THE LATE CASTLECLIFFIAN AND EARLY HAWERAN STRATIGRAPHY OF THE MANAWATU AND RANGITIKEI DISTRICTS

Griffins Road Quarry. The Upper Griffins Road Tephra is above Brad Pillan's head. The Middle Griffins Road Tephra is at his waist level, and Brent Alloway is sampling the Lower Griffins Road Tephra just above the Aldworth river gravels (OI 10).

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INTRODUCTION

The age of many mid-late Quaternary surfaces in the area between Wanganui and Palmerston North has been poorly known because:

1. The marine terraces are not as well defined as they are west of Wanganui (Pillans, 1990).

2. The wave cut surfaces are difficult to locate, and the underlying sediments are sand dominated and softer.

3. The loess cover on marine and river terraces is of the Pallic Soil facies, i.e. pale grey and mottled, making paleosols difficult to see in the poorly drained loess.

4. Dune sands, metres thick, occur within or between some loess units.

5. Actively growing asymmetric anticlines aligned N/NE-S/SW with gently sloping western limbs and steeper eastern limbs tilt the surfaces. This uplift has increased the dissection of the terrace treads. Active faults also disrupt terrace surfaces.

Q-MAP

The Q-map programme has reviewed existing data and gathered new information in the northern Manawatu. Surfaces identified during detailed examination of aerial photographs have been transferred to 1:50,000 sheets, and generalized for the Q-map.

TEPHRAS

Tephras provide important stratigraphic marker horizons in the mid-Pleistocene cover beds in the Wanganui-Manawatu region. Mineralogic characterization of these tephras has assisted stratigraphic correlation where field identification has proven difficult.

Previously known sites where mid-Pleistocene tephras had been found (e.g. Pillans 1988; Bussell and Pillans, 1992) were reexamined by Palmer et. al. (2005). Massey University and Victoria University students also documented some sites in their theses (e.g. Brown 1999; Bussell, 1984; Potter, 1984; van der Neut 1996; Woolfe, 1987). Many new sites were discovered, some during the Q-map process (Figure 1).

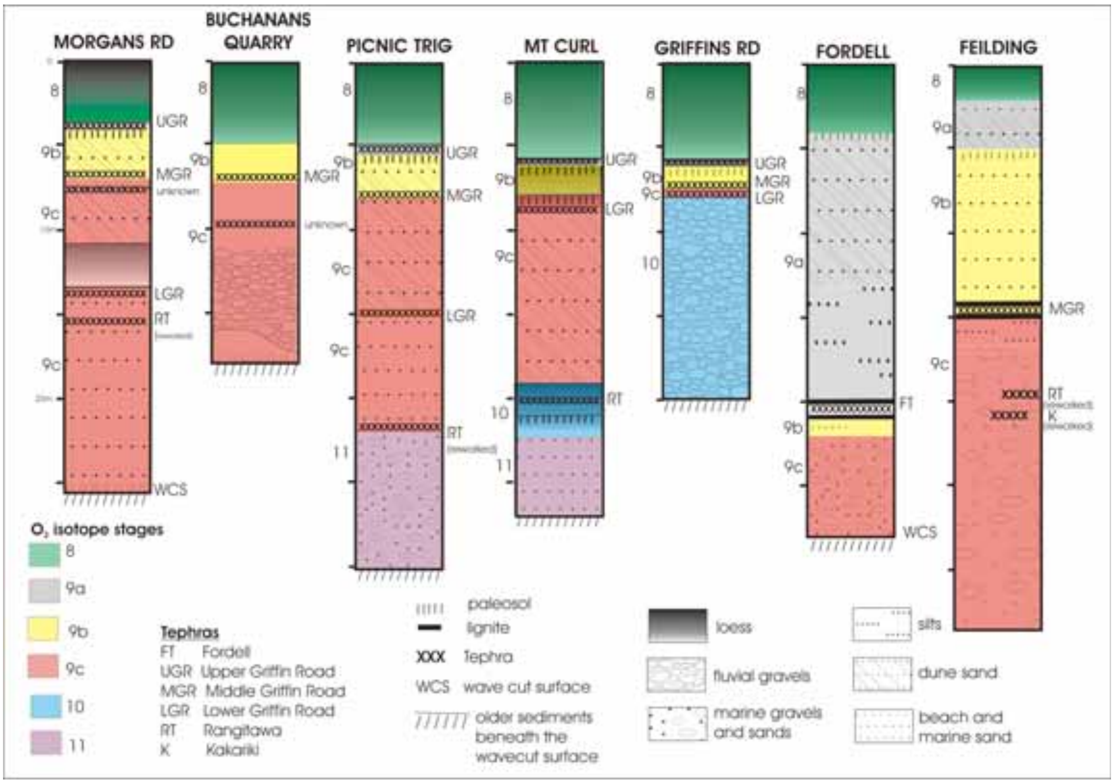


Figure 1. The stratigraphy of key selected sites.

