Marlborough District Seismic Hazard

Investigation Programme – Phase 2B

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

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

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November 2004.

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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, MARSHLANDS AREA, MARLBOROUGH DISTRICT

SUMMARY

Paleoseismic trench investigations have been undertaken on the Wairau section of the Alpine Fault at a site 9km east of Blenheim near Cloudy Bay (Marshlands). This coastal area has been rapidly accreting during the Holocene period at rates of around 1.2m year (Gibbs, 1979). There are a series of arcuate beach ridges, some of which are cut by the fault, while others that post date the most recent rupture event are un-deformed.

A paleoseismic investigation trench has been excavated in an area of fault scarp that is approximately 1.5m high and which appears to retain the original vegetation. The fault trace at this locality is relatively up-thrown on the northern side but in our opinion no clear strike slip geomorphic offsets can be confirmed. The trench site, and another close by on the last faulted beach ridge, have been selected to determine the age of the swamp which is younger than the most recent rupture event, and to try to confirm previous estimates of the beach ridge age.

The first investigation trench that is located at the fault scarp (Marshlands 1) reveals a sequence of beach gravels that is cut by a poorly defined and relatively narrow (2m) sub-vertical fault zone. One strand within the fault zone is overlain by fluvial silts in the swamp that post-date the most recent earthquake rupture at this location. The silts contain rare wood that washed into the area along with the silt material. Radiocarbon dating of the wood from the Marshlands 1 trench provides a calendric age range for the swamp formation of between 1160 AD and 900 AD. The earthquake rupture event is therefore older than this, and must predate 1160 AD.

The Marshlands 2 trench was not located on the fault scarp, but was positioned to try to obtain an age for the youngest faulted beach ridge, as well as more ages from the swamp. Unfortunately the only datable material in the beach ridge are small shell fragments in sand relatively deep under the ridge. The age obtained (calendric age range of 2880 BC to 3170 BC) suggests that the shells that were dated are from offshore coastal sands that are much older than the faulted beach ridge which overlies them. Once again a radiocarbon date was obtained from the swamp that post-dates the faulting, and this indicates an age for the upper layer of the swamp of 1290 AD to 1180 AD.

The results indicate the likely timing of the most recent rupture at the Marshlands location was prior to 1160 AD (the youngest possible age for the base of the swamp in the down-faulted area), but could be as old as the oldest possible swamp age of 900 AD. Given the rapid rate of coastal progradation it is unlikely that the youngest faulted beach ridge (and thus the most recent rupture) is significantly older than the oldest possible swamp age, but we can not be certain how much older. Thus we conclude that the Marshlands rupture event was approximately 1000 years ago, prior to 1160 AD, and probably post 900 AD.

The implied earthquake event can not be reconciled with a date inferred for the most recent rupture of the fault trace at a location near Renwick (i.e. younger than 1480 AD, Yetton 2003), and suggests that there is a complex pre-historic earthquake rupture pattern in the lower Wairau Valley.

The Renwick and Marshlands results imply that there may have been two ground rupturing earthquake events in the lower Wairau valley in the last twelve hundred years. This is a relatively unexpected result, given the results of previous investigations. If correct, the results suggest that the likelihood of a single through-going large magnitude earthquake rupture of the entire Wairau Fault in the near future may be reasonably low. Furthermore, if an earthquake were to occur in this period, the new results suggest that the event may be a lower magnitude earthquake than might otherwise have been expected (i.e. closer to magnitude 7 than magnitude 7.5). However given the apparent fault trace complexity, smaller events of this size may be more frequent than previously thought, and if such an event has an epicenter in the lower Wairau valley area then the consequences for Blenheim and the surrounding area would still be very serious.

Further fault location and 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.

TABLE OF CONTENTS

List of Figures

PALEOSEISMIC TRENCH INVESTIGATION OF THE WAIRAU SECTION OF THE ALPINE FAULT, MARSHLANDS 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 7.1 - 7.5) with widespread shaking effects.

- research up until December 2003 suggested 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, the second part of which is described here (Phase 2B), 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).

Paleoseismic trenching of the Wairau Valley subsection of the active fault trace near Renwick was undertaken in late 2003 and the results were reported in December 2003 (Yetton 2003). The original report for the Renwick site has now been updated to take into consideration informal comments from various staff of IGNS (Institute of Geological and Nuclear Sciences, Lower Hutt) and a recent peer review by Associate Professor Jarg Pettinga (University of Canterbury). The Renwick report is available on the Marlborough District Council website. This current report outlines the results of paleoseismic trenching of the short length of active fault trace near the coast at Cloudy Bay (the Spring Creek subsection in the vicinity of Marshlands).

