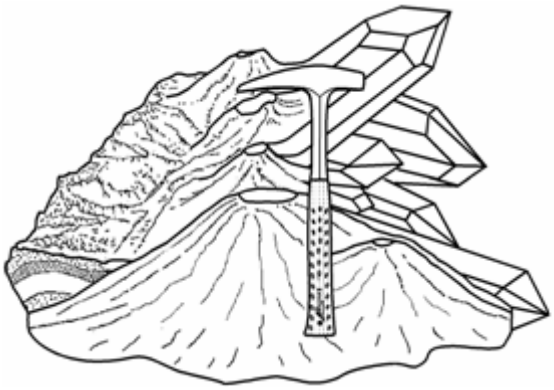


Geocene

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Geocene is a periodic publication of GeoClub, 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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COOPERS BEACH FOSSIL COCONUTS, POOP AND DAHLIA ROCKS

Heather Smith

Coopers Beach is a beautiful pohutakawa lined Far North beach on the southern part of Doubtless Bay. Here late Miocene fluvial sediments (conglomerates, sandstones, mudstones and lignite) of the Mangonui Formation outcrop from time to time but are otherwise covered by beach sand. Some erosion of these beds also occurs subtidally. The fossil coconuts and concretions described here are derived from these beds. The geology of these rocks is described by Couper (1953) and Brook and Hayward (1989).



Fig.1: Coopers Beach.

FOSSILISED COCONUTS

Over the last twenty-five years I have visited this beach many times and have spent numerous hours looking for Recent molluscs and the elusive Miocene coconuts, *Cocos zeylandica* Berry, 1926. Five years ago a number of these washed ashore along with a variety of seed cases, but I haven't seen them again.

The presence of coconuts (and other fossils e.g. colonial reef corals, foraminifera) in the Miocene have been used as evidence of a warmer than present climate. However possible modern correlatives of these coconuts, belonging to the genus *Parajubaea,* presently live at high altitudes (1700-3000 m), and cool temperatures, in South America (Endt & Hayward 1997). So the coconuts by themselves are not necessarily indicators of warm temperatures.

The beach changes on every tide. In storms large quantities of sand can be washed in or sucked out, exposing a lignite seam rarely. During the last 25 years I have only seen the seam exposed on two occasions.



Fig. 2: A selection of fossil coconuts.

The coconuts are about 40-50mm long and vary in their shape and form.



Figs 3 & 4: Coconuts have 3 holes on the top edge.



Fig. 5: Coopers Beach outcrop exposed.


Fig. 6.

Kanekane stream (Fig. 6) flows across the sand in the middle of the beach changing its path with every tide. Heavy rain can remove sand to a depth of one metre. In January 2010 the stream became gouged out exposing many rocks and stones.

POOP ROCKS


Fig. 7. “Poop” rock.

The wonderful form in figure 7, collected at the stream mouth, is perfectly bulged at one end and pinched off at the other. This rock caused much discussion and laughter! We did go through the “Who dung it conversation?” with many clever imaginative suggestions! Earth Farts surfaced!


Fig. 8.

More Poop rocks were collected in various shapes and size. Some looked as though they had been coated in iron oxide. Research began with books, discussions and the internet. During 2010 many rocks were collected.


Fig 9.

Note the zigzag back and forth movement rather like something being squeezed out and wiggled from side to side in the process.


Fig. 10

Note the bulge at one end and pinch off at the other.


Fig. 11.

All the Poop Rocks are very heavy. Some are a darker than others. These ones are smaller that the images above.


Fig. 12.

This is a cross section of a Poop Rock. Many possibilities have passed by me - coprolite, barite concretions, botryoidal goethite, limonite, siderite, hematite, iron pebbles, pseudocoprolite, iron concretions and Earth Farts. Similar shaped iron-rich rocks have been found in sediments of different ages (Miocene to Permian) from Australia, Canada, Russia, and the US.

They are possibly coprolites (the fossilised excrement of vertebrates). However there is no evidence of bone fragments, fish scales, seed, pollen or plant fibres that is evident in some coprolites. No fossilized bones of herbivores or carnivores have been found in the area. Given that the sediments are non-marine reptiles or birds are possible producers.

Mustoe (2001) wrote the following about the enigmatic origin of some ferruginous “coprolites” from the Wilkes Formation, south western Washington. “A wide range of hypotheses has been advanced to explain the genesis of excrement shaped ferruginous masses, and investigators remain deeply divided over whether these objects are coprolites. On the basis of the limited evidence available, I am inclined to believe that most if not all these specimens are pseudo coprolites produce by mechanical deformation of iron-rich sediment, perhaps as a result of methanogensis. However, the origin of these specimens remains clouded in mystery and our best hope will come if researchers combine their search for new evidence with an open mind.”

Methanogensis is the generation of methane during decomposition of organic matter, which could have occurred in the lignite sequence at Coopers Beach.


Fig. 13: Larger pieces located in a seam of rocks in the tidal zone west of the stream.

Mark Simpson and Jeff Mauk of Auckland University did a XRD (Xray diffraction) analyses on a Poop Rock which indicated the dominant mineral is siderite (iron carbonate) with some goethite (iron oxide).



Fig. 14: This 35 x 23 cm piece was extremely heavy and required a pushchair to remove it from the beach! It now sits proudly in my garden!

DAHLIA ROCKS



Fig. 15: Dahlia flower.



Fig. 16: Large Dahlia rock collected near the stream.



Fig. 17: Underside of large Dahlia Rock. Notice the coiling in the middle rather like the Poop rocks.



Fig. 18. Topside



Fig. 19. Underside.

All the Dahlia rocks have been collected in the area where the stream runs down into the sea. Some are darker and appear to be coated in iron oxide. All are very heavy.



Fig. 20. During 2010 these rocks were all collected in the area near the stream. They are all clean with no clay on the underside.



Fig. 21

In February 2011 the sand was washed out on the western side of the stream and with great excitement I discovered many Dahlia rocks sitting on clay and sand in large salt water puddles (Figure 21). At first I thought they were attached to rock below but with a little wiggle and shake the Dahlia rocks came free. During two low tides I was able to collect a number of them. They were not all perfectly dahlia shaped but all rounded and similar texture. They did not have a coating of any kind.



Fig. 22: Rock still attached to the clay.



Fig. 23: Large Dahlia Rocks.



Fig. 24: Smaller Dahlia rocks all collected in the same area.



Fig. 25: Close up view.



Fig. 26 Topside. Fig. 27 Clay underside



Fig. 28: A Dahlia rock cut in half.

Mark Simpson and Jeff Mauk once again did XRD analysis and the conclusion was siderite. I am certain these concretions are forming in the clay area which is always covered by at least a metre of sand. We can measure this by the sand level on the wooden stair case behind and to the west of the location.
This area is now once again under sand and we will have to wait until the next large storm erodes the sand out so that we can view them again.

MISCELLANEOUS


Fig. 29: Fossilized Wood coated iron oxide.


Fig. 30: Unknown.


Fig. 31: More rocks from the same stream area.


Fig. 32: A variety of rocks that are coated in iron oxide. The middle bottom rock has some of the coating peeling off. The top left 3 look like coconuts and in the centre a “Gum Nut”!

Thus a wide variety of sideritic nodules derived from the Mangonui Formation are present at Coopers Beach. For some their origin is clearly mineralogic (Dahlia rocks) but others may have a biological origin (Poop rocks). The Poop rocks may be true coprolites (i.e. of biological origin) or pseudo-coprolites produced by mechanical deformation of soft sediment. There may also be some relationship between the Dahlia and Poop rocks (e.g. see Figure 17, 19).

ACKNOWLEDGEMENTS
Thank you to Dr Alan G Beu, GNS Science, Lower Hutt, and Dr. Jack Grant-Mackie University of Auckland who cut rocks in half and found no signs of anything that would indicate real coprolite. Thanks to Dr Bruce Hayward who gave me the George Mustoe article, and kept urging me to write something down, Dr Hugh Grenfell for adding geological information, Dr Mark Simpson and Dr. Jeff Mauk of Auckland University for the XRD analysis and Margaret Morley who always is proof reading, guiding and encouraging me!

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LIMONITE-CEMENTED BEACH ROCK, AUCKLAND
Bruce Hayward

On a GeoClub trip around Musick Pt in March 2012, we came across an unusual conglomerate that appeared to be part of the Waitemata Sandstone sequence. Its mode of occurrence and appearance reminded me of similar deposits seen some years ago on a GeoClub trip near Achilles Pt, St Heliers.

