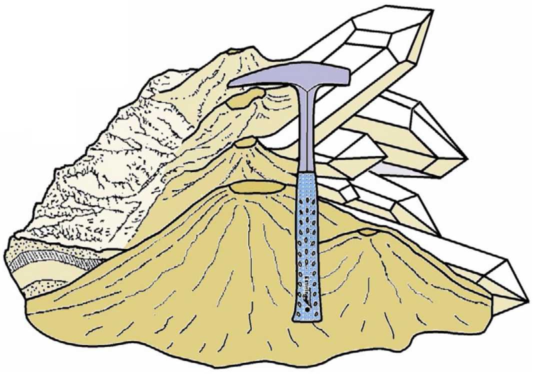

Geocene

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CONTENTS

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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THE CONUNDRUM AT QUEEN VICTORIA ROCK, RANGITOTO, REVISITED

Bruce W. Hayward & Jenni L. Hopkins

Summary

An unbaked slab of shallow-marine mud within lava flows at Queen Victoria Rock on Rangitoto's west coast contains Sydney cockles, radiocarbon dated at 42–35,000 cal. yrs. The slab is inferred to have accumulated as sediment in the mouth of an estuary in the partially flooded Waitemata River channel at 20–50 m below present sea level. It has subsequently been incorporated into Rangitoto lava flows at the time of their eruption and pushed up to sea level by continued pressure from behind. Pieces of Sydney cockle dated herein at 46–42,000 cal. yrs occur in tuff on nearby Motukorea and are inferred to be derived from shelly silt at 25–34 m below present sea level. The conundrum is that if these dates are correct, they would extend the currently accepted New Zealand age range of this locally extinct distinctive species and also indicate a shallower sea level for MIS 3 (60–24,000 yrs ago) than globally accepted. A previous hypothesis that local uplift explained the shallow sea level is rejected through lack of supportive geomorphic evidence. A preferred alternative explanation is that the radiocarbon dates are all minimum ages and the true age of the Sydney cockles is Last Interglacial (MIS 5, 120–80,000 yrs), which is consistent with their accepted local age range and also with the global sea level at that time.

Tuff within the Queen Victoria Rock sediment slab, previously identified as possibly sourced from Onepoto Volcano, consists of a mixture of glass shards that our studies indicate are geochemically most similar to those produced by the first phase of Rangitoto's eruption and Three Kings. These postdate the age of sediment accumulation and suggest that the tuffaceous material may have been injected into the weakly layered soft sediment slab at the time it was being shunted along the submerged sea floor by the Rangitoto lava flow.

Fig. 1. View northwest over the rocks off the northwest corner of Rangitoto, showing Queen Victoria Rock, south of Rangitoto Beacon.

Introduction

In 1985, marine zoologist Steve de Cook discovered fossil mollusc shells (R11/f148) in a large, tilted slab (8 m by 3 m) of stratified sedimentary rock surrounded by basalt lava on Queen Victoria Rock, a small islet just off the west coast of Rangitoto Island, 100 m south of Rangitoto Beacon (Figs 1–2). He showed the shells to Auckland University paleontologist Jack Grant-Mackie, who was excited by the occurrence of the Sydney cockle (*Anadara trapezia*),

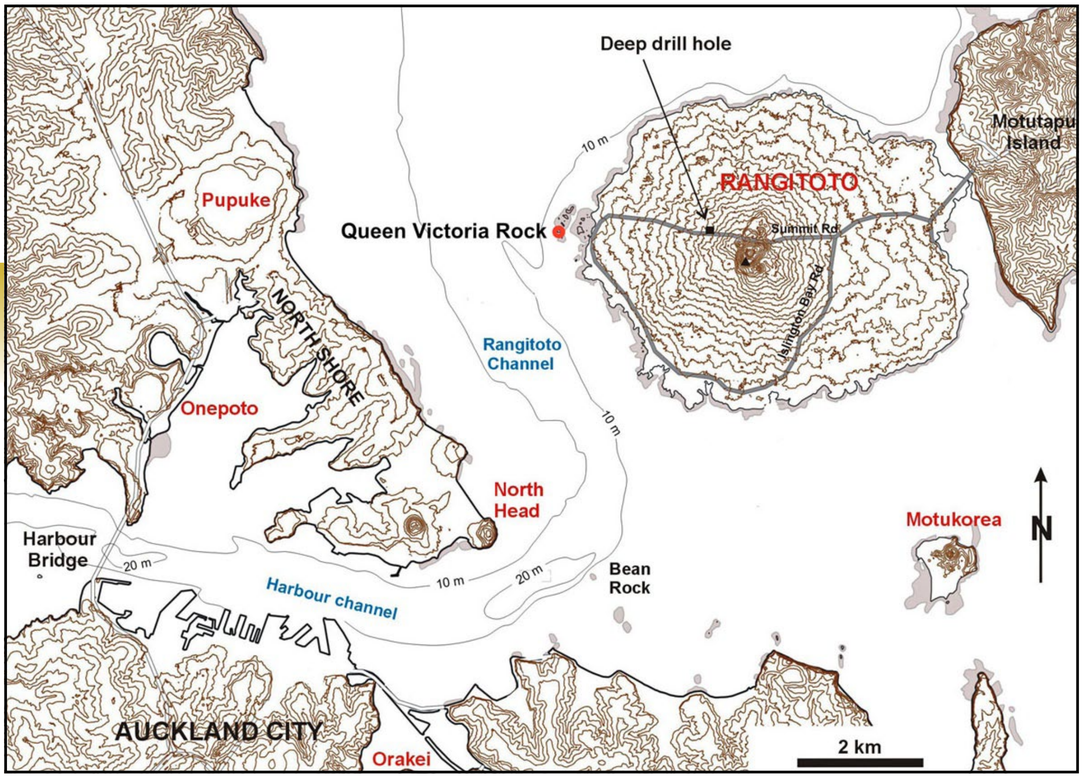

Fig. 2. Map showing the location of Queen Victoria Rock on the west coast of Rangitoto Volcano. Modern bathymetric contours at 10 and 20 m depth below low tide are shown.

Fig. 3. A modern Sydney cockle, *Anadara trapezia*, from Australia. Each shell is about 8 cm across.

which is now locally extinct in New Zealand (Fig. 3). Together they revisited the site and made a larger collection of fossils, examined the geological setting and collected a sample containing volcanic ash (Grant-Mackie & Cook 1990). In 2002, Jack Grant-Mackie led a Geoclub trip back to the west coast of Rangitoto and on the spring low tide several members managed to swim and wade across to the islet to see the exposure for themselves. In 2016, Hugh Grenfell, Simon Baker and one of the authors (BWH) returned to the islet to collect samples of the sediment slab (Fig. 4) and search most of the surrounding coast for any further sediment enclosed within the lava flows. We did find more sediment blocks, but they were mostly red baked, unlike that at Queen Victoria Rock, and might have had a different source and emplacement history (Hayward, 2022).

Extension of local range of fossil Sydney cockles in New Zealand?

Grant-Mackie and Cook (1990) recorded radiocarbon dates on shells of the Sydney cockle from Queen Victoria Rock (R11/f148) of 25,430±990 yrs BP and 37,600±1800 yrs BP. However, in Bryner and Grant-Mackie (1993) it was noted that these two dates were on the same shell and the first date should have been reported as >25,000±1000 yrs BP. In 1991, two further radiocarbon dates were obtained on shells from the Queen Victoria Rock sediment slab of 31,860±500 yrs BP (on *A. trapezia* shell) and 33,950±560 yrs BP (on *Tawera spissa* shell) (Bryner and Grant-Mackie, 1993). These are radiocarbon dates that in more recent times are calibrated using hemisphere and marine/terrestrial specific corrections to provide more accurate results within the range 42,000–35,000 cal. yrs (Table 1).

Fig. 4. Examining the sediment slab at high tide level beside the rock that gives its name to the islet - Queen Victoria Rock.

Bryner and Grant-Mackie (1993) also recorded Sydney cockle fossils in tuff deposits on nearby Motukorea Island. They inferred these were derived by phreatomagmatic eruptive blasts from a shelly silt layer within the underlying sediment-filled, former Tamaki River channel (Fig. 5) which is present at 25–34 m below present sea level in nearby drillholes (Fig. 6). They suggested that the Sydney cockles collected from both Rangitoto and Motukorea were probably of similar age. To test this hypothesis, a piece of Sydney cockle was AMS radiocarbon dated for this study and returned an age of 45,800-42,850 cal. yrs (Table 1).

