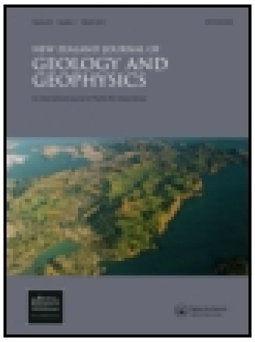


New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzg20

Late Holocene beach ridges displaced by the Wellington Fault in the Lower Hutt area, New Zealand

Mark W. Stirling

To cite this article: Mark W. Stirling (1992) Late Holocene beach ridges displaced by the Wellington Fault in the Lower Hutt area, New Zealand, New Zealand Journal of Geology and Geophysics, 35:4, 447-453, DOI: 10.1080/00288306.1992.9514539

To link to this article: http://dx.doi.org/10.1080/00288306.1992.9514539

Published online: 23 Mar 2010.

New Zealand Journal of Geology and Geophysics, 1992, Vol. 35: 447–453

0028–8306/92/3504–0447 $2.50/0

Late Holocene beach ridges displaced by the Wellington Fault in the Lower Hutt area, New Zealand

MARK W. STIRLING
Ian R. Brown Associates Ltd
P. O. Box 9043
Wellington, New Zealand

Abstract The Wellington Fault cuts a prograded, late Holocene shoreline at the southern end of the Hutt Valley. The fault scarp crosses a suite of five beach ridges (B–F; youngest to oldest). Two steps in scarp height of 2 m, and 3–4 m, between southwest Petone and north Petone/central Lower Hutt occur over a distance of about 1 km, whereas, southeast of the fault, there are no steps, and the topography is more or less level (2–2.5 m altitude) for about 2 km upvalley. Uplift of c. 6 m has occurred on the northwest side of the Wellington Fault in the last few thousand years (vertical deformation rate of c. 1 mm/yr, determined from vertical offset of beach ridge D). Net uplift southeast of the fault is no more than 2–2.5 m, and could have occurred solely during the 1855 Wairarapa earthquake. A dextral slip rate of c. 5 mm/yr is suggested for the Wellington Fault from possible lateral offset of beach-ridge F.

Near-surface stratigraphy and radiocarbon dating in eastern Petone suggest that swampy conditions developed c. 470 years ago upvalley from beach ridge C. This may have been associated with the 300–450 year last-displacement event suggested for the Wellington Fault in the Wellington – Hutt Valley area (i.e., subsidence southeast of the fault).

The 1855 uplift probably was anomalously large: repeated late Holocene uplifts of this magnitude, and of the frequency observed at Turakirae Head, would have elevated the Petone area well above what is observed today.

Keywords Holocene; Quaternary; Wellington Fault; Lower Hutt; Petone; tectonic geomorphology; beach ridges; coastal uplift

INTRODUCTION

Recent publications provide new data on the activity of the strike-slip Wellington Fault and evidence for a 75 km fault-rupture segment from Cook Strait to the Upper Hutt area (the Wellington – Hutt Valley Segment; Berryman 1990, Van Dissen et al. 1992). The evidence largely is based on fault-trace geometry and displacements from the northernmost and southernmost onshore extents of the segment, with limited data from the central part. This paper presents fault-displacement data from the central part, at the southern end of the Hutt Valley, and puts it in its regional context.

Interpretations presented in this paper are of data gathered during a seismic-hazard assessment completed for Lower Hutt City Council (now Hutt City Council) in 1991. Data are from the literature, vertical aerial photographs, field inspection, and interpretation of a digital terrain model (TECHBASE; MINEsoft 1988). The terrain model is from 0.2 m resolution topographical data from the Wellington Regional Council's map series "Photogrammetric levelling in Lower Hutt and Petone 1985".

Geological setting

The Hutt Valley is situated at the southern end of the North Island, New Zealand, within an area of northeast-trending active faults and high historical seismicity (Fig. 1). The valley has two major basins (Lower and Upper Hutt basins), separated by the Taita Gorge. The recently active Wellington Fault forms the western boundary of the Hutt Valley, separating uplifted Western Hutt hills from the downfaulted basins to the east. At the southern end of the Hutt Valley, the fault scarps typically are a few hundred metres southeast of the Western Hutt hills. The fault, traceable from Wellington to the Bay of Plenty, is a major structural feature of the North Island (Berryman & Beanland 1988).

Previous work

The geology and geomorphology of the Hutt Valley have been studied for around 100 years (e.g., McKay 1892; Bell 1908; Cotton 1950). Stevens (1956) gave the name Hutt Formation to deltaic deposits formed by Hutt River where it enters the Lower Hutt – Port Nicholson Basin (Stevens 1956, p. 214). Stevens (1973) correlated raised beach ridges in Petone with those at Turakirae Head. The beach ridges at Turakirae Head have been preserved by successive regional uplifts, the most recent being the 1855 Wairarapa earthquake.

Ota et al. (1981) provided detailed description of key sites along the Wellington Fault in Wellington and Lower Hutt. They suggested that lateral displacement markers are not preserved around Lower Hutt. The last vertical displacement on the fault was c. 0.4 m (up to the northwest) in Lower Hutt.