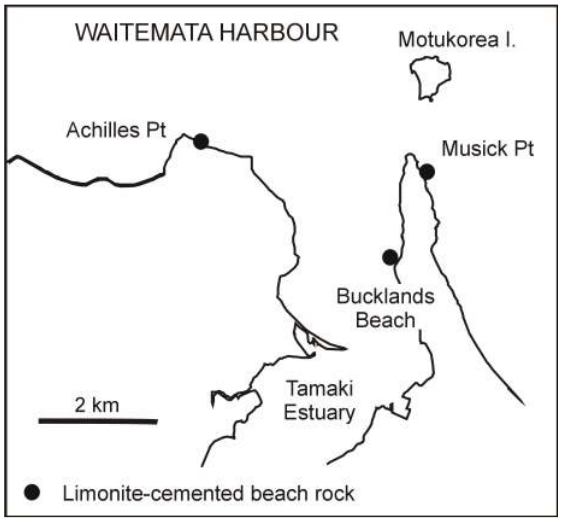


Fig. 1. Map showing location of limonite-cemented beach rock around the mouth of Tamaki Estuary.

The Musick Pt location is in a small embayment in the eastern cliffs of Musick Pt about 200 m from the northern tip. Here the conglomerate sits between mid and high tide levels near the foot of the cliff – some is cemented onto a massive sandstone bed and some is in a wedge seemingly filling a former small sea cave (30-50 cm across) and giving the impression of being within the Miocene Waitemata Group sequence.


Fig. 2. One of the exposures of limonite-cemented conglomerate at Musick Pt.

The Achilles Pt occurrences also occur between mid and high tide level near the base of cliffs sporadically preserved for 100 m between 100 and 200 m south of Achilles Pt. Some exposures form the shore platform but others have a vertical contact with the cliff or fill small caves or bedding plane depressions beneath overhangs, which also give the impression of being interbedded with the Waitemata Sandstone.


Fig. 3. One of the exposures of limonite-cemented conglomerate at Achilles Pt. Note beach rock plastered against the base of the sandstone cliff.

At both localities the conglomerate contains clasts of Waitemata Group lithologies – mostly sandstone but also mudstone and Parnell Grit – all seemingly sourced by erosion from the surrounding cliffs. The clasts are up to 1m across, but many are 3-30 cm in diameter. A few of the pebbles and cobbles are rounded suggesting that they have been rolling on the beach, but many clasts are angular or subangular suggesting that many may have been derived by rock fall from the cliff above and have hardly shifted on the beach before being buried in the sand matrix. In some places the clasts rest on each other and can be said to be clast-supported but in other places the clasts "float" in the sand matrix suggesting the rocks fell onto a sandy beach before being buried by more sand accumulation.


Fig. 4. Conglomerate beach rock near Achilles Pt. Note rounded and angular pebbles and cobbles of Waitemata lithologies in a limonite-cemented sand matrix.

Unlike the Waitemata clasts, the sand matrix is dark rusty brown-stained and cemented together by limonite

(iron oxide) which makes this rock quite hard and about the same resistance to erosion as the Waitemata Sandstone cliffs.



Fig. 5. Conglomerate beach rock cemented against base of vertical cliff of Waitemata Sandstone near Achilles Pt.

The probable explanation of these limonite-cemented conglomerate deposits is that they were deposited on the beach at the foot of the cliffs, just as boulders, cobbles, pebbles and sand form the current beaches in the same areas now. Their present elevations up to 1-1.5 m above present beach level indicates that the beach sand was much higher at the time of deposition. The cemented beach conglomerates cannot be any older than Holocene, as they are in contact with clearly Holocene erosion surfaces in the base of the cliffs. Their exact age is unknown but possibly they were deposited when sea-level was higher than present, between 7000 and 2000 yrs ago (Clement et al., 2008).

Limonite-cemented Holocene beach rocks like these are rarely found around Auckland. These two localities are quite close together on either side of the entrance to Tamaki Estuary. There is another cemented beach rock nearby, exposed 2 km up the Tamaki Estuary at the north end of Bucklands Beach. Here it is finer-grained and contains abundant basalt pebbles cemented by calcite and/or motukoreaite in coarse sand (e.g. Rodgers et al., 1997). The presence of basalt clasts may be part of the explanation for this grouping of beach rocks. The cemented sand at Musick Pt and Achilles Pt is dark-coloured and apparently much richer than other beaches around Auckland in basalt-derived iron-rich grains probably sourced from nearby Motukorea Island just off Musick Pt. Indeed beach rock occurs on the southern end of Motukorea Island itself (H. Grenfell pers comm.). This may be the origin of the limonite cement produced by oxidative weathering from the iron-rich grains.

A dog cockle, oriented in life position, from the shelly beach rock at Bucklands Beach has been radiocarbon dated at 4965-5290 cal yrs BP (Wk33780) and this may be the approximate time of deposition of the other nearby beach rocks. This predated the eruption of Rangitoto Island (600 yrs ago) and so at the time Motukorea and the entrance to Tamaki Estuary would have been a lot more exposed to storms from a northerly quarter. This greater exposure probably resulted in the relatively rapid erosion (400 m) of the tuff ring on the northern Crater Bay side of Motukorea with vast quantities of basalt pebbles and sand washed across to the adjacent mainland beaches and part way up Tamaki Estuary.

Dog cockles do not live above MLW tide level and thus its presence in the beach rock at mid tide level indicates that sea level was at least 1.3 m above present 5000 yrs ago.

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THE GEOLOGY OF VAN DAMMES LAGOON, PANMURE

Roger Evans

Tucked in between the Mt Wellington Highway, the Main Trunk Railway and Ireland Road on the western side of Panmure Basin lies a neglected oasis, where low cliffs (5 m) enclose a wandering stream, a small alluvial flat, and a sequestered lily pond. The history of the reserve is noted in Cameron et al. (1997); and the geology of the area broadly described by Kermode (1992) and in more detail in Hayward et al. (2008).

Upon entering the reserve, the geological eye is immediately taken by prominent, near-vertical walls of layered sandy silt and fine gravel, legacy of volcanic eruptions that formed the nearby Panmure Basin. The explosive blasts that piled tuff against low hills of East Coast Bays Formation to the west must have also blocked the drainage. When the impounded runoff eventually overflowed, it carved a route through the tuff to the Panmure Basin, excavating a small gorge in the process. Small springs emerging from the tuff at the head of the valley add to the overland flow, now discharged from two concrete culverts.

When the Ireland Brothers opened a tannery on or near what is now Ireland Road, the stream was dammed. Thus the Lagoon was born. Subsequent development of the Eastern rail corridor in the 1930s enhanced the sense of sequestration by raising a causeway to the level of the surrounding land, creating a hidden valley. The outlet is by way of another concrete culvert, built up against the tuff at one end of the causeway. Through this culvert the stream returns to its original course, draining to the Panmure Basin.

Later owners planted trees, and landscaped the banks with stone walls and seats. Continuing sedimentation filled the upper reaches of the lagoon with silt, which was planted in willow and swamp cypress. The result is a peaceful wooded enclave, now a public reserve; which while displaying an obvious geological history, also contains a buried geological secret.

A recent geotechnical project required two hand auger boreholes on the banks of the lagoon, and scala penetrometer tests in the middle to determine the depth of alluvial fill. The penetrometer quickly proved about 5m of sediment infill in the centre of the former channel. It was the results of hand augering that proved most interesting though. The first hand auger commenced in hard volcanic tuff, then at about pond level, broke through into stiff to very stiff clay silts and clays of the Tauranga Group. The second, on the opposite bank of the lagoon, commenced in colluvium instead of in tuff, but again, at pond level, encountered the same stiff to very stiff Tauranga Group clays.

Geotechnical testing thus proves that Van Damme's Lagoon formed as a geological window, cut through the ejecta of the Panmure tuff ring into the underlying Tauranga Group. The lower geology has since been concealed by creation of the lagoon, and by consequent alluviation.



Fig. 1. Van Dammes Lagoon 1940 (Note steam train!).



Fig. 2. Van Dammes Lagoon 2012. (Note eutrophication and water weeds infilling).

