Field Trip Guide to Tararua District Fore-arc Basin

Totaranui Limestone overlying Marima Sandstone, Tararua Road.

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Fig. 1. Location of stops: 1) Marima Domain, 2) Kakariki River Capture, 3) Totaranui Limestone, 4) Fairbrother Road – Wellington-Mohaka Fault, 5) Kumeti Stream, 6) Mangatewaiiti Stream, 7) Whakaruatapu Stream. Data sourced from QMAP 1:250 000 Geological Map of New Zealand (Lee and Begg, 2002; Townsend et al. 2008; Lee et al. 2011).

Introduction

Tararua District is part of the Fore-Arc Basin of the North Island of New Zealand. It extends from near Mount Bruce in the south to Norsewood and beyond as a complex elongate depression between the Tararua and Ruahine Range to the west, and the uplifted Waewaepa and Puketoi Range to the East. It has much to offer as a record of geological and environmental change during the Pliocene and Pleistocene.

Stop 1: Marima Domain

Please be aware at all times that the cliff face is unstable. Spend as little time as possible adjacent to the cliff

Adapted from Lee and Begg (2002)

The cliff face in front of us is Marima sandstone (Neef 1974, 1984) which consists of both muddy sandstone and sandy mudstone. It is towards the upper part of the Pliocene aged Onoke Group (Vella and Briggs 1971, Lee and Begg 2002). As we shall see, the Onoke Group also contains several units of coquina limestone. Onoke Group marine mudstones and sandstones are common throughout the fore-arc basin of the Wairarapa and Hawkes Bay, within a seaway that extended from Hawkes Bay to Palliser Bay during the Pliocene (Fig. 1). The sea-way also extended over the current southern Ruahine Range in the vicinity of Manawatu Gorge, where new exposures are plentiful on the new highway under construction, from Ashhurst to Woodville. There are few rocks of this age in the eastern part of the coastal hill country to the east, except at Castle Point. This might mean that the eastern part of the coastal hill country was emergent at this time, but the Tararua and southern Ruahine Ranges were not. Where Onoke Group rocks lie west of the Wellington fault, for example the new highway, they unconformably overlie Triassic-Jurassic Esk Head greywacke-argillite. East of Wellington Fault they conformably overlie Upper Miocene marine mudstone, except for some faulted anticlines in the Eketahuna area, where once again they unconformably overlie basement. Near this outcrop in Western Wairarapa, Onoke Group is 1200m thick, but thickens eastward to 2700m near Alfredton.

As well as several units of coquina limestone, the Onoke Group contains occasional rhyolite tephras, some up to 1m thick (Vella 1974, Shane 1990, Shane et al 1995), though they are more commonly millimetres to a few cm thick. Tephra source has not been unequivocally established, but is likely to be Coromandel and/or perhaps Northland. The limestones will be discussed at stop 3. Several outcrops to the north of stop one also contain thin sandy greywacke gravels. These may have been derived from emergent Ruahine Range to the north, or possibly from greywacke-argillite piercement structures to the east (for example the Waewaepa Range. Source might be established using geochemistry, the Waioeka terrane rocks being distinct from Rakaia and Pahau terranes (Roser et al 1995).

In the outcrop at Marima Domain (Fig. 1), Marima sandstone consists of decimetre bedded, fossiliferous mudstone and sandstone. The outcrop includes a horizon of rounded calcareous algal balls, where the algae commonly encrust macrofossils. The macro and microfossil assemblage indicate outer shelf to upper bathyal water depths. The intercalated limestones indicate deposition on a current swept inner shelf. The limestones and fluctuations in sand content of the Onoke Group sediments, as well as the macro and micro-fossil assemblages indicate that global sea-level fluctuation was underway in the Pliocene before amplifying in the Quaternary. A little to the south, Vella (1963) wrote his seminal paper on cyclothems, a forerunner of the sequence stratigraphy paradigm. The frontispiece photo shows the conformable contact between Totaranui Limestone and Marima sandstone at the nearby Tararua Road.

Stop 2: Mangahou River capture, Kakariki

The following account is adapted from Kaewyana (1980), Neef (1967) and Stevens and Palmer (1986), and Vella et al (1987).

Hukanui Stream is currently a small tributary of Mangatainoka River (Fig. 2). It is underfit, sitting in a broad shallow valley flanked by a slightly elevated river aggradation terrace, mapped by Kaewyana as the Hukanui Terrace (Ohakean). Clearly, during the Ohakean, the Hukanui Stream was a major tributary of the Mangatainoka River issuing out of the eastern Tararua Range. Meanwhile, Mangahao River was a small river, draining north to meet the Manawatu River near Manawatu Gorge. Its headwaters were dissecting headward into a low saddle of Onoke Group rocks separating the Hukanui from the Mangahao River. The low saddle was in the vicinity of the Wellington fault, a major dextral strike-slip fault. During the Last Glacial, the Hukanui Stream aggraded and overtopped the low divide with the Mangahao headwaters, and was quickly captured. Hukanui Stream is now a minor tributary joining the Mangatainoka River from the east. The underfit valley it occupies is 1.5 km wide and flanked by Hukanui and Pukewhai terraces (Ohakean Q2 and Ratan Q3 respectively) (Fig. 3). The head of the captured valley terminates against a gorge 70m deep in which flows the Mangahao River. The Mangahao exits the Tararua Range in an west-east reach, then turns a right-angle towards the north.

