Marlborough District Seismic Hazard

Investigation Programme – Phase 2

Paleoseismic trench investigation of the active trace of the Wairau section of the Alpine Fault, Renwick Area, Marlborough District

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Report prepared by Dr Mark Yetton

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- **Phase 2: Paleoseismic trench investigation of the active trace of the Wairau section of the Alpine Fault, Renwick area, Marlborough District.**

Yetton, M. D.

December 2003 (further amended 2005).

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IMPORTANT NOTES

Accuracy of Active Fault Maps

The maps contained in this report are either regional in scope and detail (Figure 1 and the inset in Figure 2), or are based on hand held GPS and aerial photograph interpretation. While every effort has been made to accurately locate the active fault features there may be location errors. The maps should not be viewed as a substitute for site-specific investigations and/or geotechnical engineering assessment wherever this is required.

PALEOSEISMIC TRENCH INVESTIGATION OF THE ACTIVE TRACE OF THE WAIRAU SECTION OF THE ALPINE FAULT, RENWICK AREA, MARLBOROUGH DISTRICT

SUMMARY

Paleoseismic trench investigations have been undertaken on the Wairau section of the Alpine Fault at a site 4km west of Renwick. The trench has been excavated in an undeveloped area of fault scarp that is approximately 2m high and which appears to retain the original vegetation. The fault trace at this locality is relatively upthrown on the south side and spring seepage from high on the fault scarp is widespread.

The investigation trench reveals a sequence of locally derived fan gravels that is cut by a 12m wide sub-vertical fault zone. Approximately 10m of this fault zone consists of thick dense clay fault gouge and the most recent fault ruptures have been concentrated on the relatively up-thrown southern side.

There is radiocarbon evidence of one rupture event prior to 1000 AD but the most recent rupture appears to have occurred in the last 500 years. Confirmation of this comes from two mutually consistent radiocarbon dates in dense hard fault bounded peat (280 ± 35 BP and 318 ± 35 BP from Wk 13189 and Wk 13190 respectively) trapped in the main fault gouge. The dense faulted peat unit is in turn overlain by typical soft peat swamp sediment that is post 1700 AD in age and is not faulted.

This result is unexpected because the closest previous paleoseismic investigations near Wairau Valley township concluded that there had been no rupture of the Wairau section of the fault in that area for at least 1000 years, and probably longer (Zachariasen et al. 2001). The new results suggest that the earthquake rupture event in the last 500 years near Renwick has either been missed in the previous

trenches, or that the Wairau section of the Alpine Fault may have a more complex rupture segmentation pattern than has been previously recognized.

Simplistically the new result could imply that both the amount of elastic strain stored at the fault, and the likelihood of the next earthquake rupture, may be lower than was previously thought. However, it is also possible that there are overlapping fault segments in this area of the Wairau valley, each with it's own pattern of recurrence and past event timing, and assessments of the hazard based on a limited number of sites may be premature and misleading.

Further paleoseismic work is recommended to provide a better understanding of the level of future earthquake hazard associated with the Wairau section of the Alpine Fault in this rapidly developing region.

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PALEOSEISMIC TRENCH INVESTIGATION OF THE WAIRAU SECTION OF THE ALPINE FAULT, RENWICK AREA, MARLBOROUGH DISTRICT.

1) INTRODUCTION

The work described here is part of the second phase of the Marlborough District Seismic Hazard Investigation programme. The first phase of the programme compiled location and background information on the main known active faults in Marlborough District, including the Wairau section of the Alpine Fault (Yetton & McCahon, 2002). This information allows Marlborough District Council to carry out their statutory functions in managing and mitigating the impacts of potential natural hazards.

The Wairau section of the Alpine Fault was identified in Phase 1 as presenting the highest potential seismic hazard in Marlborough District. An earthquake on this fault would have very serious consequences including direct ground rupture at the fault trace, strong earthquake shaking with impacts all over the district, liquefaction in areas such as the lower Wairau valley, and other secondary effects such as landslides.

The hazard presented by this fault is higher than any other in the district because:

- the active fault trace is located in the middle of the densely populated, and rapidly developing, lower and middle Wairau Valley. The fault trace passes through parts of west Renwick, and is projected to pass at depth under Blenheim.
- ground displacement at the fault trace in the next earthquake is expected to be 3.4 – 6.6m, and will be associated with a large earthquake (estimated Moment Magnitude 7.5) with widespread shaking effects.
- previous research suggests that there may be a relatively high likelihood of a future fault rupture within conventional planning periods (i.e. the next 50 -100 years).