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BRYOZOANS, RHODOLITHS AND LARGE FORAMINIFERA FROM THE EARLY MIOCENE WAITIITI FORMATION, TAITA STREAM, HOKIANGA, NEW ZEALAND

Seabourne Rust & Diane Yanakopulos

In the South Hokianga area (Northland), early Miocene sedimentary rocks of the Otaua Group overlie the Northland Allochthon, from which they are largely derived. During the NZ Otaian Stage, mudstone and sandstones of the Waitiiti Formation accumulated in a "piggy-back" basin, forming a broadly regressive sequence, up to 1 km thick (Evans 1994, Hayward 1993). In the banks of the Taita Stream near Waimamaku, the Waitiiti Formation outcrops as a shallowing-up, north-dipping section, largely obscured and deformed by recent slumping and mass movement (Wakefield 1977, Evans 1994, Hayward, 1993). We are studying the Taita section, in an effort to record macrofossil distribution and diversity (also see Rust 2009, 2011), with results recorded on the New Zealand Fossil Record File (FR# O06/f0121).

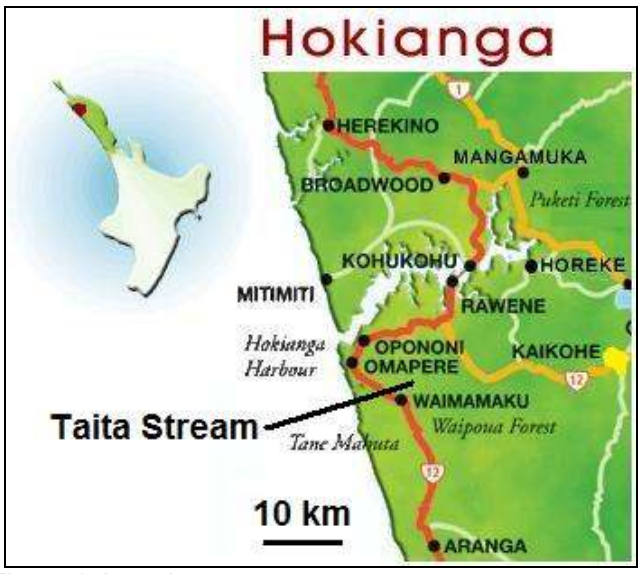


Figure 1: Location.

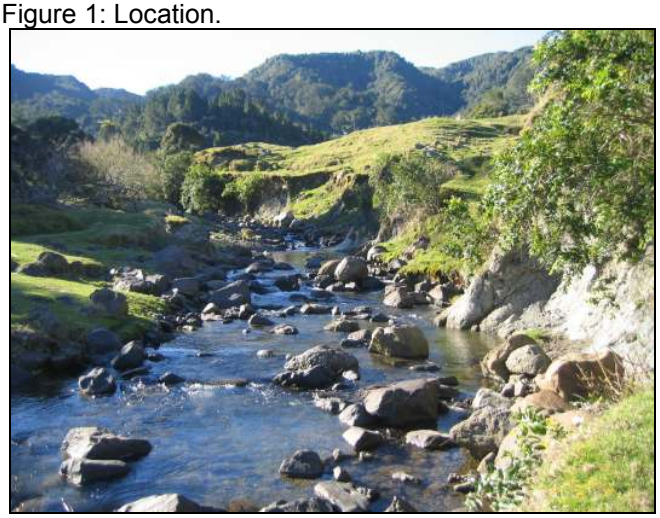


Figure 2: Taita Stream



Figure 3: Outcrop.

The Waitiiti Formation in the Taita Stream consists of poorly-bedded grey mudstone with scattered macrofossils (mainly small mollusca), passing upward into layered mudstone and fine sandstone, with some coarser lenses or channel-fill deposits of larger lithic fragments, rhodoliths and occasional worn macrofossils. Our main collection comes from the uppermost 50 m of the Waitiiti Formation section, where fine sandstone and mudstone in places contain large lithic fragments, most of which show signs of bioerosion and are encrusted by a well-preserved attached epifauna. The majority of these rocks are reworked Northland Allochthon sandstones and mudstones of probable Paleocene – Cretaceous age. Some spherical concretions up to 1.5 m across contain the bivalve Inoceramus, indicating they are likely sourced from Punakitere Sandstone. At the Taita, these rocks may represent part of the original 'bedrock' of an Early Miocene shallow reef or shoal, which once formed a significant hardground upon which a diverse epifauna developed. Besides the sessile attached bryozans, oysters and serpulid tubeworms, local macrofossils include occasional reef corals (*Plesiastrea*, *Cyphastrea* sp? - some quite large specimens); solitary corals; gastropods (some warm-water taxa); bivalves (including the rock/coral-boring pholadidea); rare echinoid and crustacean fragments, and a nautiloid (*Aturia* sp.) has been recovered. The reef rocks and associated shallow (euphotic zone) fauna were later eroded and incorporated/mixed into slightly deeper shelf settings. Microfossil analysis by Hayward (1993) indicates deposition at mid-shelf depths ~ 50–100 m.

Abundant rhodoliths occur locally in a variety of shapes and sizes (up to 15cm across & 1cm thick skin), suggesting coralline algae once covered much of the sea floor. Most were crust-like and many completely enclosed a central core of rock, possibly indicative of frequent movement and overturning (rolling). The

Waitiiti rhodoliths are often worn or overgrown by serpulids and bryozoans, usually on particular surfaces, but sometimes on all facets.

Bryozoans encrusted lithic fragments, rhodoliths, molluscs and some were free-living. We identified from 350 colonies, a minimum diversity of 42 bryozoan taxa (30 cheilostomes, 12 cyclostomes) from the Waitiiti Formation. Some zooecia are too poorly preserved to allow accurate indentification at species level. A variety of both encrusting and erect growth forms are present. Those encrusting hard substrata are often well preserved and frequently show evidence of overgrowth and colony-colony interactions. The most abundant encrusting taxa identified were cheilostomes *Celleporaria agglutinans*, *Crassimarginatella* spp., *Akatopora circumsaepta* and cyclostomes *Desmediaperoecia biduplicata* and *Disporella* sp.

14 erect bryozoan taxa are represented by numerous 0.3-0.8 mm-long branch fragments (these can dominate grit layers) and basal supports attached to hard substrata. Cyclostomes are well represented (8 taxa); *Attinopora* and *Crisia* sp. are the most abundant erect forms.



Figure 4: Rhodoliths; encrusting bryozoan



Figure 5: Various fragments incl. erect bryozoans; large foraminifera *in situ*

Upper Waitiiti Formation beds are also rich in larger foraminifera, especially the flattened discoidal *Lepidocyclina* (*N.*) *orakeiensis*. These often reach 2 – 3 cm diameter, larger sizes were accordingly rarer. From our collection of 165 tests, only 16 were greater than 3 cm across. We recently recovered what is probably the largest known *Lepidocyclina* from New Zealand with an original diameter of ~ 6 cm (Rust & Yanakopulos 2011). These symbiont-bearing larger foraminiferans once lived in warm tropical conditions in the shallow euphotic zone, with the large size of the tests suggesting stability in paleoenviromental conditions allowing for continued growth; or alternatively, a reduction in photic conditions causing delayed maturity (Berning et al 2009). Occurring in such large numbers, a build-up of tests contributed to the hardground substrata supporting the Early Miocene reef fauna.

Some of the large foram tests are encrusted by bryozoan colonies. Similar-sized, encrusted Lepidocyclina are known elsewhere in the world (Berning et al. 2009). We recorded bryozoans on 58 of 165 tests (35%); with 56 % of encrusted tests being larger than 20 mm diameter (large tests have greater surface area for bryozoan settlement). About 50% of the encrusted tests had bryozoans on both surfaces, perhaps suggestive of overturning. At least 21 bryozoan taxa have been identified from 75 colonies encrusting lepidocyclinid tests from the Waitiiti Formation, the five most abundant being cheilostomes *Figularia* sp., *Macropora* sp. and *Crassimarginatella* spp., plus cyclostomes *Desmediaperoecia biduplicata* and *Disporella* sp. “Spot”-type colonies predominate over “runners” and “patches” and “mounds”.

Acknowledgements:
Our thanks to J. Grant-Mackie, B. Hayward and D. Gordon for advice and encouragement, plus the Taita Valley landowners for access to fossil localities.