Rapid degradation of the enlarged Mangahao released huge amounts of sediment which choked the entrance to the Manawatu Gorge causing a lake to form near Woodville (Piyasin 1966). The damming was also likely facilitated by earthquake activity on Wellington Fault, and there may have been a number of temporary lakes through the late Quaternary.

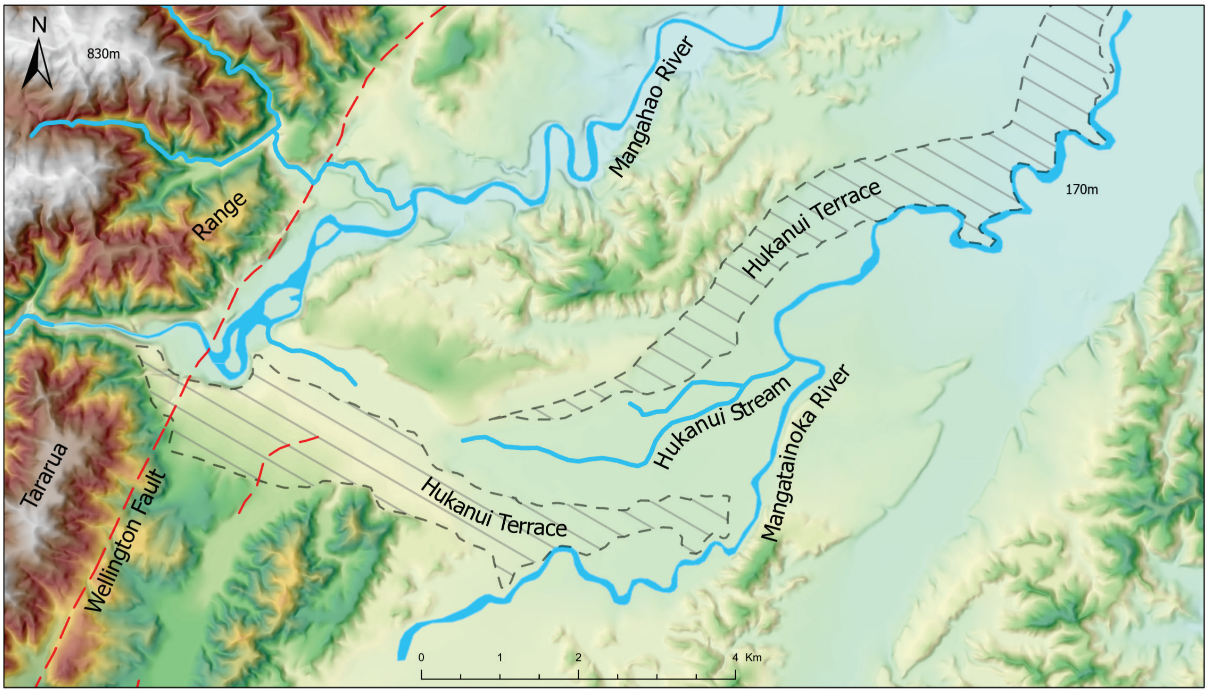

Fig. 2. Present-day Mangahao and Mangatainoka Rivers and Hukanui Stream (Kaewyana, 1980; Stevens and Palmer, 1986 Vella et al 1987).