These cockle ages (46,000–35,000 cal. yrs) indicate that they lived in the Waitemata Harbour during the interstadial (between glacial peaks) period known as Marine Isotope Stage 3 (MIS 3). This would extend the known time of local extinction in New Zealand of the Sydney cockle from 100,000 yrs ago (MIS 5e) (Murray-Wallace *et al*. 2000, Beu *et al*. 2004). Both these authors, as well as Grant-Mackie, were well aware that these dates extended the documented time of extinction. Grant-Mackie & Cook (1990) and Bryner and Grant-Mackie (1993) conditionally accepted these ages, whereas the two later papers dismissed the Rangitoto ages, with Murray-Wallace *et al.*

Table 1. Conventional radiocarbon (CRA) and calibrated radiocarbon ages with 1 sigma error (using Marine 20 calibration curve) of bivalve shells from the sediment slab on Queen Victoria Rock and from the tuff of Motukorea. The analyses were undertaken by the GNS Rafter Laboratory (NZA and INS catalogue numbers).
NZFR No. = New Zealand Fossil Record File number

NZA	INS	NZFR No.	Locality	CRA (yrs BP)	Species	Age (cal. yrs BP)
	R11152	R11/f148	Rangitoto	37,600±1800	*Anadara trapezia*	42,300–39,800
1964	R16051/1	R11/f148	Rangitoto	31,860±500	*Anadara trapezia*	36,000–35,000
1965	R16051/2	R11/f148	Rangitoto	33,950±560	*Tawera spissa*	38,700–37,250
75760	R41778/1	R11/f176	Motukorea	42,592±1895	*Anadara trapezia*	45,800–42,850

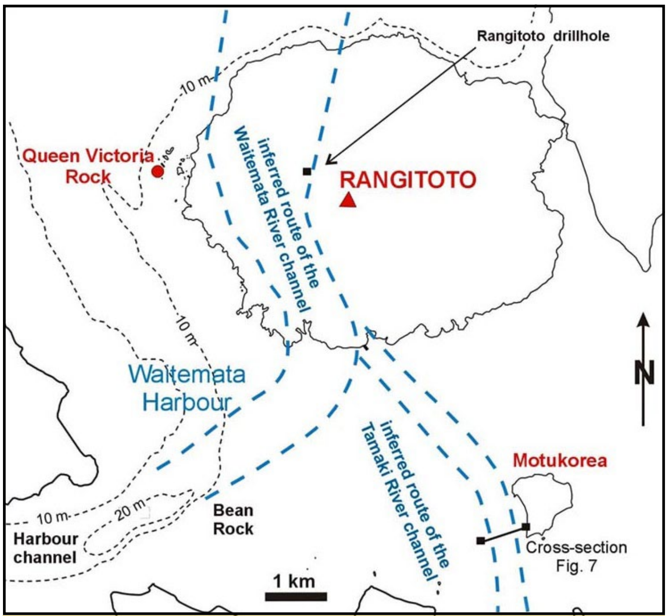

Fig. 5. Map showing inferred route of the Waitemata and Tamaki River channels during low sea levels of the Pleistocene Ice Ages (from Hayward *et al*. 2022). These would have become slightly brackish estuaries when sea level was 15–50 m lower than present.

(2000) stating that all three of the above ages "are now regarded as minimum ages" with no further explanation.

Estimated source elevations of the Sydney cockle at Rangitoto and Motukorea

Sydney cockles live today in highly sheltered, slightly brackish estuaries and bays, at intertidal or shallow subtidal depths (<5 m deep), often in sea grass or even under mangroves. Other fossil shells associated with the Sydney cockles in the Queen Victoria Rock slab (listed in Grant-Mackie & Cook 1990) are all disarticulated and come from a variety of intertidal and shallow subtidal, normal salinity environments, suggesting that the deposit is a mixture of transported shells that possibly accumulated in shallow water on the edge of the open mouth of an estuary.

Microfossil foraminiferal faunas were obtained from two samples from the Queen Victoria Rock sediment slab (R11/f 277, f 278, Table 2). These faunas are dominated by *Ammonia aoteana* (55–76% of the benthic foraminiferal fauna) and subdominated by *Haynesina depressula* (12–26%) and *Elphidium advenum* s.l. (7–17%). Quantitative estimates of the water depth at which these accumulated is 2 m below low tide, with a confidence range of 0–6 m (MAT estimates based on a dataset of over 1000 modern analogue faunas from around New Zealand, e.g., Hayward *et al*. 2022). Modern faunas with the most similar faunal compositions occur inside the shelter of harbours and outer estuaries (Hayward *et al*. 1999).

The Queen Victoria Rock sediment slab occurs within 600-yr-old lava flows and is clearly displaced. A likely scenario is that the slab has been pushed along and up from the sea floor by the front of the Rangitoto lava flow that now encloses it (e.g., Grant-Mackie & Cook 1990, Hayward *et al*. 2022). We infer that the sediment slab was relatively soft sediment that had accumulated on the floor of the Waitemata Channel, which underlies the western side of Rangitoto Island (Fig. 5; e.g., Hayward *et al*. 2022). The reason for this inference is that the mollusc and foraminiferal fossils both indicate the sediment accumulated in sheltered shallows (0–6 m depth), most likely at the mouth of an estuary. Such an environment could only have existed out here in the middle of the entrance to the Waitemata Harbour when sea level was lower than the top of the sides of the drowned Waitemata River channel

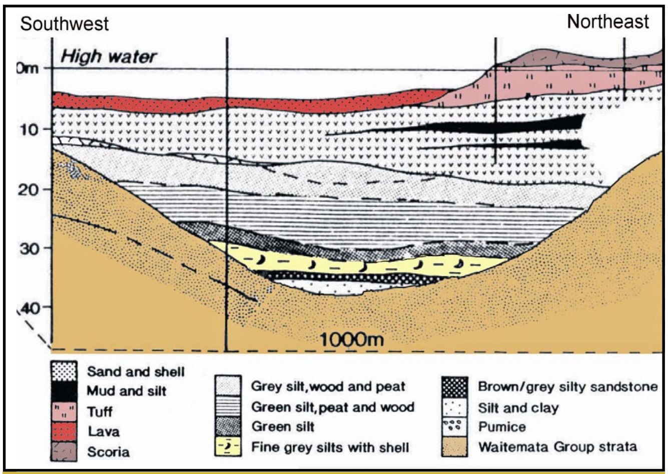

Fig. 6. Northeast-southwest cross-section extending 1 km off the southwest corner of Motukorea to illustrate the subseafloor, sediment-filled, former Tamaki River channel identified by boreholes for the aborted sewerage plant (vertical lines). Modified from Bryner & Grant-Mackie (1993). The shelly silt layer, inferred to be the source of the Sydney cockle fossils in the overlying Motukorea tuff, is coloured light yellow.

Table 2. Foraminiferal percentages in sediment samples from Queen Victoria Rock, Rangitoto.

Sample site, R11/f	f277	f278
Total specimens	88	60
Diversity Fisher Alpha	0.86	2.48
Diversity H	1.01	1.05
Ammonia spp.	55.7	66.7
Bolivina spp.	0.0	1.7
Elphidium clavatum	0.0	1.7
Elphidium advenum s.l.	17.0	6.7
Favulina sp	1.1	0.0
Haynesina depressulus	26.1	11.7
Pileolina radiata	0.0	1.7
Pileolina zealandia	0.0	3.3
Quinqueloculina spp.	0.0	6.7

(lower than ~15 m below present sea level). The incised intertidal and shallow subtidal mouth of the Waitemata River would have been the obvious place for them to thrive.

We do not know exactly what the greatest depth of the Waitemata Channel may have been in the potential source area beneath Rangitoto, but there are clues. Today the deepest part of the partly sediment-filled main Waitemata Channel is 29 m off Bean Rock (Fig. 2) but bedrock is as deep as 39 m below MSL off Devonport Naval Base (Searle 1958, figure 3). Thus 5–8 km downstream, beneath Rangitoto, the base of the channel would likely have been at least ~ 40–50 m. In a stratigraphic drillhole located on Rangitoto 2.5 km east of the Queen Victoria Rock (Fig. 2), the contact between Holocene marine sediment and weathered Waitemata local basement was 28 m below present mean sea level (Linnell *et al.* 2016). We have previously inferred that this was probably on the sloping side of the main channel (Hayward *et al*. 2022). We infer that the cockle-bearing estuarine sediment accumulated within the partially drowned Waitemata River channel at an elevation between 20 and 50 m below present sea level.

Sydney cockles have also been dredged from seafloor sediment in Rangitoto Channel (2–3 km southwest of Queen Victoria Rock) at reported depths of 13–14 m below present sea-level (Grant-Mackie & Cook 1990). This is on the gently sloping shelf above the top of the fluvially-incised slopes of the Waitemata Channel in this vicinity. As explained above, this locality could not have been a sheltered, slightly brackish estuary or bay once sea level was ~15 m below present or higher, and thus the cockle shells dredged from here must have been transported to this locality after they had died. One possibility is that they have eroded out of other slabs of soft sediment that had been bulldozed up out of the channel at the front of the Rangitoto lava flows and may have been subject to marine wave and current erosion since Rangitoto erupted 600 yrs ago.

