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Field Trip Guide

The Puketoka Formation and the age of the Hauraki Graben

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THE PUKETOKA FORMATION AND THE AGE OF THE HAURAKI GRABEN.

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Introduction

The Hauraki Graben is a major geomorphic component of northern New Zealand, but what do we really understand about its time and mode of formation? One much debated question is - "When was it formed?" The Coromandel-derived conglomerates of the enigmatic Puketoka Formation appear to offer some important clues (Battey 1949, Kear 2000, 2004).

This field trip explores the seldom-visited type locality of Puketoka Formation at the scenic Puketoka trig, near Maramarua (S12/046401). A second important outcrop at Kidds Beach (R12/720560) on the southern shores of the Manukau Harbour will also be examined in the context of pathways for the Coromandel-derived sediment and age constraints on the subsidence of the Hauraki Graben.

Fig 1: View from Monument Road - hills in the background are the type locality of the Puketoka Formation near Maramarua.

Fig. 2 Outcrop of the Puketoka Formation at Kidds Beach, southern Manukau Harbour.

Age of Hauraki Graben foundering

Edbrooke (2001, p.52) summarises most current thinking on the formation of this feature: "The Hauraki Plains and Firth of Thames are interpreted as being part of an active continental rift structure (Hauraki Rift), extending more than 250 km from a concealed junction with the TVZ to the northern Hauraki Gulf (Hochstein and Ballance, 1993). The Hauraki Rift is bounded by Firth of Thames Fault and Hauraki Fault to the west and east respectively. It consists of up to 3 half-grabens adjacent to west-dipping master faults, and contains up to 2.5 km of sediment. The rift is thought to have originated during Late Miocene uplift in the back-arc region, parallel to the Coromandel volcanic arc, and was probably accommodating sediment by 5-7 Ma (Late Miocene)."

In recent years David Kear (e.g. Kear, 2000, 2004) had made us well aware of Hugh Battey's (1949) report of Coromandel-derived cobbles in a Pliocene conglomerate at Puketoka trig, and the implications for a young age of formation of the Hauraki Graben that now lies between the Coromandel and Hunua Ranges.

Edbrooke (2001) was aware of this conglomerate and suggested the following to accommodate it: "Periods of sediment accumulation [in the Hauraki Rift] probably alternated with periods of sediment bypass, allowing pyroclastic flows and sediment to reach areas west of the rift (Hochstein and Ballance, 1993)." By the end of today's trip you can make your own judgement on how plausible this explanation might be.

The clasts within the type Puketoka Formation include rhyolite, vein quartz and silicified wood, inferred to be derived from the northern or central Coromandel Range volcanic sequence (essentially of Middle and Late Miocene age, ~18-5 Ma). The oldest rhyolitic volcanism is dated at ~11 Ma (Adams et al., 1994) giving a lower age constraint on the conglomerate.

In the southern part of the Hauraki Graben, the Kerepehi Fault has a mappable fault scarp and is considered to be active (e.g. Houghton and Cuthbertson, 1989), suggesting that the Graben may still be slowly foundering, at

least at the southern end. In the vicinity of Matamata, in the southern part of the Graben, the Hauraki Fault has a 400 m vertical offset (west side down) of the Waiteariki Ignimbrite (2.09 Ma, Briggs et al., 2005) and no offset of the Mamaku Ignimbrite (0.22 Ma) suggesting largely Pleistocene foundering in that vicinity (Houghton and Cuthbertson, 1989, p.29).

Field trip itinerary

From Auckland City we will drive south on Hwys 1 and 2 around the east and southern sides of the uplifted Hunua greywacke horst (Figure 4, 6).

STOP 1. Puketoka (near Maramarua)

We will drive onto private farmland and visit bluffs comprised of the type Puketoka Formation to examine the sequence and composition of the conglomerate clasts. We may also stop and look at some of the larger cobbles and boulders that have been collected off the paddocks and used in retaining walls by the farm house.

Puketoka Formation

The Puketoka Formation is included in the latest Miocene to Holocene Tauranga Group (Kear and Schofield 1978, Edbrooke *et al.* 2001).