At most sites, the tephras have been analysed using the Electron Microprobe at Victoria University (Palmer et. al. 2005) (Figure 2). This was done to assist with stratigraphic correlations, given the difficulties with field identification described above. The mineralogy of the tephras has been determined at their "type" sections (Figure 3).

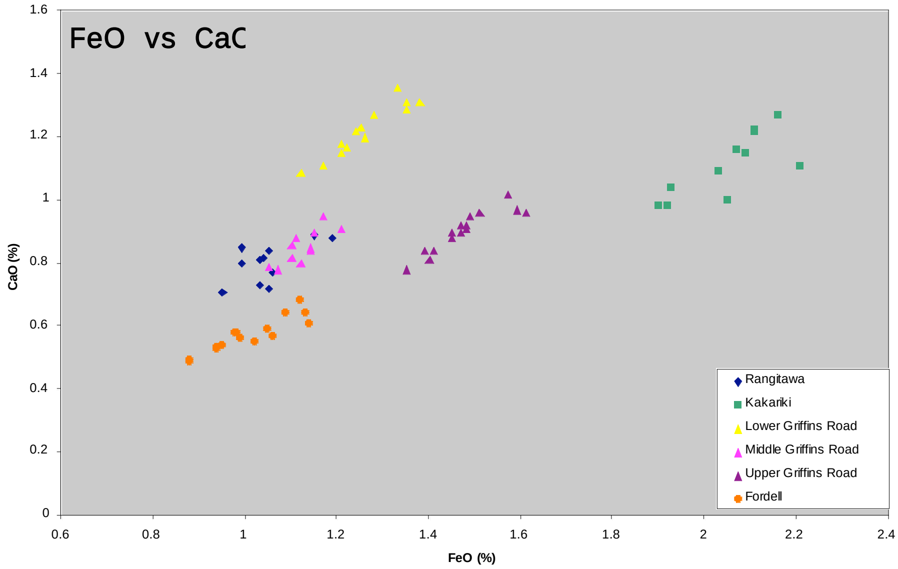


Figure 2. FeO vs CaO plot for glass analysed by electron microprobe.

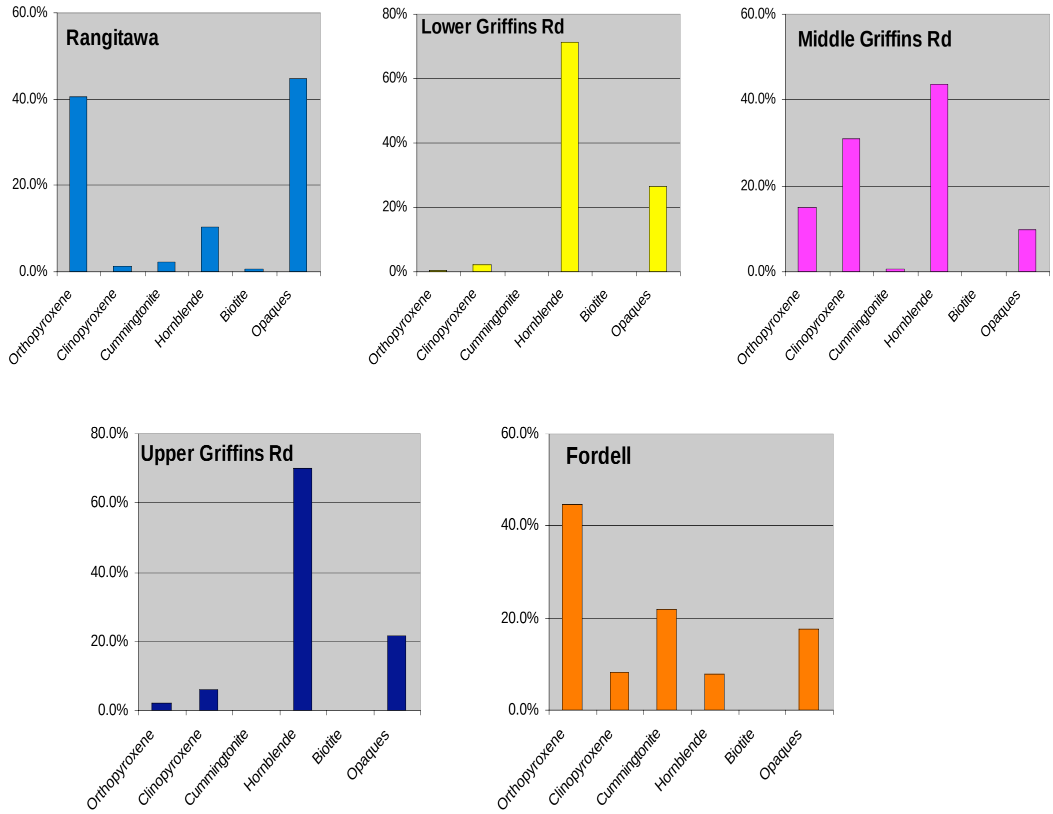


Figure 3. Ferromagnesian mineralogy of the tephras.

