Detection and characterization of concealed active faults in urban areas of New Zealand using shear wave reflection seismics

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Summary

The Christchurch earthquake of magnitude 6.3 at February 22th 2011 was the most destructive earthquake in New Zealand (NZ) since many years. 185 people died, 5900 became violated, 100000 houses were destroyed, nearly 20 Mill NZ$ loss of property were estimated. Because this earthquake happened along a formally unknown concealed fault crossing Christchurch city, the knowledge of covered active faults gained strongly in importance in the National Seismic Hazard investigations from that time on. Scientific estimations proposed several thousands of these faults, often within, beneath or close to urban areas. Because LIAG's shear wave seismic reflection method was hypothesized to detect such buried faults in urban areas in NZ, a pilot survey project in the area of Whakatane was initialized, where the detection prospects should be evaluated.

The profiling results show excellent imaging capabilities of the method regarding the Holocene and Pleistocene sediments, which are the typical settlement habitats in NZ. Penetration depths up 100 m in high-resolution gave detailed insights in the subsurface structure. More than six unknown and covered fault structures could be detected in Whakatane city already during the field operation, some of them clearly active until the late Holocene. In contrast, along the estimated fault track based on surface structure analysis, no indications of active faulting could be found.
The results of the pilot project highlight the prospects of method towards a lot of open questions around NZ and Australian areas.

Acquisition parameters

Period:	9. – 23. Feb. 2015
Instrument:	GEOMETRICS GEODE
Channels/rec:	95+ 1 aux
Seismic Source:	ELVIS version 6 shear wave source system,
Sweep Type:	20-80 Hz lin., 10 s, 200 ms taper,
Recording:	12 s , 2 s after correlation
Sampling int.:	1 ms
Recording filter:	out
Spread type:	variable spit spread Geophone type: SM6 H (10 Hz), single units, mounted on GEOSYM land streamer system
Receiver int.:	1 m
Source int.:	4 m, partly 8 m on profile 10
Vertical stack:	2-fold [+Y]-[-Y] alternated vibrations
Total length:	5.72 km
Total data:	13 Gb
No. of Records:	2962

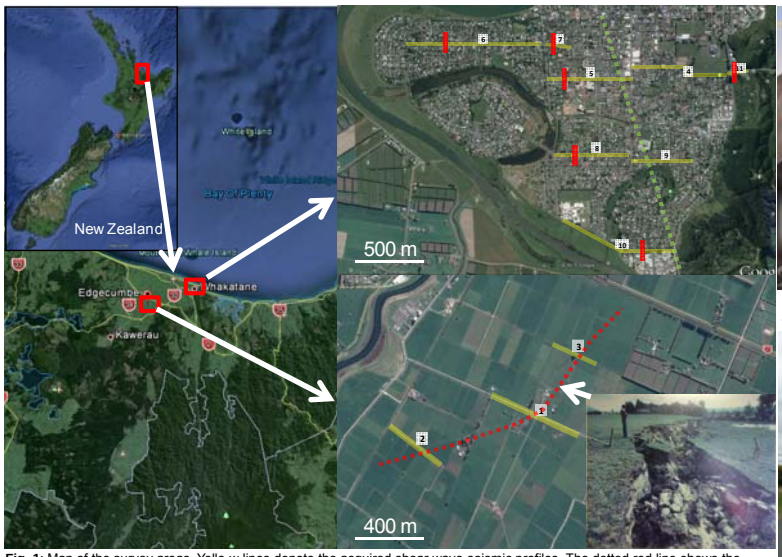

Fig. 1: Map of the survey areas. Yello w lines denote the acquired shear wave seismic profiles. The dotted red line shows the track of the Edgecumbe fault (mixture of normal and strike-slip faul type, lastly broken in 1987, see small picture). Dotted green line indicate the extrapolated track of the Whakatane fault in the area of Whakatane city. Red lines show the detected subsurface fault signatures by seismic profiling.

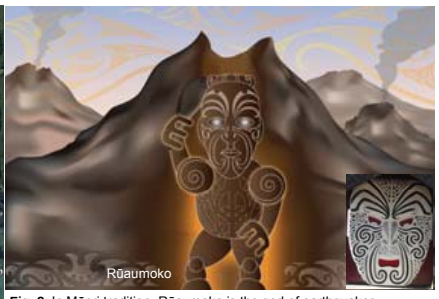

Fig. 2: In Māori tradition, Rūaumoko is the god of earthquakes and volcanoes.

Fig. 3: Data acquisition along McCracken Road near Edgecumbe.

