New Zealand's largest historic earthquake

RODNEY GRAPES

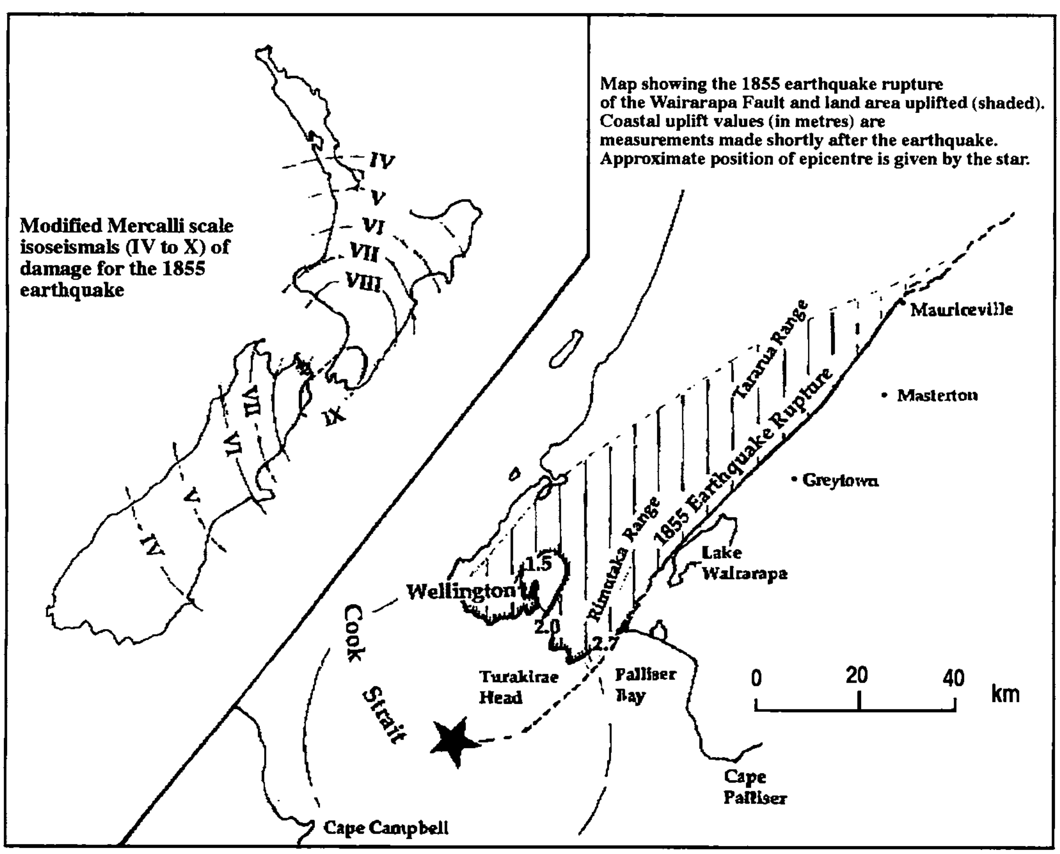
Report

Dr. Rodney Grapes, who is Head of the Analytical Facility, Research School of Earth Science, Victoria University of Wellington, Wellington, New Zealand, gave a very interesting account of New Zealand's largest historic earthquake on the 29 December 1997 at the Geology Department, University of Malaya. The author had faxed us the extended abstract of his talk for the benefit of all members.

Extended Abstract

The earthquake of January 23 1855 is New Zealand's largest earthquake since organised European settlement. Surprisingly there is no comprehensive account other than that of great British geologist, Sir Charles Lyell, based on information given to him by three eyewitnesses. Naturally, Lyell's account is mainly concerned with the geological aspects of the earthquake, faulting, uplift and subsidence, and New Zealand featured in his work as a prime example of the enormous forces accompanying a great earthquake which could lift and crack a huge tract of land in just a few moments, the most extensive such movement that was then known.

The settlement of Wellington (now the capital of New Zealand), just fifteen years old, seems to have been the closest town to the epicentre of the earthquake. On January 23 residents were enjoying the second of two days of festivities celebrating the founding of the settlement. At about 9.15 pm, the earthquake occurred, suddenly and without warning. Accounts from Wellington and vicinity indicate that it lasted at least 50 seconds and possibly strong shaking went on for up to three minutes. Some people thought they could identify two



or three separate shocks within that time. Aftershocks followed immediately, were frequent in the first two weeks, and even six weeks later at least one or two shocks were being felt daily. In Wellington, there were so many aftershocks that identifying the times of individual events seems to have been too much for the diarists of the time. One diarist had counted 250 shocks by 8 am on the morning after the first shock and another 100 more in the next twenty four hours and it is clear that he, like many others was unable to sleep that night. Many moved out of their houses into hastily erected tents. Assessment from the contemporary evidence indicates that at least five aftershocks had magnitudes of about ML6.5 and many had magnitudes greater than 5.0. Over a year later, aftershocks were still being felt.