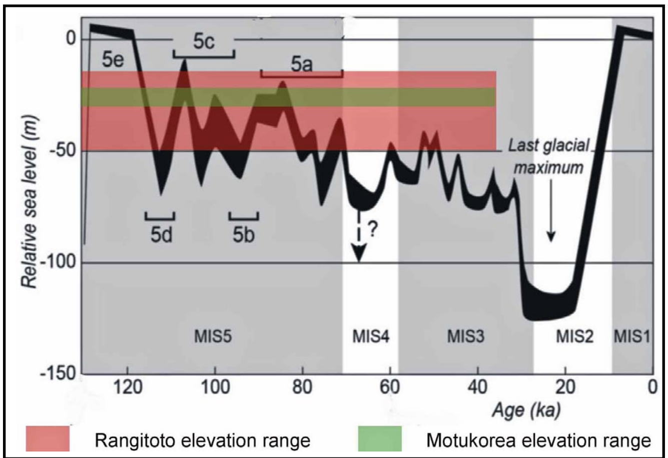

Fig. 7. Global Late Pleistocene sea-level curve based on uplifted Huon Peninsula coral reef sequence (Lambeck & Chappell 2001). Marine isotope stages (MIS) 1–5 are labelled. Warmer periods with higher sea levels have odd numbers and colder periods with lowest sea levels have even numbers. The coloured bands show the estimated elevational range at which the Sydney cockles were deposited beneath Rangitoto (20–50 m below present) and Motukorea (25–34 m below present).

Bryner & Grant-Mackie (1993) reported results from 1950's drillholes around Motukorea Island, 8 km southeast of our Rangitoto locality. In that work, the Tamaki River channel, an upstream tributary of the main Waitemata River, had a maximum recorded depth of 38 m below present mean sea level. Thus, near Queen Victoria Rock, the eroded base of the main harbour channel would not have been any shallower than this, and probably at least ~5–10 m deeper (i.e., ~40–50 m below sea level). The Sydney cockle shells in Motukorea tuff beds are inferred to be derived from shelly silt at 34–25 m below present sea level in the sediment-filled former Tamaki River channel (Fig. 6) (Bryner & Grant-Mackie 1993). This layer overlies non-marine clay and sand and is overlain by wood-bearing freshwater peat and silt (Bryner & Grant-Mackie 1993, figure 2). Thus, the shell-bearing silt appears to record a short-lived high sea-level stand that reached an elevation close to 25 m below present MSL (possibly MIS 5a, Fig. 7).

Do the fossil Sydney cockles indicate higher global sea level or local uplift in MIS 3?

In the 1990s, it was understood that sea level during MIS 3 was no higher than 50–60 m below present (e.g. Chappell & Shackleton 1986) and this posed a problem as to how the shallow-water (intertidal to ~5 m) *Anadara*-bearing sediments got to their present elevations of 25–34 m below sea level at Motukorea (Bryner & Grant-Mackie 1993), high tidal at Queen Victoria Rock (Grant-Mackie & Cook 1990) or dredged from 13–14 m below sea level in Rangitoto Channel (Grant-Mackie & Cook 1990). After considering several options, these authors plumped for an explanation of fault-related uplift of the area of >30 m in the last 35,000 yrs. We would argue that any significant tectonic uplift (>~1 m) in this short period is not supported by the geomorphology of the coast surrounding the Waitemata Harbour nor of the Waitemata Harbour itself, both of which are supportive of relative tectonic stability of the region at the present time (e.g., Searle 1959, Ballance 1968, Beavan & Litchfield 2012, Hayward 2017).

More recently, a revised sea-level record for MIS 3 (57,000–29,000 yrs ago) has been obtained from the uplifted reefs of Huon Peninsula, Papua New Guinea (Chappell 2002) and modelled from the marine-based oxygen isotope records of global ice volume from the Red Sea (Grant *et al*. 2012). These and other studies indicate that sea level fluctuated between 60 and 100 m below present during MIS 3 (Murray-Wallace *et al*. 2021), although several studies have suggested short-term (1000–2000 yr) episodes when sea level rose to 40–50 m below present (Yokoyama & Esat 2011, Pico *et al*. 2016). No currently accepted curves have sea level as shallow as 35–25 m below present sea level at any time during MIS 3, the depth indicated by the Motukorea occurrence.

Possible resolution to the conundrum

The Queen Victoria Rock slab and dated shells appear to be remarkably similar to a situation with fossil marine shells from ~25 m water depth in a core from South Australia. Here, radiocarbon dates led Cann *et al.* (1988) to infer a much shallower sea level in MIS 3 than generally accepted. Thirteen mollusc shells have returned radiocarbon dates between 48,000 and 36,000 cal. yrs BP, but a new technique, amino acid racemization dating, has been used on the shells of associated foraminifera giving an age of 77,000±7000 yrs (Murray-Wallace *et al.* 2021). This equates to the end of the Last Interglacial period (MIS 5a), which is known to have had global sea levels this shallow (Fig. 7). In their recent summary paper, Murray-Wallace *et al.* (2021) conclude that all the molluscs from this core are older than the limits of detection by radiocarbon dating and that their MIS 3 dates are minimum ages resulting from contamination by trace levels of modern radiocarbon. Although we have not tried to date Rangitoto or Motukorea shells using amino acid racemization technique, we suggest that the South Australian explanation is also the likely resolution to the Rangitoto and Motukorea Sydney cockle conundrum. The likely true age is Last Interglacial, either MIS 5a, 5c or 5e (130,000–80,000 yrs old) when sea level was similar to that indicated by our fossils (Fig. 7).

Source of the volcanic ash in the sediment slab from Queen Victoria Rock

Grant-Mackie & Cook (1990) recorded black volcanic grains (ash) within some of the sediment slab layer at Queen Victoria Rock (Figs 8–9). They recognised that the sediment was older than the Rangitoto lava that surrounded the slab and thus that the ash was unlikely to have come from Rangitoto. XRD analyses of volcanic grains from this deposit were undertaken by Terry Sameshima (in Grant-Mackie & Cook 1990) and its mineral composition compared with several of the surrounding young Auckland volcanoes. Using this limited dataset, Sameshima concluded that the best match was with ash from Onepoto Volcano, which at that time was thought to have erupted 60–40,000 yrs ago (Searle, 1964). In the last two decades, our knowledge of the geochemistry and age of Auckland's volcanoes has grown immensely, and we now know that Onepoto erupted ~185,000 yrs ago and 31 of Auckland volcanoes erupted during the MIS 5 and 3 periods - the dated and inferred ages of the associated Sydney cockles (Hopkins *et al.* 2021).

With all the newly available data on the geochemistry of individual Auckland volcanoes (e.g., Hopkins *et al.* 2017), we took the opportunity to analyse a selection of 16 volcanic glass shards from a fine volcanic pebbly sand layer in the Queen Victoria Rock slab (AU21503, Table 3). The glass shards were a heterogeneous group with numerous phenocrysts and of scoriaceous character. Chord similarity coefficient was used to compare the major element chemistry of these shards with >1000 analyses of tephra samples from the majority of Auckland volcanoes (dataset from Hopkins *et al.* 2017). The major element chemistry of 11 of the glass shards closely match those from AVF 24 (Rangitoto phase 1 eruption, 600 yrs ago) and three closely match AVF 12 (Three Kings, 28,500 yrs ago, Hayward & Hopkins 2019). The other two are less diagnostic. None of the analysed glass shards are anywhere near a close match with any of the volcanoes that erupted during periods of higher sea level of MIS 5 and 3. The logical conclusion is that the glass shards in the Queen

Fig. 8. A rib of more erosion-resistant tuffaceous sediment (brown colour) sticks up above the background level of the shore platform and through the loose basalt rocks that lie everywhere on Queen Victoria Rock islet.

Fig. 9. Close up view of the more tuffaceous, shelly horizon within the sediment slab on Queen Victoria Rock. Photo 50 cm across.

Victoria Rock slab are a mix from several sources that erupted after the sediment was deposited. A possible explanation could be that soon after the phreatomagmatic Rangitoto 1 eruption, 600 yrs ago, the Waitemata Channel floor may have been awash with abundant volcanic ash and that as the sediment slab was bulldozed along and up, some of this ash was somehow injected along a bedding plane fracture in the older sediment. At that time the most common volcanic grains would have been from the recently erupted Rangitoto phase 1. Of the other volcanoes in the field, the one known to have erupted the largest quantity of volcanic ash was Three Kings volcano (Kermode 1992, Kereszturi *et al*. 2014) and most of it was blown in a northeast direction towards the Waitemata River catchment and erosion of this could conceivably explain our result.