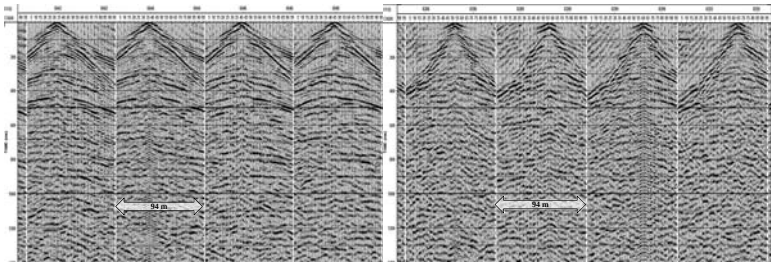

Fig. 4: Single record examples (AGC 350 ms applied) from James Street (left, profile 6), and Bridge Street (right, profile 8) representing the excellent data quality due to the very low noise level. The reflection events close to 400 ms could be used as a marker horizon during the whole survey in Whakatane. Shear wave interval velocities range from 120 m/s to 200 m/s, indicating very soft sediments and a high risk for shaking amplification in case of an earthquake.

Fig. 5: Data acquisition during night time at Stewart Street (profile5) in Whakatane. The sign at the right side of the street denotes the location of the Whakatane Hospital.

Fig. 6: Diving below a main road and operation on a bridge foundation. Some challenging profiling track conditions resulted from requirements based on emergency reasons, e.g. crossing of main roads using the streamer was not permitted by the Whakatane district council.

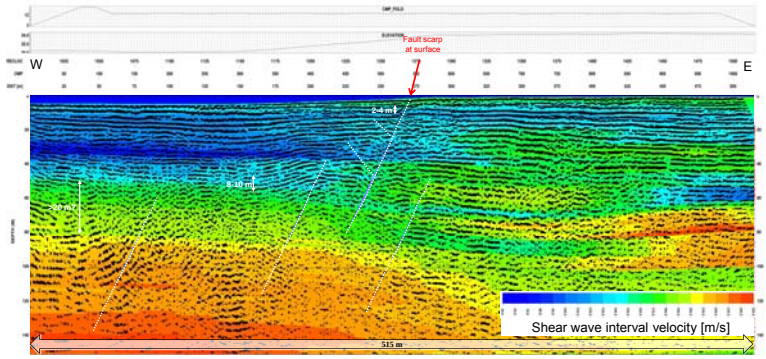

Fig. 7: Resulting depth section of profile1 across the Edgecumbe fault to evaluate the method at a position of a well known fault. It clearly shows the change of the reflection pattern from East to West when crossing the fault position. The estimated fault pattern is outlined by white lines. There are indications the fault area extends towards East in the subsurface.

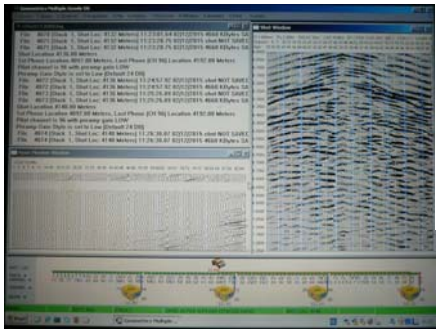

Fig. 8: Snapshot from the recording notebook during acquisition along Goudstone road, profile 4, showing the very low noise level.

Fig. 9: Profiling positions painted on the roads during data acquisition were subsequently recorded by LEICA DGPS positioning in high-resolution . In the background: Mount Edgecumbe, the dominating volcano in the area.

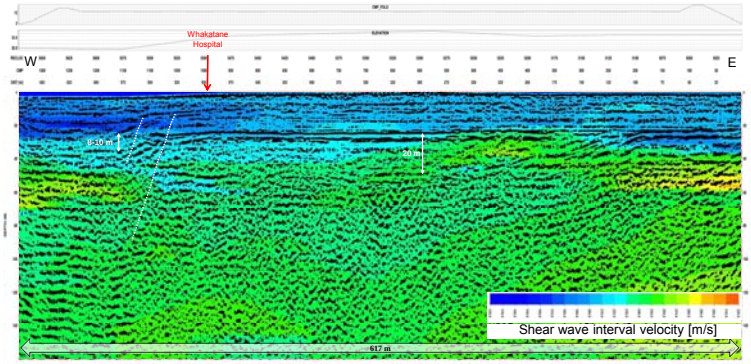

Fig. 10: Resulting depth section of profile5 along Steward Street in Whakatane. The clear marker horizon near depth of 22 m represents a early Holocene boundary between marine (above) and non-marine, dense, silty material (below). Detailed marine transgression patterns are clearly visible. The white lines denote a detected concealed fault.

Fig. 11: Operation base. The whole seismic equipment could be stored in the recording car, connected and ready to use.

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