inferred to have been the original land surface when formed 8–10 myrs ago.

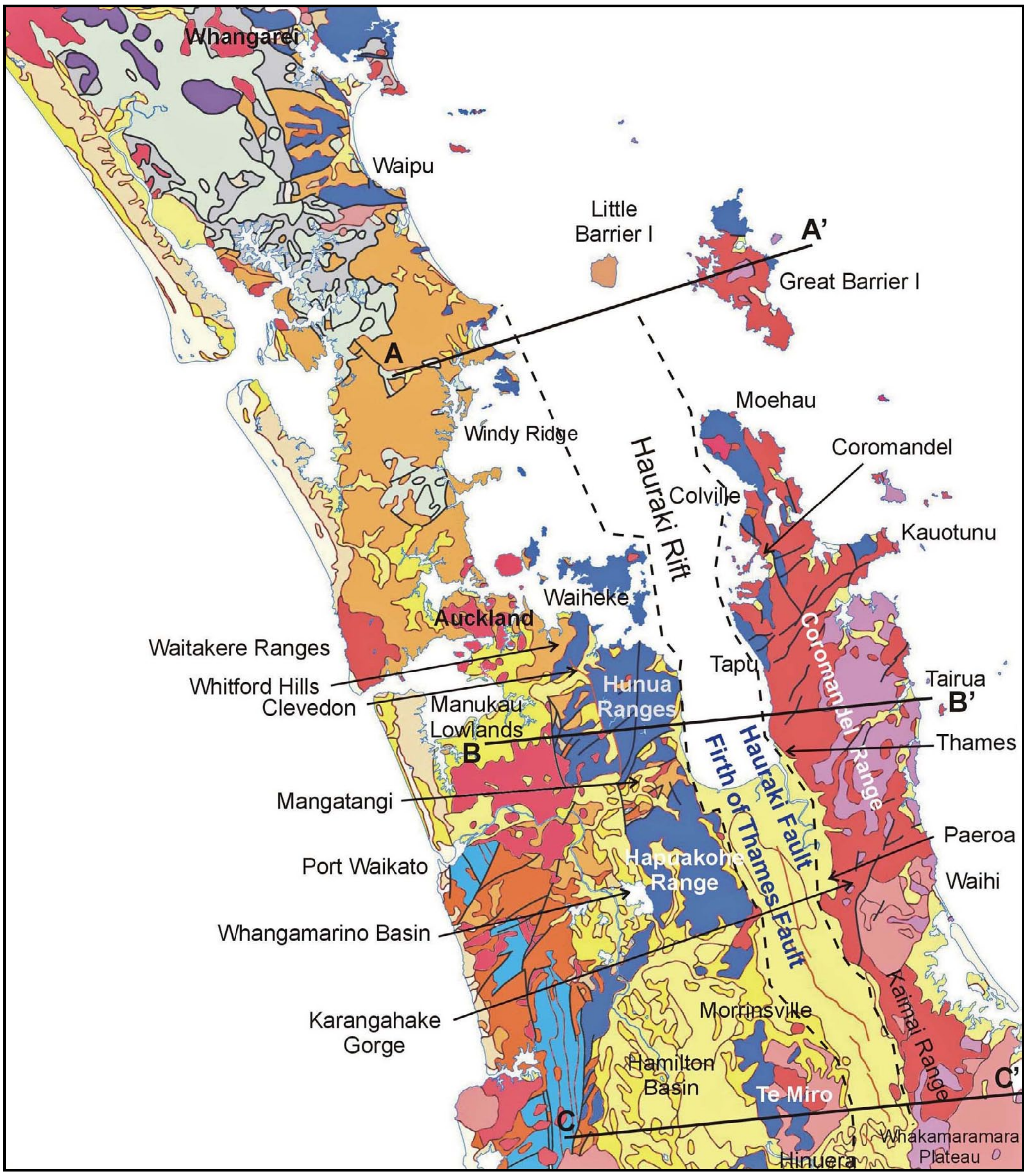

Fig. 4. Location of Hauraki Rift and its two major bounding faults (Hauraki and Firth of Thames faults) showing outcropping rock units on either side. In that area, blues = basement greywacke; reds and purples = Miocene-Pliocene andesite and rhyolite; oranges = Oligocene and Miocene sedimentary rocks; yellows = Quaternary sediment. Base map from QMap.

Time of onset of rifting

Battey (1949) noted the presence of Coromandel-derived volcanic and hydrothermally-silicified rocks in his fluvial Puketoka Formation near Mangatangi on the west side of the Hauraki Rift (Fig. 4) and inferred that their westward transport and deposition, probably in the Pliocene, predated the subsidence of the Hauraki Rift (Kear 2000). Hochstein & Ballance (1993) considered that the up to 2.5 km thickness of sediment filling parts of the Rift needed more than 2–3 myrs to accumulate and so inferred an onset of rifting of 5–7 myrs. They explained the occurrence of Coromandel-derived conglomerate on the west side of the rift as having been the result of a period “of sediment bypass” when rivers flowed east to west across the Rift instead of the present south to north direction along the Rift.

More recently, similar Coromandel-derived cobbles and pebbles have been identified in fluvial and reworked shallow marine deposits around the eastern margin of the Manukau Lowlands (Fig. 4) and have been dated by their associated molluscan fauna as Late Pliocene in age (Waipipian Stage, 3.7–3 myr) (Hayward *et al*. 2006 2023, Hayward 2017, Geary 2022). I am of the opinion that the development of east to west drainage across the Rift some time after it had begun subsiding is extremely unlikely, especially as clasts up to the size of 2 m boulders (Hayward & Grenfell 2010, Hayward & Mauk 2011) were transported across the Rift, even if this occurred in large floods or debris flows. Thus, I conclude that onset of the Hauraki Rift subsidence post-dated deposition of Puketoka Formation (i.e. younger than 3 myr), at least south of a line joining Waiheke and Coromandel.

It could have started somewhat earlier in the north and advanced southwards behind southward migrating volcanism of the Coromandel Zone. Nowadays many workers associate the eruption of voluminous rhyolite magma with tension and possible rifting (e.g. Hayward 2017). Rhyolite volcanism in the Coromandel Zone began in the north 12 myrs ago (Fig. 5), 9 myrs ago in the central Coromandel Range and 4.5 myrs ago in the south (Waihi). This suggests that onset of a tensional rifting regime migrated southwards prior to actual subsidence of the Hauraki Rift.

Uplift and tilting on the western shoulder of the Hauraki Rift

The outcrop pattern in Northland and Auckland is well-established (e.g., Edbrooke 2001, Edbrooke & Brook 2009) with basement greywacke at the surface along the eastern side (Fig. 4) and at depths of up to 3000 m or more offshore to the west (e.g., Edbrooke 2001). Between Whangārei and Auckland, the average maximum elevation of the greywacke is ~200 m, only reaching elevations of 300–400 m in the Waipu blocks, south of Whangārei. South of Auckland, the Hauraki Rift is margined to the west by an outcropping strip of uplifted greywacke and Miocene Kiwitahi Volcanic Group andesites all the way south to Hinuera (Fig. 4). This belt is divided into four uplifted blocks (Whitford hills, Hūnua Ranges, Hapuakohe Range,

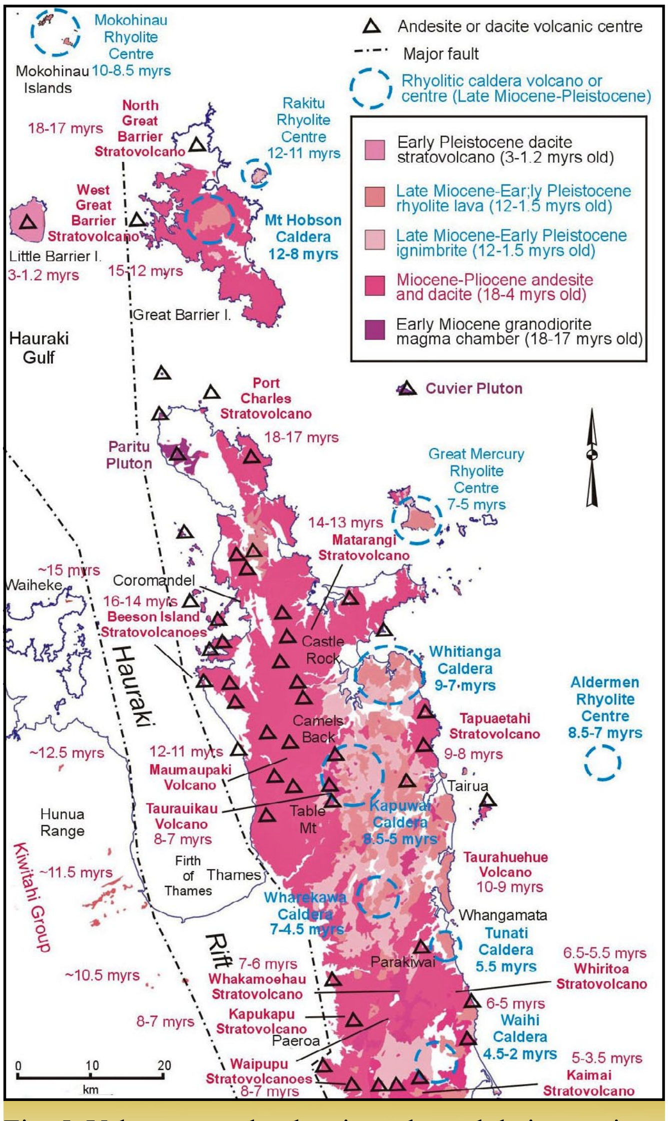

Fig. 5. Volcanoes and volcanic rocks and their eruption ages on the Coromandel Peninsula and Great Barrier Island. Adapted from Hayward (2017).

Te Miro hills) separated by three down-faulted grabens or half-grabens (Clevedon, Mangatangi, Morrinsville) where the greywacke today is below sea level. The greywacke is uplifted the greatest amount in the Hūnua Ranges, reaching a maximum of ~700 m above MSL, and further south they are uplifted up to 500 m elevation and dip gently west beneath the Whangamarino and Hamilton basins (Figs 4, 6) where their surface is ~500–1000 m below sea level adjacent to the Waimā Fault (Edbrooke 2001 2005, Leonard *et al*. 2010). Thirty km offshore to the west of Auckland, the greywacke basement surface has tilted gently down to ~3000 m below MSL (Edbrooke 2001).

Some, or even much, of this uplift is inferred to have occurred in the Early-Middle Miocene (post ~120 myrs ago) with uplift and eversion of the bathyal-abyssal Waitematā Basin migrating southwards from Whangārei through Auckland (e.g. Hayward 2017). The Auckland Erosion Surface, AES (as Auckland Peneplain in Bartrum 1937)

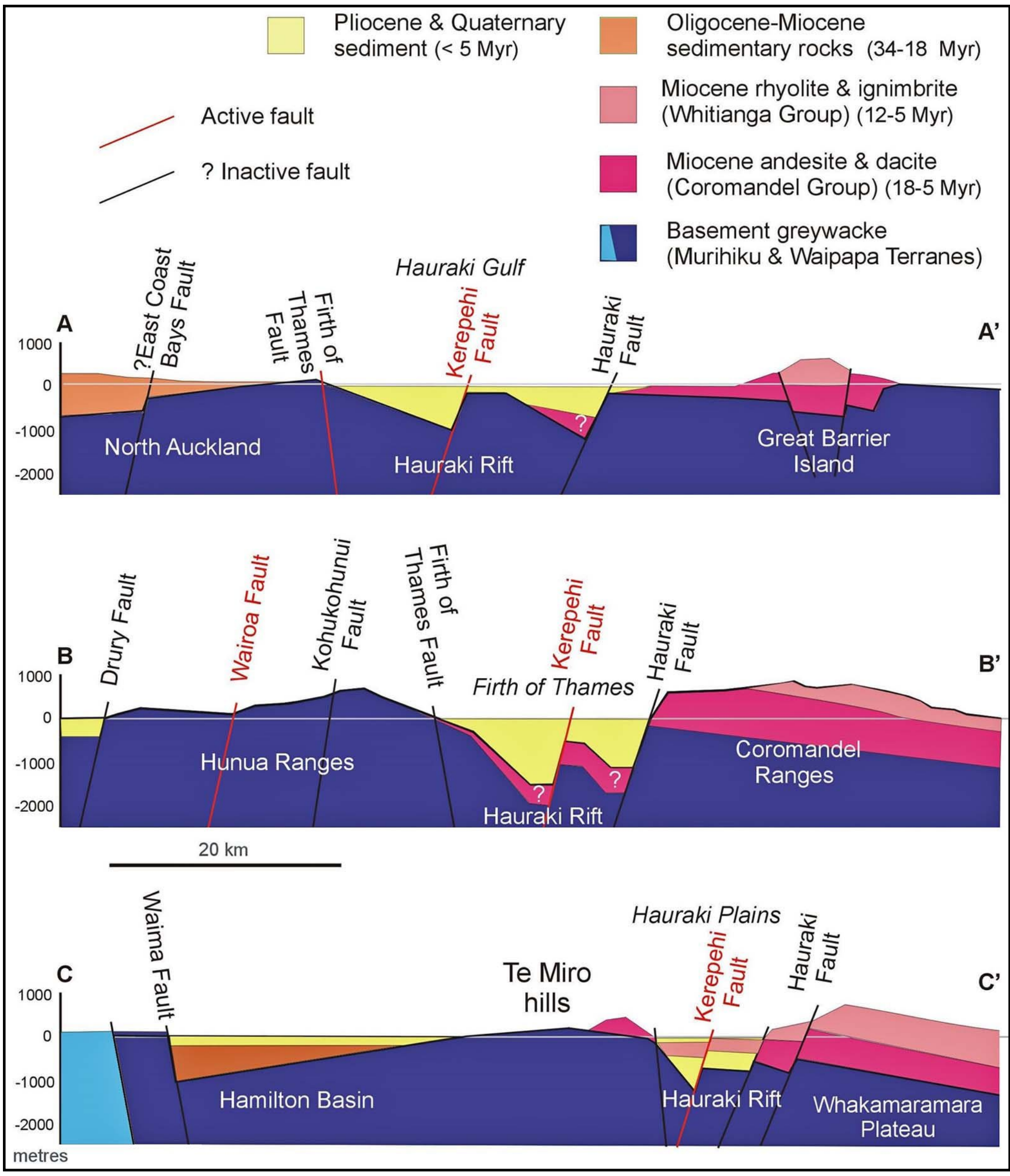

Fig. 6. Schematic cross-sections across the north (A-A'), central (B-B') and south (C-C') Hauraki Rift and its shoulders. Location of section lines are shown on Fig. 4. Data from Hochstein & Ballance (1993), Edbrooke (2001 2005), Houghton & Cuthbertson (1989) and Leonard *et al*. 2010).

appears to have been eroded across this uplifted Auckland region by about 5 myrs ago and provides strong evidence that the early period of uplift in Northland and Auckland was greater in the east than the west. (i.e. The AES was eroded at sea level and has cut down into the uplifted greywacke in the east but cuts across the early Miocene Waitematā and Waitākere Group rocks to the west).