Table 3. Average and 2x standard deviation values for analysis of major elements in 16 glass shards from the sediment slab at Queen Victoria Rock; H_2O_D* water and volatile calculated by difference. Analyses for individual shards are given, recalculated as water free. Those most similar to shards from eruption AVF24 (Rangitoto I) and AVF12 (Three Kings tephra) are labelled as such in column 1. Two samples that are unable to be clearly fingerprinted by majors geochemistry are labelled indet.

Sample No.	SiO_2	TiO_2	Al_2O_3	FeO	MgO	MnO	CaO	Na_2O	K_2O	Cl	H_2O_D*
AU21503											
Average (n=16)	45.19	3.65	15.13	11.84	0.16	5.62	12.76	4.14	1.51	0.04	1.13
Standard deviation	0.72	0.39	2.38	1.81	0.11	2.80	3.67	1.32	0.54	0.02	1.06
AVF24	45.45	3.58	15.55	12.19	0.14	5.08	12.10	4.33	1.58		
AVF24	45.30	3.60	15.62	11.56	0.17	5.29	12.77	4.14	1.55		
AVF24	45.44	3.66	15.83	11.85	0.15	5.01	12.26	4.22	1.58		
AVF24	45.12	3.62	15.67	12.45	0.11	4.93	12.17	4.36	1.57		
AVF24	45.42	3.70	15.75	11.65	0.26	4.94	12.39	4.31	1.58		
AVF12	44.29	4.17	14.29	9.66	0.05	6.94	16.57	3.03	0.99		
Indet.	44.54	3.17	14.30	12.91	0.16	8.76	10.91	3.98	1.38		
AVF24	45.62	3.64	16.13	11.58	0.20	4.71	11.93	4.49	1.70		
AVF24	45.46	3.51	15.54	11.96	0.13	5.04	12.22	4.57	1.57		
AVF12	45.43	3.54	11.70	9.99	0.15	8.62	17.17	2.50	0.90		
AVF24	45.32	3.76	15.59	12.29	0.11	4.82	12.09	4.36	1.65		
Indet.	44.82	3.79	16.19	13.03	0.26	4.11	10.53	5.25	2.02		
AVF24	45.34	3.65	15.57	12.39	0.15	4.84	11.98	4.45	1.63		
AVF24	45.33	3.61	15.70	12.38	0.13	4.83	11.87	4.51	1.63		
AVF24	45.15	3.62	15.43	12.01	0.24	5.18	12.40	4.44	1.55		
SVF12	45.06	3.68	13.28	11.52	0.14	6.88	14.75	3.44	1.25		

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THE WIDE DIVERSITY OF CLASTS IN PIHA CONGLOMERATE AT SOUTH PIHA

Bruce W. Hayward

The Auckland Geology Club has visited South Piha on a number of occasions over the past 30 years and each time we always stop at the west-facing cliff at the south end of the beach (Figs 1–2) to examine the nature of the bedding and the diversity of cobbles and pebbles present in the Piha Formation volcanic conglomerate that forms it. The conglomerate has stratification in the order of centimetres to decimetres apart, produced by horizons of cobbles and pebbles, and rarely boulders (Figs 3–4). These horizons of larger clasts are interpreted to be lag deposits dropped on the bathyal slopes of the Waitakere Volcano by passing debris flows (Allen *et al*. 2007, Hayward 2017). Also present in this exposure are lenses and shallow, erosional channel fills of coarse volcanic sandstone and grit (Fig. 3), sometimes with low angle cross-bedding. These features suggest that the depositional site was swept by strong bottom currents as the currents passed around the large submarine Waitakere Volcano impediment.

The dominant size of the larger clasts is pebble (4–64 mm greatest length) but cobbles (6.4–25.6 cm) are not uncommon and boulders (>25.6 cm) are rare. These larger clasts are mostly rounded, subrounded or subangular in shape with uncommon well rounded or angular clasts (Figs 4–6). The majority of cobbles and pebbles are hard

Fig. 1. South end of South Piha beach showing the study cliff nearest the camera.

Fig. 2. Western face of the study cliff, South Piha.

Fig. 3. Portion of the South Piha study cliff (photo 3 m across) showing the flat-lying stratification, lensing volcanic sandstone unit, and cobble and pebble volcanic conglomerate.

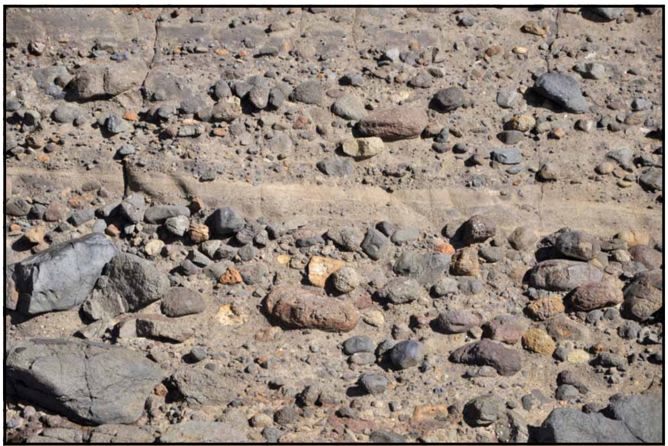

Fig. 4. 1-m-wide section of Piha Conglomerate at South Piha showing some of the wide diversity of volcano-derived cobbles and pebbles within it.

Fig. 5. 50-cm-wide section of Piha Conglomerate at South Piha showing some of the wide diversity of volcano-derived cobbles and pebbles within it. The light-coloured clasts are devitrified pumice lapilli.

andesite and basalt lithologies and it is unlikely that they would have received much abrasion or rounding during debris flow transport. Thus, I infer that the degree of rounding is inherited from the clasts' earlier history. All would have begun as angular clasts and the degree of rounding likely reflects the harshness or amount of time they spent in their source environments, such as in streams on a volcanic island or in the wave zone around the island's shore.

The cobbles and pebbles have a wide range of colours from dark and medium grey to red oxidised, cream, or rusty orange (Figs 4–6). Since these colours are restricted to individual clasts and do not pass from the clasts into the fresh matrix, I infer that the colour of the clasts is also inherited from their original composition or pre-debris flow transport environments. The different grey colours reflect the variety of andesitic and basaltic andesite compositions of the original lavas, and whether the clasts are derived from rapidly chilled outer parts of flows or more slowly cooled inner parts. The red oxidised clasts (Figs 5–6) likely acquired this colour as the iron minerals in the lava were cooling and solidifying in a subaerial environment. The cream coloured, smaller clasts (Figs 5–6) appear to be devitrified pumice that was produced by more gaseous phases of phreatomagmatic eruptions. The rusty orange clasts (Figs 4–5) were probably weathered and oxidised subaerially or in the intertidal zone prior to transport.

The clasts also have a wide diversity of textures. Some are fine-grained and almost glassy (Fig. 4), having formed by rapid cooling on the outside of lava flows or dikes. Others are coarsely speckled (Fig. 5) as a result of large white plagioclase crystals that have formed as the lava cooled slowly, either in an intrusion or thick lava flow. Smaller crystals of dark augite are also commonly visible. Most pebbles and cobbles are dense, but a few are slightly vesicular or scoriaceous, reflecting a greater quantity of gas trapped in the lava as it solidified.

For me, the most interesting clasts are the rare, rounded or subrounded boulders of volcanic breccia (Figs 7–10). These indicate that some of the debris flow material was derived from older, somewhat lithified volcanic rocks that had probably been buried and were now eroding or slumping off the volcano. These breccia boulders would not have been as hard as the solid andesite clasts, and their rounding could conceivably have been produced during debris-flow transport or could be inherited from a short pre-transport period in a stream bed or on the shore.

The four boulders illustrated in this note exhibit different levels of pre-transport weathering and development of a rusty-orange oxidised iron zone around them. The boulder in Figure 7 (also in bottom of Fig. 3) is relatively fresh and grey with only minor iron oxidation. A thin, dark brown, limonite/goethite crust completely encircles the boulder and has also developed along several fractures within the boulder (Fig. 7). This crust is probably a fairly recent weathering feature that has formed long after

Fig. 6. 60-cm-wide section of Piha Conglomerate at South Piha showing some of the wide diversity of volcano-derived cobbles and pebbles within it.

Fig. 7. A rounded boulder of fresh volcanic breccia within the Piha Conglomerate at South Piha. Photo 1 m across.

Fig. 8. A rounded boulder of partly-weathered volcanic breccia within the Piha Conglomerate at South Piha. The larger boulder (on left) has acted as a block stone and the weathered boulder has been trapped behind it at a steep angle. Photo 1.2 m across.

deposition. A similar thin dark brown crust also encircles the other three breccia boulders (Figs 8–10).