RANGITAWA TEPHRA

Rangitawa Tephra is 10-70cm thick across the region and includes all tephras previously called "Mt Curl". The tephra was deposited towards the end of Marine Oxygen Isotope Stage (OI) 10, and is found on the Ararata (OI 11) and older marine terraces, and the Waituna (OI 10) and older river terraces. It usually is preserved within loess, just below a paleosol, but also occurs in swamp deposits near Halcombe and dune sands near Palmerston North. Glass from the tephra, and pumice from the associated Whakamaru Ignimbrite is reworked through marine deposits of OI 9. The tephra is well dated by fission-track at 340 +- 40 ka (Kohn *et al* 1992).

Glass chemistry: $1/3K_2O > FeO > CaO$
Ferromagnesian mineralogy: Opx >> Hb >> Cpx = Bio

KAKARIKI TEPHRA

The tephra was reported by Bussell (1984) reworked in sands stratigraphically above Rangitawa Pumice. At sites where Rangitawa Pumice is found in loess, shards with Kakariki Tephra chemistry are also found, for example Rangitatau Road, west of Wanganui. Kakariki Tephra has not been found as macroscopic primary airfall tephra, but is reworked along with Rangitawa Tephra in marine sands on the Braemore Marine Terrace (OI 9c).

Glass chemistry: $FeO >> 1/3K_2O > CaO$.

LOWER GRIFFINS ROAD TEPHRA

Lower Griffins Road Tephra is 10-15cm thick at its type location, where it sits directly on Aldworth river gravels (OI 10), and underlies fluvial silts. At Picnic Trig and Morgans Road it is found in beach sands above the Braemore wave cut surface (OI 9c). At present it has only been found at sites between the Whanganui and the Rangitikei rivers. The tephra has not been dated by fission track analysis.

Glass chemistry: $FeO >= CaO >= 1/3\ K_2O$
Ferromagnesian mineralogy: Hb >> Cpx

MIDDLE GRIFFINS ROAD TEPHRA

Middle Griffins Road Tephra is 5-10cm thick at sections in Turakina Valley (Morgans Road, Buchanan's Quarry and Picnic Trig), where it occurs within dune sand. At Griffins Road it lies within silty alluvium. At Feilding the tephra is enveloped in lignite that records a cooling from a full Rimu-broadleaf forest to a *Nothofagus* dominated forest (Elliot & Palmer 1998) which is interpreted to represent the cooling from the OI 9c interglacial to the OI 9b stadial. The tephra has not been dated by fission track analysis.

Glass chemistry: FeO = 1/3 K_2O > CaO
Ferromagnesian mineralogy: Hb > Cpx > Opx

UPPER GRIFFINS ROAD TEPHRA

Upper Griffins Road Tephra, 10-30cm thick throughout the area, is often partially cemented by silica. At the type section the tephra rests on a strongly developed paleosol in loess or alluvium, and is overlain by loess. At most other sites the tephra occurs at the top of a thick sequence of dune-sands, usually showing signs of soil formation directly below the tephra. At sites described by Bussell & Pillans (1992) near Fordell, Upper Griffins Road Tephra directly underlies Fordell Tephra. For these reasons, the tephra probably fell during OI 9a. Berger *et al.* (1992) reported a TL age (on loess) of 328± 43 ka directly below the tephra. There are no fission track dates.

Glass chemistry: FeO > 1/3K_2O > CaO
Ferromagnesian mineralogy: Hb >> Cpx > Opx

FORDELL TEPHRA

At sites near Fordell, Fordell Tephra directly overlies Upper Griffins Road Tephra. It is found as a 5-10 cm thick ash between Wanganui and the Turakina River. At Fordell it occurs within lignites and silts that Bussell & Pillans (1992) interpret as early OI 9a. They estimate an age of 300 ka, but ages on OI stages would indicate a slightly older age of ca 310 ka.

Glass chemistry: 1/3K_2O > FeO >> CaO
Ferromagnesian mineralogy: Opx > Cgt > Cpx = Hb

CORRELATION TO SOURCE ERUPTIVES

- The Rangitawa Tephra has been correlated to the Whakamaru (and coeval) ignimbrites with a fission track age of 340 +- 40 ka (Kohn *et al* 1992), erupted from the Taupo-Maroa area.

- The source of the Kakariki Tephra remains unknown.

- Lower Griffins Road Tephra was correlated by Froggatt (1983) to a tephra near Te Piki, but it has not yet been correlated to a Central North Island source and ignimbrite.