Jill Kenny (2013a, b) has mapped the present elevation of the AES through Auckland and shown the post 5 myr vertical deformation that has occurred. This surface is only about 60 m high beneath central Auckland (Fig. 7) and rises in a number of fault-bounded steps to 140–160 m to the north (vicinity of Windy Ridge north of Puhoi). There is no evidence of down tilting to the west in the elevation of

Fig. 7. Looking north from Maungarei/Mt Wellington showing the flat Auckland Erosion Surface forming the ridge crests and rising in elevation to the north (distance).

the AES in this area (Fig. 8). Indeed, there is the opposite with uplift of the surface to 450 m, on top of the Waitākere Ranges fault blocks, where it slopes gently to the northwest.

South of Auckland, the AES is inferred to coincide with the smooth gently sloping upper surface of the Hūnua Ranges. This surface could also coincide approximately with the Waipounamu Erosion Surface (of Oligocene age) with all the softer Oligocene and Miocene sedimentary rocks having been eroded down to the top of the harder greywacke. This surface, on top of the Hūnua Ranges, rises to a maximum of ~700 m, sloping away gently towards the Firth of Thames to the east and sloping and downfaulted in several steps (on the Kohukohunui, Wairoa and Drury faults) down to the Manukau Lowlands in the west (Figs 8, 9), where the basement greywacke is buried below sea level to depths of up to 2000 m (Isaac *et al*. 1994, map 3). Further south, once again there is an uplifted block - this time of greywacke south of Port Waikato.

It would appear that the Hūnua, Whitford and Hapuakohe greywacke blocks (Fig. 4) were already uplifted (at least in part) by the late Pliocene (3.7–3 myrs ago) when the west flowing Puketoka and Clevedon rivers were flowing through the grabens between them (Hayward 2017, fig. 10.20). There was also at this time a topographic slope down to the west, right across the northern Waikato-Auckland-Northland region, resulting in many west-flowing rivers extending most of the way across these regions, even today (e.g., Hayward 2017, p. 217–222).

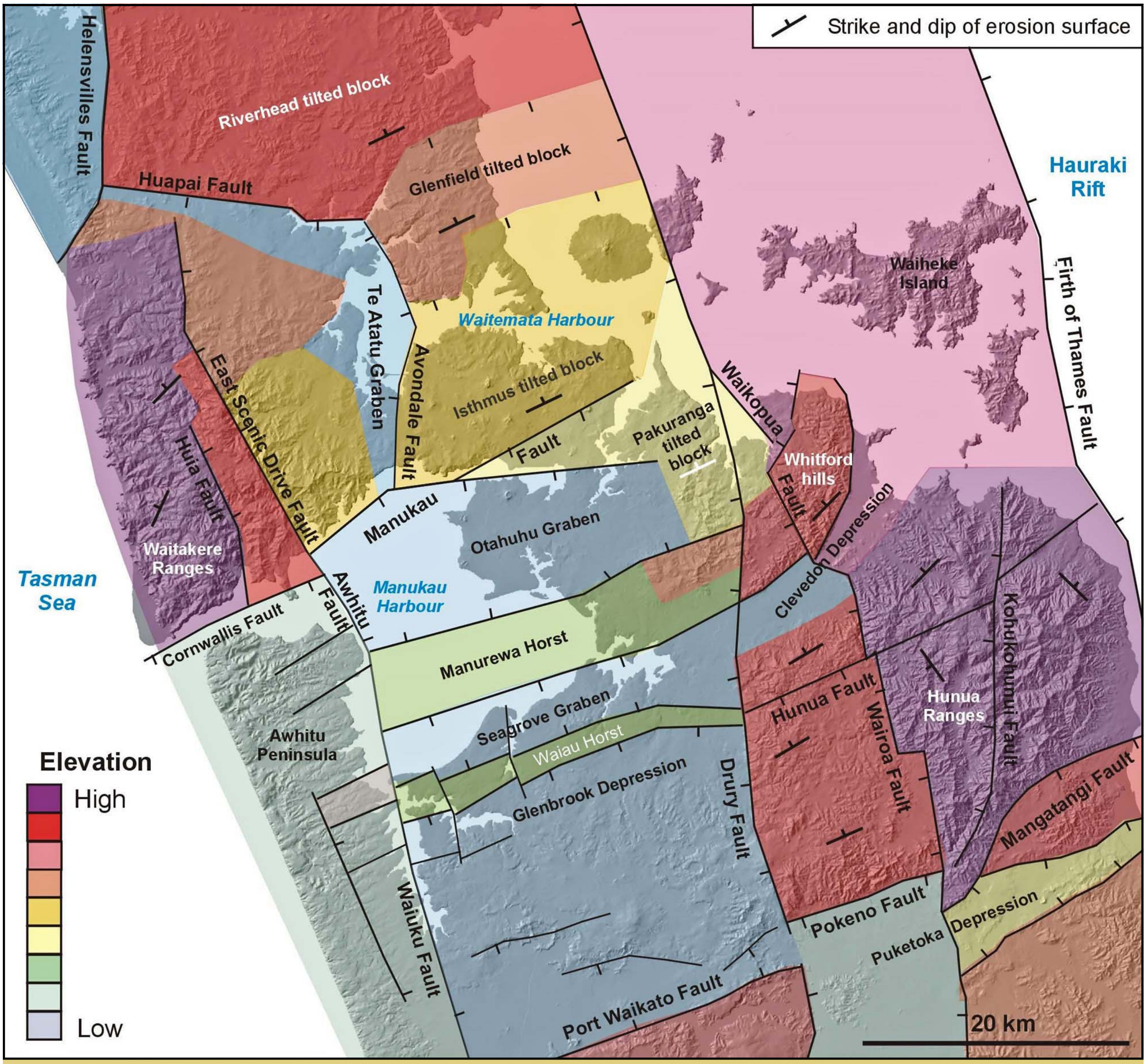

Fig. 8. Stylised map showing the approximate elevation and tilt of the Auckland Erosion Surface in various fault blocks in the greater Auckland area (simplified from Hayward 2017, fig. 10.1, adapted from Kenny 2013a, 2013b).

In conclusion for the western shoulder, the pre-mid Miocene rock units of the Auckland region are 3000–4000 m higher in the east than offshore to the west. Most of this eastern uplift and tilt appears to have occurred during the Mid (and possibly Late) Miocene. Vertical deformation during the Pliocene and Pleistocene (post 5 myrs) shows no evidence of greater uplift or arching up in the east.

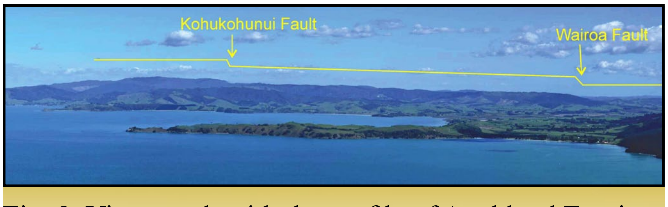

Fig. 9. View south with the profile of Auckland Erosion Surface on the top of the Hūnua Ranges. Note the westward tilt with two downfaulted jumps.

Uplift and tilting on the eastern shoulder of the Hauraki Rift

At the northern end of the Coromandel Range, basement greywacke is uplifted along the east side from Moehau to Tapu (Fig. 10). On Moehau, at ~900 m, the greywacke has been uplifted highest, and is tilted down to sea level in the north and east. North of Coromandel township the top of the greywacke is 1–1.5 km higher in the west than the east side of the peninsula (Skinner 1976). The one exception to the eastward tilt is the uplifted and east-tilted greywacke block forming Kuaotunu Peninsula in the east (Fig. 10).

In the main part of the Coromandel Range, between Coromandel township and Waihi, slightly older andesite directly overlying the greywacke outcrops in a belt along the west side and is gently tilted down to the east beneath 2–5 myr younger rhyolite and andesite (Figs 5, 10). This is consistent with the dominant eastward dip within these sequences (Fig. 10), which includes 10–20° dips on originally horizontal lake sediment around Table Mountain (Hayward 1974). A result of this easterly tilt is that the top of the greywacke surface is at least 1–1.5 km higher on the west side of the peninsula than the east (Skinner 1993, 1995). In the south around Waihi, cross-sections suggest a 2 km difference in elevation between the west and east sides of the Coromandel Range (Fig. 6) (Brathwaite & Christie 1996).

At the south end of the Hauraki Rift, the eastern shoulder is formed by the Kaimai Range and Whakamarama Plateau which tilt to the northeast, away from the Hauraki Rift at 3–5° (Briggs *et al*. 1996) with an elevational difference of ~1500 m (Figs 6, 11) (Houghton & Cuthbertson 1989; Briggs *et al.* 1996).

Thus, the majority of the eastern shoulder of the Hauraki Rift from Great Barrier Island southwards has been uplifted and tilted away with an average elevational difference of ~1.5 km over a distance of ~25 km (Fig. 6). Some of this uplift at the northern tip of Coromandel Peninsula occurred in the early Miocene (~19 myrs ago) as recorded in the

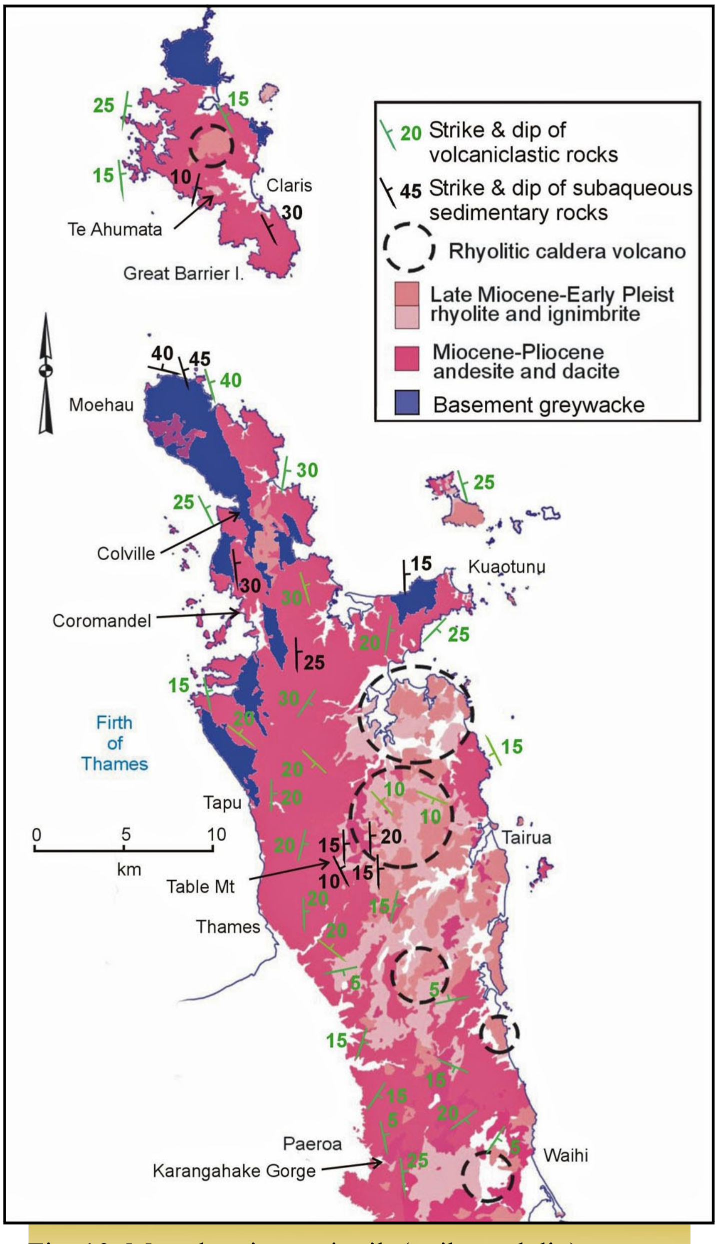

Fig. 10. Map showing main tilt (strike and dip) on volcaniclastic sedimentary rocks (green) and water-laid clastic rocks (black) of the Coromandel Peninsula and Great Barrier Island. Data from Fig. 1 (above) plus Skinner (1976 1993 1995), Edbrooke (2001), and Brathwaite & Christie (1996). Map base from GNS QMap GIS layer.

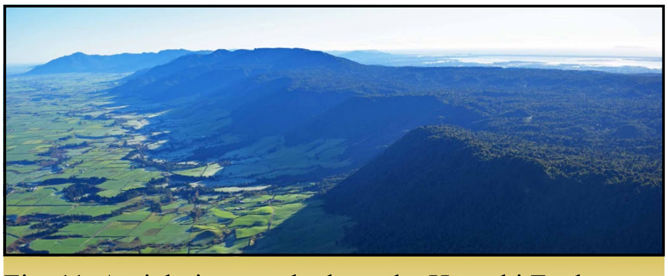

Fig. 11. Aerial view north along the Hauraki Fault scarp that margins the gently east-dipping ignimbrite cap of the Whakamarama Plateau and Kaimai Range (seen here). Flat Hauraki Plains in the Hauraki Rift on left.

shallowing of the sedimentary sequence from lower bathyal to terrestrial (~1000 m) (Skinner 1969, Hayward 2017).