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 no other trace of the Wairau section of the Alpine Fault was recognised in the Wairau Valley. The absence of a fault trace closer to Blenheim was attributed to the increasing thickness of the alluvium at the east end of the valley that presumably has absorbed and masked deeper seated past fault offsets. However, Grapes and Wellman (1986) describe a fault trace near Spring Creek that is only apparent in one set of high altitude aerial photographs taken by the NZ Airforce in 1967.

In these old air 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 swampy ground between the Opawa River and Marshlands at the coastal margin of Cloudy Bay. There has been farming and land modification in many of the more inland areas and this may in part have masked the fault trace. On the ground the trace is very hard to recognise with any confidence for most of its length, and in Figure 1 we have shown the trace as a dashed line through 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 on the NW side) with a possible horizontal dextral fault offset reported by Grapes and Wellman (1986) of around 8m. It is this short section of active fault trace that we have targeted for the paleoseismic investigation described in this report.

2.2 Results of 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 and 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 it is 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.

Zachariasen et al. (2001) outline the results of paleoseismic trenching investigation of the Wairau section of the Alpine Fault. They trenched at three locations in the middle Wairau Valley (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 trenches (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.

The paleoseismic trench excavations near Renwick (Yetton, 2003) produced an unexpected result. There is evidence that suggests the most recent fault rupture at this locality occurred post 1480 AD, which implies a considerably younger earthquake event than any other that has been previously recognized. If correct the Renwick result suggests that the post 1480 AD earthquake event may either have been missed in the trenching of Zachariasen et al. 2001, or that the Wairau section of the Alpine Fault has a more complex rupture segmentation pattern than has been previously recognized, with a segment boundary between the middle Wairau valley and Renwick.

Further paleoseismic work was recommended on areas of the fault trace close to Blenheim to obtain a better understanding of the patterns of prehistoric fault rupture. The short section of fault trace near Rarangi (the Spring Creek subsection) was selected as a promising target because of the proximity of major swamps to the fault trace. Swamps are frequently good targets for paleoseismic investigation because of their permanently saturated conditions in which organic material suitable for radiocarbon dating can often be located.

3 DESCRIPTION AND SELECTION OF THE MARSHLANDS TRENCH SITES

The area selected for trenching is located approximately 9 km from Blenheim and 4km from Spring Creek (Inset, Figure 2). From Spring Creek a road runs northeast to Rarangi Beach (Chaytors Road) past the old settlement of Marshlands, where the trenching was carried out (Grid reference for trench site, P28/952730). Marshlands was once the centre of a significant local flax industry, based on the flax that grows in a series of coastal swamps that lie sub-parallel to modern Cloudy Bay. There are

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

many old buildings that still remain from the early days of flax processing and the old Marshlands School is relatively close to the selected trench site. The land where the trench is located is currently grazing land, and part of a large farm owned by the Chaytor family [2].

The seaward coastal plain in the Marshlands – Rarangi area has formed by coastal aggradation as a series of arcuate beach ridges that become more and more obvious on the ground surface approaching the modern beach. Work by Gibb (1979), based on radiocarbon dating of sea shells, has established the position of the 6600 year and 4500 year shorelines (Figure 2) and this data was used by Grapes and Wellman, 1986 to estimate the ages of the younger beach ridges.

The active fault trace associated with the Spring Creek subsection of the fault only becomes obvious on the ground surface amongst the beach ridges for the short section near the old Marshlands School, and on eastwards to cross under a line of power pylons where it abruptly terminates approximately 800m from the current Cloudy Bay shoreline. In this area, from opposite the old school to the transmission power lines, the trace forms a scarp that is approximately 1.5m high on average, with relative uplift on the northern side. Although Grapes and Wellman (1986) describe dextral fault offsets of two channels and a beach ridge by 10m these features could not be located. However, there has been modification of the ground in this area since 1986 and this may explain the absence of obvious evidence for dextral offset.

The abrupt termination of the fault is inferred by Grapes and Wellman 1986 to reflect the continuation of coastal aggradation since the time of the most recent fault surface rupture, as opposed to the progressive die out of the surface rupture trace. We agree with this inference because of the sudden and complete absence of the fault past a particularly prominent beach ridge. There is no suggestion in the field of any progressive loss of scarp height approaching the fault termination, and there is definitely no evidence of faulting of the swamp surface that straddles the fault trace

[2] We are grateful to the Chaytor family, and their farm manager Murray Reire, for their permission to undertake the work on the property.

projection. Although the swamp could conceivably be burying another 100m or so of the fault trace, this theoretical possibility is not reflected at the swamps eastern margin, and the next adjacent beach ridge, and we consider that this is unlikely.