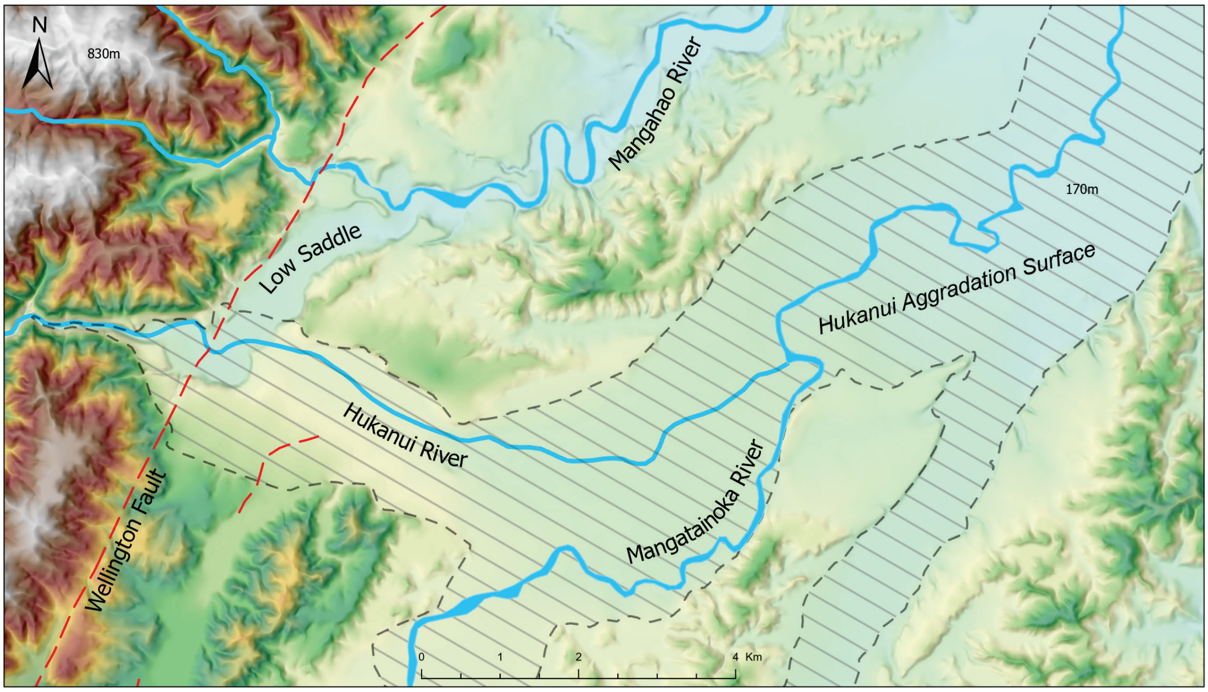

Fig. 3. Mangahao, Mangatainoka and Hukanui Rivers during the Last Glacial Maximum immediately before the Hukanui capture (Kaewyana, 1980; Stevens and Palmer, 1986; Vella et al 1987).

At this location there is also a splay on the Wellington-Mohaka Fault, with attendant offsets, small bulges and sags. The site was documented by Lensen (1967) and Grapes et al 1984. Some of the original features have now been subdued by earthworks and ploughing (Fig. 4).

Fig. 4. The Wellington–Mohaka Fault at the site of the Mangahao River capture. U = up, D = down, s = shallow sag, b = bulge.

Stop 3: Totaranui Limestone, Konini

Please be careful of traffic and stay well off the road. If you need to take a photograph from the other side of the road, take care!

Totaranui Limestone is the uppermost of at least 11 individual coquina limestones within the Onoke Group (Lee and Begg 2002) and is of latest Pliocene age. It is prominently decimetre bedded, often cross bedded, and consisting of more and less cemented bands (Fig. 5). The Totaranui limestone consists predominantly of barnacle plates with less common oyster shells and bryozoa. In a nearby quarry the limestone is 40m thick, but waxes and wanes considerably in thickness.

Totaranui Limestone is considered to be equivalent to the Pukenui Limestone in southeastern Wairarapa, where its upper contact was thought to represent the Tertiary/Quaternary (or Pliocene/Pleistocene) boundary. However, now that the Tertiary Quaternary boundary has been officially recognized at 2.588 Ma (The Gauss/Matuyama paleomagnetic boundary) Totaranui Limestone is likely to lie within the Early Quaternary.

The coquina limestones and accompanying calcareous sandstones define landscape geomorphology within the Onoke Group. They form prominent strike ridges and cuestas throughout Wairarapa and Hawkes Bay. Beu (1995) grouped the limestones according to an evolutionary sequence of the scallop *Phylopecten*, but the index fossil for the youngest limestones is part of another evolutionary sequence, the gastropod *Struthiolaria.* Another diagnostic scallop, the cold water indicator *Zygochlamys delicatula* is found rarely. It appeared in the Rangitikei at the Hautawa shellbed approximately 2.4 Ma. The brachiopod *Neothyris ovalis* is common in places.

Faunal evidence suggests the coquina limestones are cold water limestones, representing early glaciations and lower sea levels. As such, the water depths are considered to be inner shelf (Lee and Begg 2002). Although they can be followed over considerable distances, they are likely to be lateral facies changes from some of the coarser sandstones within the Onoke Group, and represent areas of particularly strong currents where the shell material was broken and concentrated into banks and reefs up to 70m thick. The limestones are a considerable economic resource. *In situ* they are aquifers with prolific yield. Outcrops are frequently mined for agricultural lime (except where pebbly), boulders for river-bank protection and crushed limestone is used as base course for cow races, feed pads and stables.

Fig. 5 Totaaranui Limestone at Tararua Road.

Stop 4: Fairbrother Road

Introduction

Fairbrother Road is one of several roads between Woodville and Dannevirke from where the Wellington-Mohaka Fault is easily accessible. In 1998, a PhD student from Massey University, Judith Hanson, studied the Wellington-Mohaka and Ruahine Faults from just south of the Manawatu Gorge at Balance, to the Mohaka River. Trenches, sometimes multiple, were opened at five sites on the Wellington-Mohaka Fault, two sites on the Ruahine Fault and one site on a splinter between the two, the Te Waka splinter fault. Accompanying the trench interpretations and radiocarbon or tephra dates within, were many measurements of offset features along the faults, including spurs, stream channels and terraces.