At the type locality, near Maramarua, Battey (1949) described the following sequence:

Top	
30 m	poorly cemented boulder bed containing well rounded boulders, often more that 0.3m in diameter, of mainly andesite, with some quartz vein-stone, crypto-crystalline silica, and banded rhyolite.
6 m	conglomerate with cobbles of greywacke and andesite up to 0.1m in diameter.
45-60 m	cream coloured pumice silt

Base not seen.

Fig. 3 Fallen block from the type locality

Provenance of Puketoka sediment

Greywacke clasts are likely to be eroded from nearby surrounding hills of the southern Hunua and Hapuakohe Ranges. The andesite clasts may be derived from the Middle-Late Miocene Kiwitahi Volcanic Group, some of which outcrops today 3-10 km to the east. Some andesite might also come from the Coromandel Group of similar age on the other side of the Hauraki Graben. The only known possible source for the rhyolite and quartz clasts is from the Late Miocene-Pliocene Whitianga Group that outcrops today 25-30 km to the east of Puketoka on the opposite side of the Hauraki Graben.

Battey (1949, p.441) was the first to speculate that the Puketoka Formation provides evidence for the age of the Hauraki Graben and describes the Formation as including "pumice silts, various sands and conglomerates; these last are commonly greywacke boulders, but in places, especially in the higher parts of the sequence, contain boulders of vein quartz and banded rhyolite which, as is shown later, imply a region of provenance in Cape Colville Range or in some westward extension of this range.".

Puketoka Formation – its significance and useage

Later in his publication, Battey (1949) also includes a "Central Volcanic Plateau" (CVZ) source for "Puketoka Formation" pumice silts (including chalazoidites) in railway cuttings of the middle Mangatangi Valley and the east end of Koheroa ridge (Battey 1949, p.439).

Schofield (1976) clearly considered these deposits (mapped as tz and pz) to be younger sediment (terrace deposits) within the Tauranga Group and not part of the Puketoka Formation. He preferred a local and southern (CVZ) source for the Puketoka Formation (Schofield 1976, p.19). Kear and Schofield (1978) mapped the Formation as occurring throughout the Waikato and of Late Pliocene to Early Pleistocene age. They appeared to prefer a Coromandel source for the sediments. Kermode (1992) mapped the Formation as part of the Tauranga Group (tp) and having a CVZ source. Edbrooke (2001) mapped the Formation as being widespread but did not discuss it's provenance. Puketoka Formation as mapped by some (e.g. Kermode 1992, Edbrooke 2001) contains a wide range of lithologies (e.g. lignites, rhyolitic ignimbrites and tephras, peat, polymict conglomerates, carbonaceous mudstone) from at least two sources. The type Puketoka Formation is of Pliocene age and contains Coromandel-derived conglomerate and pumiceous sediment. Much of the remainder of the rocks mapped elsewhere as Puketoka Formation are of Pleistocene age, contain no Coromandel-derived conglomerate clasts and the significant clastic rhyolitic component is derived from the CVZ. So why map them as the same unit?

Provenance of the pumiceous sediment and ignimbrite of the Puketoka Formation *s.l.* (e.g. Edbooke 2001)

These could be sourced from the Coromandel Range, Kaimai Range volcanics or Central Volcanic Zone (CVZ) between Taupo and the Bay of Plenty. Over the last 11 myrs there has been a southward migration of volcanism through this area. Coromandel ignimbrites and pumiceous sediment comes from Whitianga Group volcanism which north of Waihi (i.e. the area west of Puketoka) is of Late Miocene age (11-5 Ma, Adams et al., 1994). Around Waihi and south into the Kaimai Range, rhyolitic volcanism produced extensive ignimbrite and pumiceous sediment and rhyolite domes during the Middle and Late Pliocene (~4-2 Ma; Edbrooke 2001, Briggs et al., 2005). All rhyolitic volcanism in the CVZ occurred during the Quaternary (post ~2 Ma; Briggs et al., 2005).

There is no apparent overlap in time between volcanism in the NNW-trending Coromandel-Kaimai Arc and the NE-trending CVZ (Briggs et al., 2005). Thus pumiceous sediment or ignimbrite in Puketoka Formation of Pliocene age (type locality) must be derived from the southern Coromandel-Kaimai volcanism.