Phase two of the investigation programme, part of which is described here, is aimed at establishing reliable estimates of the timing of the most recent earthquake rupture on the Wairau section of the Alpine Fault. Information on the lapsed time since the most recent earthquake rupture, in conjunction with available estimates of long term fault slip rate, and the likely rupture offset in a typical earthquake event, can provide some guide to the likelihood of future fault rupture over conventional planning periods (e.g. 100 years).

2 BRIEF DESCRIPTION OF THE WAIRAU SECTION OF THE ALPINE FAULT AND PREVIOUS PALEOSEISMIC INVESTIGATIONS.

2.1 The Wairau section of the Alpine Fault

The Wairau section of the Alpine Fault enters the western Marlborough District near the Tophouse Saddle and SH 63 (Figure 1). For ease of geographic reference we divide the fault into three subsections.

Wairau Valley subsection

Immediately northeast of Tophouse Saddle the Wairau section of the Alpine Fault forms an intermittent narrow and distinct fault trace striking SW-NE that offsets old river terraces of the Upper Wairau River. For a considerable distance the locus of recent fault movement has been in the modern river bed, effectively removing and disguising geomorphic evidence of past fault movement, so that the fault appears on the maps as a dashed line.

At the Branch River there is the first significant length of continuous fault trace (8km), before the fault once again briefly follows the modern river, and approaches the Wye River fan. The fault trace recommences immediately southwest of the Wye River, but is obscured by modern gravel at the Wye River mouth. The fault trace reappears immediately northeast of the Wye River to continue as a virtually continuous fault scarp. At Hillersden the fault trace crosses SH 63 and north-eastwards from this point the fault remains consistently southeast of the State Highway.

The fault trace bifurcates (splits) into two fault traces approximately 6km northeast of Hillersden (near the settlement of Wairau Valley). The fault orientation (strike) also changes slightly at this point from approximately 075^{o} to 070^{o}. The southern most fault trace generally stays close to the hill country south of SH 63, and in part enters the hill margins in the vicinity of Centre Valley and Marchburn, to continue to the western Waihopai River valley where there are some associated secondary fault traces. The fault trace continues east through farmland on the eastern side of the Waihopai River towards Renwick, and in places has a broad zone of associated ground deformation and secondary faulting, generally on the south side of the main trace. At Renwick the clear surface expression of past fault movement is lost as the fault approaches the alluvial fan of the Omaka River.

The northern most fault strand in the Wairau Valley subsection enters the modern Wairau River bed at Black Valley stream, and it is likely that this trace connects at depth to the Bedford Road subsection described below.

Bedford Road subsection

Two short sections of fault trace are apparent on the high terrace immediately north of SH 63 and crossing Bedford Road (the small road due north to Seresin Winery). The most prominent fault trace ends at the high terrace edge while the more subtle southern trace appears to progressively die out. Recent grape plantings have largely obscured the surface expression of both of these fault traces.

Spring Creek subsection

For many years there was no other trace of the Wairau section of the Alpine Fault recognised in the Wairau Valley. This was attributed to the increasing thickness of the alluvium at the east end of the valley that presumably has absorbed and masked past offsets. However, Grapes and Wellman (1986) describe a fault trace that is only apparent in one set of high altitude aerial photographs taken by the NZ Airforce in 1967. In these photographs the fault trace has a strike (orientation) of 065 degrees and appears as an ill-defined but relatively straight line connecting some local areas of subsidence and more swampy ground.

There has been farming and land modification in many of these areas and this may in part have masked the fault trace. On the ground the trace is very hard to recognise with any confidence, and in Figure 1 we have shown the trace as a dashed line through most of the Spring Creek area. Only at the beach ridges near the old Marshlands School can the trace be located as a conventional fault scarp where it is approximately 1.5m high (up to the NW) with a possible horizontal dextral fault offset around 8m.