Hanson (1998), calculated the horizontal offset rate for the Kahuki (just south of Manawatu Gorge) to Ohara Depression section of the Wellington-Mohaka Fault at 12mm/yr. For the section from the Ohara Depression to the Ngaruroro River, the calculated rate dropped to 4.7 mm/yr as strain is transferred to the Ruahine Fault. From the Ngaruroro River to Tutaekuri River the rate decreases further to 3.3mm/yr.

Her interpretation of the fault trenches, supported by radiocarbon dates and tephra identification led her to postulate 12 M_s > 6.5 earthquakes on the Wellington-Mohaka Fault in the Kahuki-Dannevirke area in the past 30,000 years. The last earthquake in this segment occurring ca 300 years ago. The largest single offset had a 12m horizontal and 1.8m vertical offset. She estimated that earthquakes between M_s 7.4-7.8 occurred every 300 years or so on the Kahuki-Dannevirke segment of the fault, with return periods decreasing farther north. She also found that there might have been as many as 4 M_s 7.4-7.5 earthquakes on the Ohara Depression to Napier-Taupo Highway segment of the Ruahine fault since eruption of the Taupo Pumice 1850 yrs BP.

The work was controversial because a number of studies on the Wellington-Mohaka Fault (Beanland and Berryman 1987; Beanland 1995; Van Dissen and Berryman 1996), and the Qmap Bulletin for Wairarapa (Lee and Begg 2002) had estimated a much lower slip rate of 6.0-7.6 mm/yr, a single event displacement of 3.5-5 m, a recurrence interval of 550-770 years, with the last earthquake 335-485 years ago. Estimated magnitudes were similar to those of Hanson. More detailed trenching of the Wellington-Mohaka Fault in the Pahiatua section of the fault (Langridge et al 2007) calculated a dextral slip rate of 5.1-6.2 mm/yr, a single even displacement of 3.5-5.5 m, and recurrence interval of 564-1080 yrs. GNS staff have since re-trenched the Wellington-Mohaka Fault at several places north of Manawatu Gorge, but the results of this work are not yet published.

Fairbrother Road

Hanson (1998) opened two trenches across the Wellington-Mohaka Fault at the end of Fairbrother Road. At this site the fault is traversing Onoke Group marine sediments underlying Ohakean and Ratan terrace gravels, although the greywacke-argillite is less than 500m to the west. The trenches were located on the downthrown eastward and westward limbs of a complex duplex structure. The first trench, 12m long and 3.4m deep, was where Ohakean gravels had been downfaulted to the east and covered by swamp sediments, mostly peat. The second trench was 10m long and 5m deep (Fig. 6). In this case the downfaulted side was to the west. A full account is given in Hanson 1998, but here is an abridged version:

- Ohakean gravels contain a wood sample dated (Wk 3146) at 22,050 +- 150yrs B.P. This is one of the few radiocarbon dates on Ohakean gravels.
- The first earthquake is recorded post cessation of aggradation which may have been 10-12ka (Marden and Neall 1990).
- Woody peat begins to accumulate at and between the trenches
- A second earthquake deforms and tilts peat in Trench 1 and deposits gravel prior to (Wk 3145) 6080 +_ 60 yrs BP. Peat in trench 2 is undeformed with a basal date of (Wk 3147) 6750+_ 60yrs inferring the earthquake was sometime between 6750 and 10,000 yrs BP.
- A third earthquake causes silty colluvium to be deposited in trench 1 prior to (Wk 3144) 5000+_60 yrs BP. This may correlate to the pebble unit in trench 2.

- A fourth earthquake causes woody colluvium to be deposited in trench 2 between 5000 and 3000 yrs BP.
- Peat accumulation follows, at least 1m thick, which was likely to represent at least 1000 years (1mm/yr).
- A fifth earthquake deforms and drags the peat 0.8m up to the west in trench 1. Coarse colluvial woody debris (which might be from a following storm) is dated (Wk3149 at 2030 +_ 50yrs BP.
- Up to 1m of grey silt was deposited in both trenches post (Wk 3143) 2090+_50 yrs.
- A sixth earthquake drags up and buckles several units, dated by wood at the top of the deformed grey silt (Wk 3150) 960 +- 50 yrs BP.
- River gravels, possibly from a storm event, are then washed into both trenches.
- The gravels are deformed by a seventh earthquake pre (Wk 8228) 257+- 44yrs BP.
- More gravels are deposited in to trench 2 followed by colluvium which may indicate an 8th earthquake post 257 +_ 44yrs BP.

Perhaps the most controversial interpretation made by Hanson near this site comes from a stream on a Holocene surface about 500m south of the trenches (Fig. 7). The stream has apparently been offset 100m by dextral movement on the fault in a maximum of 10,000 years, giving a rate of horizontal movement of 10mm/yr. However, the orientation of the stream with respect to the fault probably exaggerates the amount of offset, and this might not be a convincing site to calculate rate of dextral movement on the fault.