- Middle Griffins Road Tephra was correlated to the Matahina Ignimbrite by Froggatt (1983). This correlation is supported by glass chemistry in this study, and a fission track age on the ignimbrite of 0.34 ± 0.02 Ma by Black *et al* (1996). Its source is the Okataina caldera.

- Upper Griffins Road Tephra was correlated to the Kaingaroa Ignimbrite by Froggatt (1983). The correlation is supported by glass chemistry here, and a fission track age on the ignimbrite of 0.31 ± 0.01 Ma by Black *et al* (1996). Its source is the Reporoa caldera.

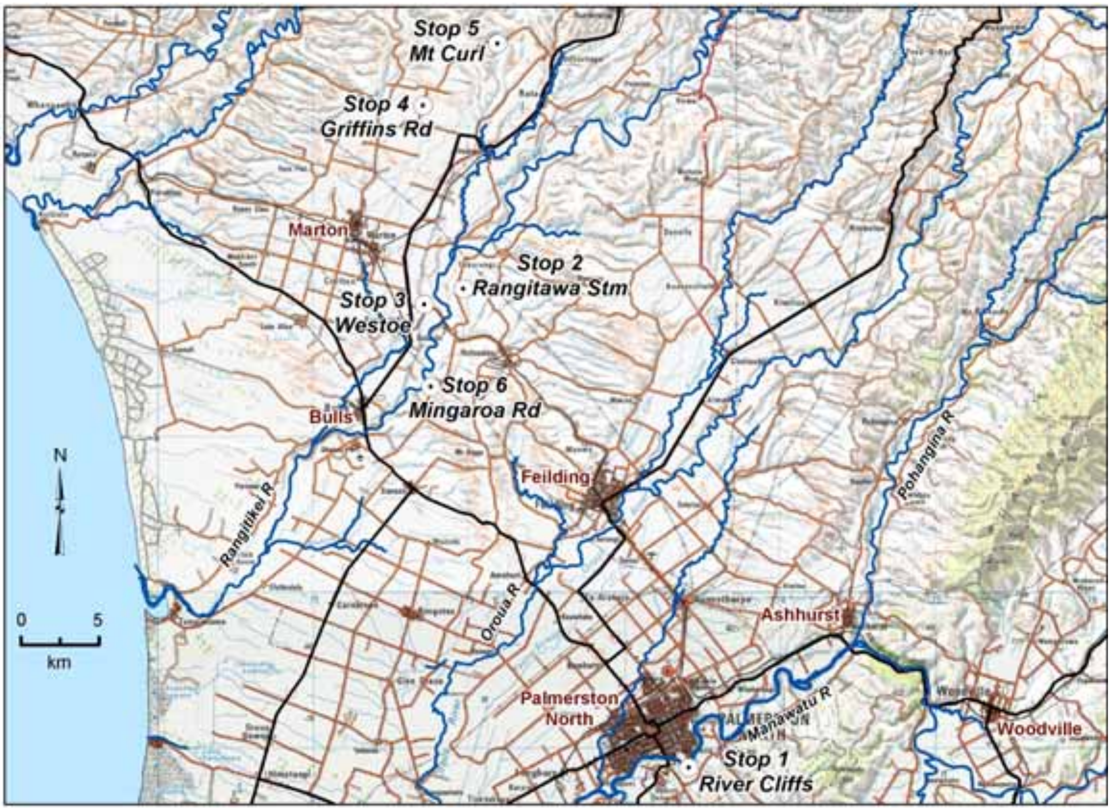
- The source of the Fordell Tephra is unknown. It does not correlate to Mamaku Ignimbrite, which is too young (0.23 Ma) and has different glass chemistry.

UTILITY FOR CONFIRMATION OF TERRACE AGES

The tephras have been used to confirm the age of marine and river terraces between OI stages 9 and 11. The Griffins Road and Fordell tephras are found in the terrace deposits above the OI 9c Braemore wave cut surface, and in the terrestrial cover beds of older marine and river terraces. The Upper Griffins Road and Fordell tephras also occur on inland parts of the OI 9a Brunswick Terrace. The Rangitawa and Kakariki tephras are restricted to the OI 10 Waituna river terrace, and older terraces.

The ages of extensive folded terrace surfaces between Palmerston North and Wanganui have been established for the first time. In particular, the marine sediments that make up Mt Stewart-Halcombe and Feilding anticlines are shown to have been deposited during OI 9c. The thick marginal marine sands that wrap around the southern end of the Pohangina Anticline were deposited in OI 11.

We have 5 stops organized with one site in reserve (Figure 4). All but the first follow the theme of following geological events in the Manawatu-Rangitikei region during OI 9 and 10.



STOP 1. MANAWATU RIVER CLIFFS

At Anzac Park, the Manawatu River is cutting deeply and swiftly into the Tokomaru Marine Terrace (OI 5e). The site is on the elbow of a bend in the river that has steadily been migrating down stream in a normal manner. The thalweg has produced a large point bar on the inside of the bend, part of which is occupied by the Hokowhitu Golf Course. Aerial photos show that the cliffs have been retreating southeast at 1-2m a year since at least the 1940s.