South of this, the entire volcanic sequence is terrestrial and so there is no way of determining if there was uplift along the length of the shoulder in the Miocene, or only in the far north. The eastward dips on the ~7 myr-old lake sediments (Wainora Formation) around Table Mountain of 10–20° (Fig. 10) are similar to the overall tilt of the peninsula (Fig. 12) and suggest that in the middle reaches most of the tilt, and western uplift, occurred post 7 myrs ago. At the southern end of the Coromandel Range, the Ohinemuri River flows west through the uplifted Coromandel Range via the antecedent 300–500 m-deep Karangahake Gorge (Hayward 2018a). The headwaters of the river are inferred to have been a lake in the Waihi caldera basin (Fig. 5), which erupted 4.5–2 myrs ago. At that time (~3–4 myrs ago) the paleoslope was westwards from Waihi to Paeroa and thus differential uplift in the west of at least ~200–400 m has occurred in the last 2–3 myrs in this vicinity (Fig. 13).

At the southern end of the Hauraki Rift, the eastern shoulder is formed by the Whakamarama Plateau (Fig. 4), composed of a Pliocene rhyolite core mantled on both sides by 1 myr-old Waiteariki Ignimbrite (Houghton & Cuthbertson 1989). This ignimbrite has been tilted down to the northeast by at least 300 m in the last 1 myrs and down-faulted ~400 m into the Hauraki Rift on two strands of the Hauraki Fault and by a further ~500 m on the Kerepehi Fault that runs down the middle of the rift (Houghton & Cuthbertson, 1989).

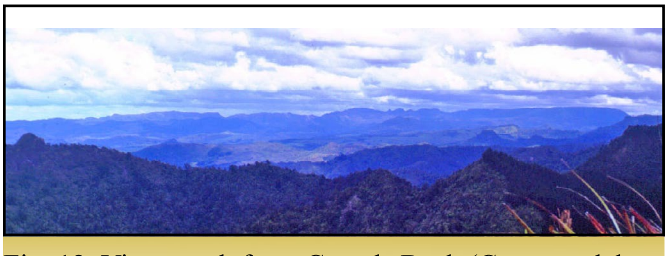

Fig. 12. View south from Camels Back (Coromandel main divide) showing the gentle eastward tilt on the relatively flat surface of the skyline ridge crests from Table Mt (right) almost to Tairua (left). This is a former flattish land surface that has been gently tilted to the east in the last ~7 myrs.

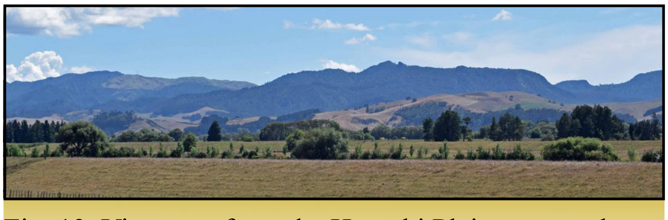

Fig. 13. View east from the Hauraki Plains across the Hauraki Fault trace with the gently-tilted flat tops of the Coromandel Range, northeast of Paeroa. Most of this uplift is inferred to have occurred since the onset of Hauraki Rift foundering post 3 myrs ago.

In summary, there is good evidence for early Miocene uplift in the northern tip of Coromandel Peninsula, for post-7 myr uplift and tilting on Great Barrier and east of Thames, of post-3 myr uplift and tilting near Paeroa, and post-1 myr movement at the southern end of the eastern shoulder of the Hauraki Rift. Thus, there is a suggestion of possible southward migration of this uplift and tilting, but this is not proven.

The present elevation of marine terraces formed along the coasts of Great Barrier and the Coromandel Peninsula during the Last Interglacial high-stand (~5–6 m above present SL at ~120,000 yrs ago) provide a crude indication of whether there is still any land movement occurring along the eastern shoulder of the Hauraki Rift. Published studies at Tairua and Claris, Great Barrier (Fig. 10), indicate there has been no significant land movement in these places since the Last Interglacial (Hayward & Morley 2014, Hayward 2018b). Unpublished observations, 7 km north of Colville (Hayward 2017, fig. 11.98) indicate no significant movement has occurred there either.

On the hillsides behind Thames and Te Puru, however, the lowest terrace remnants (assumed to be Last Interglacial in age) are consistently at ~25 m above MSL (Fig. 14). This indicates uplift here, close to the Hauraki Fault, at a rate of about 0.2 mm/yr. If this rate has been continuous over the past 3 myrs, it would account for 600 m of uplift in that time and the total amount of uplift in this vicinity having occurred in the last 7 myrs. This is coincident with the timing based on the Table Mountain lake sediments.

Thus, it would appear that maybe around half of the uplift and tilting on the eastern shoulder predated the onset of subsidence of the central part of the Hauraki Rift, but that the remainder may have occurred after onset. Certainly, in the south subsidence of the Rift and uplift of the eastern shoulder have occurred together within the last 3 myrs.

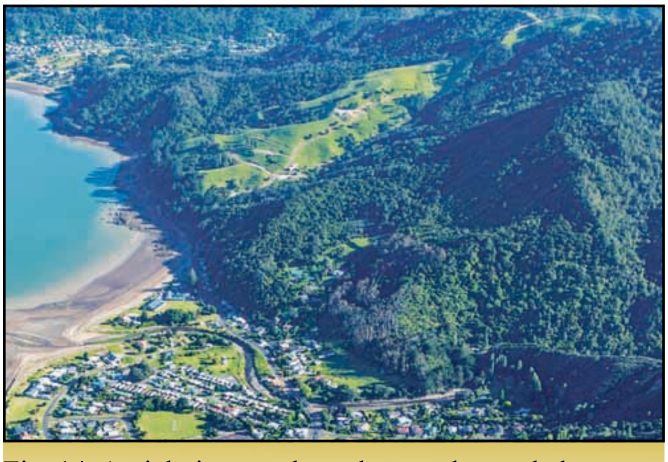

Fig. 14. Aerial view northwards over the eroded Hauraki Fault scarp at Te Puru, north of Thames. Note the three flat sections of forested ridge crest at 25 m elevation. These are inferred to be eroded remnants of the Last Interglacial coastal terrace that have been uplifted ~20 m in the last 120,000 yrs. Similar terrace remnants occur to the south in the hills around Thames.

What lies beneath the Hauraki Rift?

There is no positive magnetic anomaly beneath the Hauraki Rift (Hochstein & Ballance 1993), which led them to discount the likelihood of igneous rocks down there. They inferred the fill of both half grabens beneath the Firth of Thames was entirely sediment with an older, denser portion (? Miocene) overlain by less dense unconsolidated sediment. They inferred that basement greywacke directly underlies this sediment fill.

Along the western margin of the Rift, from Waiheke to Hinuera, there is a line of eroded remnants of small andesite stratovolcanoes (Kiwitahi Volcanic group) of Middle to Late Miocene age, younging from north (Waiheke, 15 myrs) to south (5 myrs) (Cole 1978, Black *et al*. 1992). These ages parallel the younging ages of the andesite volcanoes across the rift forming the western Coromandel and Kaimai Ranges (Edbrooke 2001) and suggests that maybe eroded remnants of similar andesite stratovolcanoes may lie between the basement greywacke and young sediment infill of the Hauraki Rift (Fig. 5; Hayward 2017, p.136). Being thin and at depth they might have no significant magnetic signature. If present, they might have provided a more proximal arched-upward source for the Late Pliocene Coromandel-sourced clasts in the Puketoka Formation of the western shoulder valleys, prior to rift subsidence.

Conclusions

The volcanic rocks of Great Barrier are tilted down to the east (with the exception of the uplifted greywacke block at Harataonga). This is similar to Coromandel and Kaimai Ranges to the south and supports an up-arching along the axis of the later Hauraki Rift prior to its subsidence. This uplift began in some places (Moehau) as early as early Miocene, but mostly occurred after eruption of the local rhyolites and migrated southwards along with volcanism. This uplift on the eastern shoulder has continued as the Rift has been foundering and is still occurring in the south (Thames-Tairua-Kaimai-Whakamarama). The basement greywacke rocks of southern Northland-Waikato that form the western shoulder of the Rift began up-arching and tilt to the west in the early Miocene, with uplift largely complete well before the end of the Miocene (~10 myrs ago). In the north, the western shoulder is currently stable, with evidence of slight uplift in the south. Subsidence of the Hauraki Rift may have begun as early as 5–7 myrs ago in the north, but the majority has occurred since deposition of the Puketoka Formation in the late Pliocene (post 3 myrs).

This review shows that the situation is far from a simple case of up-arching above an elongate plume of asthenosphere during the Miocene followed by post-Miocene subsidence of the Hauraki Rift along the axis of the arch.

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Return to contents page

DENDRITIC BARYTE CRYSTALS FROM WAIWERA

Tim Saunderson

This article is an adaptation of an article I wrote recently for the Australian Journal of Mineralogy. I have re-written some of the text and added several new photos.

Some years ago, I was given some pieces of rock from Waiwera Beach, north of Auckland. The locality is well known for zeolites such as analcime, phillipsite, chabazite and also other minerals such as calcite, pyrite, apatite and baryte.

This mineral assemblage occurs in rocks that form part of the Parnell Grit - volcaniclastic marine deposits resulting possibly from flank collapses of Miocene age volcanoes (Hayward 2017). The larger clasts in these rocks are predominantly basalt and andesite/basaltic andesite.

Baryte [chemical formula $BaSO_4$] is not uncommon at this locality, and it usually occurs as small hemispheres of tiny white blades that look very much like cowelsite crystals (for which it is sometimes mistaken) (Fig. 1). Geoclub Member, Rod Martin, has had a number of these hemispheres analysed and they are all baryte, not cowelsite. The baryte hemispheres sometimes occur as inclusions inside analcime crystals [$NaAlSi_2O_6 \cdot H_2O$] (Fig. 2). In such cases, the baryte crystals formed first, such as the 'normal' form in Fig. 3, and the analcime crystals grew at a later stage and simply enveloped the baryte.

I have been working on material from Waiwera for several years in conjunction with Lyn Hellyar (who kindly provided the rock in the first place) and we found two small pieces that contained clear colourless phillipsite crystals [$(Ca,Na_2,K_2)_3Al_6Si_{10}O_{32} \cdot 12H_2O$] in some of the cavities. On the surface of the phillipsite is a branching network of very thin dendrites which are whitish to clear and colourless (Fig. 4). I found that the best way to photograph them was to use very oblique lighting so that the dendrites show up on a reflective surface. I usually convert the photo to greyscale to avoid colour aberrations and prismatic effects from the phillipsite (Fig. 5). Sometimes the dendrites are flat iridescent scabs and I leave them as colour photos (Fig. 6). The colours are caused by thin-film iridescence, similar to that of a soap bubble.

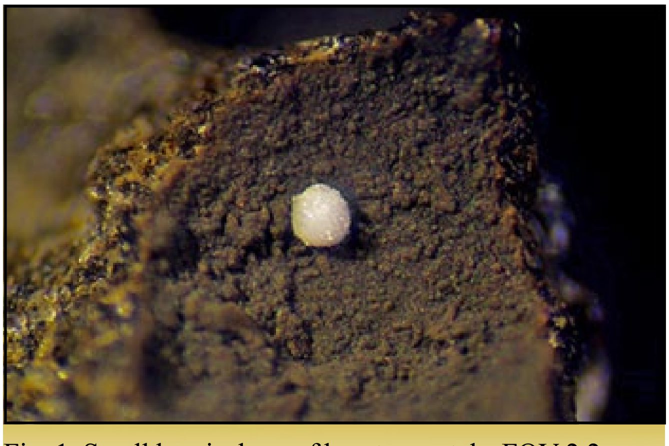


Fig. 1. Small hemisphere of baryte crystals, FOV 2.2 mm. The term 'FOV' means Field Of View, which is the horizontal measurement of what is seen in the image.

Fig. 3 Baryte crystal (the 'normal' form), from Moeraki, FOV 6.6 mm.

Fig. 2. Baryte inside a yellow analcime crystal, FOV 3.4 mm.

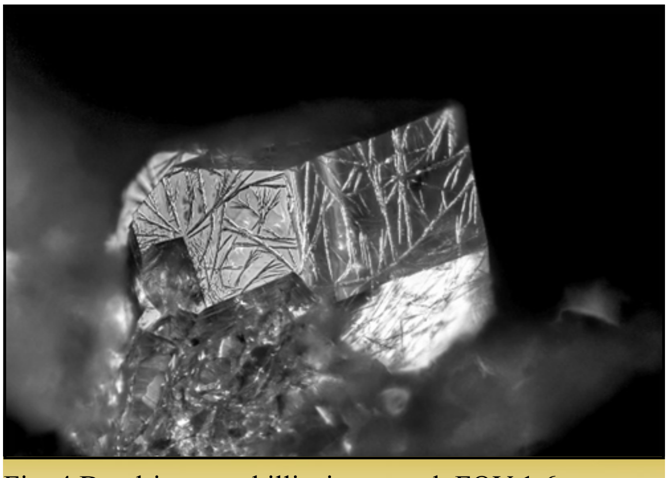


Fig. 4 Dendrites on phillipsite crystal, FOV 1.6 mm (greyscale).

Fig. 5. Dendrites on phillipsite crystals, FOV 2.2 mm (greyscale).