Much of the pumiceous sediment and ignimbrite mapped as Puketoka Formation around the Manukau and Waitemata Harbours (e.g. Edbrooke, 2001) is of Early Pleistocene (1.3-1 Ma) age (Alloway et al., 2004) and therefore likely derived from the CVZ.

We will drive back to Papakura and turn west along the southern shore of the Manukau Harbour.

STOP 2. Kidds Beach, **southern shores Manukau Harbour** (Angelsey 2007, Berry 1986, Hayward et al. 2006, 2007, Prickett 2007). [Low tide 5PM, 0.7 m]

The South Auckland Rock and Mineral Club had long noted that the gravel at Kidds Beach contained quartzose pebbles not seen anywhere else locally and most similar to what they collect in the Coromandel Ranges. Hearing of this, your trip leaders' curiosity was aroused and we visited the site on several occasions in 2006.

At Kidds Beach the normally shelly shoreline of the Manukau is replaced by a gravel beach of red, grey and white pebbles for at least a 2 km stretch. These pebbles are eroded out of the adjacent intertidal shore platform formed of weakly bedded conglomerate with some west and north-facing cross- bedding. The conglomerate overlies limonitic sandstone and includes some lenses of log-bearing, carbonaceous sandstone and mudstone.

Age of the Puketoka Formation, south Manukau Harbour

The geology of this area was mapped by MSc student Keith Berry (1986), whos maps show that this is the largest outcrop of a Pliocene "red chert conglomerate" unit that has a

number of other smaller exposures along the harbour coast between Karaka and Clarks Beach (Fig. 1). Berry also studied a number of local drillhole sequences and showed that this conglomerate is underlain by early Pliocene shallow marine Kaawa Shellbed (Opoitian-Waipipian age; Berry, 1986) and is overlain by widespread rhyolitic pumiceous sands. These latter sediments presumably were transported down the Waikato River to this area from the CVZ following the start of volcanism in that region sometime after 2 Ma ago (Briggs et al., 2005). Thus the age of the conglomerate must be somewhere within the late Pliocene (c. 3-2 Ma ago). This was confirmed by the discovery of the leaf of a "brassi" group (large-leaved) beech in one of the carbonaceous lenses (R12/f80), a group that had largely disappeared from NZ by 1.5-2 Ma ago (Cooper, 2004).

Composition and provenance of clasts in conglomerate at Kidds Beach

The conglomerate (and modern beach gravels) is dominated by subangular pebbles of red-brown cherts and grey argillite/greywacke clearly derived from the Waipapa Group (Table 1). The nearest source is the uplifted Hunua Ranges, but red cherts are rare in the southern and western parts closest to Kidds Beach (Schofield, 1976, 1979). The greatest concentration of chert units outcrop in the north-east Hunuas to Waiheke Island area (also the source of McCallum's red chip used widely on Auckland footpaths). The next most common clasts are more rounded pebbles and even cobbles of cream-white crystalline "vein" quartz. Some of this has inclusions of chert that link its source to the Waipapa rocks, but other more massive and more coarsely crystalline quartz is more reminiscent of vein quartz typically encountered on Coromandel Peninsula. Other rarer pebble lithologies that are most strongly linked to a probable Coromandel source are of silicified wood, chert, ?sinter, and silicified flow-banded rhyolite. Rounded andesite pebbles also could be sourced from the Coromandel volcanics, but an equally possible source is the Kiwitahi andesites that outcrop along the eastern side of the Hunuas (Black et al., 1992). As the crow flies the nearest andesite source is the Waitakere Ranges to the north-west, but this seems improbable as it is contrary to the direction indicated by all the other lithologies.

The shape of the pebbles reflects a combination of their hardness, jointing, and distance transported. The softest and largest clasts are well-rounded but were locally derived Waitemata Sandstone. The smallest and most angular pebbles are the red cherts - sourced from the hardest and most closely-jointed rocks but transported c. 30 km. Clasts transported the furthest (c. 50 km) are those inferred to be derived from the Coromandel volcanic region. These are all the hardest lithologies in the Coromandel Range (fresh andesite, quartz, silicified rhyolite and wood) but even so most have been rounded during their long journey. None of the more common softer lithologies found on Coromandel Peninsula (e.g. rhyolites, ignimbrites, altered andesites) are present in the conglomerate and presumably were not hard enough to survive the journey. The most convincing Coromandel-sourced pebble has vein quartz and andesite together – a combination not seen in the Waitakere Ranges nor Kiwitahi andesites.