The cliffs are composed of: 2.4m of columnar Ohakean loess containing Kawakawa Tephra (OI 2); 1.5m of orange coloured Ratan loess (OI 3); 1.5m of chocolate brown Porewan loess (OI 4); 26m of parallel centimetre bedded, mafic mineral rich marine and beach sand, and gravel of the Otaki Formation (OI 5e), overlying 27m of bedded sands, muds, thin lignites, and coarse fluvial gravels (Cooper 1999).

The age of the basal sequence has long been questioned. The beds were long considered to be Castlecliffian, yet contain none of the rhyolitic pumice typical of the Castlecliffian beds in the area. Recently Yoshihiro and Shepherd (2006) produced the first detailed map of the terraces on the eastern side of the Manawatu River, and suggest these beds are OI 7 in age. If so, there are several interesting implications:

- The Palmerston North area was subsiding during OI 7.
- The angular unconformity between the OI 7 and OI 5e deposits represents a rapid change in tectonic regime.
- The OI 5e Tokomaru Terrace surface is tilted away from the Tararua Range foothills, and from the Manawatu Gorge, yet the Tararua Range dips northward to the Gorge, also indicating a reversal of tectonic regime.

The land on top of the cliffs was historically used for sheep and beef farming, but was identified as an area of housing expansion as early as 1975. The soil on the Tokomaru Terrace is Tokomaru silt loam, a poorly drained Pallic Soil with a perched water table caused by the dense fragipan which extends from ca 0.8-2m depth. It was recognized by Cowie and Osborne (1977) that developing these terraces for housing would take pressure off the more valuable (and flood prone) Recent Soils near the city, that could then be saved for horticultural use.

However, Cowie and Osborne (1977) also pointed out the hazards and difficulties of developing housing anywhere near the cliffs and sides of the steep gullies that dissect the terrace. Jessen (1989) in an Urban Land Use Assessment, recommended that houses should be no closer than 75m from cliffs and steep gully sides. However, after much argument from the developers and new house builders, houses were soon appearing only 25m from cliffs and gully sides. Further arguments ensued as to where the actual cliff top and gully sides were as new house builders tried to position their houses with a view of the city and Mt Ruapehu. All the Palmerston North City Council now requires is an engineers report on each individual house site. Over the last decade there have been several problems with slips encroaching close to cliff top houses.

At Anzac Park, a subdivision is currently being developed on the cliff top. Despite strenuous objections from earth scientists, the development continues. We predict difficulties.

STOP 2. RANGITAWA STREAM

Rangitawa Stream is a famous locality, now no less important as we try to unravel the geological and climatic history of the lower Rangitikei and Manawatu regions. Furthermore, because the Rangitawa Pumice was first described here, it also preserves the boundary between the Castlecliffian and Haweran Stages.

While describing the strata of the Rangitikei Valley, Te Punga (1952) visited Rangitawa Stream and provided a stratigraphic framework. Bussell (1984), revised Te Punga's stratigraphic framework, but at the time of his work, the controversy over the age and correlation of the Rangitawa Pumice had yet to be resolved, and the correlation of many of the river and marine terraces and their deposits was uncertain.

Royd Bussell and Warwick Potter were both BSc (Hons) students supervised by Brad Pillans at Victoria University in 1984. Bussell worked in the Kakariki area and Potter a little farther upstream at Otatapu and Onepuhi. Between them they revised Te Punga's stratigraphic nomenclature (Table 1).

Stage	**Formation**	**Member**	**OI stage**	**Environment of deposition**
Haweran	Halcombe	Halcombe conglomerate	9c	Shallow marine beach
	Mangatapu	Upper Kakariki shell conglomerate	9c	Shallow marine beach
		Rangitawa Tephra	10	Airfall tephra
Castlecliffian		Rootlet mudstone	10	Cool climate swamp and estuary
		Sand and gravel	11	Shallow marine beach
		Rangitawa shellbeds	11	Shallow marine to estuarine

Table 1. The stratigraphy of Rangitawa Stream (after Bussell 1984).

Rangitawa Stream is on the northwestern margin of the Mt Stewart-Halcombe anticline, the most prominent of several Haweran aged growing anticlines in the Manawatu-Rangitikei districts. These anticlines strike and plunge to the south-southwest. The western limbs are generally more gently tilted than the eastern limbs. Melhuish et al (1996), modelled blind thrusts beneath these structures. The dip of sediments in the Pleistocene sequence on the Rangitikei River is generally 2-5^{o} to the south-southwest, but on the Mt Stewart-Halcombe anticline sediment~~s~~ dip 3-6^{o} to the north, northwest and west around the front of the northern part of the anticline where Rangitawa Stream is situated.