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Appendix: **An updated list of Bryozoan taxa recorded from the Waitiiti Formation (Otaian Stage, Miocene), Taita Stream, Waimamaku, Hokianga, Northland, New Zealand (NZ Fossil Record File No. O06/f0121).**

Order CHEILOSTOMATA
Adeonellopsis cf. *yarraensis* ER
Aimulosia marsupium EN*
Akatopora circumsaepta EN*
?Arachnopusia sp. EN
Bitectipora cincta EN*
Cellaria immersa ER
Celleporaria agglutinans EN*
Celleporaria emancipata EN
Celleporina sp. EN
Chaperia sp. EN
Chaperiopsis sp. EN
Cosciniopsis vallata EN
Crassimarginatella spp. EN*
Crepidacantha crinispina EN*
Escharella cf. *spinosissima* EN*
Escharoides angela EN*
Exochella cf. *conjuncta* EN
Figularia sp. EN*
Galeopsis polyporus ER
Gigantopora sp. indet. EN
Hippomenella vellicata EN*
Macropora sp. EN*
Melicerita angustiloba ER
Micropora cf. *elegans* EN*
Microporella sp. EN*
? *Onychocella* sp. EN
? *Parkermavella* sp.EN*
Smittoidea sp. EN*
Steginoporella sp. ER & EN
indet. fenestrate spp. ER

Order CYCLOSTOMATA
Attinopora zelandica ER
Crisia sp. ER
Crisina cf. *hochstetteriana* ER
Desmediaperoecia biduplicata EN*
Mesenteripora cf. *triregnator* ER
Diaperoecia purpurascens ER
Diastopora sp. EN*
Disporella sp. ER*
Hornera sp. cf. *robusta* ER
Telopora cf. *lobata* ER
Tubulipora sp. EN*
Tubuliporine indet. '*Hastingsia*-like' sp. EN*



Photo: Bryozoan-encrusted large foraminifera (*Lepidocyclina*) from the Taita section (scale=mm)

EN = encrusting colony; ER = part of erect colony;
* = at least one colony recorded encrusting *Lepidocyclina (Nephrolepidina) orakeiensis*.

PUHINUI CRATERS

Bruce Hayward, Jill Kenny, Hugh Grenfell

Hochstetter (1864) identified and counted 63 volcanoes in the Auckland Volcanic Field, but over time this was reduced to 48 mapped and identified by Les Kermode (1992). Since then Allen and Smith (1994) and Hayward et al (2010) have added two more, making the number around 50 (Hayward et al., 2011a).

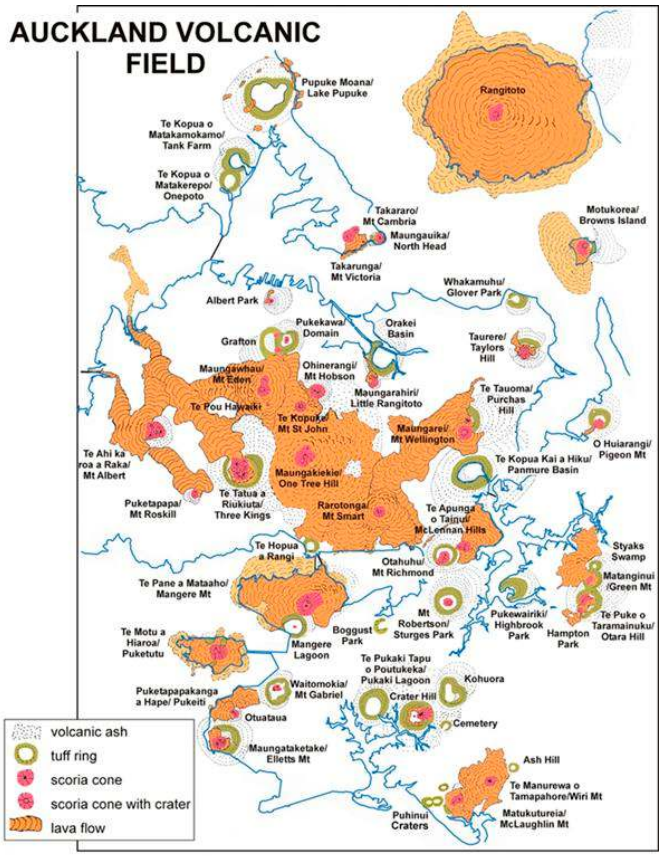


Fig. 1. Map of our current knowledge of the volcanoes of Auckland (updated from Kermode, 1992).

Recently a new web resource has been made publicly available by Auckland Council which provides a map of the entire Auckland City region with contours available down to 0.5 m intervals (Auckland Council, 2011). This has allowed us to scan the whole Auckland Volcanic Field looking for any small landforms that have not previously been recognised as having a volcanic origin. From this we confirm Searle (1961)'s recognition of a small crater in southwest Papatoetoe which he named Cemetery Crater (Fig. 1) because of its proximity to the Manukau Cemetery (Puhinui Rd) – a proximity that is less obvious today as the SW Motorway has been built between it and the crater (Hayward et al., 2011b).

Our on-line search also enabled us to identify a somewhat larger crater occupied by Boggust Park in Favona (Hayward et al., 2011b) and three small volcanic craters and their surrounding tuff rings in Puhinui Reserve, on the shore of the Manukau Harbour near Wiri (Fig. 1). To our knowledge the origin of these three craters has not previously been known. Kermode (1968) knew of the existence of two of these depressions as he mapped Holocene alluvium filling their floors but he does not seem to have recognised their fiery origins.



Fig. 2. Vertical photo of Puhinui Pond Crater. From Google Earth, 2011.

Puhinui Pond Crater

This crater lies near the entrance to Puhinui Reserve and is currently filled with a pond having a small farm dam controlling its water level (Fig. 2). The surrounding low tuff ring is 200 x 150 m across from crest to crest (21.5 m above MSL) with the near-complete oval rim just 1.5-2 m above pond level (Fig. 3. The crater sits atop a low mound of volcanic ash (tuff cone) that rises approximately 8 m above the original land surface and covers an area of ~8 ha, mostly within Puhinui Reserve but a small portion in the corner of Colin Dale Motor Sport Park. Its shape is best viewed when looking across from Puhinui Arena (Fig. 4). The pond will be underlain by an unknown thickness of freshwater sediment that has accumulated since the crater's eruption.



Fig. 3. View across Puhinui Pond Crater from the east, 2011.

Puhinui Arena Crater

A second hill with a breached crestal, oval-shaped depression (here named Puhinui Arena Crater) is 22 m above MSL and it's drained and sediment-filled flat floor is 2-2.5 m below rim level (Fig. 5). From crest to crest the crater is 250 x 150 m across, breached to the east and with a low saddle to the west. The crater floor has been enlarged and flattened for use as the arena for show jumping and dressage for the Puhinui equestrian centre located in the reserve (Fig. 6). Coring in the centre of the crater, beside the water jump, recovered 3 m+ of dark grey and black freshwater mud and peat

beneath 0.5 m dark soil and gravel fill (Fig. 7). We infer the mud to have accumulated on the bottom of an open pond whereas the interval of peat accumulated when water level was low and the crater occupied by a freshwater swamp. Orange-weathered sediment above and below the peat indicate short-lived dryer intervals when water level fell below the height of the sediment fill at this locality. The total thickness of sediment is unknown.



Fig. 4. Puhinui Pond tuff cone viewed from the southwest, 2011.

Exposures in the top of the sea cliff, 150 m to the west, show 3.5 m of red-weathered basaltic tuff overlying Pleistocene rhyolitic sediment. The basaltic tuff has a light-coloured, quartz-rich horizon 2.5 m above the base (Fig. 8) that may indicate a time break within the deposit, with only one of the layers (?lower) originating from Arena Crater. There is no indication of a soil layer at the level of the quartz-rich interval however.

The tuff cone formed by eruption of Puhinui Arena Crater rises ~8 m above the level of the original land surface and covers an area of ~10 ha, all within Puhinui Reserve. It is best viewed from Puhinui Pond tuff ring (Fig. 9).



Fig. 5. Oblique aerial view of Puhinui Arena Crater from the west. From Google Earth, 2011.

Puhinui Eroded Crater

This is the least well-preserved of the three craters and together with the other two illustrates three stages of their progressive erosion. The crater lies due east of and abuts Puhinui Arena Crater (Fig. 10) on an alignment that includes the centre of McLaughlin Mt scoria cone. The floor of the crater has been eroded by an incised meandering stream channel – a small tributary of Puhinui Stream (partly fenced off for vegetation regeneration)(Fig. 11). This small stream is the one that has breached and drains Arena Crater. The distinctive arcuate shape of the tuff ring crest is still preserved on the north and south sides of this small stream valley, rising to a maximum height of 20 m above MSL (Fig. 10). From crest to crest this crater is 250 m in diameter and the tuff cone rises ~ 7m above the original level of the land and covers an area of ~8 ha, all within Puhinui Reserve.