The three boulders in Figures 8–10 all have orange rusty weathering that has penetrated well inside them and appears to have been inherited from a pre-transport, subaerial environment. Figure 8 boulder retains a relatively fresh, grey central portion on one side, which suggests that the left side of that boulder has possibly suffered erosional loss, possibly during transport. The weathered boulder has come to rest at a steep angle against an even larger grey boulder. It would seem that the larger boulder came to a stop first and the weathered one has been blocked by it and come to a stop against it. Figure 9 boulder is uniformly rusty weathered throughout, reflecting a greater degree of pre-transport weathering than the others.

Fig. 9. A rounded boulder of fully weathered volcanic breccia within the Piha Conglomerate at South Piha. Photo 1 m across.

Fig. 10. A subrounded boulder of partly weathered volcanic breccia with a fresh core stone inside within the Piha Conglomerate at South Piha. The square cross-section reflects the original fractures that weathering was advancing inwards from, prior to debris-flow transport. Photo 1 m across.

Figure 10 boulder is the most amazing as it has a square cross-section with slightly rounded corners and a circular, fresh, grey inside surrounded by the rusty weathered zone. This is strongly suggestive of core stone weathering prior to transport. In this instance the breccia has become lithified and a rectangular set of joints developed through it. It has been at or near the subaerial surface of the volcano for some time, as oxidative weathering has penetrated inwards into the block from all the surrounding fractures. Miraculously, this block has broken free from the surrounding blocks or soil and been carried along in the debris flow down the submarine slopes of the volcano intact. Modern cliff erosion is cutting back through this core stone block, revealing its internal secrets.

Summary

The Piha Conglomerate at the south end of South Piha contains a wide diversity of cobbles and pebbles which, together with the nature of the stratification, tells us a good deal about their Waitakere Volcano source. This is significant since most of the volcano has now been eroded away and its stump is hidden beneath the Tasman Sea. The oxidised red clasts tell us that some of the eruptions occurred subaerially, and the rusty weathered clasts also confirm the existence of a volcanic island or islands in the source vicinity. The rounding of most of the clasts attests also to the presence of high energy environments such as boulder beaches or island streams in the source area. The presence of fresh and partly weathered boulders of volcanic breccia, and even a core stone, indicates that in the source area an older, more lithified part of the volcanic island was also being eroded.

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QUIZ Know your mountain profiles.

Match photos A – G with names 1 – 7.

(Answers on last page)

Names to choose from are:

1. Mt Cargill, Dunedin
2. Mt Hikurangi, East Coast
3. Mt Hikurangi, Northland
4. Mt Kaukau, Wellington
5. Mt Somers, inland Canterbury
6. Mt Taranaki, Taranaki
7. Mt Ngauruhoe, Central Plateau

A

B

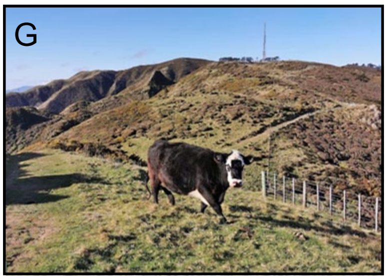
C

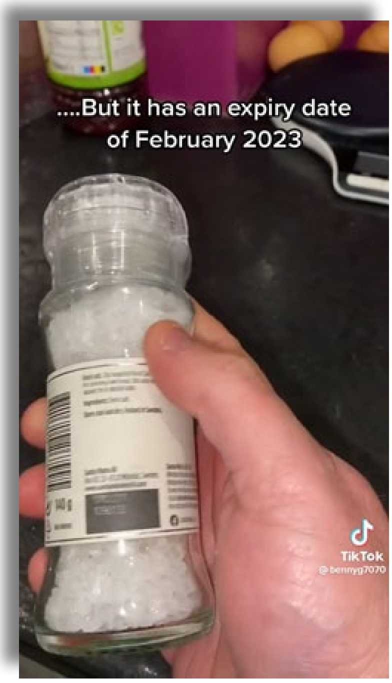
D

E

F

G





FOSSIL FAECAL PELLETS IN FOSSIL *JANTHINA* FOUND AT KAAWA BEACH, AUCKLAND SOUTHWEST COAST, EARLY PLIOCENE (5.3–3.7 MYR OLD)

Glenys Stace

Introduction

In February 2022, I was fortunate to be invited on an expedition to Kaawa Beach, an expedition to follow up our very fruitful Geoclub expedition led by Nathan Collins. With a new variation of Covid restricting movement and group socialising, my husband Kelvin and I were pleased to have an outing that was both pleasurable and possibly productive. We had been to Kaawa Beach a few times before, so looked forward to some interesting fossils. The fossiliferous member at Kaawa is considerably above the beach, but large blocks fall onto the beach with regularity. It was within a crevice between layers of one of these blocks (Fig. 1, arrowed) that I found a very soft, sandy and fossiliferous layer that I excavated and found a wide variety of common Kaawa fossils.

All were delicate and required conservation treatment when (and if) I got them home, including the large extinct violet shell, *Janthina typica*. I found 6 *Janthina* in total.

Fig. 1. Location of *Janthina* shells in a sandy, fossiliferous layer above the beach (red arrow). Photo taken during an Auckland Geoclub visit in February, 2022.

Notes and queries

The specimen this note refers to was very delicate and the top of the spiral broke off as I prepared to clean out the sand. As I replaced the top, I noticed that inside the whorl there were some tiny pellet-like ovoid inclusions, 1.5 mm long and varied slightly in length and shape (Fig. 2). What were they? They looked like egg capsules. But egg capsules were unlikely to survive death and fossilisation. Perhaps they were faecal pellets?

Janthina are pelagic snails spending their life in the open sea, feeding on other pelagic species. Neither their eggs nor their faeces are deposited in the whorl of the shell (Wilson & Wilson 1956). Modern purple *Janthina* wash up regularly on the beaches of New Zealand, particularly on the west coast. There are 3 extant species and they can be found after a good blow on Kaawa Beach today.

It is likely that the fossil *Janthina* decayed before the shell settled on the sea floor, like most *Janthina* that wash up on the beach today. But once on the sea floor, could any remaining animal have been eaten by a scavenging organism, either an annelid (e.g., a polychaete), or a crustacean (e.g., a gammarid amphipod)? Perhaps it was scavenged on a beach before it reached the sea floor by an insect (e.g., a coelopid, or other dipteran).

Are any of these organisms likely to defecate inside the shell?

Perhaps the shell was taken over for use by another organism, such as a hermit crab.

Two questions remain:
What organism? Polychaete worms, callianassid shrimps and hermit crabs are likely suggestions.
Do hermit crabs defaecate inside their shells?

They may seem simple questions.
Piles of pellets surround the burrow of an earthworm-like burrowing polychaete *Heteromastus filiformis* (Fig. 3).

Fig. 2. Faecal pellets? in *Janthina* shell, at increasing magnification left to right. Left photo - Glenys Stace, centre and right photos - Rod Martin.

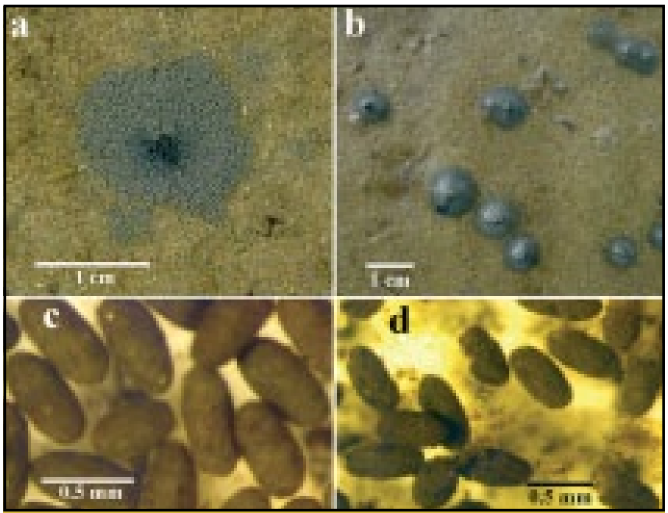


Fig. 3. *Heteromastus filiformis* - a burrowing marine polychaete worm made this freshly produced faecal pellet mound outside its burrow (Wild *et al*. 2005).

Fig. 4. Faecal strings of the two hermit crabs from Castlepoint.

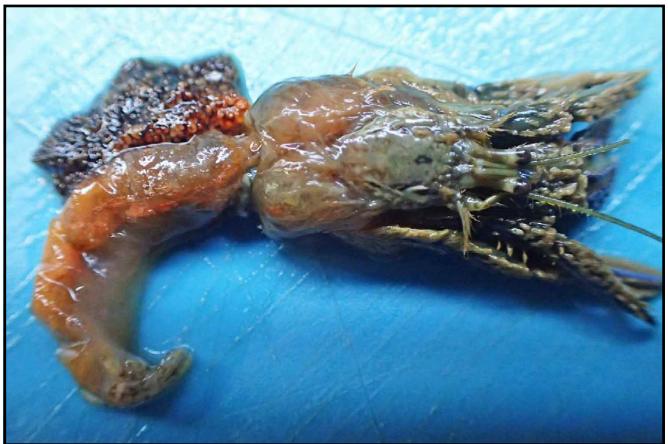


Fig. 5. Top left, grape-like eggs attached to the body of the hermit crab.