<u>Mangatapu Formation</u>

Bussell (1984) and Potter (1984) defined the Mangatapu Formation to extend from the base of the Ruamahunga Conglomerate (Te Punga, 1953) to the base of the Halcombe Conglomerate (Table 1). The three basal members: the Ruamahanga conglomerate; Pryce shellbed; and Kakariki conglomerate, are not seen in Rangitawa Stream (buried by younger members of the formation), but crop out upstream from Kakariki bridge on the banks of Rangitikei River. The Kakariki conglomerate was interpreted by Bussell (1984) to be a littoral deposit during a marine transgression, following a period of emergence and erosion (cool climate). The conglomerate, however, closely resembles the river aggradation gravels seen forming river terraces in the region and is here interpreted as a major period of river aggradation during the later part of glacial marine oxygen isotope (OI) 12. The gravels can be mapped to the west via boreholes, and they crop out near Mt Curl as scattered aggradational river terrace remnants. It is interesting that the gravels are preserved as terrace remnants at Mt Curl, implying uplift, while at Kakariki, a few kilometres downstream, are buried by younger marine deposits, implying relative subsidence.

Rangitawa shellbed member

The only known outcrop of Rangitawa shellbeds is in Rangitawa Stream, although correlation can be made to boreholes to the west and southwest. The beds were first described by Te Punga in 1952 and 1962, and contain the last appearance of *Pecten marwicki.* Te Punga, and later Bussell (1984) referred to the deposits as Rangitawa "fossil beds". Te Punga's original type section was destroyed in a large flood, so Bussell designated a new one at S23 197164. The contact with the underlying Kakariki conglomerate is not exposed, but in diagrams in his thesis, Bussell infers the two members may be correlatives.

The member consists of decimetre bedded shelly sands and shelly muds. The mud content appears to increase up the sequence and Bussell interprets this as a progression from a shallow marine to an estuarine sequence. He provides a full list of macrofossils identified by Alan Beu, and microfossils identified by John Collen. The upper part of the member also includes common leaf impressions. The fossil assemblages are used to support the interpretation of environment of deposition. Up to 10m of fossil beds are exposed in Rangitawa Stream, and are interpreted here to be a transgressive systems tract (TST) in OI 11. As such they correlate with the Ararata marine terrace, which we will see later at Mt Curl.

Sand and gravel member

In Rangitawa Stream, and again not seen elsewhere, a 12-15m sequence of pebbly sand overlies the Rangitawa shellbeds. Fossils are rare, but scattered single vlaves of *Dosinia* and *Paphies* can be found. The sand ranges from massive to finely parallel bedded, with pebble and grit layers up to 20 cm thick, and occasional muds or mud laminae. Bussell (1984) interpreted these beds as a return to open high energy beach conditions, which must have been deposited near the maximum transgression in OI 11.

Rootlet mudstone

Overlying the pebbly sands is 3-5m of greyish brown to purple lignitic muddy sand, sandy mud and mud containing common vegetation from leaves, stems and twigs, to large logs. When dry, the mudstone has blocky form, akin to a paleosol, and root channels are visible in most horizons. On the Rangitikei River section 500m upstream from Kakariki Bridge, the estuarine forms *Austrovenus* and *Amphibola* are preserved.

Bussell (1984) examined pollens from a few lignite samples on either side of the Rangitawa Pumice and found that they indicated a glacial period with a grass-shrubland vegetation, and a cold wet environment. This may well represent the early part of OI 10.

Rangitawa Pumice

The Rangitawa "tuff" was first described by Feldemeyer et al (1943), and later by Te Punga (1952) at this site. The pumice is found at several localities within Rangitawa Stream as a 50-60cm thick white to pale yellow normally graded tephra with a coarse ash and fine lapilli-grade crystal rich base, grading up to a fine ash. The upper part is commonly reworked by water, showing lamination and ripple cross bedding. Ash sized pumice is then reworked through several metres of sediment overlying the tephra, leading Te Punga to report a thickness of 6m.

The Rangitawa Pumice lies within the upper part of the rootlet mudstone. It is now well correlated to Omahina Tephra (Pillans, 1990) and Mt Curl Tephra (Milne, 1973), and is known as Rangitawa Tephra. It also correlates with the widespread Whakamaru Ignimbrite. Its correlation was one of the enduring controversies in New Zealand Quaternary studies during the 1980s and early 1990s.

While confirming the identity of the Rangitawa Pumice by electron microprobe in this study, a sample of a slightly browner coarse ash sized sand in the upper part of the rootlet mudstone, was taken about 100m downstream of the type section. This yielded a quite different glass chemistry to that of Rangitawa Pumice, being far more iron rich. Bussell (1984) had already reported this glass chemistry from within the Te Hiri shellbed, 800m downstream from the Kakariki Bridge, and called it "Kakariki tephra". Pillans (1988) reported a few shards of this chemistry when probing the Rangitawa Tephra at Rangitatau Road, west of Wanganui. The glass chemistry has also been found by me in other samples of Rangitawa Pumice, particularly reworked samples.