Other studies on recent faulting in the Hutt Valley include Berryman (1990) and Van Dissen et al. (1992). The Wellington – Hutt Valley Segment of the Wellington Fault, between Cook Strait and Kaitoke Basin, appears to be a single fault rupture, and the upthrown side of the fault varies both along strike and with time (Berryman 1990). The last displacement of the Wellington – Hutt Valley Segment was 300–450 years ago, and the recurrence interval of faulting is 420–780 years (Van Dissen et al. 1992), from data gathered near both ends of the segment.

G92037
Received 23 July 1992; accepted 31 August 1992

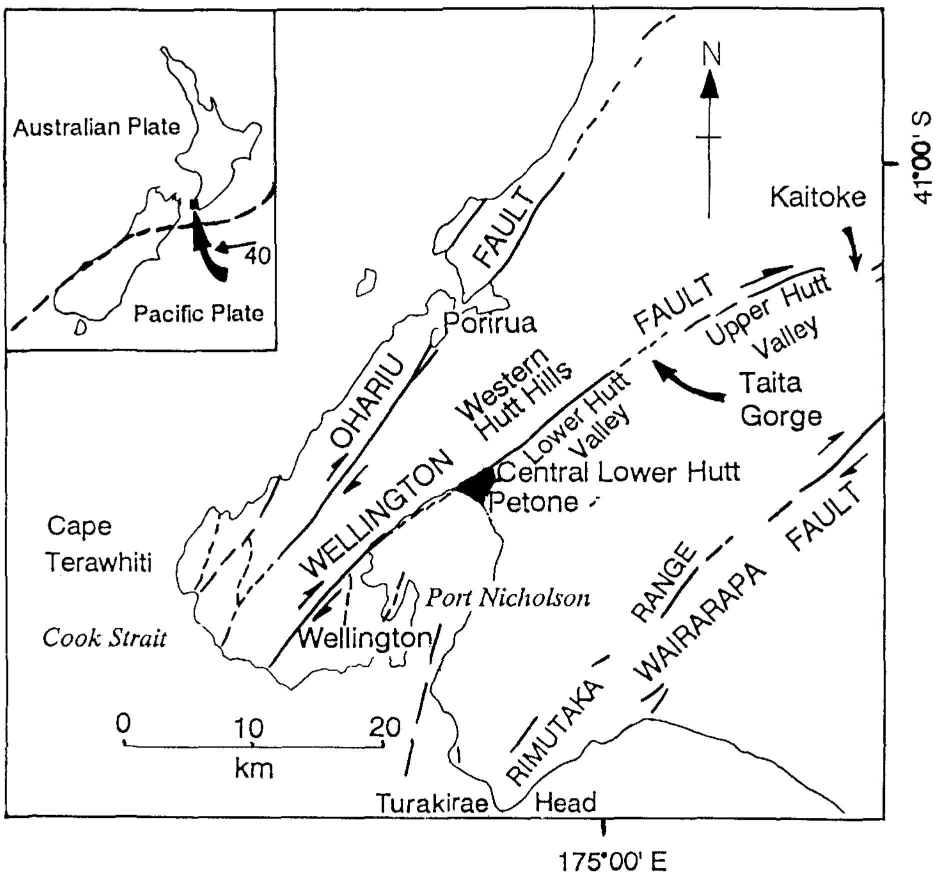


Fig. 1 The Wellington region, showing locations of known active faults in and around the study area, and relative plate motions across the boundary of the Australian and Pacific plates (inset, mm/yr; from Van Dissen et al. 1992).

TECTONIC DISPLACMENT OF THE VALLEY FLOOR

Beach ridges and uplift

Subtle landforms on the valley floor of the Lower Hutt area provide information on late Holocene tectonic activity. Five linear ridges, interpreted as beach ridges (here referred to as beach ridges B–F) trend WNW across Petone, within a broad prograded coastline (Fig. 2). The Wellington Fault cuts this surface in western Petone. The area may have been uplifted close to 2.35 m during the 1855 Wairarapa earthquake (Darby & Beanland 1992). Stevens (1973) suggested beach ridge B was stranded during the 1855 earthquake (from historical evidence); beach ridge C was uplifted c. 460 years ago (from radiocarbon dating of carbonaceous sediments immediately upvalley from the beach ridge; NZ1580); and beach ridge D (The Rise) was uplifted c. 1800–2350 years ago (on the basis of radiocarbon dating of its sediments; NZ1577 and 1579). Stevens (1973) used the observation of the 1855 uplift to suggest that the ridges upvalley from beach ridge B were stranded by earlier uplifts (those recorded by beach ridges at Turakirae Head). Topographical continuity of beach ridges B, C, and D suggests that the Hutt River has not shifted significantly westwards over Petone for at least the last c. 1800–2350 years, and that the land surface increases in age upvalley from the coast.

Subtle WNW-trending ridges upvalley from beach ridge D possibly are older beach ridges (i.e., beach ridge E, immediately north of Udy St; and beach ridge F, immediately north of Wakefield St, northern Petone; Fig. 3A, B). They are younger than the c. 4000 year old Melling Peat (Stevens 1956), which they overlie.