Table 1. Character of the cobbles and pebbles in the Pliocene Conglomerate

Lithology	%	Size	Shape	Provenance
Sandstone (local)	30	<50 cm	r-wr	Waitemata Sandstone
Red-brown chert/argillite	30	<8 cm	sa-sr	Waipapa Gp, N Hunuas -Waiheke
Grey argillite/greywacke	25	<10 cm	sa-r	Waipapa Gp, Hunuas-Waiheke
White "vein" quartz	10	<20 cm	sr-r	Coromandel Hunuas (Waipapa Gp)
Grey andesite	5	<10 cm	r	Coromandel, ?Waiheke, ?Waitakeres
Flow-banded rhyolite	<1	<10 cm	r	Coromandel
Silicified wood	<1	<10 cm	sr-r	Coromandel
Chert/sinter	<1	<6 cm	sa-sr	Coromandel

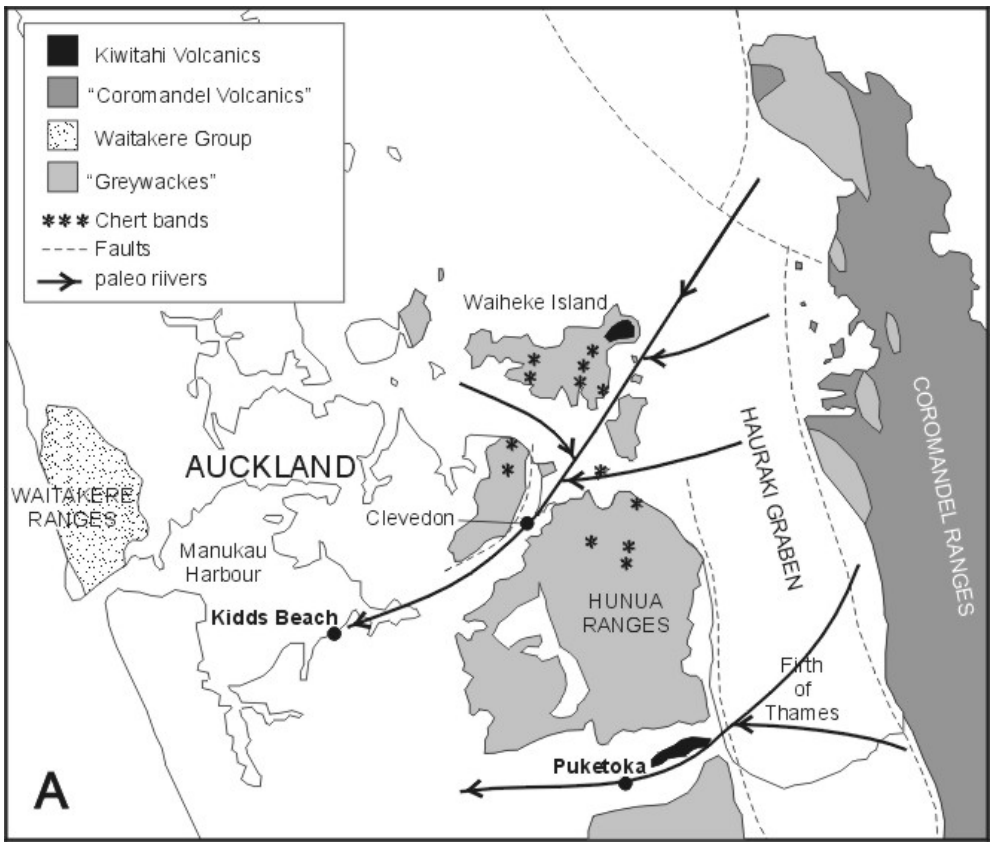

Fig.4. Simplified geological map of the Auckland region, showing location of the conglomerates at Puketoka and Kidds Beach and possible sources of their different pebble lithologies. The inferred N Hunuas-Coromandel provenance of the conglomerate points to the existence of a west-flowing "Clevedon River" prior to the major subsidence of the Hauraki Graben.