The apparent juxtaposition of high sea-level log bearing estuarine sediments with cold climate pollens, suggests that a systematic sampling of outcrops in the area is needed. There are probably undetected unconformities in the sequence. At locations such as Mt Curl, Rangitawa Pumice is found in loess, and was apparently deposited during late MIS 10. It is most likely that the "rootlet mudstone" represents late MIS 11 cooling to OI 10, and that Rangitawa Tephra fell in OI 10. The base of the Rangitawa Pumice/Tephra is defined as the base of the Haweran Stage in New Zealand.

Overlying Rangitawa Pumice in Rangitawa Stream is up to 2m of pumiceous mudstone, a continuation of the rootlet mudstone. There is then an unconformable contact with Halcombe Conglomerate. However, 600m upstream of Kakariki Bridge over the Rangitikei River, and 1.5 km north of the main localities on Rangitawa Stream, the rootlet mudstone is unconformably overlain by a 0.5m thick shell conglomerate (named Upper Kakariki shell conglomerate by Bussell (1984), and a further 9.5m of marine sand, underlying Halcombe Conglomerate. The Upper Kakariki shell conglomerate is significant because it contains *Pecten aotea* among a shallow-beach fossil assemblage.

The sequence appears to record a transgression at the end of OI 10, warming to OI 9c. Several questions remain about relative sea levels and paleoclimate during the deposition (and erosion) of sediments in and near Rangitawa Stream.

Halcombe conglomerate.

The distribution of Halcombe conglomerate was first mapped by Te Punga (1952), but it was Bussell (1984) who designated a type section in Rangitawa Stream (S23 194167), 400m downstream from the Rangitawa Pumice section (S23 196165). The conglomerate consists of sandy gravels and gravely sands. The sands typically contain concentrations of ferromagnesian and mafic minerals, and a few andesitic pebbles among the more common greywacke. Rare diorite and granite pebbles can also be found. In the Kakariki district, Halcombe conglomerate both conformably and unconformably overlies Mangatapu Formation, and is up to 23m thick. In many sections in Rangitawa Stream it is truncated by Ohakea Terrace gravels. The conglomerate is considered to be nearshore marine, though shells are rare and may be reworked. The base, when on rootlet mudstone, is frequently bored.

The Halcombe conglomerate is considered to have been deposited in a shallow marine environment during a sea level highstand in OI 9c, and is thus 320-350 ka.

At the section 600m upstream from the Kakariki Bridge, Bussell (1984) sampled a 10cm thick tephra within Halcombe conglomerate, just below the Ohakean terrace cover. He identified this as the Lower Griffin Road Tephra. We have subsequently confirmed this identification, and also found it in a fallen block of Halcombe conglomerate at the site of the Te Hiri shellbed (S23 179159).

Another tephra occurs in sands and gravels 0.7 m above road level in a roadcut (too dangerous to visit on this field trip) at S23 212164 between Rangitawa Stream and Halcombe township. This tephra correlates well to Upper Griffin Road Tephra (Table 2).

OI stage	**River Terrace**	**Marine Terrace**	**Loess**	**Dunesand**	**Tephra**
8	Burnand		Burnand		
9a		Brunswick		Brunswick	Fordell UGR
9b			Griffins Rd?	Mt Curl	MGR
9c		Braemore		Mt Curl	LGR
10a	Aldworth		Aldworth		Kakariki Rangitawa
10b	Waituna		Waituna		
11		Ararata		Ararata	

Table 2. Summary diagram for late Castlecliffian and Early Haweran river and marine terraces, and tephras in the Manawatu-Rangitikei region. UGR

= Upper Griffins Road; MGR = Middle Griffins Road; LGR = Lower Griffins Road.

STOP 3. WESTOE

Note: Please be aware of traffic at all times.

The Westoe section enables us to see the stratigraphy above that exposed in Rangitawa Stream. The upper 5m of Halcombe Conglomerate (OI 9c) consists of interbedded grey to black parallel laminated sands and thin pebble-cobble sandy gravels. The pebbles are mostly wave flattened greywacke, but a few andesite, and rare diorite and granite can be found.

Bussell (1984) defined the top of the Halcombe conglomerate as the uppermost pebble-cobble bed. There follows approximately 1.3m of medium sand, interpreted by Bussell to be alluvial. This might be because overlying this sand is 30cm of diatomaceous earth. Margaret Harper (in Bussell) found that there was a rich freshwater diatom assemblage, typical of a fresh water environment. More alluvial sand follows, which grades up into dune-sand with steeply dipping cross-beds visible in places. Within the dune-sand, and 4m above the contact with Halcombe Conglomerate, is a 3-5cm thick tephra, which was not correlated by Bussell. However we think it is a good match to the Middle Griffin Road Tephra. A further 5.5m of dunesand follows, capped by 2m of grey mudstone. Above the mudstone is gravel and loess of the Porewa River Terrace, a small remnant nested beside the more extensive Greatford River Terrace.