Fig. 6. View across Puhinui Arena Crater from the south rim, 2011.

The Puhinui Stream valley is eroded into the tuff ring on the southeast corner creating a steep 14 m high bank covered in trees.

Age of Puhinui Craters

Four of the nearby volcanoes (Crater Hill, Kohuora, Wiri Mt, Ash Hill) have been dated at around 32,000 years old (Lindsay et al., 2011). The other two nearby volcanoes (Cemetery Crater, McLaughlin Mt) have not been dated and could be of similar age, but that is speculation. Coring the sediment infill in Puhinui Pond and/or Puhinui Arena craters and finding the oldest identifiable dated tephra has the potential to provide a minimum age for these craters and test the speculation above.

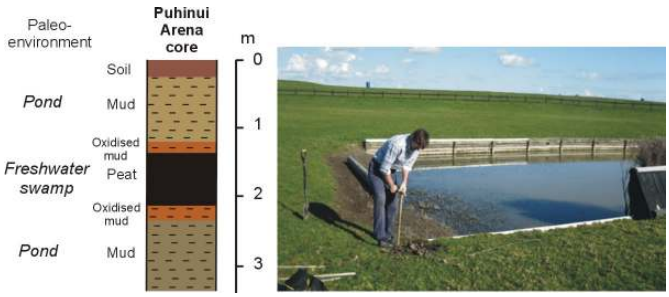


Fig. 7. Coring beside the water jump in Puhinui Arena Crater and a schematic log of the 3.5 m deep sediment core.



Fig. 8. Cliff exposure of quartz-rich horizon within the weathered volcanic tuff west of Puhinui Arena Crater.

Despite the differing degrees of erosion of the three Puhinui craters we consider it most likely that all three erupted during the one period of volcanic activity and thus we have named them jointly as the Puhinui Craters. These craters are 0.75-1.1 km from the centre of McLaughlin Mt scoria cone (Fig. 12) and one hypothesis could be that all are part of the same eruptive sequence. This hypothesis needs testing by comparing the geochemistry of erupted basalt from the various centres and obtaining good ages.



Fig. 9. Puhinui Arena tuff cone and breached crater viewed from the northeast, 2011.

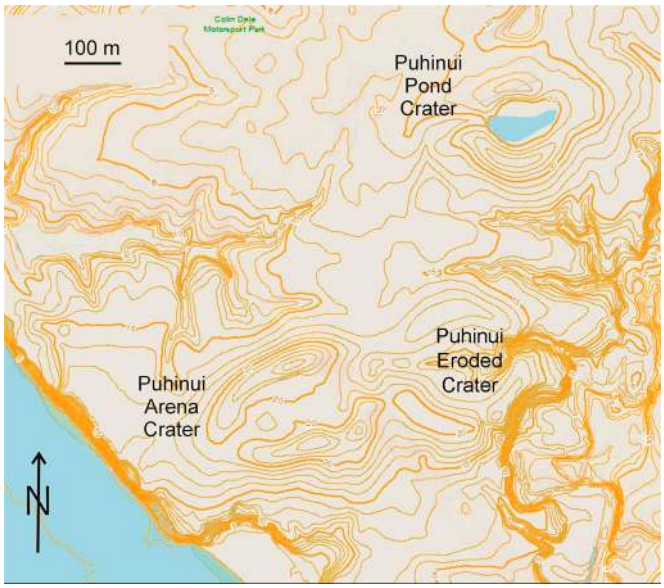


Fig. 10. Contour map (1 m interval) of the three Puhinui Craters and their surrounding tuff rings (cones). From Auckland Council GIS Viewer, 2011.

We know that some of the identified volcanoes in Auckland erupted as part of the same event as their nearest neighbour (e.g. Otara Hill and Hampton Park, 0.5 km apart; Mt Wellington and Purchas Hill, 0.6 km) and others definitely did not (e.g. Mt Richmond and McLennan Hills, 0.75 km apart). There are a number of other recognised volcanoes that are ~1 km away from their nearest neighbours and are currently considered to be separate, even though it is possible that some of them were twin vents of the one erupting batch of magma (e.g. Otuataua and Pukeiti, 0.3 km apart; Mangere Lagoon and Mt Mangere, 0.9 km; Green Mt and Styaks Swamp, 0.6 km; Mt Eden and Te Pou Hawaiki, 0.7 km; Mt Hobson and Mt St John, 0.8 km; Orakei Basin and Little Rangitoto, 1 km; Grafton and the Domain, 0.5 km; Onepoto and Tank Farm, 0.8 km; Mt Victoria and Mt Cambria, 0.7 km). Using the same criteria of geographic separation, we consider the Puhinui Craters should be considered one of Auckland's volcanoes in its own right, at least at the moment.

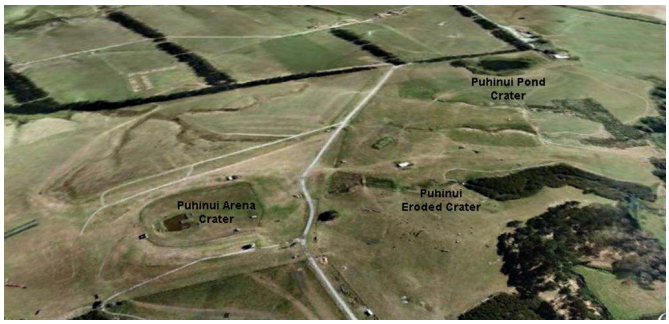


Fig. 11. Oblique aerial view north across the northern part of Puhinui Reserve showing the three tuff cones and volcanic craters. From Google Earth, 2011.

Heritage Values

The presence of three small volcanic craters clearly formed by explosive (phreatomagmatic) eruptions and clustered closely together in one area like this, is unique in the Auckland Field. At 150-250 m diameter these craters are at the small end of the spectrum for maar craters in Auckland (Table 1). They are of similar size to three other craters in the field – each of which have been "accepted" and named as an individual volcano in its own right. These are Styaks Swamp Crater (East Tamaki), Cemetery Crater (Papatoetoe), and Ash Hill (Wiri) (Fig. 1). All three have now been essentially destroyed by industrial or residential subdivision and are virtually unrecognisable.

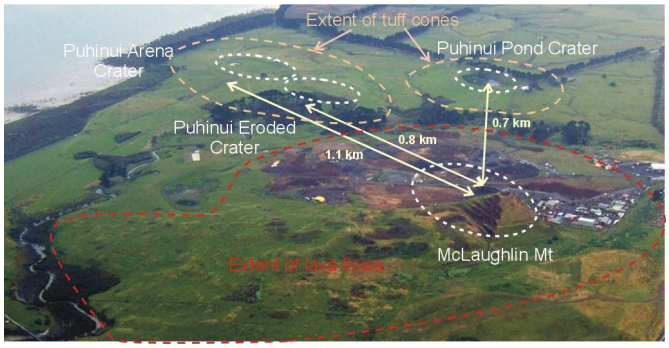


Fig. 12. Oblique aerial view from the southeast showing the relationships between the Puhinui Craters and nearby McLaughlin Mt, 2008.

Two other, smaller (less than 150 m diameter), shallow maar craters are also known to have been present in the Auckland Volcanic Field, but neither has been named and both are considered to have been part of the eruption sequence of the adjoining large volcano – Crater Hill and Pigeon Mt. The small crater at Crater Hill (Hayward et al, 2011a, p.213) was inside the northeast corner of the main explosion crater and was destroyed when the SW Motorway was built through this sector of the volcano. Pigeon Mt's small crater (Hayward et al., 2011a, p.174) erupted through the main volcano's tuff ring on the northwest side and was essentially destroyed when the area was subdivided. Its location can still be recognised as a private reserve communally owned by the surrounding houses.

Thus, not only is this cluster of three small craters and surrounding tuff rings unique in Auckland, but it also contains the only examples of the eight smallest craters in the Auckland Volcanic field that have not been destroyed by urban sprawl.