West-flowing Pliocene Clevedon River

The probable provenance of the pebbles in the Kidds Beach conglomerate require a transport route from the North Hunuas-Waiheke area. Geological maps (e.g. Edbrooke, 2001) show the existence of a narrow elongate "half graben" directly linking the two areas and now occupied by the Clevedon Valley and Ardmore-Papakura lowlands. This valley lies between two uplifted NW-tilted blocks of Waipapa "greywacke" with the Hunua Ranges to the south and the Whitford – Maraetai block to the north uplifted along the NW-trending Papakura Fault. Coal exploration drillhole 8427 in this "half-graben" intersected Eocene and Miocene sedimentary rocks sitting atop greywacke basement (Edbrooke et al., 1994) and indicate that it is clearly downfaulted and not purely erosional through the greywackes. Thus it would seem that a west-flowing river passed through this valley in the mid or late Pliocene. The present arrangement of islands and flooded valleys at the eastern end of the Tamaki Strait (between Waiheke and the Hunuas) suggests that several west-flowing tributaries fed this ancient "Clevedon River", and one or more of these could have originated from the vicinity of Coromandel township, prior to the subsidence of the Hauraki Graben.

A substantial west-flowing river through the Auckland region may seem counter-intuitive given the present geography, but further north much of northern Auckland and Northland is predominatly drained by west-flowing rivers (e.g. Hoteo, Manganui, Wairoa, Hokianga) and reflect the general western tilt of the geology of the Northland-Auckland peninsula (Figure 5). Prior to the foundering of the Hauraki Graben this western tilt seems to have extended south-eastwards to the Hunua-Coromandel region. Much of the central Coromandel Range is tilted eastwards today and suggests that maybe the Hauraki Graben may have been an area of thermal up-doming prior to the graben's formation.

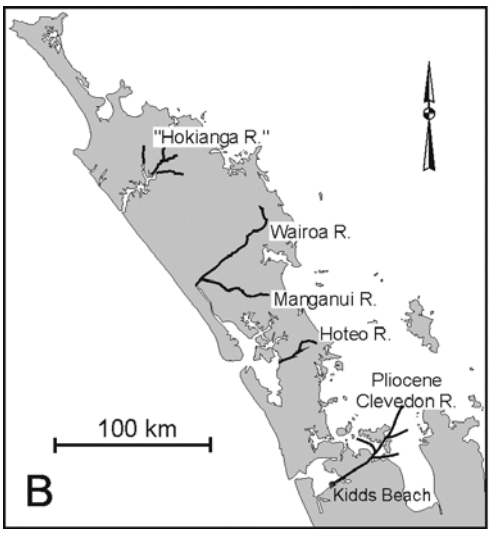

Fig. 5. Present day west-flowing Northland rivers due to regional tilting

Summary

Puketoka Formation use

The Puketoka Formation has been used to include a wide variety of sediments from at least two different sources and directions in the Waikato and Auckland regions (e.g. Waitemata and Manukau Harbours (Kermode 1992, Edbrooke, 2001) and the Waikato Basin (Kear and Schofield 1978). It seems to have been applied too broadly. Certainly the Tamaki Estuary (e.g. St Kentigens section) and other Manukau Harbour (e.g. southeast of Ihumatao) sediments have quite a different provenance (i.e. CVZ derived fluvial, pumiceous sediments, palaeosols, ignimbrites and tephras). This contrasts with Kidds Beach and indeed Battey's type locality at Puketoka trig (greywacke, cherts, Coromandel rhyolites, andesites). Arguably the younger CVZ-derived deposits should be differentiated from the Coromandel / greywacke-sourced sediment typified at the type locality and Kidds Beach.

Age of the Hauraki Graben

The presence of Coromandel-derived clasts in the Pliocene Puketoka Formation at Puketoka and Kidds Beach suggest that this middle section of the Hauraki Graben had not foundered far, if at all, prior to the Middle Pliocene (~3 Ma). We therefore imply that most foundering of this major geomorphic feature has occurred in the last 3 myrs and is still on-going, at least at the south end.