The scarp of the Wellington Fault is recognised as far south as Petone Avenue, southwest Petone (Fig. 3A, B). It is 3–4 m high between central Lower Hutt City and north Petone, and 2 m high from north Petone to southwest Petone. The step in height of the scarp along its strike indicates successive vertical displacements on the fault. Following from the 3.2–4.7 m horizontal, single-event offsets and order-of-magnitude-smaller vertical offsets that characterise the fault (Berryman 1990), the scarp must have developed from a number of displacements, with the greatest number represented at the 3–4 m high section of the scarp (i.e., the oldest surface that has been offset). The 2 m scarp height adjacent to beach ridge D (1800–2350 year age) suggests a vertical displacement rate of c. 1 mm/yr. This deformation rate is somewhat faster than rates estimated by Berryman (1990) in the Upper Hutt area, possibly due to localised warping adjacent to the fault. In coastal southwest Petone, the absence of visible vertical offsets on beach ridges B and C suggests that the ridges formed after the last fault movement. Historical evidence verifies that the fault has not moved at least since uplift of beach ridge B in 1855.

A possible 20 m dextral offset of beach ridge F across the Wellington Fault (Fig. 3) suggests a dextral slip rate of c. 5 mm/yr, based on the maximum c. 4000 year inferred age of the beach ridge. This slip rate is similar to rates determined elsewhere on the Wellington – Hutt Valley Segment (5–7.6 mm/yr; Van Dissen et al. 1992). A possible c. 100 m dextral offset of beach ridge D was also assessed (Fig. 3), but

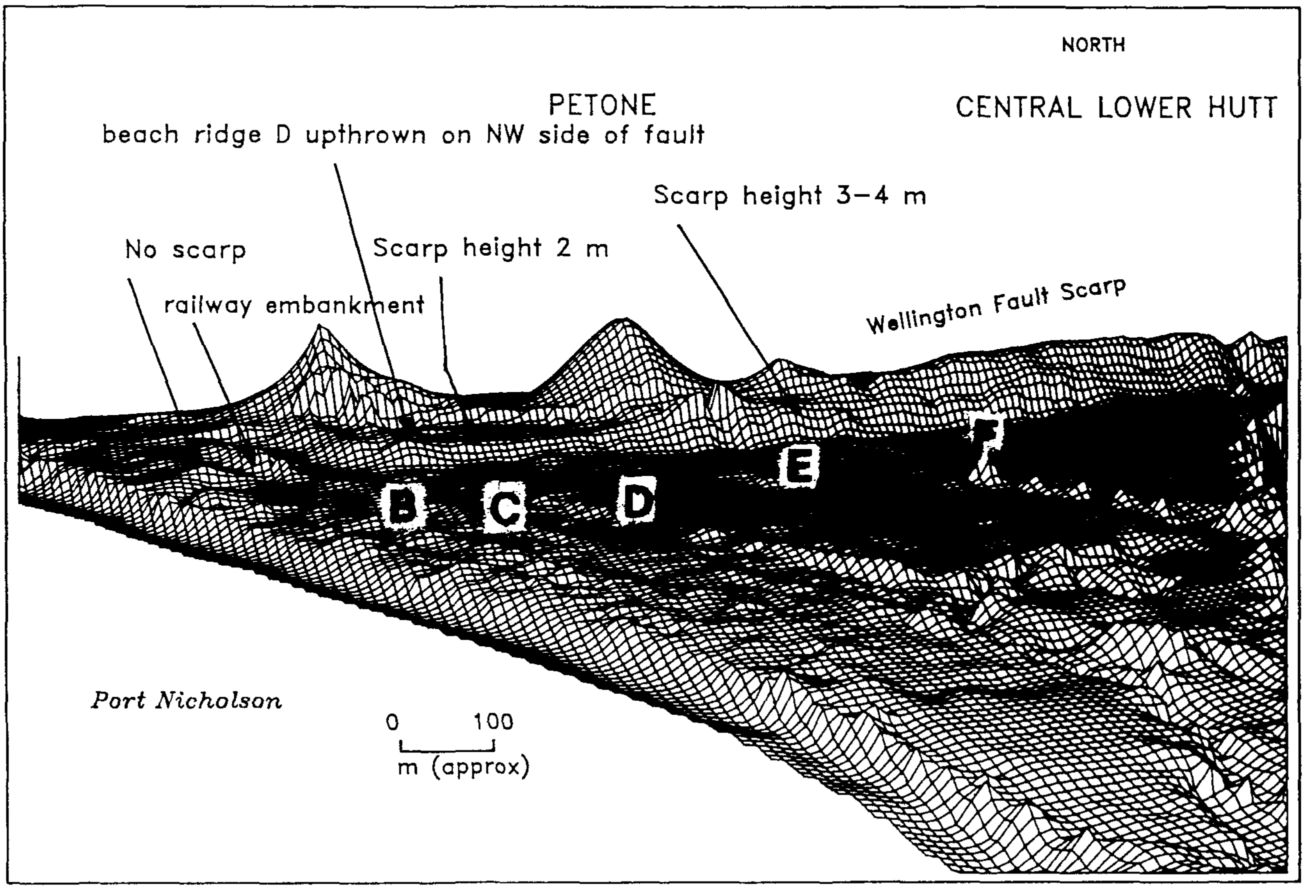


Fig. 2 "Wire frame" computer model (from TECHBASE, using minimum curvature estimation) of the study area, as viewed from the SE (vertical exaggeration = 20× horizontal scale shown). The model shows the stepped scarp of the Wellington Fault, beach ridges B–F, and the level ground surface southeast of the fault.

the suggested slip rate derived from this was an order-of-magnitude faster than the rates of Van Dissen et al. (1992). The apparent offset is therefore unlikely to have been caused by lateral slip on the fault and is more likely to be due to nontectonic effects.