These pellets look similar to the pellets in the *Janthina* shell. Could a species of polychaete, having eaten the *Janthina*, deposit its faeces inside the shell?

Generally, ghost shrimps defaecate around their burrows, or they remove the pellets and deposit them outside.

Hermit crabs are another possible option. The *Janthina* shell would certainly make a good but fragile hermit crab home. Do hermit crabs defaecate in their shells? As far as I have been able to ascertain, they might defaecate inside the shell but immediately remove the faecal material and push it out. Hermit crabs defecate through their anus, which is found at the very end of their tail, which is the furthest part of their body to be coiled round inside their snail shell home. I understand another species of hermit crab makes little balls of faeces and pushes them out of the shell. Others might pack them in the shell until space becomes a premium and they have a clean out !

I am surprised at how little scientific information there is on hermit crab lifestyle. Most of what I could find on the internet came from people who keep hermit crabs as pets!

I made a collection of hermit crabs on our recent Geoclub trip to Castlepoint, Wairarapa, and later extracted the animals. The very first one, in a *Turbo smaragdus* shell, came out easily, complete with a faecal string along the body. Twelve came out of their shells complete, but only one other with a faecal string (Fig. 4). This, however, was evidence enough that at least this species of hermit crab does not make faecal pellets and store them in their shell.

Another point of interest is that many of the specimens had grape-like egg clusters attached to their abdomen Fig. 5).

Maybe these pellets were produced by a subtropical species? The climate in New Zealand in the Early Pliocene was considerably warmer than it is today, closer to the mid-Queensland coast. Maybe a northern species would pelletise their faeces?

The fossil record

There is scant record of fossil faecal pellets in the scientific literature. Three papers were found that detail faecal pellets, but none have arrived at a conclusion regarding what organism made them.

The closest they conclude is 'an invertebrate'! (Manning & Kumpf 1959).

The collection of faecal pellets in steinkerns (Godfrey *et al*. 2022) in the Miocene of the Chesapeake Group of Maryland, USA, were deposited in shells (mainly bivalve), cavities in the skeletons of fish and in barnacles, in a naticid gastropod and in hollows of echinoderm tests.

Going further back in time, Bruthansová & Kraft (2003), looking at Bohemian Ordovician body fossils, found similar faecal pellets in the body cavities of many trilobites, other body cavities and a gastropod shell (Fig. 6). They mention that many invertebrate eggs are circular in outline and a cylindrical shape is unusual, so they favour faecal pellets.

They conclude that:
"It is apparent that the pellets are not related to the animals that secreted the shells… The producers of the pellets used only empty shells as hiding places. They could also be carcase-feeders feeding on the soft parts inside the shells or be using the shells as protection… The accumulations of pellets which in some cases fill up the space available in the cavities show that the producers used these places only temporarily… No cluster of pellets was found related to any apparent producer, therefore the producers remain enigmatic."

I have asked everyone I can think of, in New Zealand and overseas. What animal deposited these pellets in

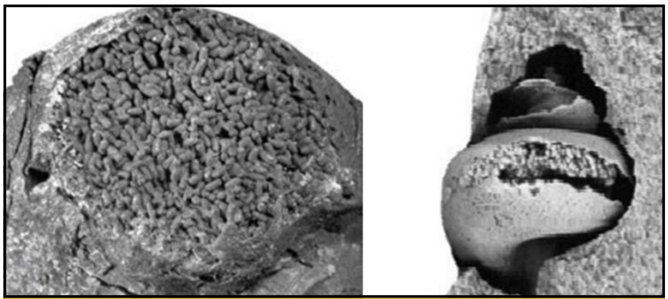


Fig. 6. Fossils from the Ordovician of the Chesapeake Group, Maryland, USA (Bruthansová & Kraft 2003).
Left - Trilobite, anterior part of cephalon filled with pellets.
Right - Gastropod shell with one convolution filled by thousands of pellets.

this shell about 4–5 million years ago? An invertebrate or insect that found the shell lying on the sea floor or on the beach before fossilisation? Crustacean? Could they be egg capsules? At present I must concur that it was "an invertebrate".

I would be grateful for any information leading to the identification of this fossil depositor!

Acknowledgements
Special thanks to Bruce Hayward for encouraging me to research this topic, and again to Bruce and to Richard Willan and Jill Kenny for their suggestions on improving the text.

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RED BEACH - WHAT'S IN A NAME?

Bruce W. Hayward

In August 2022, Auckland Geology Club ran a field trip to Red Beach at the northern base of Whangaparaoa Peninsula (Fig. 1), mainly to look at the Waitemata Sandstone in the cliffs at the east end. While on the trip, no one, not even the leader, enquired or made any comment about the reason for the beach's name. I guess because everyone accepted that whoever gave it its English name thought the sand looked red. A number of beaches around New Zealand have been named for the colour of their sand, like Pink Beach, Whangaparaoa (pink from the dominant barnacle plates in the shelly beach) (Hayward 2017) or Golden Bay (golden from the orange iron-stained granite, quartz and feldspar of the beach sand) (Hayward 2022). On the other hand, Whites Beach, north of Piha, and Browns Bay, south of Whangaparaoa, are named after early Europeans.

Fig. 1. Location of Red Beach, Auckland.

If you squint your eyes in certain light you too could be forgiven for imagining there is a hint of red in Red Beach (Fig. 2). Close examination of the beach shows the "red" colour is coming from the dark orange-brown of iron-stained shells (Fig. 3). The sand grains are dominantly a light brownish-grey colour (Fig. 4), presumably mostly derived from erosion of the similarly-coloured sand in the

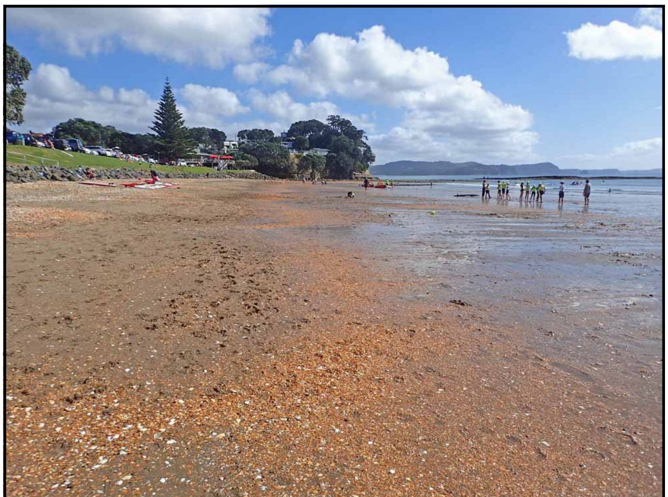

Fig. 2. In certain lights, Red Beach does have a hint of red in the beach.

Fig. 3. The "red" colour comes from the intense iron-staining of broken bivalve shells.

Fig. 4. In parts of the beach the sand is a mix of brownish-grey particles from the Waitemata Sandstone, small orange-brown and white shell fragments and here a pebble of iron oxide (limonite or goethite) from the oxidised Waitemata Sandstone.

Waitemata Sandstone cliffs at either end of the beach. With further inspection, one perceives that almost all the iron-stained shell is broken up bivalve shells, mostly in small pieces up to about 2 cm across (Fig. 3). Larger brown shell fragments were white on the inside when I broke them. By far the majority of the whole bivalve shells (tuatua and fine dosinia) are white (Fig. 5). I assume the whole shells are relatively fresh (young) and haven't had time to be broken up on the beach and the broken brown fragments have been around on the beach for many years – hundreds to maybe even thousands of years.

Just a few of the whole tuatua shells have a little bit of orange colouration in bands on the outside of their shells, but here at Red Beach the majority do not.

Fig. 5. On Red Beach the majority of young, whole shells are white, whereas the older broken shell fragments are iron-stained.

Fig. 6. Natural iron-oxide-rich leachate seeping out of the oxidising Waitemata Sandstone and onto the beach sand at Red Beach.

These observations lead to the hypothesis that the iron staining of the shell fragments has occurred in the beach since the shells were fragmented and deposited there. Indeed, it is likely that most of these shells were not broken on the beach but on the rocks either offshore or at either end of the beach, or were fragmented by fish or birds biting into them for food. Today the beach is composed of 30 cm+ thick layers and lenses of broken iron-stained shell, sometimes exposed to view and in other places covered by a thin layer of grey-brown sand. Presumably the iron staining occurred as the fragmented shell layers were on the beach, mostly at mid-high tide, and the source of the orange-brown iron oxide was from liquid leaching out of the Waitemata Sandstone cliffs, as still happens in a few places today (Fig. 6).