2.2 Previous investigation of the past earthquake rupture history of the Wairau section of the Alpine Fault

There have been no historical earthquake ruptures of the Wairau section of the Alpine Fault. Although Eiby (1980) suggests the 1848 Marlborough earthquake was centred in the Wairau valley, and involved movement of the Wairau section of the Alpine Fault, subsequent authors refute this (for example Grapes & Wellman, 1986; Grapes *et al.* 1998; Benson et al. 2001).

Part of the evidence refuting historical rupture of the Wairau Fault is the existence of ancient beach ridges that have not been faulted at the termination of the Spring Creek subsection of the fault trace at Cloudy Bay. This section of fault trace dies out approximately 700m landward of the modern beach line and, although natural die out of the fault trace can not be entirely ruled out, it is more likely that this pattern arises because there had been no fault rupture since deposition of much of this beach sediment. The age of the beach sediment has been estimated by Grapes & Wellman (1986) based on assumed shoreline progradation rates. They suggest that the most recent 700m of beach sediment in this area has accumulated in the last 800 years, and on this basis the authors estimate that the last rupture of the fault was more than 800 years ago.

However, because of the absence of reliable age data at the point at which the fault trace ends, this is a considerable approximation, and in our opinion the Grapes & Wellman (1986) estimate of the lapsed time since the last fault surface rupture should be treated with some caution.

Zachariasen et al. (2001) outline the results of paleoseismic trenching investigation of the Wairau section of the Alpine Fault. They trenched at three locations (designated Wadsworth, Dillons and Marfell), at and near the point at which the Wairau Valley subsection of the fault bifurcates into a southern and northern strand. One of these trenchs (the Wadsworth Trench) provides good data that suggests that the most recent earthquake rupture of the Wairau section of the Alpine Fault at this location occurred after 760 BC and before AD 1000.

Yetton (2002) presents evidence of rupture on the Wairau section of the Alpine Fault in the Tophouse area at some time between AD 200 and AD 1840 (European settlement).

Fougere (2002) notes a young mode of weathering rind ages of gravel clasts on offset terraces immediately adjacent to the fault in the upper Wairau Valley, near Tophouse saddle. He attributes the age mode to the exposure of the gravel clasts (boulders) by earthquake shaking associated with rupture of the Wairau trace of the Alpine Fault[1]. The age mode corresponds to AD 550 ± 150 yrs, which is a good fit to the previous inferences, but the date is based on a relatively small number of sites and weathering rinds.

Table 1 provides a summary of the key seismic hazard data for the Wairau section of the Alpine Fault up until the recent excavation of the Renwick trench described further below.

[1] The exposure of gravel clasts during ground shaking close to fault traces has been observed in many historical earthquakes

Average long term slip rate	3.5 – 5.5 mm/yr
Likely surface offset in each successive earthquake event	3.4 - 6.6m
Date of last surface fault rupture	1000 – 1800 years ago, most likely around 1500 years ago.
Return period of successive earthquake ruptures	600 – 1800 years
Lapsed time since the last rupture	> 1000 years, probably 1500 years
Crude assessment of the relative likelihood of rupture in the next 50-100 years.	Moderate – High

Table 1: Summary table of key seismic hazard data for the Wairau section of the Alpine prior to excavation of the Renwick paleoseismic trench, based on the various references cited above in the text.

3 DESCRIPTION AND SELECTION OF THE RENWICK TRENCH SITE

The area selected for trenching is located approximately 4km equidistant from Renwick and the Waihopai River (GR P28/750650). Figure 2 shows details of the area and an inset map at 1:40,000 scale of the fault trace between the Waihopai River and Renwick. The site is located within the broad alluvial valley and former floodplain of the Wairau River and its tributaries. The immediate area selected for trenching is well away from the current influence of the major local rivers (i.e. the Wairau River and the smaller Waihopai and Omaka Rivers).

The land where the trench is located is part of a new vineyard partnership that is rapidly converting former pasture land to new grape plantings[2]. The adjacent farms are Windrush Farm on the eastern side and Airfield Farm on the west. The latter name derives from former temporary buildings and encampments that were built in

[2] We are extremely grateful to Barbara Steele, John Brownlie and other members of the partnership for their help and permission to undertake the work on the partnership property.

the area between 1940 and 1945 as part to the New Zealand Airforce build up in the Blenheim area. Woodbourne airfield is approximately 7km east of the site.