The mainshock was felt over about 135,000 square kilometres, almost the entire land area of New Zealand. People on ships at sea also felt it, thinking that the ship had struck a reef or grated over rocks. The effects on people, buildings and the environment have been assessed using the Modified Mercalli scale of felt intensity (MM scale, adapted for New Zealand) to produce an isoseismal map in which contours enclose areas that have experienced approximately the same MM intensity. The isoseismal map is shown in the figure. Comparison of the isoseismal map of the 1855 earthquake with those of the instrumentally determined 1931 Hawke's Bay and the 1929 Buller earthquakes, both with magnitudes of 7.8 show that the 1855 event must have been greater with a magnitude between 8 and 8.2.

Auckland in the north and Dunedin in the south felt the main earthquake at intensity MM3, but in Wellington and the central part of New Zealand, the damage was greatest and resulted in at least five, and possibly nine deaths. Wellington and environs were badly damaged, to intensity MM9, but few buildings were totally demolished. Most well-constructed wooden buildings suffered little structural damage other than from chimneys falling through the roof. The Government Offices, though wooden, collapsed because the supports, constantly wet, had rotted. In the northeastern part of the South Island most sod and cob (i.e. clay) houses were badly cracked and many completely destroyed. Chimneys as far away as New Plymouth in the north and north Canterbury in the south were cracked. In Napier, over two hundred kilometres NE from Wellington, the Reverend William Colenso, the well known missionary and traveller, ran from his house and clung to the ground. There, he says in a letter to his friend Joseph Hooker at Kew Gardens in England, *"the tall weeping willows with which I was surrounded threw their long drooping branches about in an imploring, frantic way — now lashing the earth, and now sweeping the sky ...... the post and rail fences too, which were very dry, joined in with their unnatural notes and creaked and clattered prodigiously"*. Unfortunately Colenso, like many other settlers, often chose to build their houses close to rivers or the sea, areas frequently underlain by alluvium, and it has been found that these areas are often subject to stronger shaking, resulting in greater building damage. In addition, the ground in these areas when subject to very strong shaking can liquefy, that is, lose its strength to support structures and act as a liquid. Sand fountains often occur and the ground can settle differentially.

Reports of superficial ground deformation in the form of extensive cracking and fissuring, sand fountaining, subsidence from compaction, and landsliding occurred over about 52,000 square kilometres. A graphic description of how parts of the Wairarapa Plain, east of Wellington appeared after the earthquake comes from William Bennet, a civil engineer, and serves to illustrate the typical nature of the ground deformation; *"the ground (had) opened in many places 8 or 9 feet [2.4–2.7 m], and sunk in one place for 300 yards [270 metres] square to a depth of 8 or 9 feet [2.4–2.7 metres]. The cracks were very frequent, and at first were of considerable depth (deemed unfathomable because people could not see their depth), perhaps 15 or 20 feet [4.5–6.0 metres] in depth, and extending for many hundred yards [metres]. Ploughed ground and mud, dry river or pond-beds were thrown into all sorts of undulations like a short cross sea, the ridges in some cases 2 feet [6 m] in height, the prevailing direction of the cracks and ridges being generally at right angles to the apparent line of force, NE-SW"*. The Rimutaka Range, between Wellington and the Wairarapa Valley where it reaches Cook Strait, was described as being *"torn to pieces"* by extensive landslides that carried away almost a third of the vegetation on both the eastern and western flanks.

Larger scale deformation of the earths crust caused by the earthquake were even more dramatic and were described by Sir Charles Lyell as, *"the formation of a great fault and of an upheaval which is greatest in vertical height and horizontal extent that all dislocations of this kind that I am aware of to date"*. Surface rupture occurred on what is now known as the

Wairarapa Fault and according to Lyell's informants and fissure ran for an *"amazing distance of 90 miles [150 km]"* along the western side of the Wairarapa Plain close to the base of the Rimutaka Range. Uplift of the Rimutaka Range side of the fault at Palliser Bay was 9 ft [2.7 m] and was measured from the elevation of a white band of coralline encrustation that grew on the rocks up to low tide level. All along the western side of Palliser Bay, around Turakirae Head and along a large part of the south Wellington coast, the uplift stranded a wide gravel beach together with rock platforms both inside and outside Wellington Harbour. Along the fault break uplift gradually decreased to the NE.

Horizontal displacement also occurred on the Wairarapa Fault during the earthquake and amounted to 12 m with the Rimutaka Range side of the fault moving northeast relative to the Wairarapa Valley side. However, such movement was not recognised at the time. This is not surprising as disruption of man-made features such as a road or fence line are the most obvious reference lines for indicating horizontal movement on faults. It took another 100 years before the offset of various features such as streams and river terraces extending across the Wairarapa Fault were recognised as indicating that the land on either side of the fault could move horizontally as well as vertically. Contemporary evidence that horizontal movement did occur on the Wairarapa Fault in 1855 is possibly implied by reports of sudden rise in water level by 2–3 m along the southwestern side of Wellington Harbour immediately after the first shock of the earthquake that flooded the beachfront shops and houses along Lambton Quay. This rise in water level could be explained by the effect of a sudden northeast shift of the land west of the Wairarapa Fault and is analogous to the effect produced when a water-filled basin is jerked horizontally.