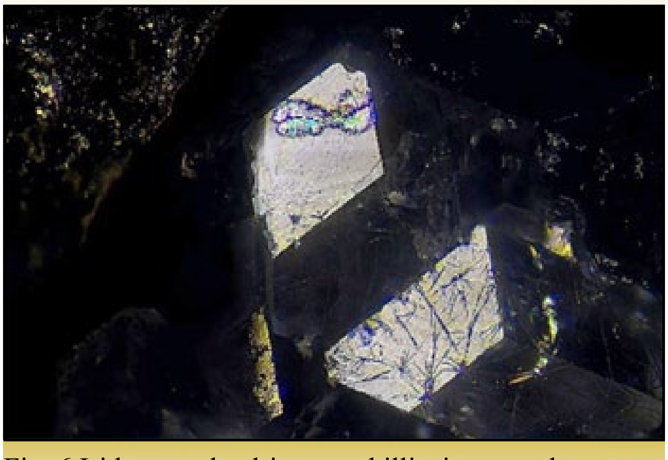
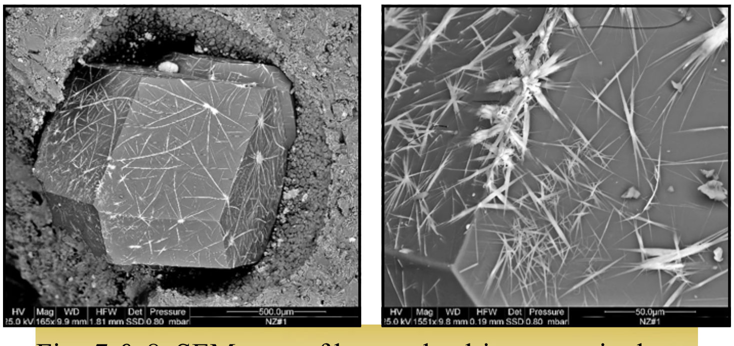


Fig. 6 Iridescent dendrites on phillipsite crystals, FOV 1.6 mm.

I wondered what these dendrites might be until I found several specimens that also had tiny white hemispheres of baryte on the phillipsite as well as the dendrites. I had never heard of baryte forming dendrites before (baryte usually forms flat blades with a pointed termination, as in Fig. 3). I searched the internet for dendritic baryte and found an interesting article covering the formation of both normal bladed baryte and dendritic baryte in deep sea hydrothermal vent deposits from Juan De Fuca Ridge, northeast Pacific Ocean (Jamieson *et al*. 2016).

It seems that baryte can indeed form dendrites under certain conditions where there is a mix of hydrothermal fluids and seawater. Jamieson *et al*. (2016) describe how baryte forms either bladed crystals or dendrites, depending on the ratio of barium-rich hydrothermal fluids to sulphate-rich seawater. This is a somewhat simplified version of the process; it is a bit more complicated but that is the gist of it. Dendritic and acicular baryte forms near the exterior vent walls while euhedral blades tend to form in chimneys of hydrothermal vents. To be sure though, I sent a specimen off to Italy and had it analysed using energy dispersive X-ray spectrometer (EDS). They could not get a pure reading from the dendrites themselves, but by subtracting the chemical composition of phillipsite from the scan results you are left with barium, sulphur and oxygen - barium sulphate, or as we know it, baryte. Some of the photos taken during the SEM scan show the dendrites particularly well (Figs 7, 8).

These dendrites from Waiwera would have originally formed in rocks on the submarine slopes of a Miocene volcano when it was active. Subsequent collapse of the steep flanks of the volcano have created turbidity flows - essentially underwater avalanches - which have deposited debris at Waiwera and other places. As hot water (heated by magma) moves through the rock, it dissolves and mobilizes certain elements, which later combine to form crystals such as phillipsite in cavities as the water begins to cool. Baryte seems to be one of the last minerals to form and for some reason, it has an affinity for the surface of phillipsite crystals. Oddly, some cavities contain analcime and chabazite along with the phillipsite and the dendrites have only formed on phillipsite.



Figs 7 & 8. SEM scan of baryte dendrites on a single phillipsite crystal almost filling a small cavity.
SEM scans by Michele Mattioli of University of Urbino Carlo Bo, Italy.

Acknowledgements
Many thanks to Michele Mattioli of University of Urbino Carlo Bo, Italy, for producing the SEM scans and for granting permission to use them here. My thanks go to Mr Fabio Tosato of Padua, Italy, for arranging the SEM scans and to Lyn Hellyar for bringing the dendrites to my attention and for sharing the material with me.
Thanks also to Rod Martin for his assistance.

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Return to contents page

A LATE MIOCENE PALEOVALLEY AT HIHI: INSIGHTS INTO THE HISTORY OF THE ANTECEDENT ORUAITI RIVER, DOUBTLESS BAY, NORTHLAND

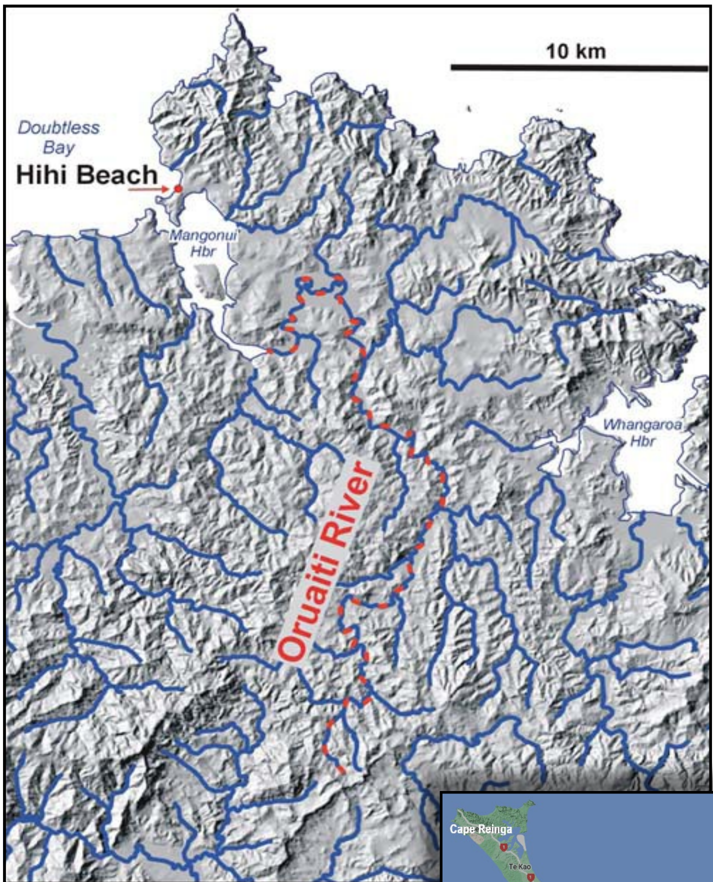
Bruce W. Hayward

In May 2019, a Geoclub party visited Hihi Beach in Doubtless Bay (Fig. 1). We headed to the west end of the beach at low tide to examine the geology in the eroding weathered cliffs. Once we had determined what was the result of the colourful red and orange weathering and what was the original structure, we were able to see that the cliff comprised an eroded cross-section through a paleovalley (Fig. 2) incised into highly weathered Tangihua Complex volcanic rocks (e.g., Isaac *et al*., 1994). The paleovalley itself was filled with fluvial sediment - mostly conglomerate, but also minor sandstone and lignite of the Mangonui Formation (Brook & Hayward 1989).

The Hihi Paleovalley

Age and fossils

Two well-preserved miniature coconuts (*Parajubaea*) have been found in the carbonaceous gravelly sandstone near the base of the valley fill. This strengthens the correlation of these weakly lithified rocks with similar conglomerate and sandstone plus in-situ forests at Coopers Beach, 2 km to the west, which is best-known as the source of numerous fossil small coconuts (e.g., Endt & Hayward, 1997). A pollen flora from minor lignite near the base of the valley fill at Hihi (O04/f6) indicates a Late Miocene (Waiauan-Kapitean, Sw-Tk, 11–5 million years old) age (pers. comm., Dallas Mildenhall 1987).



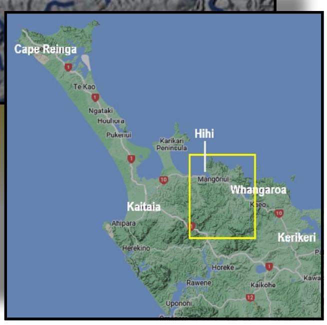


Fig. 1. Location map of the Hihi Beach paleovalley (arrowed) on the southeast shore of Doubtless Bay and the present route of the Oruaiti River, the inferred ancestor of the progenitor of the paleovalley.

Brief description

The paleovalley is at least 20 m deep and 100 m wide, with the base in the centre of the valley just below mid-tide beach level. In the cliff face, the sides of the valley are composed of deeply weathered Tangihua igneous rocks (Fig. 3). Beneath the unconformity is an 8–10 m thick zone of orange weathered clays overlying ~3 m of leached green-white basalt (spilite) before reaching fresh basalt and gabbro.

The fill consists of layers and lenses of rounded cobble and pebble conglomerate and lesser sandstone and mudstone, sometimes carbonaceous (Figs 4–5). Cross-bedded and channelised lenses are present, indicating strong fluvial currents operated at times. Near the base of the valley fill there is a horizon containing subvertical,

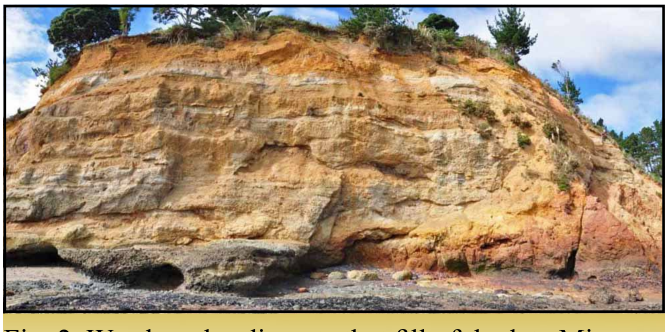


Fig. 2. Weathered sediments that fill of the late Miocene paleovalley incised into Tangihua Complex rocks in the cliff of Hihi Beach. Height of cliff ~20 m.

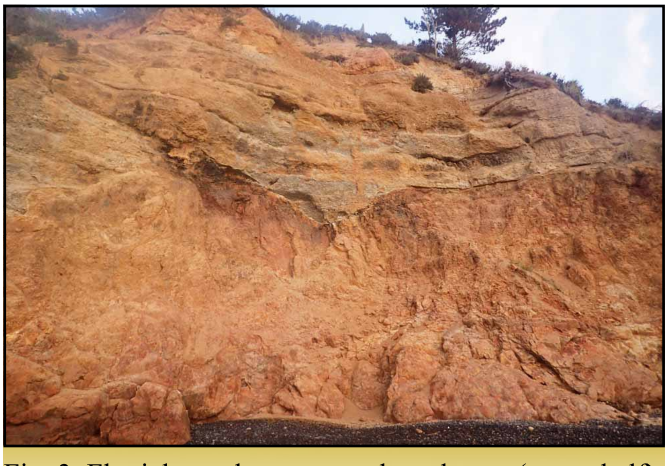


Fig. 3. Fluvial conglomerate and sandstone (upper half) deposited over the highly weathered Tangihua Complex basalt rocks. Height of cliff ~20 m.

carbonised, in-situ roots and stumps (1–5 cm diameter; Fig. 6). Also, at the base of the valley fill, in the lower 5 m of conglomerate, there are a number of botryoidal, cobble-sized nodules of dense siderite (iron carbonate, specific gravity ~4) that presumably grew within these more carbonaceous fluvial sediments (Fig. 7).

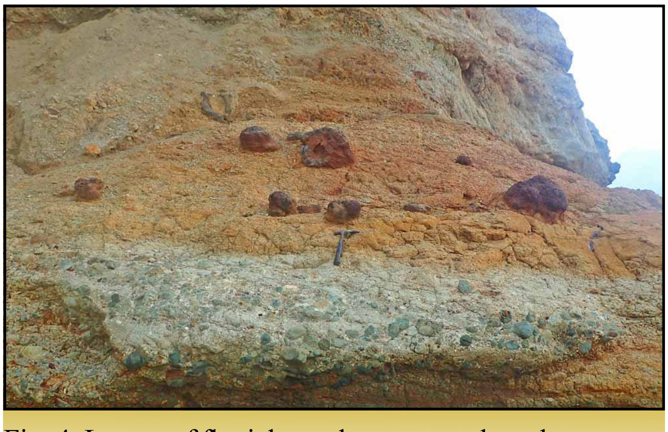


Fig. 4. Lenses of fluvial conglomerate and sandstone in the Hihi paleovalley fill. The large brown clasts are siderite nodules that grew within the sediments after deposition. Rock hammer for scale.

Fig. 5. Carbonaceous sandstone and fine conglomerate within the fluvial paleovalley fill. Hammer handle for scale.

Fig. 6. Carbonised tree stump buried within the lower layers of pebble conglomerate and mudstone.

Conglomerate clast rock types (Fig. 8)
Cobble and pebble clasts in the lower conglomerate lenses provide information on the rock types that were present and eroding in this stream's catchment, ~11–5 million years ago (Table 1).

Table 1. Estimated relative abundance of cobble and pebble clasts in the paleovalley conglomerate lenses.

Grey-green gabbro (rounded-subangular), Tangihua Complex	~50%
Weathered porphyritic andesite (rounded), Wairakau Volcanics	10-30%
Dark-medium grey spilitic basalt (subrounded-subangular), Tangihua Complex	15-20%
Red argillite (angular-subangular), Waipapa Terrane	5-10%
Diorite (subangular), Wairakau Volcanics	0-10%
Cream-grey medium sandstone (rounded), Mangakahia Complex	0-5%
Muddy limestone (subangular-subrounded), Motatau Complex	0-5%
Black argillite/slate (angular-subangular), Waipapa Terrane	0-5%

Fig. 7. Irregular siderite nodules within the lower sediment fill of the Hihi paleovalley.
Photo 1.5 m across.

Fig. 8. Relatively fresh fluvial conglomerate with a wide variety of cobble and pebble lithologies (Table 1).

The degree of rounding of the cobbles and pebbles appears to be related to the strength of the rock types with the hardest (e.g., chert, argillite, diorite) being less rounded than softer lithologies (e.g., sandstone, andesite, gabbro) (Fig. 9).