Serendipitously all three are within Puhinui Reserve – classified as one of Manukau's Premier Parks by its former management –Manukau City Council. There has been slight damage to the crater in Puhinui Arena Crater when the equestrian arena was developed, but this could easily be restored. The presence of these three craters and their tuff rings forming the landforms at the northern end of Puhinui Reserve further raises its heritage value and places it on the list of potential volcanic reserves that should be included in an Auckland Volcanoes World Heritage Area.

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Table 1. Comparative sizes of small maar craters in the Auckland Volcanic Field and the distance from the centre of the nearest named volcano

Crater	Diameter (crest to crest)	Tuff ring elevation	Distance to nearest volcano
St Heliers	500 x 400 m	40 m	2.2 km to Taylor Hill
Te Hopua	500 x 500 m	9 m	2.8 km to Mangere Mt
Boggust Park	450 x 300 m	8.5 m	2.7 km to Mt Robertson
Styaks Swamp	400 x 400 m	?12 m	0.6 km to Green Mt
Cemetery Crater	250 x 250 m	10 m	1.3 km to Kohuora
Puhinui eroded	250 x 250 m	7 m	0.8 km to McLaughlin Mt
Puhinui arena	250 x 150 m	8 m	1.1 km to McLaughlin Mt
Puhinui pond	200 x 150 m	8 m	0.75 km to McLaughlin Mt
Ash Hill	200 x 200 m	6 m	0.9 km to Wiri Mt
Pigeon Mt tuff ring	150 x 140 m	5 m	0.6 km to Pigeon Mt
Crater Hill tuff ring	130 x 130 m	?8 m	0.2 m to centre of Crater Hill

TI POINT BASALT KARST
Bruce Hayward

In 1956 Alan Hopgood mapped the geology around Cape Rodney for his MSc thesis. He published a formal account a few years later (Hopgood, 1961) and in that report he inserted a photograph of a strongly fluted basalt boulder (p. 226), titled "Fluting in basalt. Ti Pt". Since then people seem to have forgotten the existence of basalt karst at this location, and in a recent review of karst in New Zealand (Kenny and Hayward, 2010), we were unaware of this location, believing that karst basalt in New Zealand occurred only at Stony Batter, Waiheke Island and in Northland. Hopgood's paper was brought to my attention by Hugh Grenfell.



Hopgood (1961, p. 226) wrote "Residual boulders exposed now in open paddocks are strongly fluted. The lapiez and solution pits are similar to those described by Bartrum and Mason (1948) from Hokianga and by Halcrow (1956) but probably at an earlier stage of development. Solution of the rock is ascribed to acid solutions dripping from mosses and epiphytes in trees of surrounding bush." I believe a better explanation is that the pits or basins on top and fluting down the sides of the basalt boulders were formed over thousands of years by acidic water associated with soil around the roots of epigean plants such as *Astelia* growing on the top of the boulders (Hayward and Kenny, 2011).



Unfortunately Hopgood gave no detailed description as to where at Ti Pt these boulders were to be seen and a GeoClub field trip was scheduled for Jan 2012 to look for them. I undertook a reconnaissance trip a few days before the GeoClub trip so as to narrow down the search with the group. On a walk around the foreshore on the Ti Pt walkway from the wharf a lot of basalt boulders were seen intertidally and on the lower slopes, but not one had any sign of solution. Later I drove along Tatham Rd, the only side road near the end of Ti Pt, and then along the private driveway at the end. Here I met the owner who knew all about fluted boulders and he showed me some well-developed examples with 10-20 cm deep basins on top and fluting on the sides. Some were now out in the open on the crest of the hill, whereas others were in the native forest on the southern side, often with *Astelia* growing on the top.





These boulders occur in a 150 x 100 m area at 50-60 m above sea level and would seem to be those that have been exposed and least disturbed for the longest time.



The boulders at lower elevations have clearly rolled or slid progressively downslope in the late Quaternary. Once again the location of these fluted basalt boulders suggests that their solution has taken tens of thousands of years or more. The basalt at Ti Pt is Late Miocene in age with a K-Ar date of 8.73 ± 0.54 Ma (Smith et al., 1993). It has been interpreted to be lava flows at Ti Pt (Hopgood, 1961), but some aspects of its setting suggest it may have been intrusive.

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IMBRICATED SHELLS ON AUCKLAND'S COASTS
Bruce Hayward

On several GeoClub trips over the past 15 years participants have stopped to puzzle over the strange sight of tightly packed shells all lined up on their edge, called vertically packed or imbricated. Invariably only one kind of shell is involved at any one site. When seen on the beach the shells always lie flat, either convex or concave up, so how could they have all become packed together and oriented on their sides?

Cockles, *Austrovenus stutchburyi*, have been the most commonly observed in this formation and usually occur in this orientation within a shell spit, or chenier, that has built up near high tide around the edge of extensive tidal sand or mud flats. We have seen these forming the shell spits off Pollen Island in the Waitemata Harbour and at Miranda in the Firth of Thames (also noted by Woodroffe et al., 1983).

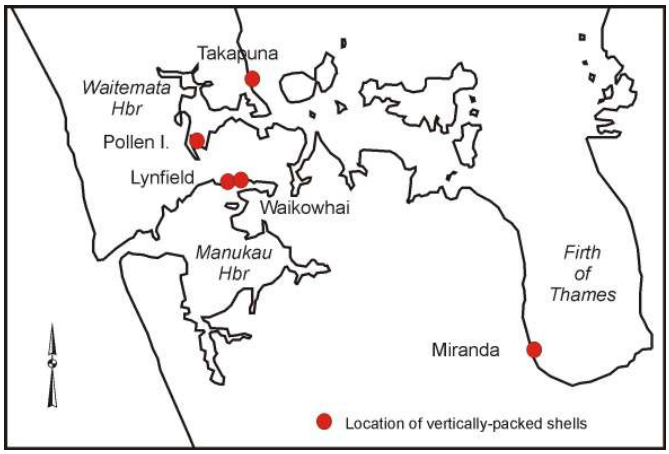


Fig. 1. Map of Auckland area showing intertidal locations where imbricated shells have been observed in recent years.

On several recent trips to the northern coast of the Manukau Harbour we have seen areas of imbricated shells of the Pacific oyster, *Crassostrea gigas*, around mid tide level forming subhorizontal pavements fractionally elevated above the level of the surrounding muddy rock platforms. Notable places for these have been on the coast east of Lynfield Cove and east of Faulkner Bay, Waikowhai.

Back in the 1990s, there was a mass death and storm wash-up of thousands of horse mussel shells, *Atrina zelandica*, onto North Shore beaches. Soon afterwards GeoClub visited the basalt rocky shore between Takapuna and Milford and a number of the small pools within the rocks at high tide level were filled with tight, imbricated shells of the washed-up horse mussels all aligned on their edges. These were washed away again during storms over the next few months, but the cockle and oyster deposits with imbrication are more long-lived and potentially permanent.

This edgewise vertical stacking of shells and disc-shaped stones has been recorded and studied around the coast of England (e.g. Greensmith & Tucker, 1969; Sanderson & Donovan, 1974) and the USA (e.g. Wiedemann, 1972; Grinnell, 1974). The orientation and tight packing has been attributed to the action of small waves on the shore acting on disc-shaped or concavo-convex stones and shells. These studies have concluded that the vertical packing results in stable beach formations and involves well sorted shells in their size and shape. Sanderson and Donovan (1974) noted that the presence of "crevices and large boulders aid the initiation of vertical packing but are not essential for its development". Greensmith and Tucker (1969) noted that shell spits with imbricated mussel (*Mytilus*) shells tended to be more stable and contributed to their stabilities compared to the more mobile spits that lacked them.

Our observations support those of Sanderson and Donovan (1974) and suggest that the imbrication of the large horse mussel shells on the North Shore only occurred in crevices and depressions in the basalt rock and probably was initiated by the shells being stacked up against the steep rock walls. This seems to be the case also with the oyster shells on the Manukau Harbour where most of the imbricated shell patches occur in depressions in the sandstone shore platform and possibly started by stacking against a low steep rock face or in a crevice.


Fig. 2. Shell chenier at Pollen Island, Waitemata Harbour with imbricated cockle shells on the lee (left) side (Fig. 3).