4 RESULTS FROM PALEOSEISMIC TRENCHING

The position of the fault trace with respect to the swamp that abuts it is fortuitous. Given the rate of coastal advance over the last 6600 years (which averages around 1.2m/yr), and the position of the swamp approximately 800m from the current coast line, the swamp must be reasonably old. Based purely on the average aggradation rate of Gibbs (1979) the estimate for the age of swamp formation is approximately 650 years.

To increase the likelihood of obtaining a reliable age for the swamp the decision was made to excavate two trenches. The first trench (designated Marshlands 1) straddled the fault approximately 15m from the eastern fault termination, and adjacent to the westward incursion of the swamp limits along the base of the fault scarp. Logically this area of westward swamp incursion around the scarp base must one of the youngest areas of the swamp, and the location most likely to closely post date the scarp formation. The second excavation (Marshlands 2) was located to provide a section through the prominent beach ridge at the fault termination, in the hope of obtaining a radiocarbon age for the beach ridge itself, and obtain an age for the swamp immediately east of the beach ridge for comparison with Marshlands 1.

4.1 Trench Stratigraphy

Marshlands 1

Figure 3 presents a face log of the trench that was excavated across the active fault trace. The Marshlands 1 trench was approximately 30m long and about 3m deep at the northern end. The saturation of the ground and the nature of running gravels made the sides unstable, despite attempts at benching, and this restricted the total depth in some areas. However, the dimensions were sufficient to establish the most important relationships between the units that are present.

The face log in Figure 3 has the numbering of the units in order of their relative stratigraphic age. The stratigraphy is relatively simple with the oldest unit 1 gravel consisting of a slightly sandy fine to medium gravel composed mainly of greywacke, but with occasional clasts of hard white Amuri Limestone (all the gravels encountered at the Marshlands site had this mix of clast lithology). The deepest unit is in turn overlain by a finer and sandier gravel (clasts up to 75mm) that forms a relatively cohesive bed in the trench side, and provides the only real sign of fault disruption at the scarp. The topmost unit is the coarsest, consisting of a medium to coarse gravel with very little fines, which lost any internal structure it may have had upon excavation when it tended to collapse easily into the trench.

On the southern side of the scarp there are two younger units (units 4 & 5). Unit 4 is a grey-blue slightly sandy silt with some clay and rare wood fragments. Unit 5 is a peat unit including root mats of flax and raupo. We infer that the silt unit underlying the swamp is a fluvial overbank silt from flooding of the Wairau river behind and between the foremost beach ridges. There are no shells or sand lenses typical of an estuarine environment.

Marshlands 2

The Marshlands 2 trench went deeper into the old beach ridge. It was not safe to enter the trench at the deepest point and the digger bucket was used to bring the unit 1 material (a uniform coarse sand with minor pebbles and small shell fragments) up to the surface for logging. The older gravel units closely resembled those in Trench 1 and the same two units were apparent in the swamp.

4.2 Faults exposed in the Marshlands 1 trench

There are two inferred faults exposed at the swamp margin in the Marshlands 1 trench. We designate these F1 and F 2, but their presence is inferred from the apparent truncation and suggestion of downward displacement of unit 2. There was no sign of sub-vertical clast alignment (a common feature of faults in gravels) despite a reasonable number of disc shaped gravel clasts. We attribute this to the relative looseness of the unit 3 gravel, and exposure of the fault only at the near surface. The sub-vertical nature of the inferred fault zone is consistent with strike slip faulting, but given the stratigraphic configuration exposed in the trench there is no evidence that permits a more detailed interpretation of slip orientation.

Although inferred fault F1 daylights in the scarp, F2 is further south and under the swamp surface, where we could confirm that there is no faulting of swamp silt by this most recent rupture event.

4.3 Radiocarbon dates and inferences regards event timing

Marshlands 1

Despite careful examination we could not find any datable material (driftwood or shells) in the old beach ridge (units 1 – 3). This was a little surprising in comparison to the modern beach front, which is littered with driftwood and shells. While oxidation and decay may explain the absence of organic material in unit 3, which was above the local water table, we had hoped there would be dateable material deeper below swamp level.

However, we were able to obtain a small (30mm) partly abraded branch of manuka, with local areas of bark still adhering, from the base of the silt layer in the swamp (unit 4). A subsequent ring count of a section of the branch indicates a self age of up to 10 years at the branch heart, and therefore an average self age of approximately 5 years, which is negligible. The radiocarbon age was 1041±34 BP (Wk 15101) [3] which corresponds to a calendric age range at the 95% confidence level of 1160 AD

[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).