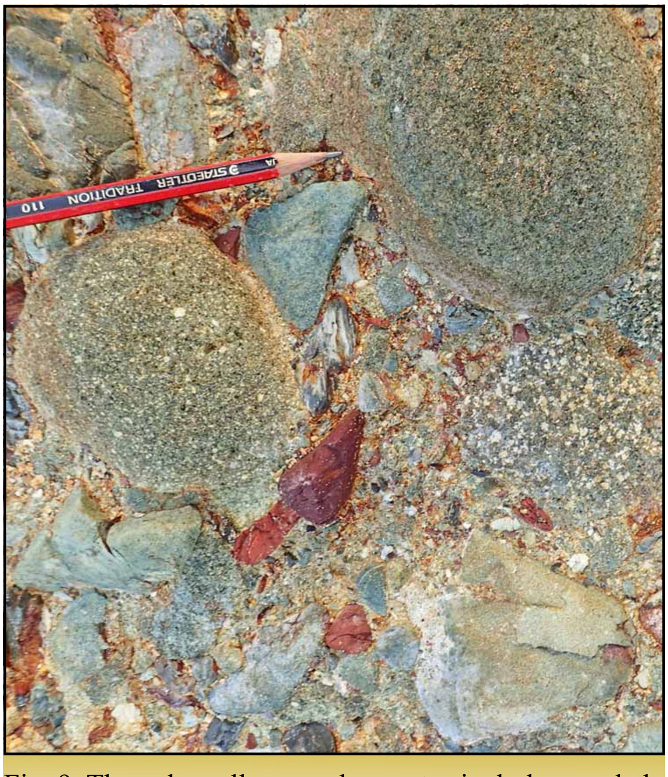


Fig. 9. The paleovalley conglomerates include rounded cobbles of Tangihua diorite and basalt and Wairakau andesite and less rounded, harder pebbles of red chert (Waipapa greywacke) and small pebbles of calcareous mudstone (Motatau Complex).

Not surprisingly, the dominant conglomerate clasts (basalt, gabbro) are derived from Tangihua Complex of the Northland Allochthon, which forms the local paleovalley substrate and the only rock unit that outcrops in the catchment of the eastern Doubtless Bay today. Next most common are the andesite and diorite clasts eroded from the Early Miocene Wairakau Volcanics, which at that time probably extended as an eroding ring plain over some of the paleovalley's catchment. Today the nearest remaining outcrops of Wairakau Volcanics are 10 km to the southeast (Fig. 10).

Lesser numbers of clasts have been derived by erosion of deeper nappes in the Northland Allochthon (Mangakahia and Motatau Complexes) and from the underlying basement Waipapa Terrane. Today the nearest Mangakahia and Motatau rocks outcrop 6–8 km to the west or 12–15 km to the south. The nearest Waipapa Terrane outcrops today are even further away at 20 km to the southeast (Fig. 10).

Paleovalley of Oruaiti River?

The paleovalley is oriented almost north-south across the neck of a narrow peninsula that stretches part way across the mouth of Mangonui Harbour, Doubtless Bay (Fig. 1). Its location and orientation indicate that it is an abandoned route of an early ancestor of the modern Oruaiti River (Fig. 1). The size of the paleovalley suggests that this route may have been short-lived or an accessory flood pathway before it was filled with fluvial sediment. Its size is much smaller than the present Oruaiti River valley.

The modern Oruaiti River flows northwards from its headwaters 20 km to the south near Mangapa (Fig. 1). In doing so, it flows right through the uplifted Maungataniwha Range (Fig. 10) composed of erosion resistant Tangihua Complex volcanic rocks in the axis of the Maungataniwha

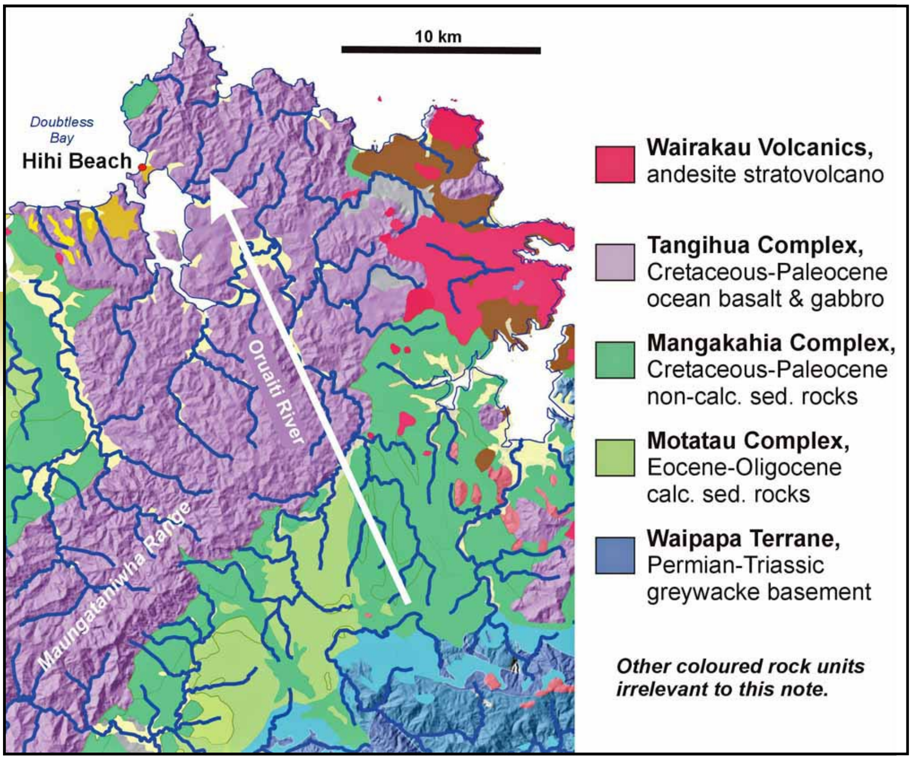


Fig. 10. Geological map in the vicinity of the Oruaiti River catchment today showing the present-day distribution of the main rock types found in the paleovalley conglomerates.

Syncline (Brook & Hayward 1989). This route is contrary to the logical route today that would have been 10 km northeastwards through much softer rocks and into the Whangaroa Harbour. The conclusion is that the Oruaiti River is an antecedent river having maintained its early northwards route by eroding into the hard Tangihua rocks as the Maungataniwha Range was uplifted.

Discussion

How did all these rock types get gathered together in the Hihi paleovalley? As discussed above, the location and orientation of the paleovalley suggest it could have been one of a number of pathways for an ancient version of the present-day north flowing Oruaiti River. This inference appears to be supported by the composition of some of the less common conglomerate clasts at Hihi, especially the basement Waipapa-derived black argillite and red chert, the Mangakahia Complex sandstone and Motatau muddy limestone, and the Wairakau andesite and diorite (Fig. 10).

Assuming that in the Late Miocene, there had been considerably less erosion than today, the projected known geological structure of this region (Brook & Hayward 1989) would not place the Waipapa Terrane basement nor overlying Mangakahia and Motatau complexes any closer to Hihi than they are today. The ring plain of the Wairakau stratovolcano complex more than likely extended a lot closer to Hihi than it does today, unconformably over the top of the Northland Allochthon rocks. This would help explain the relatively greater abundance of andesite in the Hihi conglomerate than allochthon and basement sedimentary rocks.

It is tempting to infer that at the time of the Hihi paleovalley (11–5 myrs ago) land 10–20 km to the south was relatively higher than Hihi and that the ancestral Oruaiti River flowed downslope towards the north. Since then, this northwards flow direction and river valley has been maintained by erosion as the Tangihua rocks of the Maungataniwha Syncline slowly rose and/or the softer allochthonous Mangakahia and Motatau Complex rocks in the nappes beneath the Tangihuas were eroded down. Thus, an origin for the ancestral Oruaiti River at least as early as late Miocene (10–5 myrs) is indicated.

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Return to contents page

ORBICULAR GRANITE: AN UPDATE ON THE MURCHISON BOULDER AND ANOTHER SITE, LITTLE HOHONU RIVER, KUMARA, WESTLAND

Glenys Stace

This article adds to recent information on the orbicular granite boulders of northwest South Island (Kobe 1988, Grapes 1996, Grenfell & Fleming 2016, Hayward & Sagar 2020, Simpson 2021, Hayward 2021 2022,).

Many readers will be familiar with the large orbicular granite boulder (the "Murchison Boulder") that was on display outside the Murchison Information Centre on Highway 6 through Murchison (Fig. 1) (Hayward & Sagar 2020). The Centre has now closed, and the boulder has been repositioned outside the Murchison Museum building on Fairfax Street.

Fig. 1. The Murchison Orbicular Granite Boulder on display outside Murchison Museum.

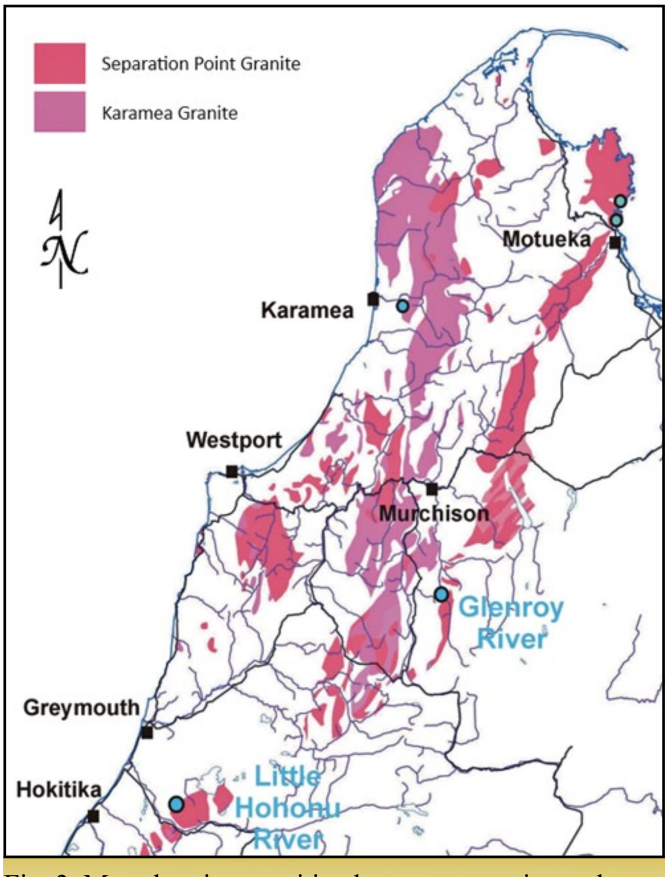

Fig. 3. Map showing granitic pluton outcrops in northwest South Island, the location of our two orbicular granite finds and other known orbicular granite localities (blue dots). Base map from GNS QMap.

A little way further up Fairfax Street is the Ngahere Gallery of Indigenous Art, owned by Mike Loach, who has about 14 specimens of orbicular granite on display (e.g. Fig. 2).

It is moderately well known, especially in the district of Murchison, that the orbicular granite is found in the Glenroy River (Fig. 3). Although pieces have been found as low as Murchison itself, none has been found in the Mātakitaki River higher than its confluence with the Glenroy. An Auckland Geology Club field trip to Murchison area in 2020 included a visit to the Glenroy River and the variety of rocks that can be found there. Unfortunately, the weather didn't permit more than a superficial look at the roaring river and a determination to return!

Fig. 2. Two examples of orbicular granite in Ngahere Gallery. Murchison.

With the consent of the farm owner we drove up the Glenroy as far as was possible without fording the river. There we searched amongst the boulders along the river. We found a boulder weighing about 50 kg (Fig. 4).

Fig. 4. Kelvin Stace extracting the boulder from the Glenroy River sand and the boulder on the river bank.

Fig. 5. Our Glenroy River boulder sliced. Left is the first cut end. Right is the slice. Two dollar coin for scale.

The Little Hohonu River was a new site for us. I located it after seeing a small piece on display in the Hokitika Information Centre. There is also a piece on display at the Heritage Shantytown, Greymouth, in the West Coast Rock and Mineral Society display. After some investigation we contacted John Caygill from Greymouth. John has been fossicking the Little Hohonu River for many years. He has been up to the area of interest at least 17 times and has only found 7 pieces.

After heavy rain and anticipating fresh boulders in the cascading river, we set off up the Little Hohonu from the "first bridge", actually, the second, if approaching from Kumara. The river had gone down and the going was not difficult. We took the right-hand branch (true left) and proceeded as far as possible before turning back. Reaching the confluence, where we had searched on the way up, Kelvin spotted a rock with circles. It is not the best example we've seen from this river but there was no mistaking it (Figs 6 & 7).

Spurred on by another major rain event in Westland, and by our interest, John Caygill went up the river again in early February 2024. He climbed far up the river, about twice as far as we had gone. There at his feet he discovered two boulders, one the largest he had ever seen. Even the smaller one was too heavy to carry out (Figs 8 & 9).

Fig. 6. Our find at the Little Hohonu River (left) and with a boulder from John Caygill's collection from the same river bed for comparison (right).

Fig. 7. A slice (left) and the butt end (right) from the Little Hohonu River boulder collected by the Staces.

There are two points of interest that I think are worth commenting on:

1. The specimen Kelvin and I found in the Hohonu River is undoubtedly orbicular granite but it could be a less developed form than the other examples. All indicate a transitional, possibly edge formation of the orbicules.

2. Both Rivers extend up into Separation Point Granite.

Acknowledgments

I thank Kelvin Stace for his energetic assistance in the field, Mike Loach for his assistance with specimens he has on display in Murchison, John Caygill for his welcoming discussion on the Little Hohonu source area and for sharing his photographs for publication, and Bruce Hayward for preparing the map and other suggestions on the draft manuscript.