The shell spits of cockle shells on the other hand, develop on the featureless sand flats where there are no steep faces for shells to stack against. In this instance I infer that the initial shell spit has loosely packed and subhorizontally-oriented shells. Once the spit has developed it has a gently-sloping seaward slope and a steep, leeward, landward slope (steeper than 40 degrees). In storms waves wash shells up the seaward slope and they wash over down the landward slope coming to rest at a steep, subvertical orientation. This seems to be one place where the shells develop their dense, tightly packed imbrication as the shell spit advances over them (Pollen Island). At Miranda, close investigation suggested that some cockles developed their imbrication on the shore face where they are directly underlain by sand. Each shell seems to have had one edge impaled in the sand to hold it in its

vertical orientation until many others have been stacked around it.



Fig. 3. Plan view of imbricated cockle shells in a chenier at Pollen Island.

Thus in the case of the cockles and horse mussels the imbrication may have developed during the highest energy storm wave conditions within a somewhat sheltered harbour edge environment. Both these deposits are formed close to high tide level, whereas the imbricated oysters and Miranda cockles occur nearer mid-tide level, but still probably require some wave action to form.

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OIL RIG TERMS
Rhiannon Daymond-King

The oil industry is full of intriguing words. Here is a list of some amusing ones, and their meanings, in alphabetical order.

Bell Nipple – a short length of pipe with a widened end to guide tools into the hole, installed on the top of the blowout preventer.

Blooey Line – a discharge pipe from a well being drilled by a pneumatic drill (air drilling), conducts the air away from the rig to reduce fire hazard.

Boll Weevil – an inexperienced worker or hand, new employee.

Bomb Hanger – device set in tubing or collars to help land recording devices (also called bombs) which measure pressure or temperature in the wellbore.

Buck Up – to tighten a threaded connection.

Bull Plug – a threaded pipe with a rounded closed end used to stop up a hole or close the end of a line.

Bullheading – pumping fluid into the well against pressure, risky due to having no control over where the fluid goes, but occasionally a necessary way of stopping a gas kick before a blowout, especially if the gas contains toxic hydrogen sulphide.

Bumper Sub – a percussion tool that is dropped onto stuck tubing or pipe to knock the stuck object free.

Cathead – a rotating drum on the draw-works around which rope is wound for hoisting and pulling. This rope is called catline.

Clabbered – slang to describe flocculation of mud due to contaminants.

Dead Man – a piece of wood or concrete, usually buried, to which a wire guy line is attached for bracing a mast or tower.

Derrickman – one of the rig crew members who works halfway up the mast and supervises the attachment of new stands of pipe as the casing is lowered. One of the most demanding jobs on the rig in terms of skill, physical exertion and perceived danger.

Bottoms Up - The circulation of mud from the bottom of the wellbore to surface (usually measured in the number of pump strokes required). This is often done for recovering geological samples.

Dizzy Nut – a mechanism used in packers to lock components together.

Doghouse – steel sided room adjacent to rig floor close to drillers controls – combination of tool shed, office, communications centre, lunchroom and crew meeting place.

Donkey Pump – a little pump used for many kinds of small temporary pumping operations.

Dutchman – a piece of pipe that has been twisted off inside a connection; or a short section of material used to lengthen existing equipment.

Fish – stuck pipe or tubing or tool string lost downhole. Trying to recover this is Fishing.

Geronimo Line - Escape line running from monkey board to deck (or ground level) to enable derrick-man to escape in an emergency.

Gooseneck – the curved connection between the rotary hose and the swivel.

Gun The Pits – to stir the drilling fluid in a pit with a mud gun, electric mixer or agitator.

Half Mule Shoe – a cutoff joint below a packer used as a fluid entry device or seal assembly guide.

Iron Roughneck –a floor mounted combination of a spinning wrench and a torque wrench which eliminates the manual handling involved with suspended individual tools (and thus increases the safety of the drill floor).

Jack Board or Lazy Board – a device used to support the end of a length of pipe while another length is being screwed on.

Kelly Bushing – a device that, when fitted into the master bushing (device in rotary table to accommodate slips), transmits torque to the Kelly (metal polygonal piece used to turn the drill stem) and permits vertical movement of the kelly.

Macaroni Rig – a lightweight workover rig built to run a string of only ¾ inch to 1 inch tubing.

Monkeyboard – work platform 26m up the derrick (mast) where the derrickman handles the top end of the pipe stands.

Moonpool – a walled round hole or well in the hull of a drill ship through which the drilling assembly passes while a well is being drilled from the drill ship.

Mousehole – Hole in rig floor used to store next section of pipe for addition to the drill string.

Mosquito Bill – a tube mounted at the bottom of a sucker rod pump and inside a gas anchor to provide a conduit into the pump for well fluids containing little or no gas.

Mule Shoe – a sub, part of which is formed in the shape of a horseshoe and used to orient the drill stem downhole.

Packing off – When the wall of the wellbore caves in around the drill-string causing stuck pipe.

Persuader – a big tool for a small job, used to overcome excess friction.

Possum Belly – tank into which returning mud flows just prior to passing over the shakers. The logging unit gas trap is normally placed here.

Poor Boy – degasser, gas separator (also slang for home made, done on a shoestring basis).

Pup Joint – Generally a non-standard or short section of drill pipe often used for spacing and during a coring run;also used when casing to achieve an specific length.

Rabbit – A metal "plug" which drops out of a core barrel to show that the entire core has been recovered.

Rat Hole – either the hole in rig-floor used for racking the Kelly, or the section of hole below the casing shoe and the T.D. of the original hole which is "cleared out" on drilling out from the shoe.

Roughneck – worker on a drilling or workover rig, subordinate to the driller, whose primary work station is on the rig floor. There are usually three or more roughnecks on each crew.

Round trip – the time it takes to hoist the drill stem out of the wellbore to perform one of a number of operations such as changing bits, taking a core etc, and then to return the drill stem to the wellbore.

Roustabout – oil rig worker employed for temporary or unskilled jobs; handles the equipment and supplies that are sent to the rig from the shore base, assists the crane operator or the foreman in the general work around a producing oil well.

Shale Shaker – screens over which the drilling mud flows when it comes back up the hole. The cuttings are separated from the mud by the shaking of the screens. Cuttings samples are taken from here.

Spider Deck – Platform or work area around wellhead.

Spud Cans – Literally the "feet" on which a "jack-up" type rig stands.

Squnch Connector –A connector for connecting two tubular members, with a pin and a box to receive the pin, and locked by a split wedge ring.

Stuffing Box – device to prevent leakage along amoving part that passes through a hole in a cylinder or vessel.

Toolpusher – employee who is in charge of the entire drilling crew and the rig – also called a drilling foreman, rig superintendent or rig supervisor.

Trombone Joint – Slip joint on marine riser to enable semi-sub rigs or drillships to remain in contact whilst moving up and down with swell.

Whipstock – Sometimes used in directional drilling, it is a long steel casing with an inclined plane which causesthe bit to deflect from the original borehole at a slight angle.

Wildcat – An exploration well in a new field or frontier basin, unknown territory.

GEOPUZZLES
Rhiannon Daymond-King

GEOWORDOKU
KILOGRAMS: base units of mass in International System of Units, equal to the mass of one litre of pure water

O		A		L	S			
	R	S	I	K	A	L	G	
		L			R			
R			A	I	O			
I								R
			G	R	L			K
			K			S		
	S	M	R	O	I	G	K	
			L	S		R		A

CRYSOLITE: a gem variety of brown to yellow-green olivine

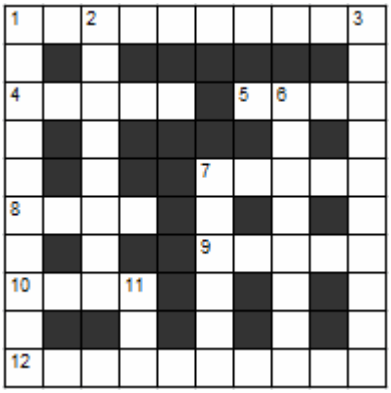
R		E					I	
S				T		C	L	
O				L		R		S
Y		T	R	E				I
L			C		O			E
E				Y	L	S		C
C		Y		S				R
	O	S		R				L
	R					I		Y