At several sections in the district, Middle Griffin Road Tephra is found in similar dune-sand (e.g. Picnic Trig, Mangaone Road). About 12km to the north at Griffin Road Quarry and Mt Curl, Middle Griffin Road Tephra occurs within loess or alluvium (see stops 4 and 5). Fifteen km to the southeast at Feilding Landfill, it occurs within lignite (Elliot and Palmer 1998).

STOP 4. GRIFFIN ROAD

This site is now definitely past its best, however, it remains one of the most important early Haweran sections in the region. The site is a gravel quarry, cut into the riser of the Aldworth River Terrace (OI 10c). In other words, the terrace was forming by river aggradation in a glacial episode, during which time, the Rangitawa Tephra was erupted. Thus

Rangitawa Tephra is missing at this site and would only be present were it to be fortuitously preserved in the river gravel (as for example at Ahiaruhe in Wairarapa). Lower Griffin Road Tephra directly overlies the terrace gravel.

Above the Lower Griffin Road Tephras are two more prominent tephras, the Middle Griffins Road and Upper Griffins Road tephras. A prominent paleosol occurs immediately beneath the Upper tephra, interpreted as being a soil formed in OI 9a. The material enclosing Middle Griffins Road Tephra, and in which the soil has formed beneath the Upper tephra, was described by Pillans (1988) as loess. If so, it must have been deposited during the cooler OI 9b, between the OI 9c and 9a warm periods. It does contain a few rounded pebbles, suggesting the material could alternatively be over-bank silts. Grain-size distribution does not shed light on its origin because it is moderately weathered.

During OI 9c, the Braemore Marine Terrace was forming on the Wanganui coastline (Pillans 1990), and is preserved between the Whangaehu and Turakina rivers, but is not preserved in this district. The high sea level during OI 9a saw the formation of the Brunswick Marine Terrace. This terrace and its deposits are extensive west of Wanganui, and east of Wanganui as far as Marton, where it is replaced by Rangitikei River Terraces. East of Rangitikei River, the Brunswick Marine Terrace is folded by the Mt Stewart – Halcombe and Feilding anticlines.

The prominent E-W trending cliff in front of the Griffin Road Quarry is thought to have been cut by the OI 9c and 9a high sea levels that formed the Braemore and Brunswick terraces respectively. There are few exposures on the broad terrace below. Some auger holes and water wells encounter sands below the loess cover, while others encounter river terrace gravels. Therefore this surface may in fact be both the OI 9a Brunswick Marine Terrace and the OI 8 Burnand River Terrace, or the latter, covered in places by dune sand.

STOP 5. MT CURL

Mt Curl remains one of the most important Quaternary sites in the Lower North Island. The stratigraphy here has been documented by Milne 1973a, b, c; Milne and Smalley (1979) and Pillans (1988), and slightly revised by Palmer et al (2005). The site is on the Ararata Marine Terrace (OI 11), and we shall see the wave cut surface of this terrace after we have examined the main outcrop. At the base of the section weathered sands overlie the Ararata Marine Terrace. This is followed by Waituna and Aldworth loesses, each about a metre thick and separated by a well developed paleosol. These loesses were deposited in OI 10a and 10b respectively. In the upper part of the Aldworth loess is the 500-600mm thick Mt Curl Tephra, now known to correlate with the Rangitawa Tephra (340 +/- 40 ka, Kohn et al 1992). Features to look for in the tephra are common flakes of a pale green mica mineral, and rare but beautifully formed bipyramidal quartz crystals. There is only a few centimetres of weathered loess overlying the tephra, suggesting it fell in the later part of OI 10.

There follows up to 10m of Mt Curl Dunesand (Pillans 1994), that was deposited during OI 9c while the Braemore Marine Terrace was forming a few km to the south. The Lower Griffin Road Tephra occurs in the uppermost part of the sand. Much thicker dune sand occurs at Picnic Trig (Pillans, 1988), a few km to the west, that contains the Lower Middle and Upper Griffin Road tephras below Burnand Loess. At Mt Curl, the Middle and Upper Griffin Road tephras occur in what appears to be loess. If this material is loess, it must have been deposited in the cool period between OI 9c and 9a, i.e. 9b.

A few hundred metres west of the Mt Curl Section, the wave cut surface of the Ararata Terrace is exposed in a farm track. Here, the underlying stratigraphy is the Lower Kai iwi Siltstone passing down to the Kaimatira Pumice Sand. The major component of this pumice is from the ca 1 Ma Potaka Pumice.

To the east of Mt Curl, remnants of higher, older river terraces remain.

Stop 6. Mingaroa Road

A reserve stop that may be visited if required.

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