Progressive uplift of the valley floor of the Lower Hutt area is confined to the northwest side of the Wellington Fault (Fig. 4A), in contrast to Stevens's (1973) suggestion of progressive regional uplift of the valley. Southeast of the fault scarp, the topography is about level, generally 2–2.5 m in height from the coast inland for a distance of c. 2 km (Fig. 4B–E). Before the 1855 earthquake, this surface was very close to sea level, as it was the extensive Te Mome Swamp, and the course of the Hutt River was meandering (Stevens 1973). The Te Mome Swamp area is now c. 2 m above sea level (upvalley and immediately downvalley of beach ridge D; Fig. 4), the uplift consistent with the recent 1855 uplift estimate for the Petone area (<2.35 m; Darby & Beanland 1992).

Changes in the Lower Hutt area at the time of the last Wellington – Hutt Valley Segment event

The lack of height difference between the upvalley bases of beach ridges B and C suggests either that their ages are so closely spaced that there was no uplift or subsidence between the times of their formation, or that a significantly older beach ridge C was once at a higher altitude than beach ridge B, and was downdropped by a Wellington Fault event. The second alternative is unlikely, as a small (e.g., 0.5 m high) scarp would presumably be present immediately upvalley from beach ridge B, and this is not observed. In addition, there are fault traces buried beneath near-surface sediments at the position of beach ridge C at the Gear site, southwest Petone (D. L. Woodward pers. comm.), which suggests that the beach ridge developed since the last Wellington Fault event. The age of beach ridge C presently cannot be independently constrained.

A trench through beach ridge D in the William St area (Stevens 1973, fig. 5; Fig. 5) suggests abrupt sedimentological changes in the area around the time of the last Wellington – Hutt Valley Segment movement. Immediately downvalley of beach ridge D, a c. 1 m thickness of peaty clays and silts overlies bedded beach sands at a sharp erosional contact. Samples near the base of the peaty sediments have been dated at 460–477 ± 55 yr B.P. (NZ1580; Stevens 1973 — these are the same radiocarbon dates used for the timing of beach ridge C development). The peaty sediments underlie the present land surface, presumably representing deposition in the Te Mome Swamp, which covered the area as far north as central Lower Hutt before 1855. They would have been deposited between c. 470 and 137 years ago. The stratigraphy suggests that the shoreline was prograding at, and after, the time of beach ridge D development (c. 1800–2350 years ago; Stevens 1973), but, at c. 470 years ago, a (Te Mome) swamp developed, and peaty sediments were deposited until the area was uplifted in 1855. The development of swampy conditions