GEOWORDFIND

W	O	R	G	R	I	D	G	E	W	L	A	H	T
R	A	D	O	N	O	N	M	E	T	A	L	P	N
T	I	T	A	N	I	U	M	D	E	D	O	R	E
N	R	S	E	S	A	G	T	S	U	R	H	T	M
E	R	A	A	R	N	N	A	V	D	R	I	P	I
M	E	C	P	O	N	A	I	L	E	N	R	A	C
E	G	T	R	E	S	E	D	D	R	I	A	A	E
S	U	I	H	T	Z	C	I	O	I	T	N	B	P
A	L	N	A	I	L	O	B	M	O	R	T	S	S
B	A	I	T	A	N	B	H	E	A	I	T	O	U
E	R	U	I	I	E	A	A	E	F	D	O	R	O
S	K	M	R	R	L	L	G	I	D	E	Y	B	R
K	N	C	L	A	S	T	I	C	A	R	E	E	R
E	I	M	A	A	R	A	L	U	G	N	A	R	E
R	K	R	O	W	E	R	E	T	A	N	U	L	F

ABSORB
ACTINIUM
AGILE
AGING
ANGULAR
BAIT
BANDS
BASEMENT
BORNITE
CAREER
CARNELIAN
CASING
CAST
CLAIM
CLASTIC
COBALT
CRINOID
CUT
DAM
DESERT
DIG
DIRT
DOME
DRIP
DROP
ERODED
ESKER
EYOT
FERROUS
FIT
FREE
GASES
GRID
GROW
IRON
IRREGULAR
KINK
LAG
LUNATE
MAAR
MESA
NAIL
NITRIDE
NONMETAL
OCEAN
PLATE
RADON
REEF
REWORK
RIFT
RIDGE
ROWER
SEAL
SPECIMEN
STAIRS
STORM
STROMBOLIAN
THALWEG
THINK
THRUST
TILT
TITANIUM
TOE
TOR
TRAPEZOHEDRAL
VEINS
WACKE
WATER

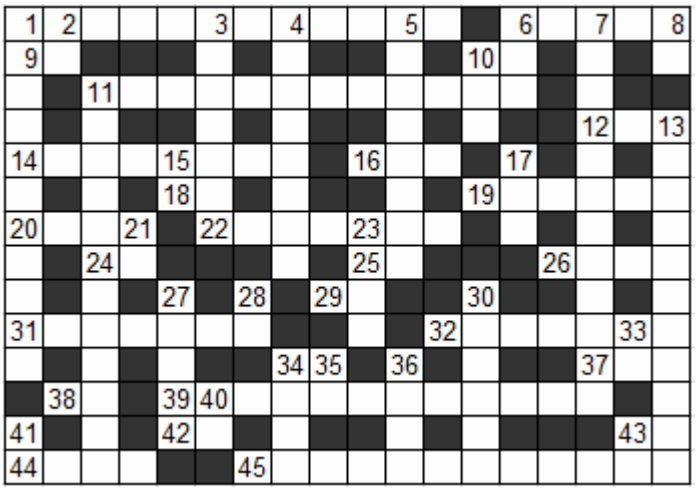
GEOCROSSWORDS



CROSSWORD 1: This has a set of normal clues and a set of cryptic clues. Choose which you'd prefer to answer.

Clues Across
1: Organism without cell nucleus
4: Test for minerals
5: To let out (e.g. radiation)
7: Unit of time in geochronology
8: Typical varve bed size
9: Map of sea
10: Planets counting Pluto
12: Pathway between reservoirs
Clues Down
1: Floating forams
2: Rapidly cooled felsitic rock
3: Death of a species
6: Felt earthquake motion
7: Returning regularly
11: Long stage in geo timescale

Cryptic Across
1: For carrying non-nucleated cereal type
4: Donkey shouts for survey
5: Let out in some mitigating circumstances
7: Reader spends time in a journal
8: Small layers, but with internal consistency
9: Choose map beginning drawing
10: Near in number even counting Pluto
12: Fix together with charged atom
Cryptic Down
1: Board floating on ocean of sparkling medicine
2: Observe rapid cooling outside non-plutonian
3: Distinct ionic traces exist showing deaths
6: Merchants' alliance scrambled by shakeup
7: Council cyclists continually go backwards
11: Take time to roll back a long canoe



CROSSWORD 2

Across
1: Rock with large, round clasts
6: Distance down a well
9: Element symbol named after universal man
10: Symbol of green-oxide element 59
11: Study of rock layering
12: Prefix for centre of earthquake
14: Rocks deposited in oxygenated ocean zone
16: Unit of resistivity
18: Symbol of black ore in glassmaking
19: Deepest part of the ocean
20: Crinoids have many of these
22: The pointed side of a disc foraminifera
24: Symbol of most abundant noble gas
25: Symbol of least reactive element
26: A hole or shaft to underground stream
29: Symbol for most diamagnetic element
31: Mountain building
32: Island attached to mainland by bar or spit
34: Symbol of heaviest group 8 element
37: Cracked from oil in mature source
38: Symbol of lowest density metal element
39: Surface seperating strata of two ages
42: Symbol of metalloid semiconductor
43: Symbol of light space-age metal element
44: Coral formation
45: Warmish period during ice age

Down
1: Dissolved minerals hardening rock
Symbol of brittle, densest element
3: Like an early form of deposited quartz
4: Gas going into atmosphere
5: Alkali feldspar igneous rock
6: A well containing no hydrocarbons
7: Study of fossils
8: Symbol of a very fast messenger element
10: Unit of grain size
11: Early oxygen-makers
13: Trace left behind without body or shell
15: Symbol of 2nd least abundant lanthanide
17: Spreading or volcanism due to plate boundary
21: Symbol of yellowish reactive metal element
23: A standard amount of measurement
27: First in binomial nomenclature
28: Symbol of rare-earth magnetic-oxide element
30: Way to encode, layout or convert data
33: Symbol for 0th f-group element
34: A glacier-eroded pyramidal mountain peak
35: Symbol for metal used for cans before aluminium
36: The lowest temperature oil still flows
40: Symbol of element, synonym columbium
41: Symbol of smelly red-brown liquid element
43: Symbol of corrosion-resistant element like 40

ANSWERS

O	G	A	M	L	S	K	R	I
M	R	S	I	K	A	L	G	O
K	I	L	O	G	R	A	M	S
R	L	K	A	I	O	M	S	G
I	A	G	S	M	K	O	L	R
S	M	O	G	R	L	I	A	K
L	O	R	K	A	G	S	I	M
A	S	M	R	O	I	G	K	L
G	K	I	L	S	M	R	O	A

R	L	E	S	O	C	Y	I	T
S	Y	I	E	T	R	C	L	O
O	T	C	I	L	Y	R	E	S
Y	C	T	R	E	S	L	O	I
L	S	R	C	I	O	T	Y	E
E	I	O	T	Y	L	S	R	C
C	E	Y	L	S	I	O	T	R
I	O	S	Y	R	T	E	C	L
T	R	L	O	C	E	I	S	Y

P	R	O	K	A	R	Y	O	T	E
L	■	B	■	■	■	■	■	■	X
A	S	S	A	Y	■	E	M	I	T
N	■	I	■	■	■	■	E	■	I
K	■	D	■	■	C	H	R	O	N
T	H	I	N	■	Y	■	C	■	C
O	■	A	■	■	C	H	A	R	T
N	I	N	E	■	L	■	L	■	I
I	■	■	O	■	I	■	L	■	O
C	O	N	N	E	C	T	I	O	N

C	O	N	G	L	O	M	E	R	A	T	E	■	D	E	P	T	H
E	S	■	■	■	P	■	M	■	■	R	■	P	R	■	A	■	G
M	■	S	T	R	A	T	I	G	R	A	P	H	Y	■	L	■	■
E	■	T	■	■	L	■	S	■	■	C	■	I	■	■	E	P	I
N	E	R	I	T	I	C	S	■	O	H	M	■	A	■	O	■	C
T	■	O	■	M	N	■	I	■	■	Y	■	T	R	E	N	C	H
A	R	M	S	■	E	V	O	L	U	T	E	■	C	■	T	■	N
T	■	A	R	■	■	■	N	■	N	E	■	■	■	T	O	M	O
I	■	T	■	G	■	D	■	B	I	■	■	F	■	■	L	■	F
O	R	O	G	E	N	Y	■	■	T	■	T	O	M	B	O	L	O
N	■	L	■	N	■	■	H	S	■	P	■	R	■	■	G	A	S
■	L	I	■	U	N	C	O	N	F	O	R	M	I	T	Y	■	S
B	■	T	■	S	B	■	R	■	■	U	■	A	■	■	■	T	I
R	E	E	F	■	■	I	N	T	E	R	S	T	A	D	I	A	L