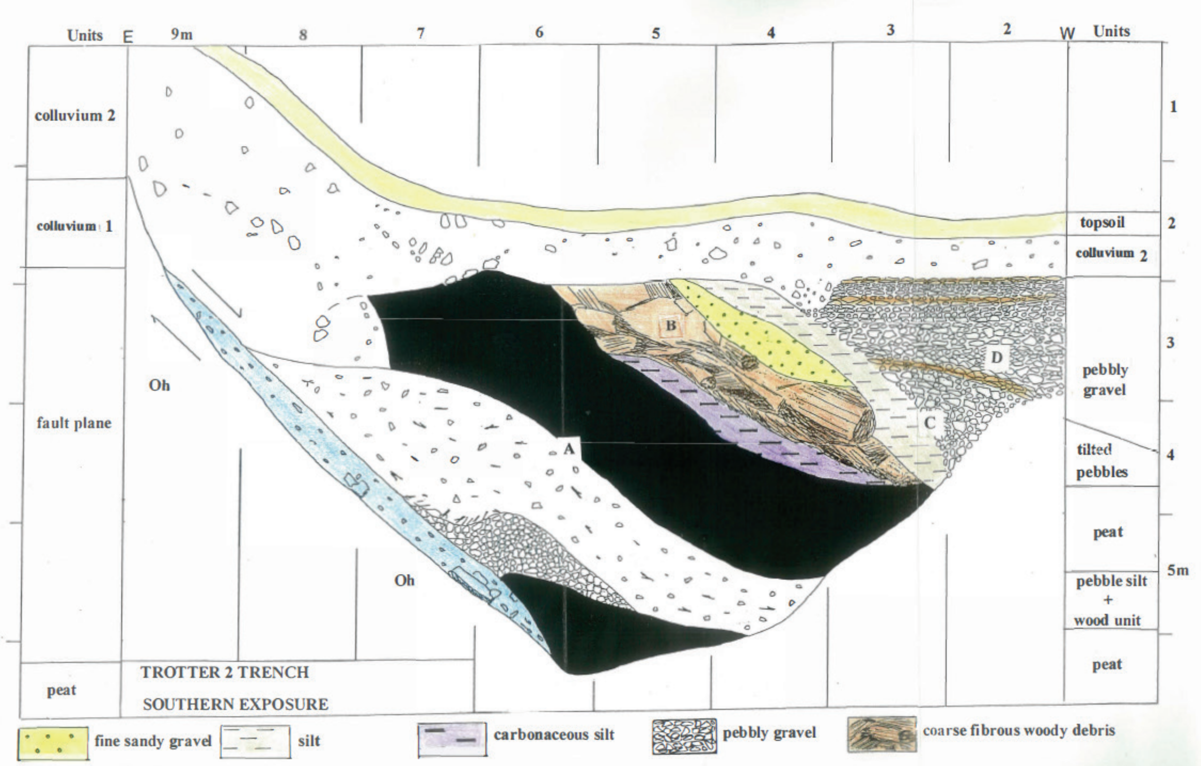

Figure 17. Cross section of the Trotter 2 trench southern exposure excavated across the Wellington Fault at Fairbrother Road, showing younger strata faulted against older Ohakean gravels, logged on a scale of 1:20. Oh are Ohakean gravels. A, B, C and D are radiocarbon dated wood samples, A (Wk 3148) age 3110 +/- 60 yrs B.P., B (Wk 3149) age 2030 +/- 50 yrs B.P., C (Wk 3150) age 960 yrs B.P., and D (NZA 8228) age 257 +/- 44 yrs B.P. 54

Fig. 6. The “ Trotter 2” trench, south wall at Fairbrother Road (Hanson 1998 p.54)

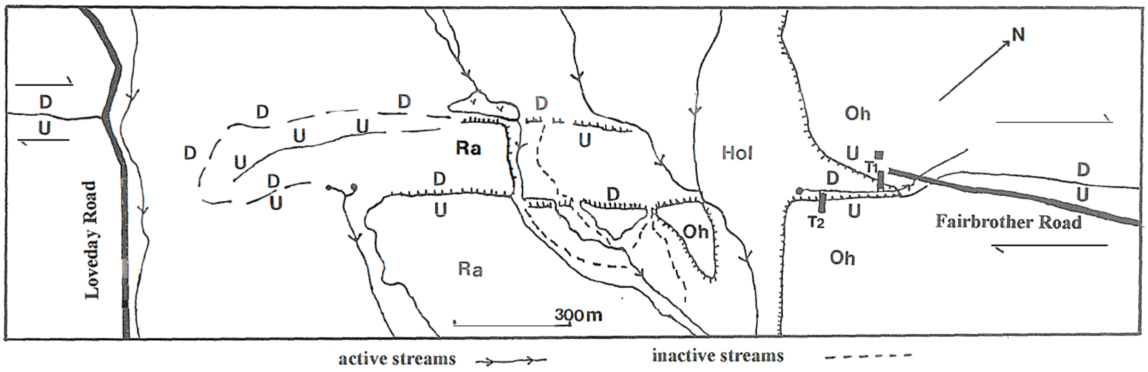

Figure 18. Map of the Duplex on the Wellington Fault between Loveday and Fairbrother Roads showing the upthrown southern section and the downthrown northern section where the trenches were excavated. T1 and T2 are the trench localities U are upthrown areas and D are downthrown areas. Ra are Ratan terraces aged 30,000 to 40,000 yrs B.P., Oh are Ohakean terraces aged 10,000 to 25,000 yrs B.P., and Hol are Holocene terraces less than 10,000 yrs B.P., (Marden 1984).