– 900 AD. Because the silt post-dates the most recent fault rupture at this location 1160 AD is the youngest possible age for the fault rupture event on this subsection of the fault.

Marshlands 2

Figure 3 show the available radiocarbon dates from the trench in relation to the trench face logs. The oldest radiocarbon date in the Marshland 2 trench of 4711± 39 BP (Wk 15103) comes from a collection of shell fragments in the sand unit at the base of the trench. This radiocarbon date corresponds to a calendric date range at the 95% confidence level of 2880 – 3170 BC, which is much older than the estimated approximate age of the beach ridge based on the old shoreline positions (estimated at approximately 660 years ago [i.e. 1340 AD]).

At the time of sample collection it was hoped that these shell fragments would date the prominent beach ridge at which the fault trace terminates. However, the dated unit 1 is at a depth of around 4m below the beach ridge, and there is an obvious change above unit 1 to gravels that are more typical of the beach ridges in this area. We conclude that the relatively old date obtained comes from shallow offshore marine sands over which the beach ridges have subsequently prograded.

The swamp area in the Marshlands 2 trench once again contained dateable material but in this case the wood was near the top of the silt layer (unit 5). We collected a mixture of small branch fragments of unknown self age. These were ground up and mixed (to average the unknown self ages) and yielded a radiocarbon date of 825± 34 BP (Wk 15102). The calendric age range for this sample at the 95% confidence limits is 1290 AD – 1180 AD. The age is a reasonable match to the Marshlands 1 date (1160 AD – 900 AD). Strictly speaking the two swamp ages do not overlap (there is a minor discrepancy of around 25 years). However, the oldest date comes from the base of the silt layer and the younger from near the top, and it is most likely that the silt accumulated in a series of river flood events over periods of at least tens of years, as opposed to a single flood incursion.

5 DISCUSSION

The results from the paleoseismic trenches at Marshlands are consistent with respect to the approximate age of swamp formation (at around 1200 AD) and the youngest possible age of the rupture event in this area (pre – 1160 AD).

In the absence of a definitive age for the youngest faulted beach ridge it is more difficult to assess the maximum age of the rupture event. Using the average progradation rates Grapes and Wellman (1986) suggest the likely age of the youngest faulted beach ridge is approximately 800 years old (1200 AD), which is a very good fit to the swamp age. Because the average aggradation rates are so rapid in this area the youngest faulted beach ridge is very unlikely to be much older than the oldest possible age of the swamp, which is 900 AD. Thus we conclude that the rupture event was approximately 1000 years ago, prior to 1160 AD, and was most likely post 900 AD.

Comparison with previous work

It is not possible to reconcile the results from the Marshlands trench with the earlier paleoseismic investigation near Renwick (Yetton, 2003). The Renwick results suggest a rupture of the fault in that area since 1480 AD. Therefore the new result from the Marshlands area implies two different ground rupturing earthquakes in the lower Wairau Valley in the last approximately 1000 years.

Comparison to the reported results of paleoseismic trench investigations in the middle Wairau Valley (Zachariasen et al. 2001) also indicates a discrepancy. The authors concluded that the last surface rupturing earthquake event in that area occurred more than approximately 1400 years ago and possibly as much as 2600 years ago.

Implications for seismic hazard

The evidence collected in the Renwick and Marshlands work suggests that there may have been two different ground rupturing earthquakes in the lower Wairau Valley in the last approximately 1000 years, which has important implications for future seismic hazard.

The results imply that the elastic strain that has now accumulated on this section of the fault trace may be relatively low, and at most around 2.7m. (i.e. 5.5mm/yr as the maximum of the range of long term average slip rates of the Wairau section of the Alpine Fault multiplied by the maximum lapsed time of approximately 490 years). It is most likely that the accumulated elastic strain is considerably less that this (i.e. the long term average slip rate may be as low as 3.5mm/y, and the lapsed time based on the Renwick result is most likely to be 400 years or less, which equates to only 1.4m of elastic strain).

Given that the estimates of single event slip for this section of the fault are 3.4 - 6.6m (Lensen, 1976), <u>and assuming that the Wairau fault ruptures as a single through going structure</u>, then the available data suggests that the likelihood of fault rupture in the next 100 years is reasonably low, and that were an earthquake rupture to occur within this period, it is likely to be a considerably smaller earthquake event than previous estimates might otherwise have suggested.