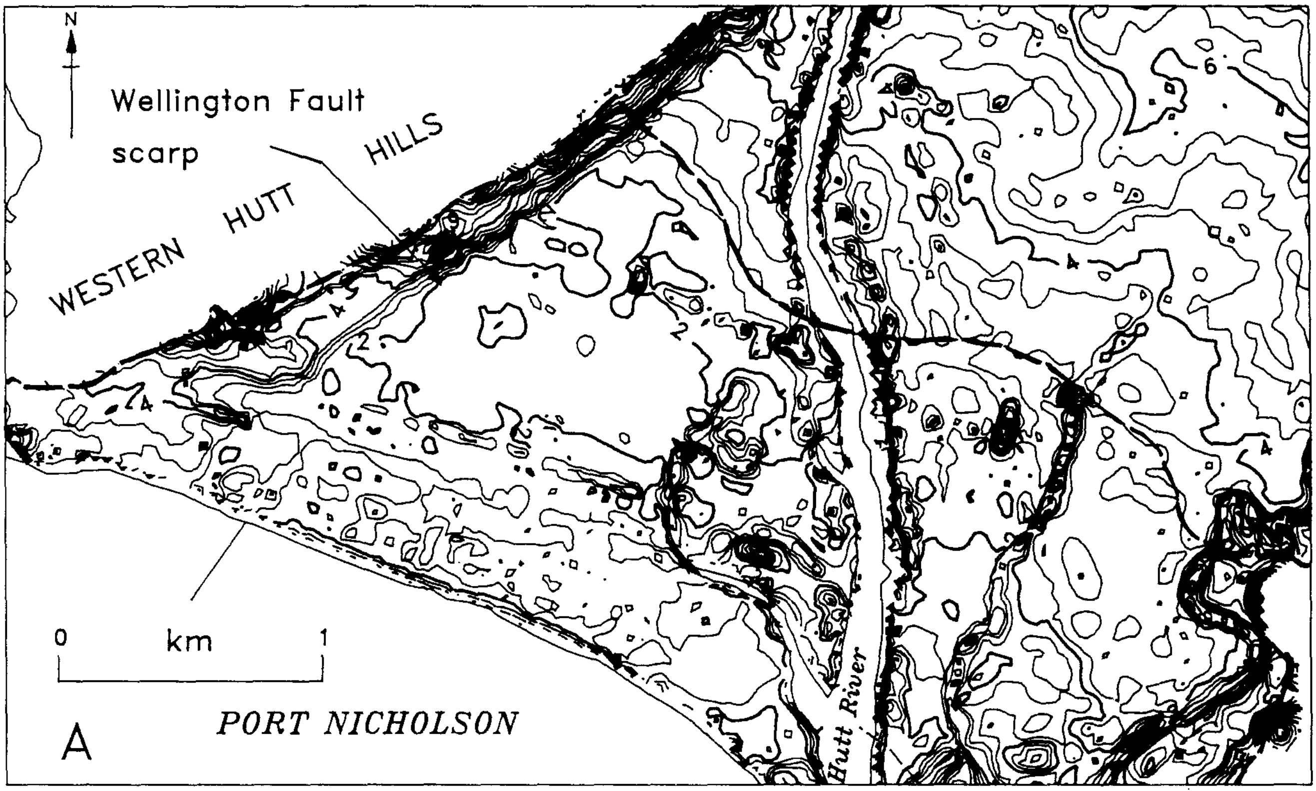


Fig. 3A Contours of valley-floor topography (contour interval 0.5 m). The dashed line at the northwestern side of the valley floor marks the approximate greywacke/sediment boundary, and the dashed line through the valley floor indicates the approximate upstream boundary of coastal topography (negligible downvalley gradient and beach ridges).

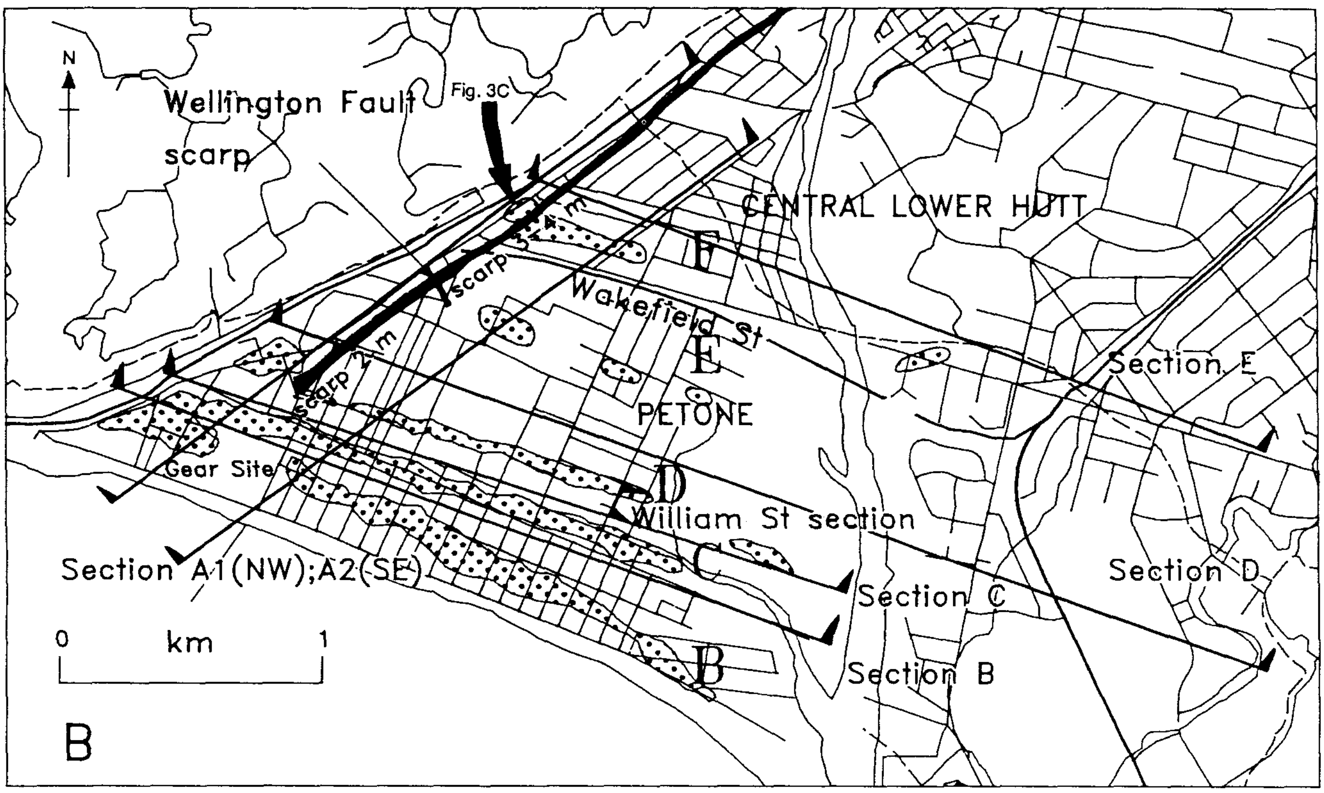


Fig. 3B Plan view of study area, showing location of Wellington Fault scarp and beach ridges B–F in relation to streets of Petone and central Lower Hutt. Locations of Fig. 3C and sections shown in Fig. 4 and 5 are also shown (sections A–E, Fig. 4A–E; sections B–E, Fig. 4F; and William St section, Fig. 5).