At the western side of the site (Figure 2) the fault trace forms a clear scarp in front of Airfields Farm house that is approximately 2.4m high. On crossing the boundary into the partnership land the scarp rapidly disappears. This may simply be scarp die-out associated with a right step-over, however there are two other possible explanations. There is a local unnamed ephemeral stream that drains a remnant high area of loess and Miocene gravel terrace to the south. This stream (which is now entrenched in a new diversion drain) has formed a gently sloping alluvial fan in this general area which may have buried the fault trace since the last rupture.

In addition it is clear from a run of aerial photographs taken by the NZAF during the later stages of the Second World War that there was an extensive temporary camp and development in this area. There is no current trace of this camp, and the land, including some subtle continuation of the scarp, may have been re-graded as part of the site clean up once the camp was no longer required.

A definite fault scarp reappears in the central site, which is stepped slightly south from the Airfields fault trace. This scarp progressively increases in height to around 2m in the area selected for trenching and continues eastwards at this height into Windrush Farm. Landscaping and drainage works have been carried out as part of vineyard development, with several ponds and drains on the down-faulted northern side. The fault in this area is very wet with spring seepage at many points along the top of the scarp.

Figure 2 shows an area between the fault traces south of the alluvial fan that may either be an old riser that was cut during a period of fan degradation, or alternatively could be the southern margin of partly fan-infilled fault graben associated with a local fault step-over.

The site for the trench was selected because of the locally swampy conditions associated with spring flow from the upper scarp, and the presence of raupo, cabbage trees and sedge grass vegetation that suggested the area may still have the original vegetation. Finding areas of the fault scarp that have not been modified by farming and development is becoming increasingly difficult in this rapidly growing region of Marlborough.

4 RESULTS FROM PALEOSEISMIC TRENCHING

4.1 Trench Stratigraphy

Figure 3 presents a face log of the trench that was excavated across the active fault trace. The trench was approximately 20m long and on average about 1.8m deep. The saturation of the ground made the sides unstable, despite benching, and this restricted the total depth. A deeper drainage sump for pumping was excavated at the northern end.

The face log in Figure 3 makes a distinction between the stratigraphic units at the south end (S prefix), as distinct from fault zone units (no prefix), and the materials on the northern side (N prefix). The numbering of the units indicates our interpretation of their relative stratigraphic age (with 1 being the oldest).

Commencing at the top (southern) end there are a sequence of local fan gravels that we infer are sediments from the small ephemeral creek that we noted in section 3, and show in Figure 2. The units are all fine to medium sandy greywacke gravels with minor silt and, in some cases, very rare organic material (only Unit S3). These materials were completely saturated to the ground surface with groundwater water inflows from this area of trench of approximately 20 litres/minute.

The fault zone was encountered at the surface about 5m from the south end. It is clear that the locus of recent faulting has consistently been on the south side of the fault zone. Fault zone units on this side of the trench were characterised by clay rich angular gravels with poor sorting and dark blue grey colours. There were two organic units (Units 5 and 7). Unit 5 was readily distinguishable from Unit 7 by having a much higher density and hardness.

Further north in the fault zone there is uniform dense silty clay. This is a clean fault gouge with no gravel clasts and this fault unit is surprisingly wide (12m). This type of gouge must be derived from depth, and the thickness and consistency indicates it is part of an old and well developed shear zone that extends from depth right up to the modern ground surface. The overall fault zone appears to be sub-vertical and probably widens with depth, at least in the immediate subsurface.

At the north end of the trench there are a series of undisturbed alluvial units that are notably siltier than those on the relatively up-thrown south side. We interpret these as being overbank silts and local fan gravels. They can not be directly correlated with the fan gravel units on the south side, but could conceivably be related. No where in the trench can we identify sediments that are typical of those of the main rivers in the area.

4.2 Faults exposed in the trench

There are total of four faults exposed at the south side of the overall fault zone. We designate these as F1 – F4. F1 and F2 predate Unit S3 and appear to be associated with an earlier episode(s) of fault rupture and fault gouge Units 3 & 4.

F3 and F4 are the boundary faults that enclose gouge associated with most recent rupture of the fault. These can be traced virtually to the ground surface at the base of unit 7, which is a relatively young swamp deposit that has accumulated over the rupture zone.