However, the other important fact demonstrated by the difference in dates for the most recent event between Marshlands and Renwick is that the Wairau Fault has a more complex pattern of segmentation than has previously been recognised. This possibility was first suggested when comparing the Renwick result with earlier trenching by Zachariasen et al. (2001) near the township of Wairau Valley, and this recent Marshlands result confirms the complexity. There is a very real possibility that the Lower Wairau valley may be an area of multiple fault segments with relatively complicated overlaps and potential fault interactions. Because of this pattern there may be slightly lower magnitude earthquakes than a single through-going fault could produce (typically assessed as up to moment magnitude 7.6, e.g. Stirling et al., 2000), but nevertheless significant large earthquakes (i.e. still magnitude 7 scale events) that occur at more frequent and less predictable intervals.

6 RECOMMENDED FURTHER WORK

Once again the results from this Marshlands investigation demonstrate the importance of specific paleoseismic investigation at as many points along a fault trace as possible. This is particularly important where, as we have with the Wairau section of the Alpine Fault, there are multiple disconnected recent fault traces, and the data from one area may not be applicable at another.

7 SUMMARY AND CONCLUSIONS

Paleoseismic trench investigations have been undertaken on the Wairau section of the Alpine Fault at a site 9km east of Blenheim near Cloudy Bay (Marshlands). This coastal area has been rapidly pro-grading over the Late Holocene period at rates of around 1.2m year. There are a series of arcuate beach ridges, some of which are cut by the fault, while others that post date the most recent rupture event are un-deformed.

A paleoseismic investigation trench has been excavated in an area of fault scarp that is approximately 1.5m high and which appears to retain the original vegetation. The fault trace at this locality is relatively up-thrown on the northern side but in our opinion no clear strike slip geomorphic offsets can be confirmed. The trench site, and a second close by on the last faulted beach ridge, were selected to determine the age of the swamp that is younger than the rupture event, and to confirm previous estimates of beach ridge age.

The first investigation trench at the fault scarp (Marshlands 1) reveals a sequence of beach gravels that are cut by a poorly defined and relatively narrow (2m) sub-vertical fault zone. One strand within the fault zone is overlain by fluvial silts at the base of the swamp which post-date the most recent earthquake rupture at this location. The silts contain rare wood that

washed into the area along with the silt material. Radiocarbon dating of the wood from the Marshlands 1 trench provides a calendric age range for the swamp formation of between 1160 AD and 900 AD. The earthquake rupture event is therefore older than this, and must predate 1160 AD.

The Marshlands 2 trench was not located on the fault scarp, but was positioned to try to obtain an age for the youngest faulted beach ridge, as well as more ages from the swamp. Unfortunately the only datable material in the beach ridge are small shell fragments in sand relatively deep under the ridge. The age obtained (calendric age range of 2880 BC to 3170 BC) suggests that the shells that were dated are from offshore coastal sands that are much older than the faulted beach ridge which overlies them. Once again a radiocarbon date was obtained from the swamp that post-dates the faulting, and this indicates an age for the upper layer of the swamp of 1290 AD to 1180 AD.

The results indicate the likely timing of the most recent rupture at the Marshlands location was prior to 1160 AD (the youngest possible age for the base of the swamp in the down-faulted area), but could be as old as the oldest possible swamp age of 900 AD. Given the rapid rate of coastal progradation it is unlikely that the youngest faulted beach ridge (and thus the most recent rupture) is significantly older than the oldest possible swamp age, but we can not be certain how much older. Thus we conclude that the Marshlands rupture event occurred approximately 1000 years ago, prior to 1160 AD, and probably post 900 AD.

The implied earthquake event can not be reconciled with a date obtained for the most recent rupture of the fault trace near Renwick (i.e. younger than 1480 AD), and reveals the complexity of the pre-historic earthquake rupture pattern in this area of the lower Wairau Valley.

The Renwick and Marshlands results suggest there may have been two ground rupturing earthquake events in the lower Wairau valley in the last

twelve hundred years. This is a relatively unexpected result, given the results of previous investigations. The results suggest that there is a complex pattern of fault strands and/or earthquake rupture segments in the lower Wairau valley. Although each of these may produce slightly smaller earthquakes than a single fault (say closer to M 7 than M 7.5) , the faults in combination may generate more frequent earthquake events, with shorter return periods and a less predictable recurrence pattern. Even if the magnitude of future events is closer to M7 than M 7.5, if the epicenter of the earthquake is located in the lower Wairau valley, then the consequences for the area will be serious.

8 ACKNOWLEDGEMENTS

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