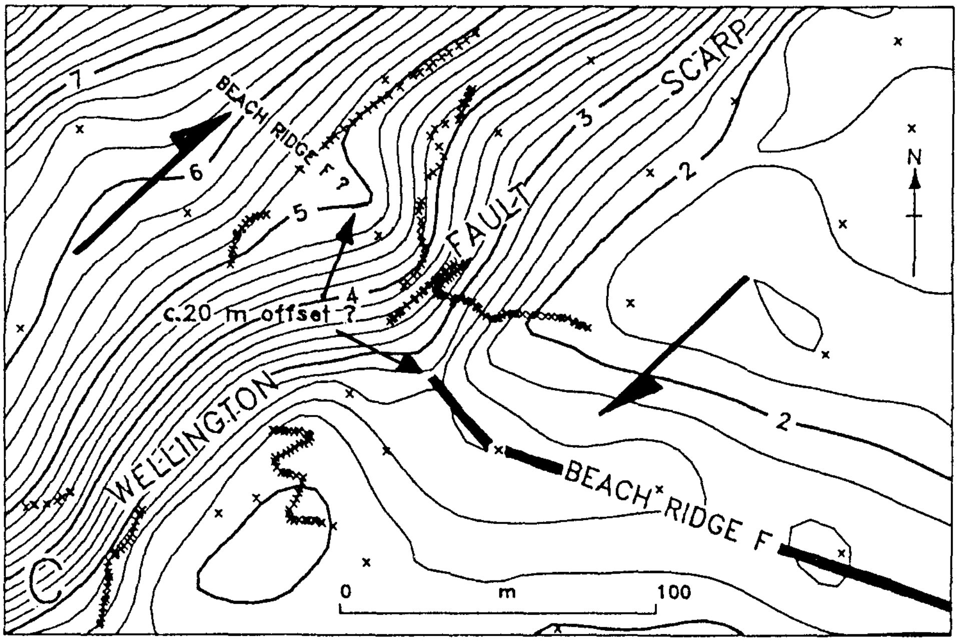


Fig. 3C Contours of beach ridge F, showing a possible 20 m dextral offset across the Wellington Fault. Contour interval is 0.2 m. Crosses indicate the positions of topographical data used to model the topography.

may have been associated with subsidence on the Wellington Fault, as the radiocarbon dates for the sediments are similar to the 300–450 year last-displacement event suggested for the Wellington – Hutt Valley Segment. However, the association is tenuous, as the carbonaceous sediments could have accumulated without tectonism.

REGIONAL IMPLICATIONS

Observations of progressive uplift northwest (but not southeast) of the Wellington Fault in the Lower Hutt area suggest either that the 1855 Wairarapa regional uplift was unique in the late Holocene, or that the effects of "1855 style" regional uplifts subsequently have been negated by displacements of the Wellington Fault (i.e., subsidence southeast of the fault). The latter has been suggested by Wellman (1969) to account for the regional contrast in uplift geometry between the broadly uplifted 1855 beach-ridge profile (i.e., uplift of the coast as far west as Cape Terawhiti) and older beach-ridge profiles around the south Wellington coast (for which deformation associated with Wairarapa Fault movements has not extended west of Wellington Harbour). Wellman's model is consistent with long-term deformation patterns, which show greywacke upthrown to c. 400 m above sea level northwest of the Wellington Fault (Western Hutt hills) and downthrown c. 300 m below sea level southeast of the fault (Stevens 1956).

A vertical displacement rate of c. 1 mm/yr is suggested for the Wellington Fault from scarp heights adjacent to beach ridge D, but over time this rate would not fully negate the effects of 1855-style Wairarapa Fault uplifts southeast of the Wellington Fault. Rapid uplift of c. 4 mm/yr has been occurring at Turakirae Head over the late Holocene (e.g., Moore 1987). If this uplift rate were associated with a series of 1855-style uplifts (i.e., uplift and northwest tilting of the area between Turakirae Head and Cape Terawhiti), then uplift rates of c. 1.5 mm/yr would be expected in southeast Petone. Some "residual" Wairarapa Fault uplift, therefore, would have to be preserved over southeast Petone after a number of Wellington and Wairarapa Fault events had occurred, in contrast to the historical evidence of the area being close to sea level before 1855. Additionally, the 2 m Wellington Fault scarp height at its southernmost point (truncated by beach ridge D) suggests that several fault events occurred while the beach ridge D shoreline was active, an unlikely occurrence if 1855-style uplifts were regularly stranding the shoreline. The magnitudes of pre–1855 Wairarapa uplifts are therefore unlikely to have been as great at Petone as in the 1855 event, which suggests that the 1855 uplift was uniquely large in the late Holocene.

CONCLUSIONS

1. The scarp of the Wellington Fault is regularly stepped along its length at the southern end of the Hutt Valley, where it displaces an actively prograding shoreline. This indicates progressive vertical displacement with time. Scarp heights of up to 4 m in northern Petone, adjacent to late Holocene beach ridges, suggest multiple movements, and vertical displacement rate of c. 1 mm/yr. Possible dextral offset of the maximum c. 4000 year old beach ridge F suggest a horizontal slip rate of c. 5 mm/yr on the fault.
2. Progressive uplift of the valley floor has been confined to the northwestern side of the Wellington Fault. The area southeast of the fault presently is no higher than the 1855 Wairarapa earthquake uplift would have raised it. Previous suggestions of progressive regional uplift by Wairarapa Fault events are incorrect.
3. Near-surface stratigraphy and radiocarbon dating in a trench in William St, eastern Petone, suggest that swampy conditions developed in the area c. 470 years ago. This may represent subsidence associated with the 300–450 year last displacement suggested for the Wellington Fault in the Wellington–Hutt Valley area.
4. Uplift during the 1855 Wairarapa earthquake was anomalously large, as similar uplifts of this magnitude repeated at the frequency observed at Turakirae Head would have raised the Petone area above what is observed today, despite active subsidence southeast of the Wellington Fault.