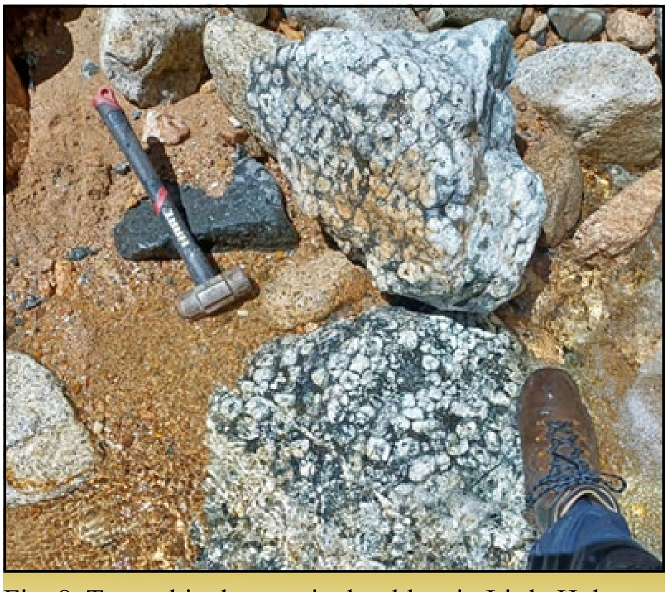

Fig. 8. Two orbicular granite boulders in Little Hohonu River discovered by John Caygill in Feb 2024. Photo by John Caygill.

Fig. 9. A specimen from John Caygill's collection (left) and one found by a local club member on a recent visit.

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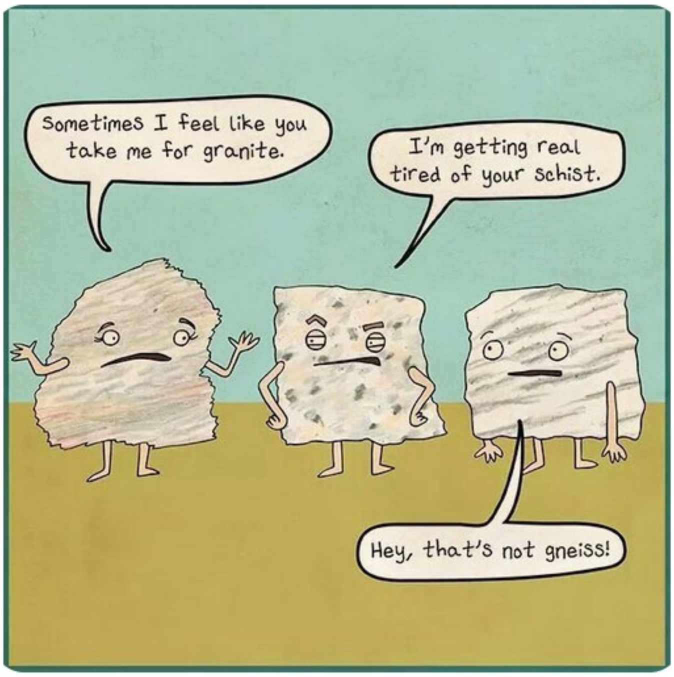
Return to contents page



THE RUSSELL COLLECTION

Hugh R. Grenfell

Introduction

In 1896–97, Thomas Russell (1830–1904) (Fig. 1) gifted the Auckland Institute and Museum (AIM) £100. A year later Russell decided the money should be used to establish a mineral collection from the Hauraki Mining District where he had significant investments (e.g. Figs 2–4). Sometime in 1897–98, the Museum's Curator, Thomas Cheeseman, went to the area and with the help of Russell's agents came back with 1,853 specimens of rocks, minerals and ores, which were split into three collections. He wrote a detailed catalogue of the material, which survives today but only some of the AIM specimens do so.

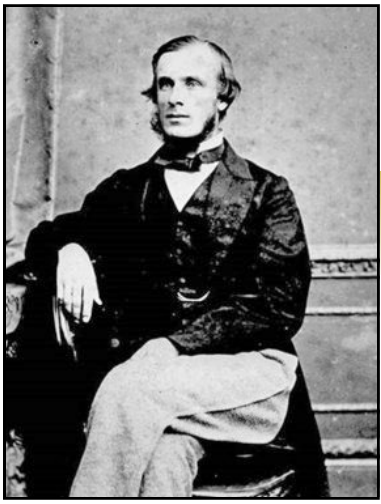


Fig. 1. Thomas Russell as a young man.

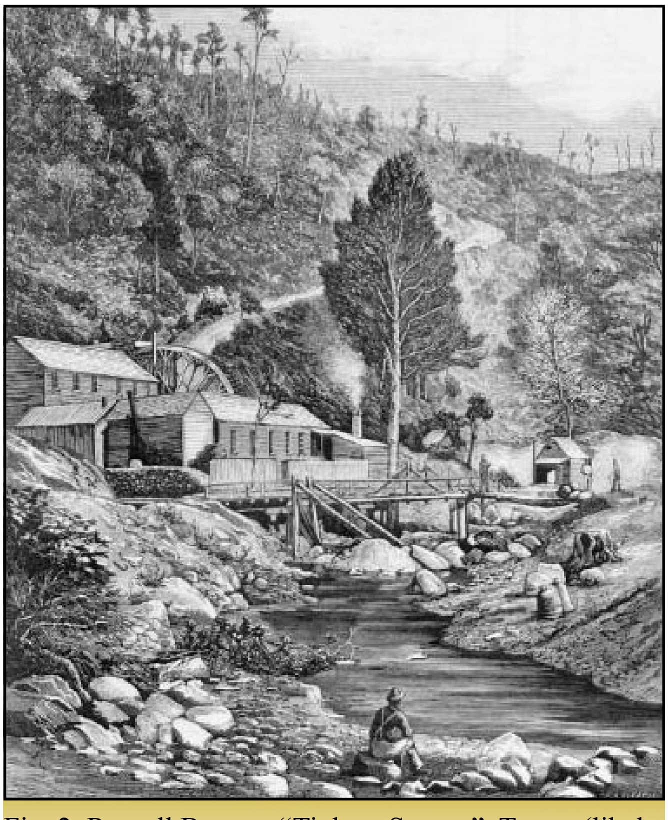


Fig. 2. Russell Battery, "Tinkers Stream", Tararu (likely owned by Russell).
Alexander Turnbull Library.

Working on the Russell Collection

At the end of 2018 and into 2019, I was fortunate to be able to work on the Russell Collection of "Rocks, Minerals and Ores from the Hauraki Goldfields" in the Geology Collections of the Auckland War Memorial Museum.

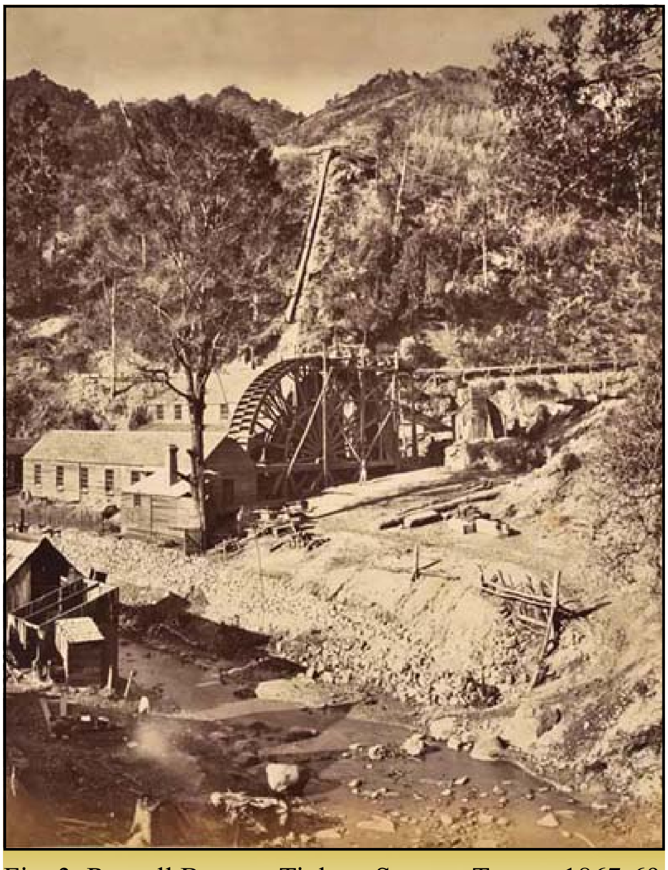


Fig. 3. Russell Battery, Tinkers Stream, Tararu, 1867-69 (likely owned by Russell).
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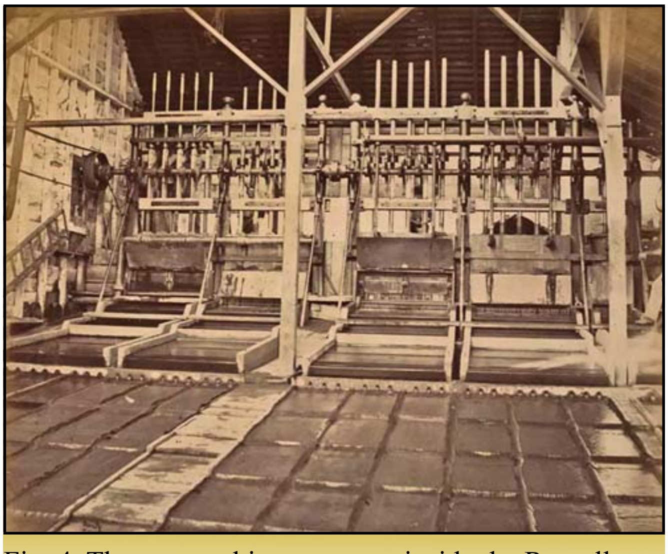


Fig. 4. The ore crushing stampers inside the Russell Battery.
AWMM: PH-ALB-86-p27-1

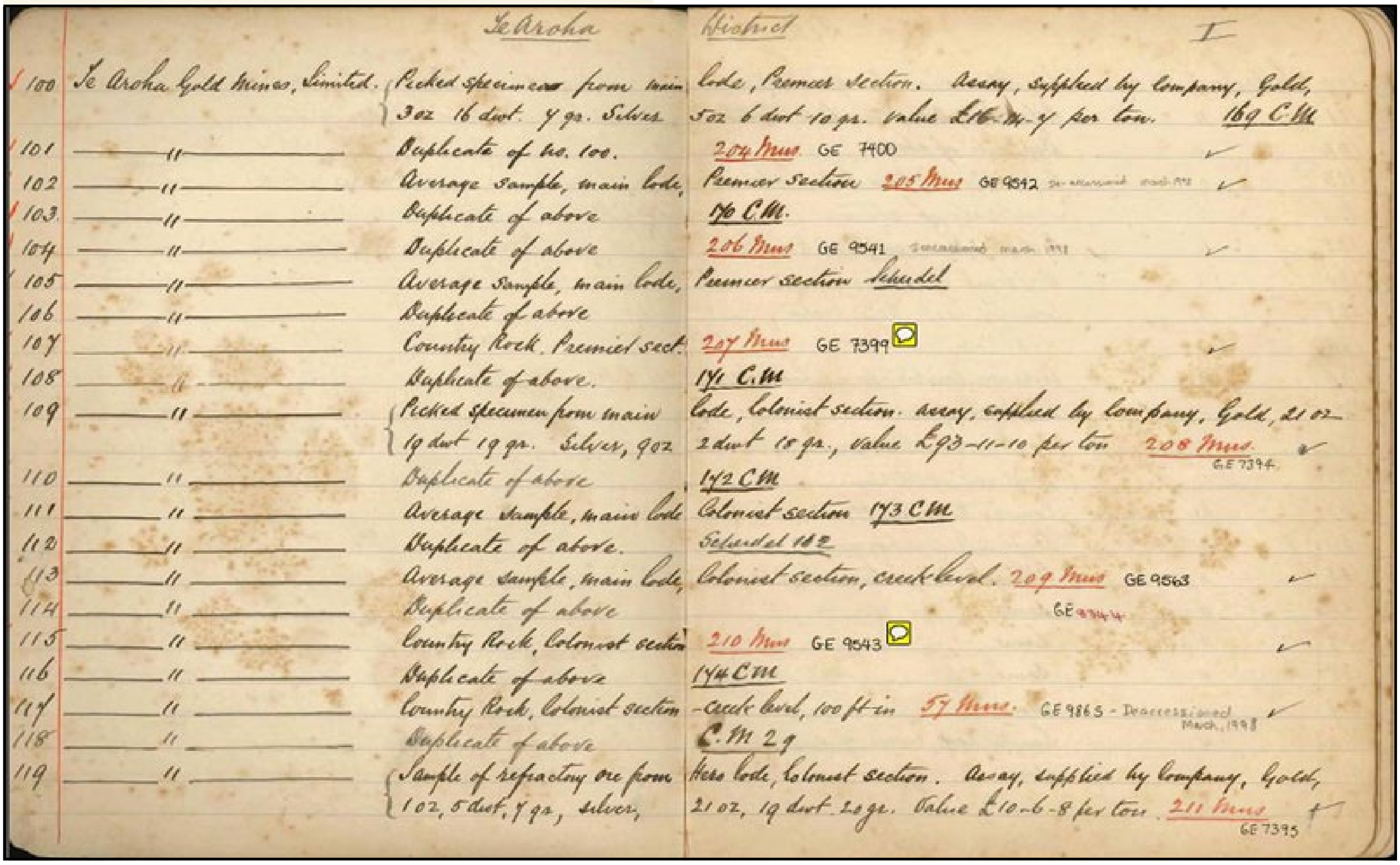
Funding from the Gregory Trust was instrumental in completing the project. Lola Gregory was for many years a GeoClub member. This important collection was acquired by the Museum in 1897–98 and is unique because it provides a snapshot of the then known geology, mineralogy, mining production and mining history across the Hauraki District, and contains specimens from mines and sites that are no longer accessible for research purposes. The Museum's Curator, Thomas Cheeseman (1845–1923), personally went to the various mining districts and came back with 1,853 specimens, which he meticulously catalogued. Ultimately, according to the Russell Catalogue (Fig. 5), as its share the Museum retained 572 specimens. Today we have 315 known survivors. The Gregory Trust funding enabled new work and work previously done by me to be pulled together and the Collection catalogued in much greater detail than before. All new data, including detailed Excel spreadsheets, have been incorporated in the AWMM Vernon database. The entire Geology Collection has been scoured for possible Russell specimens and to rule them in or out as such. All specimens have been rehoused and are now all held together ready for use.