Outstanding questions and future work

1. Can the rhyolitic sediment of Pliocene southern Coromandel-Kaimai age be distinguished from similar sediment of Pleistocene age derived from the CVZ – geochemistry of fresh glass?
2. Can a more precise age be obtained for Puketoka Formation s.s. at the type locality and Kidds Beach? And are they of similar age?
3. Has the Hauraki Graben rifted apart and was the Coromandel and Hunua Ranges originally closer together?
4. Are there rhyolitic sources for the Puketoka clasts buried within the Hauraki Graben?
5. What is the age of the oldest sediment within the Hauraki Graben (needs a drillhole)?

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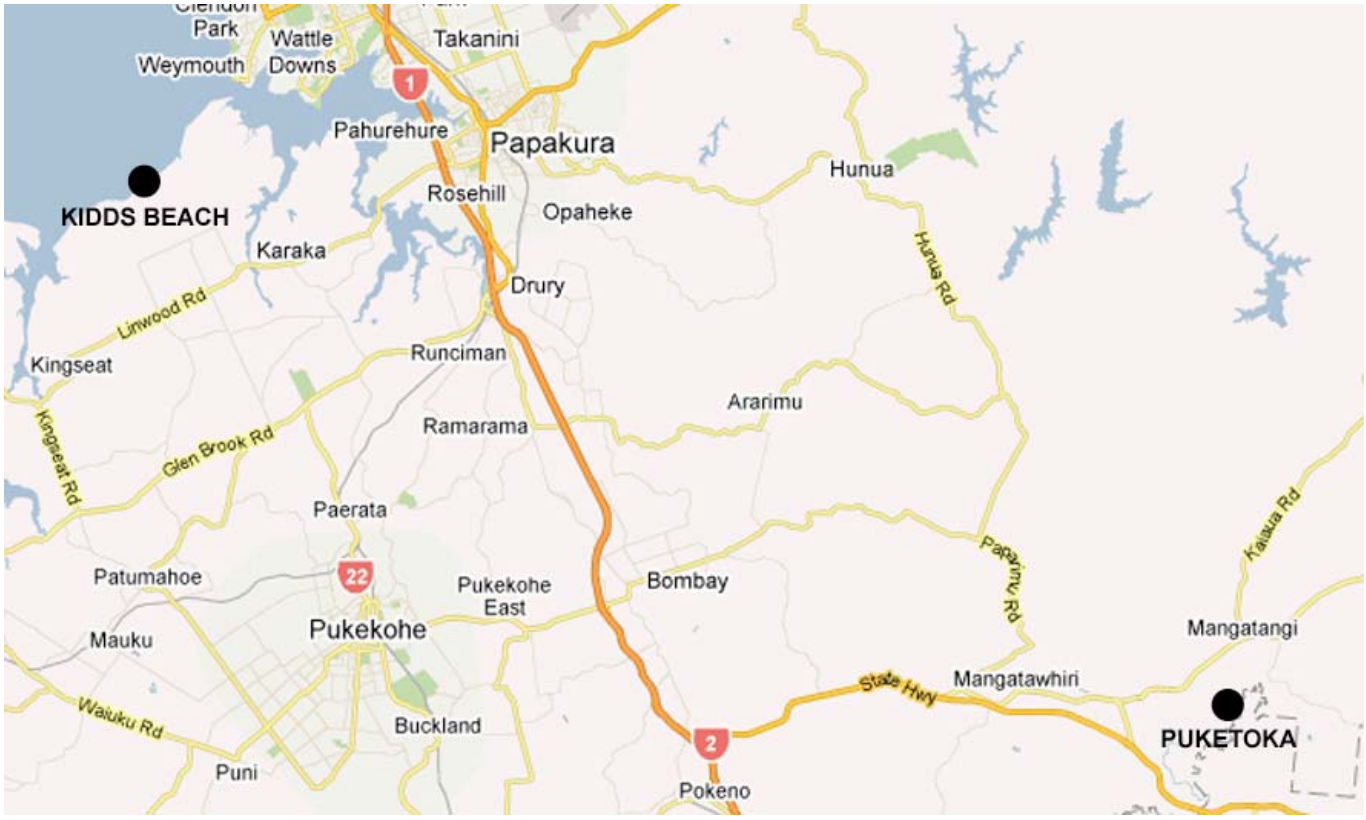

Fig. 6 General road and locality map.