4.3 Radiocarbon dates and event timing

The inset in Figure 3 shows the available radiocarbon dates from the trench in relation to an enlargement of the trench face log. The oldest date comes from a 25mm diameter branch fragment in Unit S3 (Wk 13188). This returned a radiocarbon date[3] of 962 ± 38 BP. This date converts to a calendric date range of 1020 AD to 1190 AD. The date shows evidence for a rupture on F1 and F2 before this time, and rupture on F3 (and by association F4) after this time.

The most important dates in the trench are Wk 13189 and 13190, both taken from the very dense peat of Unit 5. This unit is peat that has been trapped in the shear zone during the most recent fault rupture. It presumably once had a much softer consistency which is characteristic of peat in the normal depositional state (e.g. the peat in Unit 7), but the unit 5 material became trapped and squeezed between two tongues of fault gouge that broke up to the surface during the most recent fault rupture. It is now a very dense hard peat of a type previously encountered in several Alpine Fault paleoseismic trenches (Yetton, 2000; Yetton, 2003). Both radiocarbon dates come from twigs and stems of plant material picked out of the dense peat, rather than the amorphous fine organic material of the matrix that can sometimes be affected by the allogenic substitution of carbon within the soil profile.

The radiocarbon dates for Unit 5 are 280 ± 35 BP and 318 ± 35 BP respectively, which both agree within the radiocarbon error range. The calendric date range for these samples at the 95% confidence level is 1510 AD to 1810 AD (Wk 13189) and the more restricted range of 1480 AD to 1670 AD (Wk 13190). Given both samples are part of same peat unit, and the unit age must be compatible with both, the potential age range can be narrowed to 1510 – 1670 AD. The unit is incorporated within the shear zone and predates the rupture event.

The faulted materials are then overlain by swamp deposits that incorporate bracken stems and flax stems. Taking samples of stem material from the very base of the swamp deposit (samples Wk13192 & 13193) yields radiocarbon dates of “modern”, which convert to some time post 1700 AD, and up until 1950 AD. Unfortunately, it is

[3] Throughout this report radiocarbon dates are indicated by the conventional suffix BP. This is not simply “Before Present” but designates radiocarbon years before 1950 AD when atmospheric carbon around the world was modified by contamination from hydrogen bomb testing. Radiocarbon years do not simply equate with calendric years. We utilise here calendric conversions provided by the University of Waikato Radiocarbon Laboratory based on Stuiver *et al.* (1998) and the NZ Delta-R correction of McCormac *et al.* (1998).

not possible to be any more accurate with radiocarbon dating within this most recent time period.

Further discussion of the origins of Unit 5

We have also considered alternative origins of the peat in unit 5 other than incorporation and burial by faulting. Could it simply be coincidence that there is a linear trough of dense peat in the middle of the youngest fault gouge? Might this be some sort of an old peat infilled drainage ditch, or a peat infilled tree root plate hole? There are a number of reasons why these alternatives are very unlikely including:

- The clean upper truncation of the dense peat by unit 7 (the surface peat) with no sign of any change in unit 7 across the top of unit 5, which does not fit either the “old drain” or the “tree hole” alternative
- Neither the dimension and shape of unit 5, with a rounded profile and an overturned northern side does not fit a hand dug drain, though it is conceivably more of a tree hole shape, but from our experience tree holes are typically irregular in outline and have root remnants remaining in some areas.
- There is a rapid reduction in the width of unit 5 to a narrow 75mm wide band on the west side of the trench that does not fit either alternative hypothesis
- The age of the peat infill predates European occupation of the area, and the associated widespread drainage of wet areas, so it would have to be some sort of Maori drainage feature.
- Both the “old drain” and the “tree hole” hypothesis’s require a random natural and gradual backfilling after drain abandonment or tree removal, and before uniform capping by unit 7 (the surface swamp peat). However, the dense peat infilling the “hole” in the fault gouge is completely uniform with no sign of exotic materials having washed, or fallen in, as the hole gradually infills.
- Similary there is no suggestion of any upward “younging” in the infill material, atleast within the error range of the radiocarbon dates
- The high density of the peat is unlike any peat that we have encountered in natural depositional settings even at depths of several metres, and is identical in appearance and density to faulted peat that we have seen elsewhere (in

particular in paleoseismic trenches at Haupiri River and Crane Creek in central Westland, Yetton 2000).