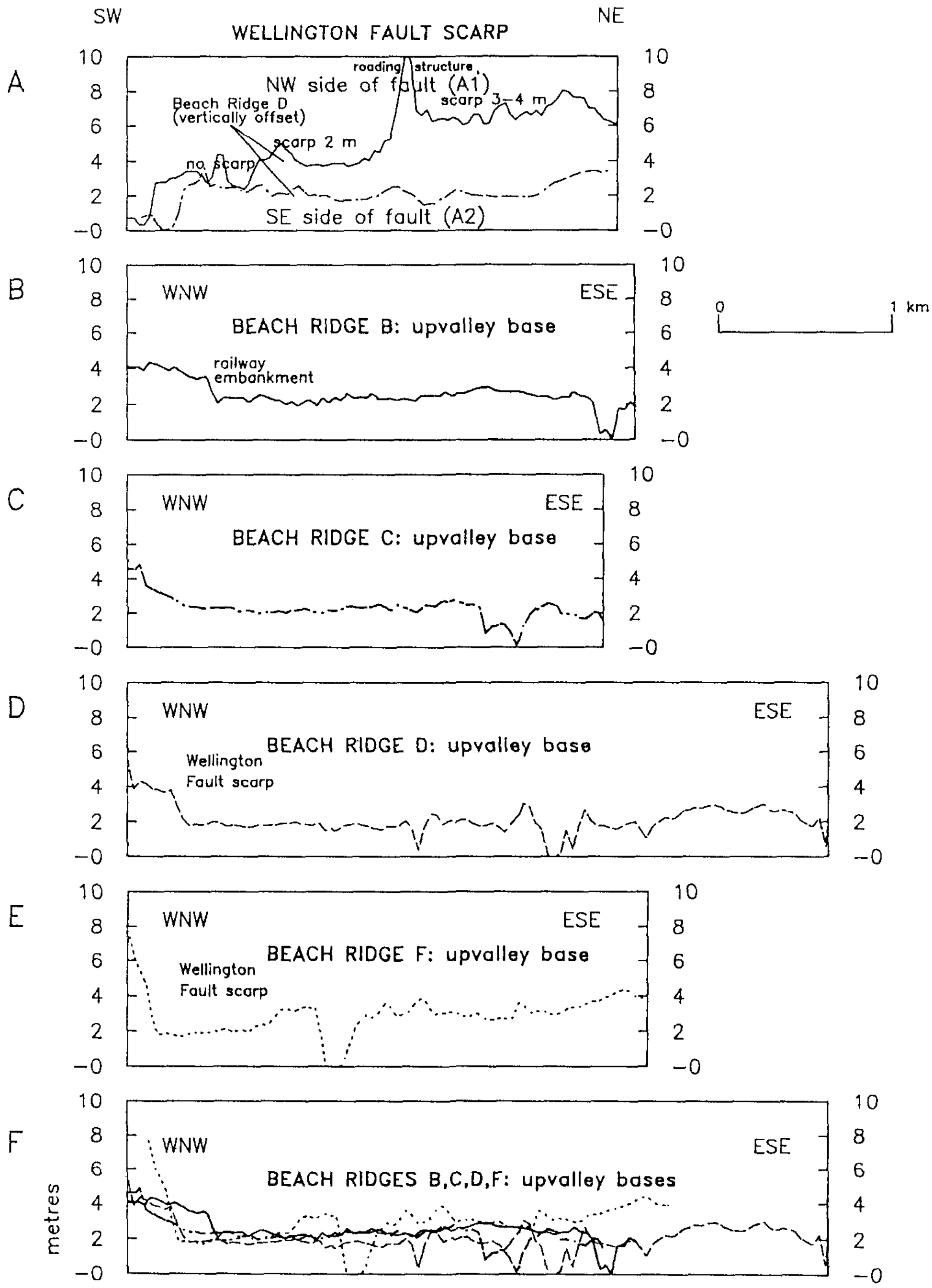
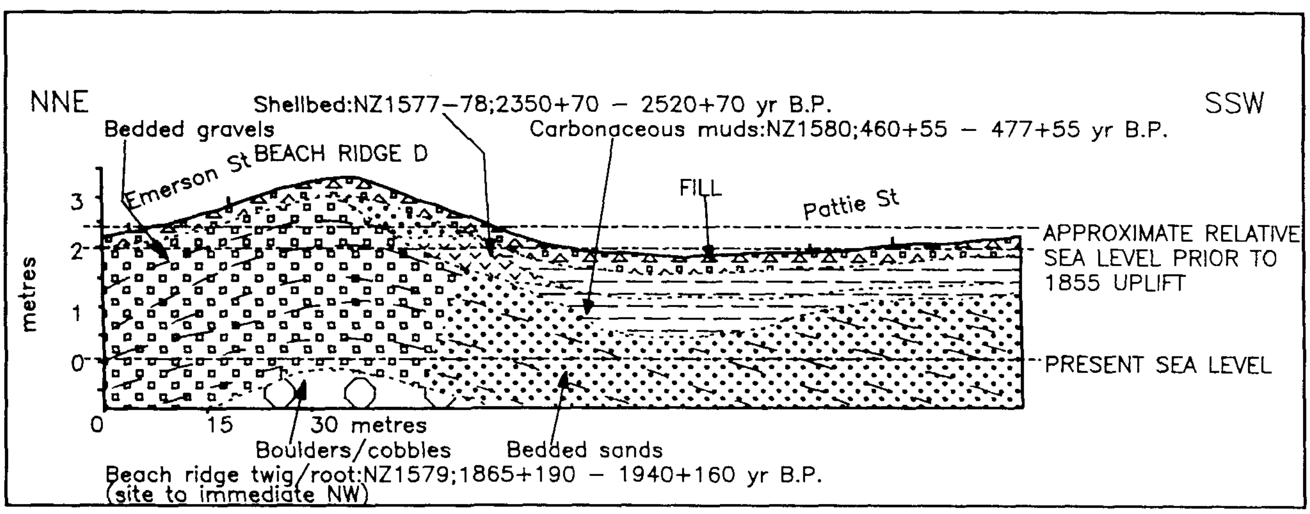