Another possible hypothesis is that much of the iron staining occurred several thousand years ago when sea level was 1–2 m higher. There was possibly a coastal swamp extending up the flat-floored valley behind Red Beach and natural leachate rich in orange-brown iron oxide could have seeped out onto the beach (e.g., Fig. 6) and distributed through the underlying shell layers.

In summary, Red Beach is named for the hint of red colour in the beach, which is due to the deep orange-brown iron-staining of broken-up old bivalve shells. Most, if not all, of the iron-staining has occurred since the shells were fragmented and deposited in layers on the beach. Most iron-stained shells and minerals have a less dense orange colour that imparts more of a golden colour to the beaches.

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AUCKLAND GEOLOGY CLUB 30th BIRTHDAY

Bruce W. Hayward

In November 2022, members of Auckland Geology Club celebrated the club's 30th birthday at a pot-luck dinner hosted by Liz and Rick Hoskin. Liz had made and decorated a special birthday cake that was cut by the club's oldest foundation member, Keith Tomlinson. The slide show and quiz afterwards included some facts about the club's foundation and history, and some are repeated here.

First meeting (attended by "24 enthusiasts")
Tuesday 3rd November,1992, at 7.30 PM at Auckland Museum School Room.
"Do it yourself geological field trips around Auckland" by Les Kermode
Invitation from Geoclub co-founders Bruce Hayward and Les Kermode.

First field trip (attended by 35 participants)
Sunday 6th December, 1992, carpool leaving back of Museum 9 AM.
"Whatipu geology" led by Bruce Hayward

Auckland Geology Club Foundation Members
(who joined in 1992)

Ivan Andern
Kel Anglesey
Fred Bensemann
Maureen * & Merv Burke
Garry Carr *
Trevor & Anita Clarke
Glenn Carter *
Rachael Carter
Colin Christie
Doug Denise
Mike Eagle *
Struan Ensor
Pat Eden
Jack Grant-Mackie
Lola Gregory
Glenda * & Fred Haueter
Bruce Hayward *
John Hyde
Les Kermode
Emile King
Alan Lane
Merelene McCauley
Linda McGregor *
Norman McGregor
Margaret Morley
Kath Prickett *
Glen Prime
Mary Rose
Ann Ross
Joshua Salter
Christine Scriven
Wayne Shinton
Mary Sinclair
Warren Spence
Glenys & Kelvin Stace **
Keith Tomlinson *
P. Wills (41)

* Still a member in Nov 2022 (11)

Auckland Geology Club Committee members (1992-2022)

Kel Anglesey 1992–2015
Murray Baker 1996–2005
Maureen Burke 2017–present
Garry Carr 2005–present
Glenn Carter 1992–2016
Peter Daymond-King 2017–2021
Doug Denize 2007
Struan Ensor 1992–1994
Graeme Gibson 1995–1999
Wendy Goad 2012–present
Hugh Grenfell 1994–present

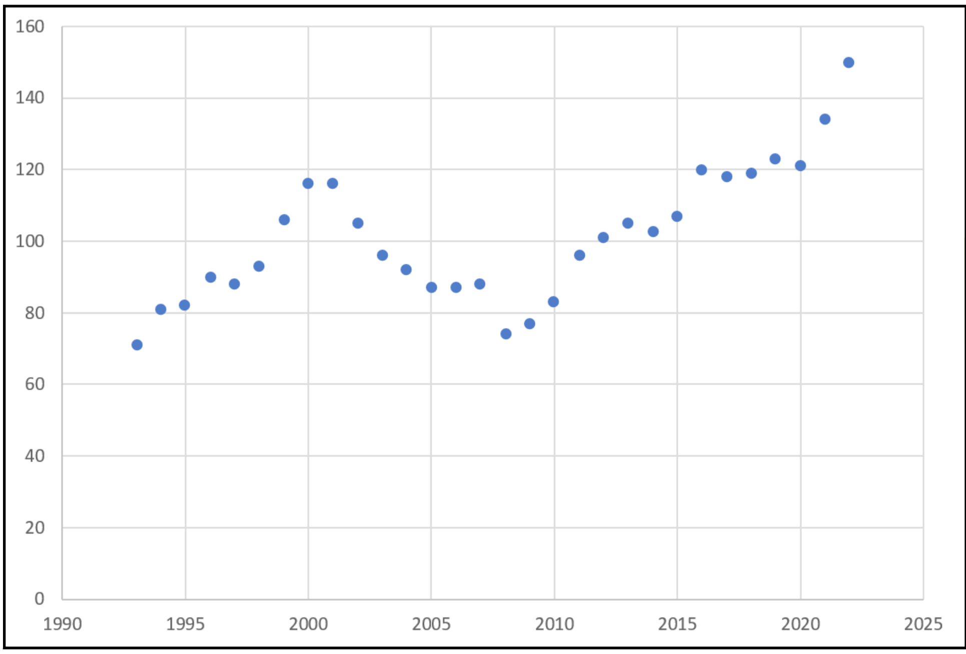
Foundation member Keith Tomlinson cuts our 30th Birthday cake.

Bruce Hayward 1992–present
Helen Holzer 2002–2018
Liz Hoskin 2021–present
Geoff Jenkins 1994–2008
Jill Kenny 2016-–present
Les Kermode 1992–2002
Christine Major 2008–present
Linda McGregor/Hill 1992–93, 2021–present
Margaret Morley 2005–2016
Kath Prickett 2017–present
Lee Sawyer 2021–present
Peter Scott 2009–present
Ken Smith 2021–present
Peter Stewart 2012–2014
Glenys Stace 1994–1999
Total = 26

Treasurers
Kel Anglesey 1992–1994
Geoff Jenkins 1994–2008
Christine Major 2009–2021
Garry Carr 2022–present

Geocene Editors
Helen Holzer 2009–2015
Hugh Grenfell 2009–2015
Jill Kenny 2016-–present

Auckland Geology Club (1992-2022)
331 monthly newsletters
398 field trips 1992–2022, average attendance of 22, including 48 multi-day trips (average attendance 19).
Plus 63 Heritage Week geology guided walks since 2007, with an average attendance of 37.
427 people have been members of Geoclub during this time.



Numbers of Auckland Geology Club members, 1993–2022

List of multi-day trips (with number of attendees in brackets)

NORTHLAND		
JAN 94	3 days	Whangarei geology, led by Bruce Hayward. (35)
JAN 95	3 days	Whangaroa-Doubtless Bay, led by Bruce Hayward. (31)
MAY 97	3 days	South Hokianga, led by Bruce Hayward (22)
OCT 00	3 days	North Kaipara, led by Hugh Grenfell (for BWH) (28)
MAY 07	4 days	North Cape, led by Bruce Hayward, Hugh Grenfell (28)
DEC 10	4 days	Whangarei geology, led by Bruce Hayward. (41)
MAY 11	2 days	Hukatere Peninsula, led by Glenn Carter, Bruce Hayward (29)
NOV 16	8 days	Kerikeri and Opononi, led by Bruce Hayward (36)
MAY 19	4 days	Northeast Northland, led by Bruce Hayward (30)
COROMANDEL		
NOV 96	2 days	Coromandel, led by Phil Moore (26)
MAY 98	2 days	Whitianga area, led by Phil Moore (26)
APR 00	2 days	Kauaeranga Valley, led by Bruce Hayward (31)
APR 01	2 days	Broken Hills & Whangamata, led by Stuart Rabone & Phil Moore (35)
APR 13	2 days	East Coromandel coast, led by Roger Briggs (25)
MAY 14	2 days	North Coromandel Pen, led by Alastair Brickell, Bruce Hayward, Liz Hoskin, Johnny Irons (22)
REST OF NORTH ISLAND		
MAY 94	2 days	Tongariro, led by Les Kermode. (16)
JAN 96	4 days	East Cape, led by Jill Kenny (23)
APR 96	2 days	Rotorua geothermal, led by Stuart Simmons (20)
FEB 99	3 days	North Taranaki, led by Graham Gibson, Bruce Hayward (31)
NOV 99	6 days	Mayor Island, led by Bruce Hayward and Hugh Grenfell (40)
APR 02	3 days	Eastern Bay of Plenty, led by David Kear, Bill Wingate, Bruce Hayward (24)
MAR 03	4 days	Napier, led by Arne Palletin, Vincent Caron, Kyle Bland (32)
APR 04	2 days	Mt Taranaki, led by Vince Neall (24)
APR 05	3 days	Rotorua, led by Will Esler, Ashley Cody, Bruce Hayward, Murray Baker (28)
NOV 05	2 days	Kaimais-Tauranga Harbour, led by Bruce Hayward, Phil Moore (15)