Thomas Russell (1830–1904) – a brief biography

Thomas Russell (Fig. 1) arrived in New Zealand via Australia aged about 10. His father was a farmer and a carpenter at different times; his mother ran a drapery store in Shortland Street, Auckland, at one time. His mother died in 1847 when he was aged 17 (Stone 1990). To further disrupt family life, his father, infected with gold fever, later left New Zealand for the Californian Gold Fields in 1850. Thomas, aged 20, was left behind to be custodian of the family. At that time he was an employee of Thomas Outhwaite, the foremost Auckland lawyer at the time, to whom he had been articled since 1844. Outhwaite Park (Grafton Volcano), on the corner of Carlton Gore and Park Roads just outside the Domain, is named after him. In November 1851, as soon as he was licensed to practise, Russell characteristically asked Outhwaite for a full partnership. When Outhwaite turned him down, he set up in practice on his own. Russell has been politely described as "extraordinarily ambitious".

As a lawyer, Russell cannot be described as one with a social conscience but more one motivated by making money and self. The Radio NZ podcast (Radio New

Fig. 5. Russell Collection Catalogue (cover and example page) written by Thomas Cheeseman.



Te Aroha District I

100 Te Aroha Gold Mines, Limited. Picked specimens from main lode, Premier Section. Assay, supplied by Company, Gold, 3 oz 16 dwt. 7 gr. Silver 5 oz 6 dwt 10 gr. Value £16-14-7 per ton. 169 C.M.
101 " Duplicate of no. 100. 204 Mus GE 7400
102 " Average sample, main lode, Premier Section 205 Mus GE 9542
103 " Duplicate of above 170 C.M.
104 " Duplicate of above 206 Mus GE 9541
105 " Average sample, main lode, Premier section Schedel
106 " Duplicate of above
107 " Country Rock. Premier sect. 207 Mus GE 7399
108 " Duplicate of above. 171 C.M.
109 " Picked specimen from main lode, Colonist section. Assay, supplied by company, Gold, 21 oz 19 dwt 19 gr. Silver, 9 oz 2 dwt 18 gr., value £93-11-10 per ton 208 Mus. GE 7394
110 " Duplicate of above 172 C.M.
111 " Average sample, main lode Colonist section 173 C.M.
112 " Duplicate of above. Schedel 182
113 " Average sample, main lode, Colonist section, creek level. 209 Mus GE 9563
114 " Duplicate of above
115 " Country Rock, Colonist section 210 Mus GE 9543
116 " Duplicate of above 174 C.M.
117 " Country Rock, Colonist section - creek level, 100 ft in 57 Mus. GE 9865 - Deaccessioned March, 1998
118 " Duplicate of above C.M. 29
119 " Sample of refractory ore from Hero lode, Colonist section. Assay, supplied by company, Gold, 1 oz 2, 5 dwt, 7 gr, silver, 21 oz, 19 dwt 20 gr. Value £10-6-8 per ton. 211 Mus GE 7395

Zealand 1) is a damning indictment of the activities of Russell and his contemporaries in, for instance, their part in the promoting the Maori Wars and land speculation (Stone 1990, 2001). His dodgy dealings clearly so incensed one man, Cyrus Haley, that he committed a number of arsons and shot up Russell's Onehunga home (Radio New Zealand 2) at what is now the site of the later Pah Homestead (Monte Cecilia) built by James Williamson (1814–1888). Russell returned to the UK by 1874 but continued to visit New Zealand from time to time to keep an eye on various investments (Stone 1990).

Another significant earlier donation to the Museum by Russell was the plaster replicas of famous classical sculptures in and around the front foyer of the Museum today.

Origin of the Collection

1896–97: Auckland Institute and Museum Annual Report. Russell promises £100 for some "desirable addition" to the Museum.

1897–98: Auckland Institute and Museum Annual Report. Russell is said to decide that his donation "should take the shape of a mineral collection to illustrate the resources of the Hauraki Mining District".

"At the request of Mr. Russell's agents the Curator (i.e. Thomas Cheeseman) has made a tour of visits to most parts of the district, collecting a full suite of specimens, Mr. Russell defraying the whole of the expenses. Over 1,500 specimens have been obtained, and have been catalogued and roughly determined. In a few weeks time the collection will be finally arranged and placed on exhibition. It will include a series illustrating the general geological structure of the whole district; also local collections from the smaller districts, or from groups of mines, showing the character of the "country "rock and the various lodes traversing it; and finally, selected specimens of the various minerals occurring in the lodes or elsewhere." (AIM Annual Report 1897–88).

Once Thomas Cheeseman contacted Russell's agents in the Hauraki Goldfields, he personally went to the Hauraki/Coromandel mining districts (Te Aroha, Karangahake, Kuaotunu, Waihi, Thames, Waitekauri and Coromandel). He came back with 1,853 specimens (some were duplicates), which he meticulously catalogued. They came from many different mines, a number of which have interesting names such as "Midas & Ajax", "Golden Fleece", "Queen of the May", "Non Pareil", "Welcome Find", etc. A couple of typical examples of the nicely made hand specimens are shown in Figures 6a&b. The material was disbursed to 3 parties – the Auckland Institute and Museum (Mus#s), the Auckland Chamber of Mines (C.M.#s) and to Dr August Schiedel (Schiedel#s) – geochemist, innovator and developer of the ore processing plants at Thames. Of the 1,853 specimens, the greatest Mus# Cheeseman used and noted in the Catalogue appears to be 572Mus. So ultimately, according to the Catalogue, as its share the Museum retained 572 specimens. Similar numbers of specimens seem to have been allocated to the Chamber of Mines and Scheidel although some don't seem to have any specific original number except a general catalogue number in the first column of each double page spread. The fate of the Chamber of Mines and Schiedel Collections is unknown.

We are very fortunate to have the original 1898 Russell Collection Catalogue hand-written by Thomas Cheeseman (Fig. 5). It is archived in the Marine Department and a paper facsimile for handling is in the Marine Library. Two digital .pdf versions of the Catalogue have been attached to all records in the Museum Vernon database. One version is "as found" with annotations over the years by various people. The second version has copious comments added in Adobe Reader by me, which identify other specimens not previously noted as held, specimens which have been deaccessioned, and adds further corrections and clarifications to specimens. All this data is in the Vernon database.

Today, of the putative 572 "Mus" specimens discussed in the Catalogue, we have 315 known specimens and also now know conclusively that the Museum stupidly deaccessioned 218 specimens in 1998. Some of the specimens deaccessioned were the only ones from that locality! The difference of 39 specimens are considered to be lost at this stage. A number of specimens have been discovered in the Geology Collection that do not have a specific Mus#, but do appear to have a Cheeseman Catalogue number (the left hand column). These have been assigned to the Russell Collection because their lithology and mineralogy, and the paper number used by Cheeseman on the specimen, matches data in the Catalogue, and they match other specimens seen from the same mine or area. Others appear to have a number matching the list of Mus numbers in the Catalogue index (following p.62) but Cheeseman doesn't appear to have used the number (e.g. 542Mus).

The Collection has been arranged as per Cheeseman's Catalogue, that is by mining district and mine. This correlation between the existing Catalogue and the specimens was considered preferable to some other arrangement (e.g. by lithology) since it facilitates quick access to the original Catalogue data and corresponding Vernon data for any particular specimen or mine if required. Classification has been updated or corrected as necessary. Comments and notes have been added where necessary in the Object

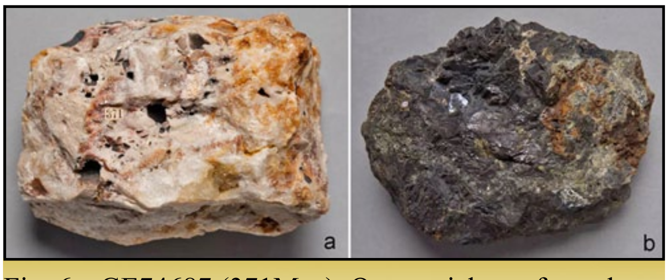


Fig. 6a. GE74687 (371Mus). Quartz rich ore from the Prospect Mine, Kuaotuna. (c. 8cm long).
Figure 6b. GE7522 (249Mus). Sulphide ore from the Golden Fleece Mine, Karangahake (c. 8cm long).

window. Under Identification/Brief Description, notes have annotated and corrected where necessary. Under "Site Details/Site", the data has been streamlined by using a single site number (GL#) for each mine. The different samples from a particular mine and their locations are noted in the "Sites Notes" where their details are unique to that Accession number. In this way dozens of unnecessary duplications of site records (often incorrect or spurious) have been cleaned up. The cleansed sites ultimately used have all been verified and this noted in Vernon. The specimens have all been rehoused in acid free materials and up-to-date labels join any pre-existing labels. The specimens have all been imaged for reference.

The long history of the Hauraki Goldfields has been very complex (e.g. Figs 7–8). Many of the maps and government

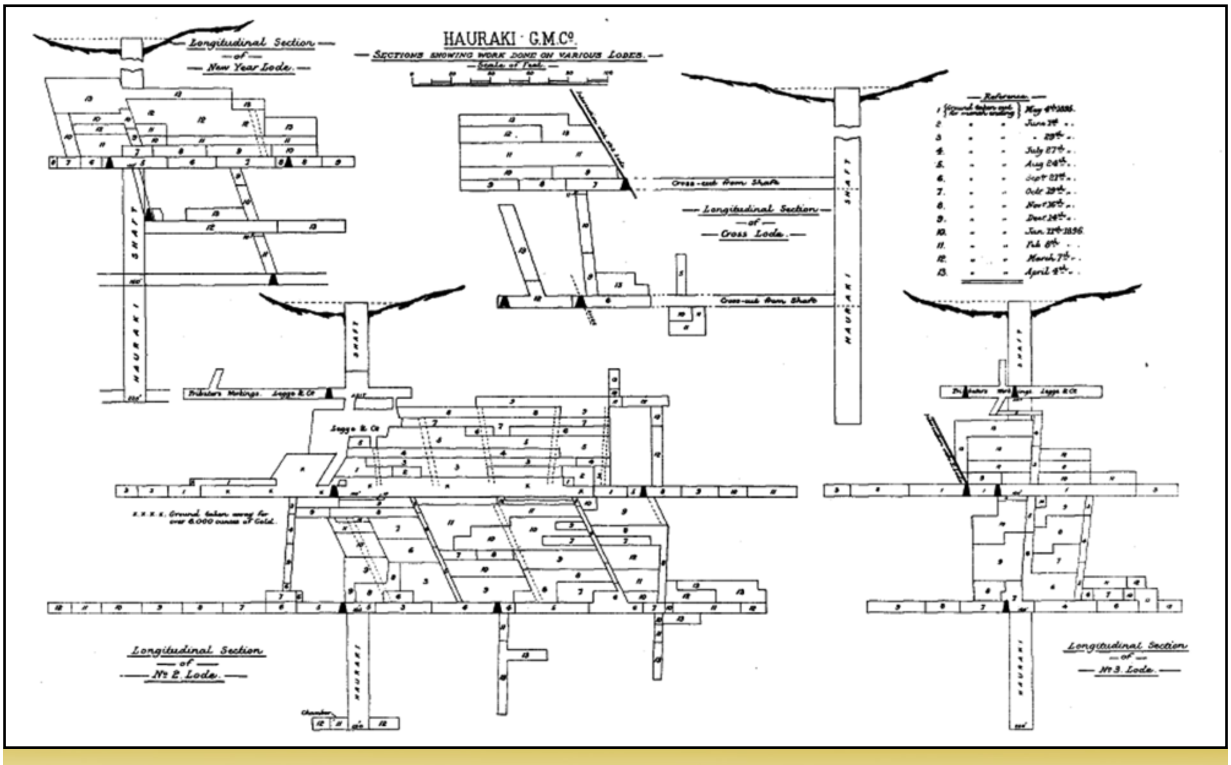


Fig. 7. Sections of the underground workings at the Hauraki Mine, Coromandel 1896.

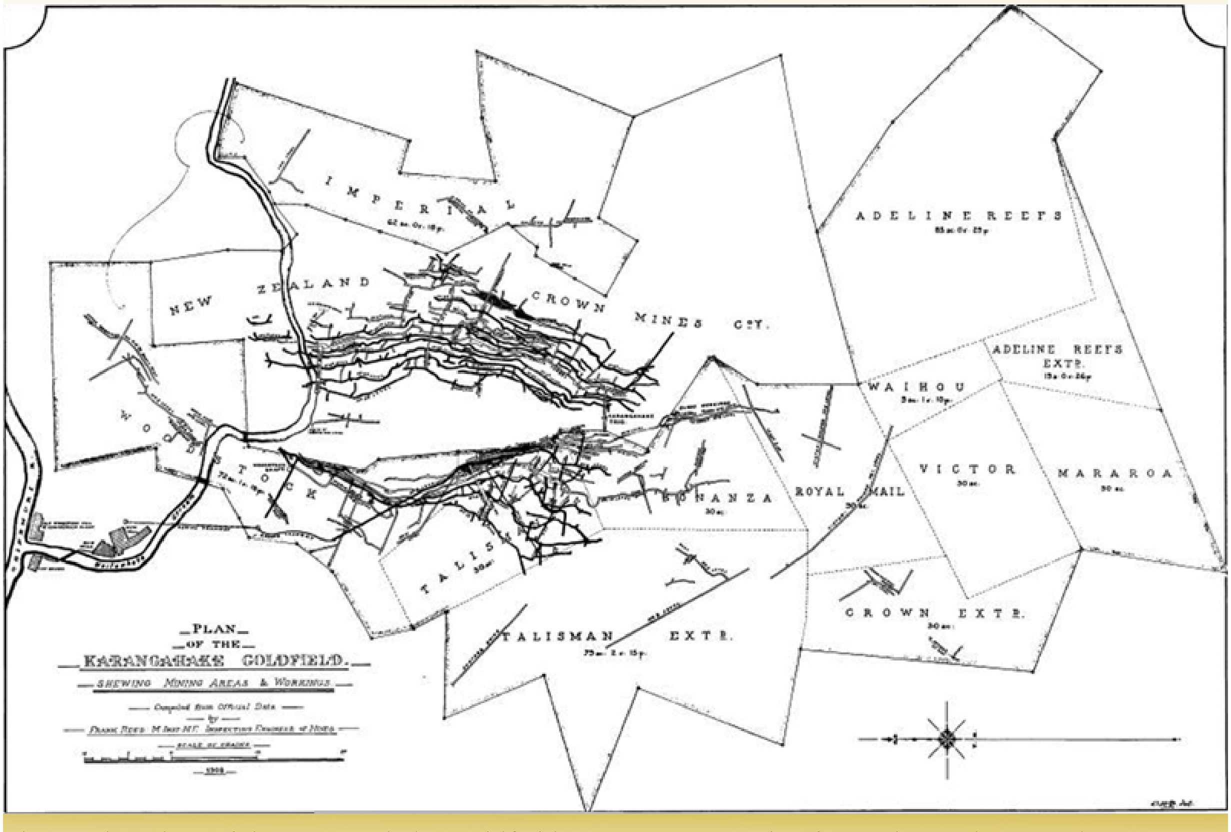


Fig. 8. Plan view of the Karangahake Goldfield 1908 – an example of complex underground

mining reports examined from the late 19thC attest to this (e.g. Government Report, 1896). An invaluable text has been J.F. Downey's "Gold Mines in the Hauraki District" (Downey 1935). Although published sometime after the heyday of the Thames and Coromandel fields, it still provides excellent data and maps to help track down accurate mine locations and claims for this piece of work. It is likely, had more time been available, even more precise site and historical data could have been obtained.