Fig. 4 Sections showing the topography of the southern end of the Lower Hutt area (vertical scale = 100× horizontal scale). **A**, Downvalley sections on upthrown and downthrown sides of the Wellington Fault. Upthrown section (solid line) shows the steps in scarp height along the profile. Downthrown section (mixed line) shows near-level topography. **B**, Cross-valley section along the upstream base of beach ridge B. **C**, Cross-valley section along the upstream base of beach ridge C. **D**, Cross-valley section along the upstream base of beach ridge D. **E**, Cross-valley section along the upstream base of beach ridge F. **F**, Composite section showing cross-valley sections B–E (above). Note the lack of height difference between the profiles ESE of the Wellington Fault scarp.

Fig. 5 (*below*) Simplified log of trench across beach ridge D (The Rise), William St, Petone (based on fig. 5 of Stevens 1973). Locations of radiocarbon samples discussed in the text are shown, as well as the present and inferred pre-1855 sea level (sea-level limits derived from this study and Darby & Beanland 1992).



ACKNOWLEDGMENTS

I thank the Hutt City Council, in particular Ernie Albuquerque and Ray McIndoe, for permission to publish interpretations that were based on data gathered during the Lower Hutt seismic-hazard assessment. I also thank Wellington Regional Council, in particular Wayne Hastie, for allowing their topographical data to be used. Pete Manning and Miranda Nelson (Ian R. Brown Associates Ltd) are thanked for their early assistance with computer modelling. Critical evaluations of this paper by Mauri McSaveney (Institute of Geological & Nuclear Sciences Ltd) and an anonymous referee were of considerable value. Comments by Ian Brown, Bill Leask (Ian R. Brown Associates Ltd), and Russ Van Dissen (Institute of Geological & Nuclear Sciences Ltd) helped clarify the manuscript. Earlier comments on the research from John Begg, Kelvin Berryman, and Derek Woodward (Institute of Geological & Nuclear Sciences Ltd) were of considerable value in the development of this paper.

REFERENCES

Bell, J. M. 1908: The physiography of Port Nicholson Harbour, New Zealand. *Australian Association for the Advancement of Science report 11*: 438–439.

Berryman, K. R. 1990: Late Quaternary movement on the Wellington Fault in the Upper Hutt area, New Zealand. *New Zealand journal of geology and geophysics 33*: 257–270.

Berryman, K. R.; Beanland, S. 1988: Ongoing deformation of New Zealand: rate and tectonic movement from geological evidence. *Transactions of the Institute of Professional Engineers of New Zealand 15*: 25–35.

Cotton, C. A. 1950: Tectonic scarps and fault valleys. *Bulletin of the Geological Society of America 61*: 717–757.

Darby, D. J.; Beanland, S. 1992: Possible source models for the 1855 Wairarapa earthquake, New Zealand. *Journal of geophysical research 97 (B8).*

McKay, A. 1892: The geology of Marlborough and southeast Nelson, New Zealand. *New Zealand Geological Survey report on geological exploration 1890–1891.*

MINEsoft 1988: TECHBASE user manual. MINEsoft Ltd, Denver.

Moore, P. R. 1987: Age of the raised beach ridges at Turakirae Head, Wellington: a reassessment based on new radiocarbon dates. *Journal of the Royal Society of New Zealand 17 (3)*: 313–324.

Ota, Y.; Williams D. N.; Berryman, K. R. 1981: Part sheets Q27, R27 and R28 — Wellington. Late Quaternary tectonic map of New Zealand 1:50 000. With notes. Wellington, New Zealand. Department of Scientific and Industrial Research.

Stevens, G. R. 1956: Stratigraphy of the Hutt Valley, New Zealand. *New Zealand journal of science and technology B38 (3)*: 201–235.

———1973: Late Holocene marine features adjacent to Port Nicholson, Wellington, New Zealand. *New Zealand journal of geology and geophysics 16*: 455–484.

Van Dissen R. J.; Berryman, K. R.; Pettinga, J. R.; Hill, N. L. 1992: Paleoseismicity of the Wellington – Hutt Valley Segment of the Wellington Fault, North Island, New Zealand. *New Zealand journal of geology and geophysics 35*: 165–176.

Wellman, H. W. 1969: Tilted marine beach ridges at Cape Turakirae, N.Z. *Tuatara 17 (2)*: 82–93.