In addition to fault rupture, some 5,000 square kilometres of the southern part of the North Island west of the Wairarapa Fault was elevated. Coastal measurements of this uplift indicate that it gradually decreased in a northwest direction from the greatest elevation along the west side of Palliser Bay. At Wellington the uplift was about 1.5 m and at Porirua on the west coast about 0.4 m. Across Cook Strait in the lower part of the Wairau Valley, in the north eastern part of the South Island, subsidence occurred. Reports of the amount of subsidence vary between 1.5 and 0.6 metres and can best be explained by differential compaction of soft alluvium coupled with regional tectonic subsidence.

Another notable feature associated with the 1855 earthquake was the tsunami and seiche effects. A seiche is a regular side-to-side oscillation of an enclosed body of water which may be induced by earthquake, but by far the most common cause is wind. Seiching in Wellington Harbour following the mainshock is described in many accounts but there is also evidence for seiching in lakes and rivers in both islands and Lyttelton Harbour near Chrischurch and probably in Otago Harbour in the South Island. About 10–15 minutes after the first shock of the earthquake a tsunami swept the coasts on both sides of Cook Strait and water levels rose and fell for some hours. In Cook Strait the wave was estimated to have been about 9–10 metres high. The water in Wellington Harbour continued to ebb and flow for about twelve hours after the first shock, the movement being a combination of at least three effects, the sudden lateral displacement of the land west the Wairarapa Fault, regional uplift and the tsunami generated in Cook Strait entering the harbour. At the same time because of the uplift there was an *"excess"* of water in the harbour which had to drain out, not to mention the normal tidal oscillation. The morning after the earthquake an enormous number of dead fish were seen floating on the surface in the middle of Cook Strait. It was remarked that these were mainly a bottom-dwelling variety (ling). Such fish are sensitive to rapid pressure changes and may have been killed when they were forced to quickly ascent due to landslide-generated turbidity currents caused by the earthquake. Fish were also stranded by the tsunami along the south Wellington beaches and on sand dunes along the southern part of the west coast of the North Island. These were probably near shore-feeding shoals that were caught by the tsunami.

Information on the distribution of building damage and ground damage of this earthquake and other historical and present day earthquakes is not just interesting but provides valuable information needed to understand the hazards that we are likely face in a large earthquake. Using such information, earthquake engineers can design structures and services to resist the effects of strong shaking and geologists and seismologists can identify areas susceptible to enhancement of shaking and faulting. Emergency response organisations in New Zealand can better prepare for the time when we may have a large earthquake. Even in 1855 the damage and casualties in Wellington were less than they might have been because seven years earlier in 1848 another earthquake, of lesser magnitude and centred in Marlborough, had taught the settlers that wooden structures survived where bricks and mortar fell. The early settlers were resilient, they had come to a new country far away from their homeland and were not easily daunted. Repairs were made, and a study of the best methods of building to resist earthquakes was carried out. The structural damage suffered by Wellington provided the data. Charles Carter, a builder and one of the authors of a damage report was perhaps first in the world to suggest the adoption of a building code. Unfortunately it was to be another 20 years before building regulations were adopted.

The Wairarapa Fault which moved in 1855 shows geomorphic evidence of repeated movement over the last 10,000 years. The youngest Last Glacial alluvial surface cut by the Wairarapa Fault has been dextrally displaced by 127±5 m and vertically displaced by ca. 20 m. This, in conjunction with progressively smaller displacements preserved in a flight of degradation terraces (e.g. Waiohine River) suggest the possibility that 10 or 11 coseismic displacements similar to that of 1855 have occurred on the Wairarapa Fault during Holocene-Late Quaternary time. Carbon 14 dating from one locality suggests that four earthquake displacements prior to 1855 have occurred within the last 6.5 ka and that the time interval between them varies between 1,100 to 1,900 years. The 1855 pattern of regional uplift and northwest tilting across Wellington peninsula is also shown by older earthquake-standed beach ridges dating back to 6.5 ka when present-day sea level was established.

New Zealand sits astride the boundary between two converging tectonic plates, the Australian and the Pacific. The Wairarapa Fault which shows evidence of repeated movement is the most active fault in the southern part of the North Island with a dextral slip rate of ca. 12 mm/yr and accounts for about half the Ca. 21 mm/yr margin parallel slip rate associated with oblique subduction of the Pacific Plate along the Hikurangi Trough east of New Zealand. Stresses and strains created by this convergence are relieved by many small and moderate magnitude earthquakes, and less frequently, a large earthquake. In the last one hundred and fifty five years, New Zealand has experienced three large earthquakes of magnitude 7.8 or more, the 1855 earthquake, the 1929 Buller earthquake and the 1931 Hawke's Bay earthquake. What happened during a large earthquake a hundred years ago is very relevant to understanding what might happen in a future earthquake of comparable magnitude. Information from past and present earthquakes is required to build a more complete picture of their causes and occurrence in New Zealand and the hazards they pose.

G.H. Teh