The high density of the peat and its similarity to faulted peat encountered in other fault zones, in combination with the stratigraphic position of Unit 5 and the shape and dimensions of the unit, are the key lines of evidence for the fault related compression and burial of unit 5. We conclude that the Renwick trench provides strong evidence of a rupture of the Wairau section of the Alpine Fault some time after 1510 AD, and most likely some time in the period between 1510 and 1670 AD.

5 DISCUSSION

The results from this paleoseismic trench have several important implications. Previous inferences that the Wairau section of the Alpine Fault has not ruptured for the last 1000 years, and most probably ruptured about 1500 years ago, are clearly incorrect, at least for this section of the fault trace. Corresponding inferences that the Wairau section of the Alpine Fault is necessarily “due” for a characteristic large earthquake are not supported by the data at this Renwick location.

Why do the recent results appear to conflict with the results of earlier work? The result is not in direct conflict with the poorly constrained results from the Tophouse trench of Yetton (2002), which indicated a rupture of the fault sometime since 200 AD. The new result appear to be in conflict with the weathering rind estimates of Fougere (2002), which suggest the most recent earthquake event in the Tophouse area was about 1500 years ago. However, Tophouse is a long way from Renwick; the rind dating method has considerable errors; rind dating is an indirect method; and Fougere’s sample population of weathering rinds is too small for much confidence.

The result is in direct conflict with the paleoseismic trench results of Zachariasen et al. (2001), and also the estimates of Grapes & Wellman (1986). Considering firstly the trench evidence of Zachariasen et al. (2001) there are basically two possibilities for the differences. The first possibility is that the more recent rupture event has somehow been missed in the trenches from which the key dates have come. It is generally more common to miss evidence for past rupture events in fault trenches, rather than to infer events that have not happened.

Nearly all the key data came from one trench (the Wadsworth trench), with apparently contradictory data from the another (the Dillon trench), while the third Marfell trench had no datable material. Furthermore the dates on which all the work relied came from very small fragments of charcoal or gum resin. Both materials can survive indefinitely in sediments, and can be recycled by subsequent erosion to end up in places where they may suggest a much older age than the sediment in which they are finally contained.

The other possibility raised by the conflicting dates is that the Wairau Fault has a more complex pattern of segmentation than has been previously recognized (refer also discussion further below). The trenches of Zachariasen et al. (2001) were at, or very close to, a change in the average strike of the fault, which is also a point at which the fault splits into two. Changes of average fault strike and bifurcation are both common features at earthquake rupture segment boundaries where surface ruptures of a fault trace are often observed to stop. Perhaps the Zachariasen et al. (2001) conclusions best apply to the more northern of the two fault strands, on which their trenches mainly focused, and the southern section of the fault trace has actually been the most recently active.

There is also some apparent conflict between these new results and the conclusions of Grapes & Wellman (1986), who suggest there has been no rupture of the Spring Creek subsection of the fault near Cloudy Bay in the last 800 years. Once again there are two possible explanations for this apparent conflict i.e. given the assumptions in their approximate date estimate this could easily be wrong; or alternatively, the Spring Creek subsection of the fault may be connected at depth to the northern fault strand that possibly includes the Bedford Road subsection of the fault trace, and connects through to the more northern strand at the Wairau Valley township where Zachariasen et al. (2001) sited their trenches. The general strike and location of these fault trace strands (Figure 1) does suggest that this is a definite possibility.

Adopting a simplistic characteristic earthquake model for a single through-going fault this new result might suggest that in general terms the most elastic strain that could have accumulated on this section of the fault trace is 2.7m (i.e. 5.5mm/yr as the maximum range of long term average slip multiplied by the maximum lapsed time of 490 years). It is most likely that the accumulated elastic strain is considerably less (i.e. the slip rate may be as low as 3.5mm/y, and the lapsed time is most likely to be more like 400 years, which equates to only 1.4m of elastic strain). Given the estimates of single event slip for this section of the fault (3.4 - 6.6m) this in turn suggests that the likelihood of fault rupture in the next 100 years is reasonably low, and furthermore that if there is an earthquake rupture within this period, this will be a considerably smaller earthquake event than previous estimates might have otherwise suggested.