Fig. 7. Sketch of the fault features and trench locations (T1 and T2) at Fairbrother Road (Hanson 1988 p60).

Stop 5: Kumeti Stream

In Kumeti Stream please watch your footing because the rocks could be slippery.

Kumeti Stream is typical of the many small streams that drain the eastern side of the southern Ruahine Range. The streams descend steeply from sources near the summit of the flat-topped Range. The Range consists of Late Triassic to Jurassic Esk Head Belt (Lee and Begg 2002), a 20km wide significantly deformed and sheared belt of greywacke-argillite between the Rakaia Terrane to the west and the Pahau Terrane to the east. Lee and Begg describe the sequence as “cm to decametre bedded alternating sandstone and mudstone sequences commonly with sheared argillite”.

The Wellington-Mohaka Fault crosses Kumeti Stream at the foot of the Range. To the south, the Fault trace crosses a large landslide in the Esk-Head rocks. To the north, the Fault has Esk-Head rocks to the west and Neogene limestone to the east, which have been dragged up against the fault and over-steepened (> 40^{o}).

The Kumeti, and other streams like it, carry a high bed-load, so much so that avulsion is common on to surrounding farmland once the streams leave the Range, all the way down to SH2 and beyond. Downstream of the fault a reserve has been created using a variety of exotic species to try to capture and slow down the gravel bedload.

There was a noticeable increase in erosion slip and debris avalanche scars (Fig. 8), stream bed-load and avulsion following WW2. The National Water and Soil Conservation Organization (NWASCO) (formerly Ministry of Works but now part of LandcareResearch) and the NZ Forest Service established the Ruahine Range Control Scheme to study and combat the erosion. A report was produced in 1981 (Neall, 1981).

A number of causes for the apparent increase in erosion have been suggested:

- The increase in erosion is only perceived, and erosion has been ongoing, while waxing and waning) for decades and perhaps centuries.
- The sediment loads in the streams are culminations of past earthquakes acting upon a fault, sheared and rapidly uplifted parent rock (Esk Head belt rocks). Earthquakes in 1931 and 1934 (not on the Wellington-Mohaka or Ruahine Faults) caused landslip and debris avalanche damage in different sectors of the Range.
- Periods of storminess. This was suggested by Grant (1981) to explain periods of aggradation versus degradation and terrace formation in the Ruahine Range. His Waihirere and Matawhero erosion periods were pre European. He related recent activity to storminess in the 1880s and 90s, mid 1930s and 1950s to present. In Waipawa Valley he estimated sediment transport in the 1970s was 13 times that of the 1940s. Note that both La Nina and El Nino weather patterns can be responsible for storm damage in the Ruahines. El Nino can deliver westerly storms with high rainfalls and subsequent floods to the Ranges, and wind damage from accompanying westerly gales. La Nina is more likely to deliver cyclonic storms from the north and east with very high rainfall totals and damaging winds.
- An alternative theory is based around the cycles of excavation, recovery, residence time (of sediment and soils), and subsequent excavation from small drainage basins (Tonkin 1994). In theory these cycles may be random in time for each drainage basin, but in actuality the process might be triggered by earthquake, storms or knick-point retreat.
- The impact of introduced deer, goats and possums. Red deer and goats were present in the Ruahines from the 1920s and were at "plague numbers" by the late 1940s, resulting in culling campaigns. They ate much of the broadleaf understory which then resulted in sheet erosion on the forest floor. It is theorized that this might have weakened or damaged the roots of canopy species, making them vulnerable to wind damage and perhaps insect attack. Possums were widespread by the 1940s and heavily browsed many broadleaf species and *Meterosideros* (Northern Rata). Canopy damage led to forest collapse in the 1950s, with canopy trees like Kamahi (*Weinmania racemosa)*, Rata, Rimu (*Dacrydium cupressinum)* and Matai (*Podocarpus spicatus)* disappearing from the mid-slopes to be replaced by shrubs such as Pepper tree (*Pseudowintera colorata)* and tree ferns, and *Olearia* at higher altitudes.
- It is possible that removal of the understory by browsing animals, lowers the overall evapotranspiration of the forest leading to wetter soils and more slips. Browsing by goats and deer prevent the slips from recovering back into tall woody vegetation.
- In an effort to combat the erosion, some slip scars were planted in Pinus contorta.

The difference in bare ground erosion scars and channel deposits between 1946 and 1970 clear (Stephens 1981) (Fig. 9). It would be interesting to compare the current situation.

Fig. 8. Slip (L) and debris avalanche (R) in the headwaters of Kumeti Stream.