The Collection has been used for research before, but in a limited way due to lack of access at the time and the poor state of the data (e.g. Simpson *et al*. 2011, Simpson 2017). The work done will enable even more detailed and useful geological research to be done. Though mining is unpalatable to some, it is a fact that minerals underlie, and are essential to, all of our current technologies. They will continue to do so even if we can move away from a throw away consumer society with very limited recycling (e.g. cellphones, computers, household appliances, cars, etc.). Increasingly, there are issues around the ethics of the exploitation of minerals in countries that have little or no environmental regulation (usually Third World countries) while we as NIMBYs leave ours in the ground. But are we happy to continue to "consume" at an increasing rate while the environmental cost is someone else's? The Russell Collection continues to be highly relevant today, just as in 1898 when specimens went on display to educate and be of "immense practical importance" (Annual Report 1897–98).

The geological, mineralogical, the complex historical mining information and Russell Catalogue data presented now make this an outstanding research collection as well as being extremely useful for display and education, and is an asset to the Museum. It was a privilege to work on this unique Collection and to bring it fully "into the light".

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Return to contents page

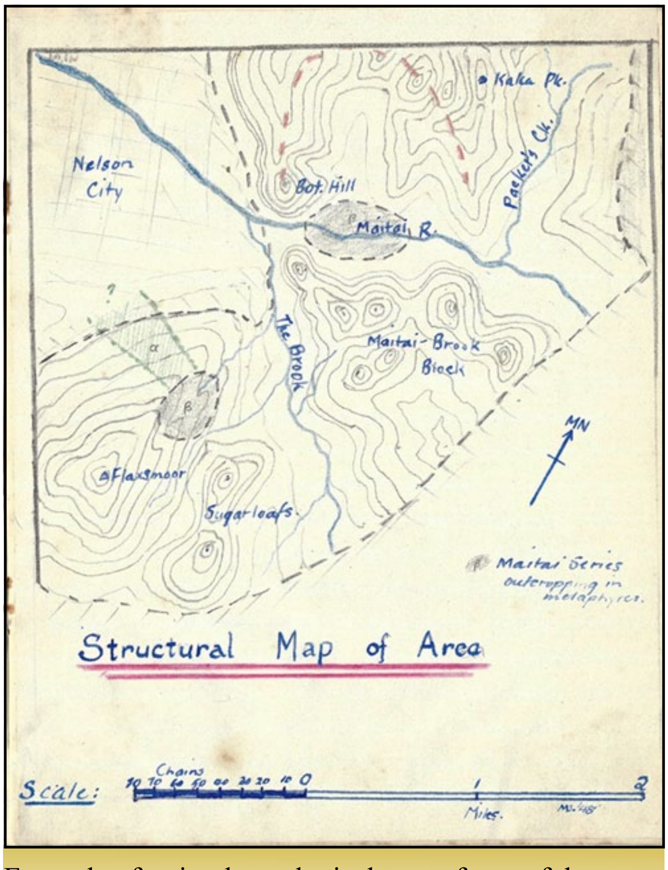
MEMORIES OF MALCOLM SIMPSON (1936–2022), GEOCLUB'S GENTLEMAN–STATESMAN

Bruce W. Hayward & Hugh R. Grenfell

Malcolm Simpson was Geoclub's gentlemanly statesman for 25 years (1994–2020). He joined our group in 1994, soon after its formation, and attended the majority of meetings and field trips, including most of the longer week-long trips outside of Auckland. Only in the last several years did he slow down, as old age made it difficult for him to drive at night.

Malcolm Simpson, in 1948, the year he discovered New Zealand's oldest fossils in the Cobb Valley.

Malcolm was interested in geology from his childhood in Nelson. An example of his early interest is a topographical and geological map he made of the area to the east of Nelson (as seen on his funeral pamphlet). When a 14-year-old at Nelson College, Malcolm had been recognised as a keen young geology enthusiast and joined Professor Noel Benson (Otago University) and Nelsonian Reg Meredith on a field trip to Northwest Nelson. On the afternoon of 14 January, 1948, Reg drove Benson and Simpson to the Cobb Dam where local engineer Eric Heine took Benson and Simpson by boat to the head of the hydro lake. While there the three of them visited several humps of limestone on the floor of Cobb Valley. Malcolm knocked off a piece with his hammer, saw something interesting and handed it to Benson, who initially considered the fossils to be broken Ordovician molluscs (Benson had identified previously recognised Ordovician graptolites in the Cobb). Benson took a few hand samples back to Dunedin and after more careful examination with a microscope contacted Malcolm to say he thought they were trilobites. The specimens were sent to a trilobite specialist in England who identified them and dated the rock as mid Cambrian (Mason & Watters, 1999) – which are still the oldest fossil and rocks in New Zealand. Malcolm was awarded the GSNZ Wellman Prize for a significant fossil find on the 50th anniversary of the event in 1998.



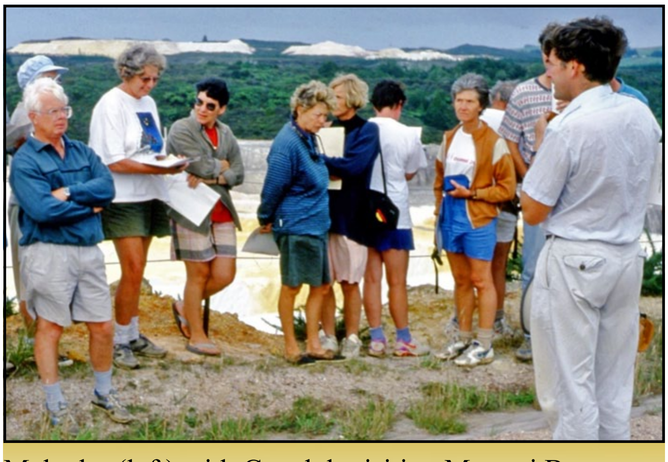
Example of a simple geological map of part of the Nelson area made by Malcolm while still at high school. From Caroline Simpson.

Malcolm at Trilobite Rock with Geoclub in 2007 – his first visit back since his discovery of trilobites there in 1948.

Malcolm talking about his trilobite find while standing on Trilobite Rock in 2007.

A highlight for Malcolm and Geoclub was our 2007 trip to Trilobite Rock in Cobb Valley, north-west Nelson. It was Malcolm's first trip back there since his earth-shattering discovery in 1948. The vegetation had grown up, and he could not recall exactly where the rock was, but fortunately some members of our group could show him.

Malcolm (standing on top of the rock) and Geoclubbers at Trilobite Rock, Cobb Valley in 2007.



Malcolm (left) with Geoclub visiting Matauri Bay in 1995 with leader Roger Evans (right). Others identifiable are Margaret Morley (orange jacket) and Hugh Grenfell (partly obscured by Roger).

With his strong avocational geological background, Malcolm contributed greatly in his relatively quiet way with observations and questions on field trips and at lecture evenings. He also contributed a number of 10-minute talks on a diversity of topics at the club's annual members' evenings: NZ's oldest fossils (1999), fossil rock borers (2002), Geology of Crete (2008), serpentinite (2009), South Island diamond rush (2010), origins of the name porphyry (2011), the Alpine Fault at Lake Rotoiti (2012), identifying amphiboles and pyroxenes (2013), Canterbury offsets (2013), 1844 feast at Mt Hobson (2014) and the discovery of Glossopteris by Scott's party in Antarctica (2016).

As a youngster, Malcolm had been encouraged to take a university degree in natural sciences and geology. As he was finishing High School, Malcolm joined Ian Hayter doing field work for his masters thesis on Great Barrier Island. He told his family he nearly starved on that trip and that Hayter had discouraged him from pursuing a career in geology as there was a lot of maths involved, as well as a lot of travel. Maths was Malcolm's least favourite subject, and he couldn't see how so much travel would work with marrying and raising a family, so, he decided that a career in geology wasn't for him. Instead, he followed a path to accountancy (with even more maths). For all that, Malcolm was a true "Westie" and settled in Glen Eden, which of course had the advantage of being

Malcolm (front right) with Geoclub on Maungarei/Mt Wellington in 2000. Others present are (from left): Glen Carter, Margaret Morley, Garry Carr, unknown, Les Kermode (megaphone), Hugh Grenfell and Murray Baker.

Geoclub trip in the rain around the former sea cliffs of the Auckland CBD in 2007. From left: Warren Spence, Malcolm Simpson, Maureen and Merv Burke (background), Peter Daymond-King, Helen Holzer, unknown, George Wingate.

Malcolm (right) leads Geoclubbers through mangroves in Okura Estuary in 1995. Others identifiable behind him are Helen Holzer (white hat), Margaret Morley (blue hat), Lola Gregory (green shirt) and unknown (white shirt).

proximal to the Waitākere Ranges and the west coast beaches if he felt like indulging in a bit of geology or botany.

Malcolm was also a member of another natural history organisation for a long time – the Auckland Botanical Society. For many years his accountancy skills were handy to Bot. Soc. as their auditor. He was also Treasurer of Northwest Auckland U3A, 2003–2014, and was made a life member of that organisation.

He contributed three articles to the Geoclub magazine, Geocene (see references).

We always enjoyed Malcolm's company and dry sense of humour on field trips around Auckland and beyond. He had had such an interesting life, and had a lot of knowledge and many anecdotes to share (HG particularly enjoyed sharing kindred political views, overseas travel and interesting cars with him). Although we all miss Malcolm a great deal, we are often reminded of his contributions by the presence of his much younger brother Ian and his wife Judy at most Geoclub events, where Ian follows the family tradition with many erudite observations and questions.

Acknowledgments
We thank Malcolm's brother Ian and daughter Caroline for providing additional information and a copy of Malcolm's map (first figure of this article).

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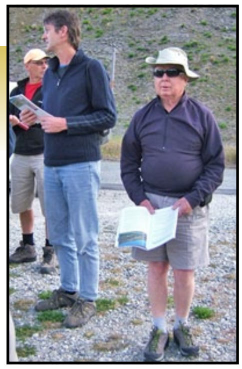
Malcolm Simpson at the Geoclub Christmas BBQ at Muriwai in 2007.

Geoclub lunch at Ohakuri Dam, Waikato, 2009. From left: Colin Christie, Margaret Morley, Rhiannon and Peter Daymond-King, Doug Denize, Malcolm Simpson and Glenda Haeuter.



From left: Mark Robbins, Hugh Grenfell and Malcolm Simpson use Daphne Lee's guidebook to understand the geology on a Geoclub trip at Lake Dunstan, Cromwell in 2009.

Below: Malcolm Simpson (left) on a joint Auckland Geoclub and Whangarei Rock and Gemstone Club field trip to Whakapirau, Kaipara Harbour, 2012. Also recognisable (far right) is joint member Jean Hawkins.

Geoclubbers sheltering from the bitterly cold wind behind the lighthouse at Waipapa Point, Southland in 2012. From left: Liz Hoskin, Peter Turnwald, Maureen Burke, Malcolm Simpson, Margaret Morley, Wendy Goad, Bill Jamieson, Glenys and Kelvin Stace, Trevor Goldschmidt, Kath Prickett, Warren Spence (back).

Malcolm (second from right) with Geoclubbers at Paritu, Coromandel Peninsula in 2014. Others are (from left): Peter Daymond-King, Peter Scott (obscured), Garry Carr, Warren Spence, Jill Kenny (seated), Alastair Brickell and leader Liz Hoskin (right).

Malcolm Simpson (right) with geoclub party circumnavigating Norfolk Island in a small boat in 2015. Also recognisable are Bill Jamieson (left), George Wingate and Christine Major (white hat).

The Discovery of the New Zealand Cambrian

Last year marked the 50th anniversary of one of the most important paleontological discoveries in New Zealand this century.

On the afternoon of 14 January 1948 a Nelson schoolboy, Malcolm Simpson, a member of the party on Professor Benson's first visit to Cobb Valley, knocked a fragment off a low limestone mound on the floor of the valley to disclose indistinct fossils. Those were later identified as Late Middle Cambrian trilobites and represented the first discovery of Cambrian fossils in New Zealand. They are also New Zealand's oldest fossils. Further collecting trips to the locality were made in 1949 and 1950, and an account of those is given by Lillie (1988).

One of the present authors began investigating the history of the first (January 1948) trip about ten years ago and published two short notes on the subject (Watters 1988 and 1991). Recently, contact has again been made with Malcolm Simpson and also with Eric Heine, another member of the party. Both have prodided valuable information on Professor Benson's visit. This is a shortened version of an account originally published in the GSNZ Historical Studies Newsletter 17: 21-29, 1998.

Alan Mason & Bill Watters, 1999: The Discovery of the New Zealand Cambrian. *Geological Society of New Zealand Newsletter 118*: 15-20.

Return to contents page

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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Return to contents page

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