However, it is important to note that the geomorphic pattern of the Wairau valley eastwards from about the Waihopai River shows a progressive widening that appears to reflect the break up of a relatively narrow fault zone into a wider oblique strike slip fault zone of more distributed shear. In contrast to middle and upper Wairau valley there are multiple surface fault traces, each of relatively limited continuity, and the strong possibility that there are also other hitherto unidentified fault strands that remain hidden beneath the thick fluvial gravel sequences.

In a setting such as this it is not realistic to attempt an assessment of future seismic hazard from just one trench location. Furthermore, the combination of multiple separate fault rupture segments, each with their own pattern of recurrence and past event timing, may result in more regular earthquakes in the lower Wairau Valley, albeit of slightly lower magnitude that a single through-going structure.

6 RECOMMENDED FURTHER WORK

The results from this Renwick investigation demonstrate the importance of specific paleoseismic investigation at as many points along a fault trace as is feasible. This is particularly the case where, as we have with the Wairau section of the Alpine Fault, there are multiple disconnected recent fault traces. Results from one area may not be applicable at another.

The only way to determine if there is some form of persistent rupture segmentation of the fault is to gather more widely spread data from as many trench locations as possible. In terms of priorities the next closest section of the fault trace to Blenheim is the short Spring Creek subsection of fault. We recommend that this subsection be trenched at the coastal flax swamp area near the commencement of the first unfaulted beach ridges. The aim of the trenching should be to establish the timing of the most recent fault rupture in this area, as well as the age of the unfaulted beach ridges. Other slightly lower priorities include the trenching of the southern section of the fault trace east of Wairau Valley township, and trenching the main trace west of Wairau Valley. These latter two targets are particularly relevant to any proposed hydroelectric or irrigation canal developments proposed for the Wairau Valley, and could possibly be undertaken on some sort of cooperative basis with the canal designers.

7 CONCLUSIONS

Paleoseismic trench investigations have been undertaken on the Wairau section of the Alpine Fault at a site 4km west of Renwick. The trench has been excavated in an undeveloped area of fault scarp that is approximately 2m high and which appears to retain the original vegetation. The fault trace at this locality is relatively upthrown on the south side and spring seepage from high on the fault scarp is widespread.

The investigation trench reveals a sequence of locally derived fan gravels that is cut by a 12m wide sub-vertical fault zone. Approximately 10m of

this fault zone consists of thick dense clay fault gouge and the most recent fault ruptures have been concentrated on the relatively up-thrown southern side.

There is radiocarbon evidence of one rupture event prior to 1000 AD but the most recent rupture appears to have occurred in the last 500 years. Confirmation of this comes from two mutually consistent radiocarbon dates in dense hard fault bounded peat (280 ± 35 BP and 318 ± 35 BP from Wk 13189 and Wk 13190 respectively) trapped in the main fault gouge. The dense faulted peat unit is in turn overlain by typical soft peat swamp sediment that is post 1700 AD in age and is not faulted.

This result is unexpected because the closest previous paleoseismic investigations near Wairau Valley township concluded that there had been no rupture of the Wairau section of the fault in that area for at least 1000 years, and probably longer (Zachariasen et al. 2001). The new results suggest that the earthquake rupture event in the last 500 years near Renwick has either been missed in the previous trenches, or that the Wairau section of the Alpine Fault may have a more complex rupture segmentation pattern than has been previously recognized.

Simplistically the new result could imply that the amount of elastic strain stored at the fault, and the likelihood of the next earthquake rupture, may be lower than was previously thought. However, it is also possible that there are overlapping fault segments in this area of the Wairau valley, each with it’s own pattern of recurrence and past event timing, so that assessments of the hazard based only on a limited number of sites may be premature and misleading.

Further paleoseismic work is recommended to provide a better understanding of the level of future earthquake hazard associated with the Wairau section of the Alpine Fault in this rapidly developing region.

8 ACKNOWLEDGEMENTS

This report was initially submitted to Marlborough District Council in 2003 and made available shortly after on the Marlborough District Council website. Following informal comments from IGNS (Lower Hutt) the work was peer reviewed by Associate Professor Jarg Pettinga (University of Canterbury) whose general comments have improved the report, which is now presented here as an amended version. We are grateful for the input of Associate Professor Pettinga and the support of Marlborough District Council (in particular Neil Morris) in making this research work possible.

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