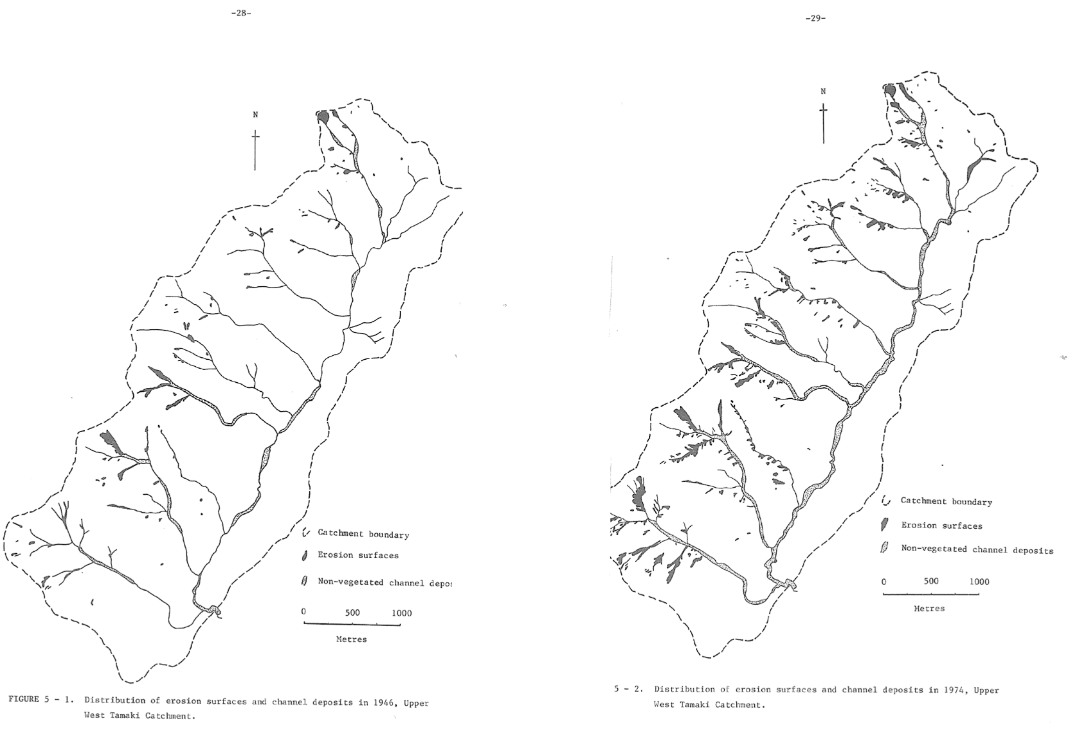

Fig. 9. Distribution of erosion surfaces and channel deposits, West Tamaki Catchment, southern Ruahine Range in 1946 (L) and 1970 (R) (Stephens 1981).

Stop 6: Mangatawaiiti Stream

We will take a walk down in to Mangatawaiiti Stream from SH2. On the south bank of the stream, Potaka Pumice dips to the SE towards the Dannevirke syncline. The pumice is mostly sandy, but incudes many clasts over 10cm in size, and some charcoal. It appears to have been deposited rapidly in a fluvial setting close to the terminous of the ignimbrite. The Potaka Pumice is overlain by overbank silt and mud followed by a peaty paleosol, complete with tree stumps. This land surface has been inundated by Kaukatea Pumice, near the axis of the syncline. A little farther downstream, the sequence is repeated as it now dips to the west.

Stop 7: Whakaruatapu Stream

Although there is plenty of room between the roadside and outcrop, please be mindful of traffic if you are taking photographs etc.

Introduction

Within the fore-arc basin in the Dannevirke-Ormondville area a series of gently folded and faulted strata reveal rocks of Castlecliffian and Nukumaruan age (Lillie 1953; Kingma 1971). The upper part of the sequence consists of conglomerates, channel and levee sands, overbank sands and silts, organic rich muds, lignites, paleosols and remobilized silicic volcaniclastics and airfall tephras. These strata have been locally named the Mangatarata Formation, which in several places is over 500m thick. Towards the base of Mangatarata Formation several marine incursions are denoted by marine sands in the otherwise terrestrial deposits. Mangatarata Formation conformably overlies Kumeroa Formation, a fully marine sandy mudstone of the Upper part of the Onoke Group (Lee and Begg 2002). Sedimentary facies within Managatarata Formation were detailed by Krieger (1992) and are dominantly fluvial and lacustrine. As well as well documented vertical facies changes within the section, there are also lateral facies changes, from being dominated by gravels close to the Ruahine Range in the west, to a far higher proportion of sandy and muddy terrestrial facies, and marine facies to the east near Manawatu River.

The fine-grained units of the Mangatarata and Kumeroa Formations offer excellent opportunity for paleomagnetic determination, and several units of remobilized pumice and tephras can be chemically fingerprinted (EMPA analysis of glass) and thus correlated to locations where the same pumices and tephras have been dated by isothermal plateau fission track (IPFT) dating (Alloway et al 1992; Shane 1991; Shane and Froggatt 1991; Black 1992; Shane et al 1993; Krieger (1992).