REST OF NORTH ISLAND continued

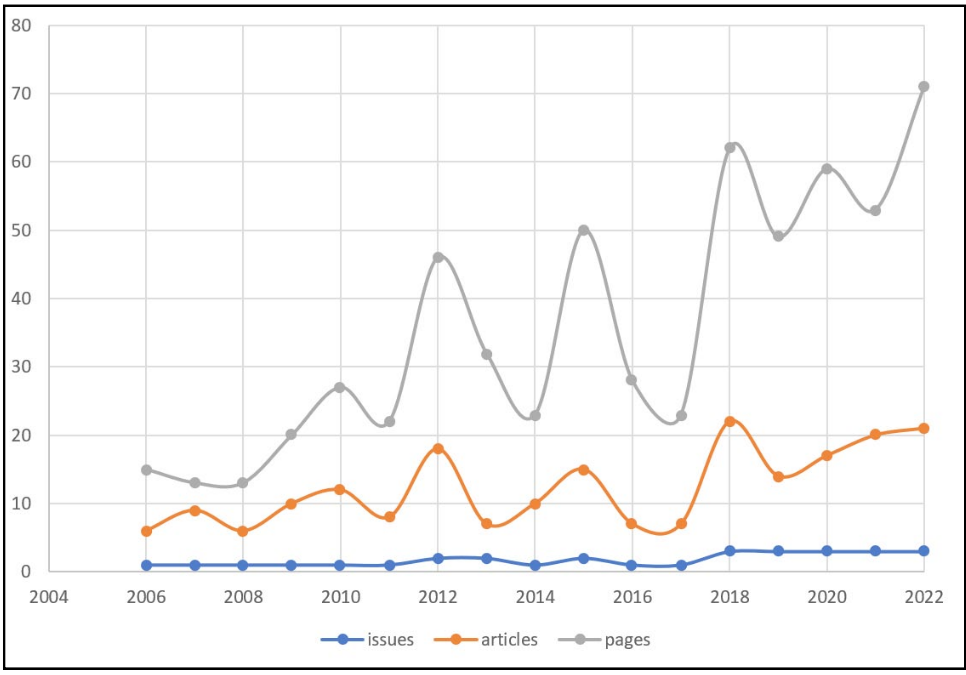
MAR 06	4 days	Mahia, led by Bruce Hayward, Murray Baker (18)
NOV 06	4 days	Wairarapa, led by Bruce Hayward, Martin Crundwell (22)
APR 08	2 days	White Is, Tarawera, Matata, led by Garry Carr & Kel Anglesey (18)
APR 12	3 days	Southern Ruapehu, led by Garry Carr (17)
MAY 15	6 days	Gisborne & East Cape, led by Bruce Hayward, Mike Marden, Phil Moore (21)
MAY 16	3 days	Taumaranui-Whanganui, led by Julie Palmer (27)
MAR 17	2 days	Otorohanga fossil forest, led by Christine Major (17)
MAY 17	3 days	Wellington, led by Bruce Hayward and Hamish Campbell (19)
MAY 21	5 days	King Country and Taranaki, led by Bruce Hayward (27)
NOV 22	8 days	Wairarapa and southern Hawkes Bay, led by Bruce Hayward (26)

SOUTH ISLAND

NOV 07	6 days	NW Nelson, led by Bruce Hayward (28)
NOV 11	5 days	Marlborough, led by Bruce Hayward (24)
NOV 08	6 days	Northern West Coast, led by Bruce Hayward (25)
NOV 09	6 days	Central and North Otago, led by Bruce Hayward & Hugh Grenfell (25)
NOV 12	6 days	South Otago-Southland, led by Bruce Hayward and Ross Ramsay (25)
NOV 13	6 days	Canterbury, led by Bruce Hayward, Margaret and John Bradshaw, Zane Bruce (30)
NOV 14	7 days	West Coast-Mt Cook, led by Bruce Hayward, Margaret and John Bradshaw (29)
NOV 17	7 days	Eastern Fiordland, led by Bruce Hayward and Ross Ramsay (23)
NOV 18	7 days	Kaikoura Earthquake-Chritchurch, led by Jesse Kerse, Kate Pedley, Bruce Hayward (29)
NOV 19	8 days	NW Nelson, led by Bruce Hayward (28)
NOV 20	8 days	Tasman District, led by Bruce Hayward (24)

OVERSEAS

NOV 16	8 days	Norfolk Island, led by Bruce Hayward (18)
JUL 17	7 days	New Caledonia, led by Hamish Campbell and Chris Adams (18)



Auckland Geology Club's journal Geocene (2006–2022), issues, articles, pages per year.

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GRAHAM GIBSON, AUCKLAND GEOLOGY CLUB COMMITTEE MEMBER, 1995–99

Bruce W. Hayward & Hugh Grenfell

In the 1990s, the late Graham Gibson (1936–2016) was a staunch Geoclubber who participated in all Geoclub activities on offer. He served on the committee from 1995 to 1999. He is remembered by our long-time club members as an enthusiastic and regular attendee at most activities, and as a friendly and supportive gentleman who always had the welfare of others at heart. An obituary for Graham was written by Hollis *et al*. (2016).

Graham was born and educated in Taranaki and attended Victoria University of Wellington from 1956 to 1962. He graduated with a BSc (Hons) in Geology in 1960 and a PhD on late Miocene foraminiferal biostratigraphy in 1962. While at University he undertook a two-month field season in the Dry Valleys of Antarctica. His time there is now recorded by the name - Gibson Spur. After graduation, he joined Shell and worked on Taranaki oil exploration.

In 1966 he was appointed as a lecturer in the Geology Department of the University of Auckland, where he remained for the rest of his working life, retiring in 1994. He mainly lectured on New Zealand stratigraphy and mapping techniques to undergraduates, and micropaleontology to advanced classes. He concentrated his energies on improving his and the department's teaching techniques, exercises and field classes, which left minimal time for his own research, although he supervised the micro-paleontology and stratigraphy research theses of a number of graduate students.He introduced inquiry-based learning well before many of his peers. For many students, their most memorable laboratory exercise was his introduction to taxonomy, in which fossils were replaced by a selection of bolts, screws, nails, nuts and washers. Graham was also pivotal in producing the field guide used for many decades for Stage 2 classes at Port Waikato and he produced an excellent laboratory guide for identifying foraminifera for his Stage 3 classes. He also masterminded the construction of an *in situ* plaster cast of New Zealand's largest fossil bivalve, *Magadiceramus rangatira* (1.2 m long), found in Cretaceous mudstone on the Kaipara shoreline. Casts can still be seen on the walls of several museums.

Graham Gibson at Geoclub Christmas BBQ, 2007.

In retirement, Graham devoted considerable time working for school science fairs and making geology experiments and apparatus for teaching simple geology in schools. He was a keen member of U3A and enjoyed DIY projects. He was also part of the West Auckland Resource Centre scheme, which sources unused paper products and other materials and makes them available to schools, playcentres and the like, free of charge.

In his later years at the University of Auckland and in retirement, Graham suffered from bipolar disorder, for which he was required to take regular medication. He complained that the lithium put him in a state of "constant brain fog" and occasionally he could stand it no longer and refused to take his medication. Unfortunately, this resulted in some rather erratic and anti-social behaviour that eventually led to periods of hospitalisation as he was put back on his medications. These episodes of illness led to the breakup of his first marriage, and during his Geoclub days, his second marriage. Sadly, on one occasion, during a Geoclub weekend trip to Urenui, we witnessed the debilitating impacts of this on him. For the majority of his time, however, Graham stayed on his medication, and was the polite, generous and ever-so-helpful friend we all remember with great fondness.

Reference

Hollis CJ, Hayward BW, Black PM, Grant-Mackie JA 2016. Obituary: Graham William Gibson (1936–2016). *Geoscience Society of New Zealand Newsletter* 20: 61–66.

Graham examining obsidian on the crater rim of Mayor Island, 1999.

Graham (centre) in the middle of a Geoclub group at Algies Beach, 2000.

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HYPERLINK INSTRUCTIONS

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

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

If you wish to return to the previous page you were reading, and you have Windows operating system and standard Adobe Reader, just right click and chose 'previous view' on the drop-down menu, or you can use a shortcut Alt + left arrow. For Macintosh or Ubuntu operating systems, contact the Editor for instructions.

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QUIZ ANSWERS

Know your mountain profiles.

1. Mt Taranaki, Taranaki
2. Mt Hikurangi, Northland
3. Mt Ngauruhoe, Central Plateau
4. Mt Hikurangi, East Coast
5. Mt Somers, inland Canterbury
6. Mt Cargill, Dunedin
7. Mt Kaukau (or just 1 kau !), Wellington

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or

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