One of the most complete sections is seen at Mangatawaiiti Stream a few km north of Dannevirke, downstream from SH2. The top of the sequence is Matuyama Chron (reversed) and contains the 0.87 Ma Kaukatea Pumice* as a 2m thick remobilized sandy pumice as an over-bank deposit drowning a paleosol with fossil tree stumps. A few metres below, is a 10m thick unit of very pumiceous alluvium, sometimes containing charcoal. This is the Potaka Pumice (1.05 Ma IPFT Alloway et al 1993). Only a few km to the north and along SH 50, the unit occurs as an indurated ignimbrite, and is also correlated to Kidnappers Tuff at Cape Kidnappers. Potaka Pumice alluvium is widespread in the Manawatu-Rangitikei-Whanganui region. It has been found as airfall tephra near Palmerston North, Wairarapa and North Canterbury. Fine sediment associated with the pumice alluvium is of normal polarity and fits nicely in the Jaramillo Chron. Shane et al (1993) measured approximately 150m of normal polarity sands and silts with lignites, below Potaka Pumice in Mangatawaiiti Stream, which would represent only 80 kyrs, the length of the Jaramillo Chron.

The sequence continues downstream, initially dipping to the east but then crossing the axis of the Dannevirke syncline (in which lies Kaukatea Pumice), and then dipping to the west. Older recognizable pumice units, all in the Matuyama reversed Chron, include Rewa (ca 1.2 Ma) and Pakihikura Pumice (ca 1.6Ma). The latter actually occurs in the adjacent Mangatawainui Stream, along strike from Mangatawaiiti Stream, very close to the contact with Kumeroa Formation marine mudstone.

As well as the better-known eruptive units, Melhuish (1990), Shane et al (1993) and Krieger (1992), document glass chemistries from pumices of unknown correlation. The most prominent of these are "Tuff chemistry C" 150m below Potaka Pumice at Mangatawaiiti Stream, at the base of normally magnetized Jaramillo Chron, and "Tuff Chemistry F" about 100m below Rewa Pumice in reversely magnetised Matuyama Chron sediment.

Upstream (west) of SH2, parts of the same sequence repeat several times because of anticlines, synclines and faults (Krieger1992). However, laterally equivalent facies become more and more dominated by gravel units as the Ruahine Range is approached.

It is interesting to contemplate the tectonic situation of the Mangatarata Formation. Land to the east and west was actively rising. The transition from fully marine Kumeroa Formation to dominantly terrestrial Managatarata Formation about 1.6 Ma at first glance appears to be simple uplift. However, sedimentation rates for at least parts of the Managatarata Formation were quite high (e.g around the time of Potaka Pumice at 1Ma). Whilst this could be simple aggradation of voluminous pumiceous sediments, Krieger (1992), through discovery of shell beds, careful facies analysis, and paleocurrent determination was able to show that, particularly east of SH2, marine incursions occurred through most of the sequence. This infers that accommodation space was being created through subsidence and the depositional environment was responding to global sea-level cycles. It is not known whether any of the folds or faults that now deform this sequence were active at the time of deposition, or whether deformation has come later.

Whakaruatapu Stream

This section was beautifully exposed in 2016 during road construction. Over 100m of the upper part of the Mangatarata Formation is exposed and dips east at 32º. The section contains a number of pure pumiceous units, lignites, paleosols, muds, sands and gravels. At the southern end of the section, near the base, is at least 10m of pumiceous units with a 2m white fine ash base followed by more or less pumiceous sands and rounded pumice gravels up to 4cm diameter and containing charcoal. This is thought to be Potaka Pumice. At the top of the sequence, almost 100m above is a thick, white, fine sandy pumice unit overlying 3m of blue grey mud and a 1.8m banded lignite. This pumice unit resembles Kaukatea Pumice, but if so, the thickness of sediment between Kaukatea Pumice and Potaka Pumice is much greater at this section than at Mangatawiiti Stream.

The pumice samples from here have been sampled and await analysis.

Fig. 10. Whakaruatapu section, general view. The lignite in the foreground appears along strike behind the orange road cone on the exposed cut.

Fig. 11. Whakaruatapu Stream section. Thick units of fluvially deposited pumice sand, mid section, equivalent to the Kaimatira Pumice sand in Whanganui. *Note. The term “pumice” is used here for reworked tephras and ignimbrites, whether they be fluvial or marine. Tephra is reserved for *in situ* airfall deposits.

Fig. 12. Whakaruatapu Stream section. Deformed sedimentary structures in fluvially deposited pumice sands, probably sourced from 1 Ma Potaka Pumice.

Fig. 13. Whakaruatapu Stream, top of exposed section. A thick white sandy pumice alluvium unit is beside the person, thought to be 0.87 Ma Kaukatea Pumice. The pumice conformably overlies blue-grey mud and lignite. Beds dip 32°@ 086°.

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