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The Christchurch earthquake's hidden secrets

An invited comment
by Erol Kalkan

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The catastrophic Christchurch earthquake is a strong reminder to engineers and scientists of the hazards pose by fault lines, both mapped and unknown, near major cities. In February 2011, the relatively moderate earthquake that struck the cities of Christchurch and Lyttleton in the Canterbury region of New Zealand's South Island surprised many with its destructive power. The magnitude 6.2 temblor killed 181 people,118 of whom were killed in the collapse of a single building in the city center. The quake damaged or destroyed more than 100,000 buildings.

It was the deadliest quake to strike the nation in 80 years—since the 1931 earthquake that struck the Napier and Hastings area of the North Island. The Christchurch quake was part of the aftershock sequence following the September 2010 magnitude 7.1 earthquake near Darfield, 40 kilometers west of the city. The Darfield earthquake was in a sparsely populated area, causing no loss of life. By contrast, the Christchurch earthquake was generated on a fault in close proximity to the city.

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Christchurch ...

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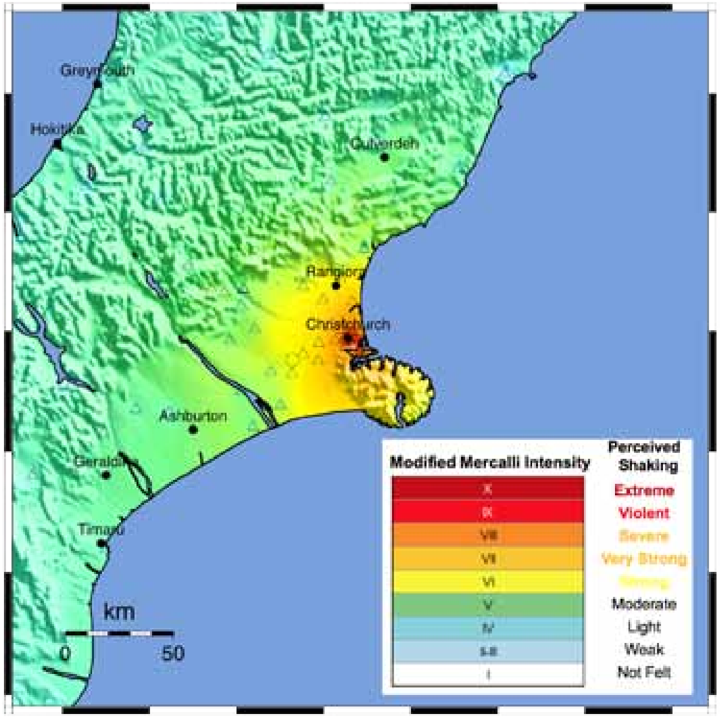


New Zealand seismicity

Every year, New Zealand has between 100 and 150 earthquakes large enough to be felt. Since record keeping began in the 1840s, New Zealand has been hit by an average of several magnitude 6 earthquakes every year, one magnitude 7 every 10 years, and a magnitude 8 every century.

Despite the high seismicity of New Zealand, the Canterbury region of South Island had remained nearly silent for a centuries. The newly revealed Greendale fault, on which these earthquakes originated, was unknown. The ground rupture revealed a portion of it during the Darfield earthquake. Clearly the fault segment that ruptured during the February 2011 earthquake appears to be a continuation of the first, although no direct connection between the fault segments has been recognized. Technically, Christchurch and Lyttleton could have been better prepared if the location of Greendale fault and its potential to create large earthquakes had been known.

According to GNS Science seismologist Bill Fry, the Christchurch earthquake was relatively strong compared to its moment magnitude. The amount of energy released for the February event was larger than the amount of energy that would be released on average for the same magnitude earthquake. This was because the fault was held together by a large amount of friction. So the rupture resulted in sudden release of a large amount of seismic energy. It generated the strongest recorded ground acceleration in New Zealand's history.

Numerous records obtained from a dense network of seismic stations provide valuable information on the event, offering the opportunity of relating damage to ground shaking. This strike-slip event with oblique motion (mostly side-to-side motion but some up-and-down) moved at 2g, or twice the acceleration of an object caused by the force of gravity. As shown in the ground shaking map below, this level of shaking, greater than that expected particularly for a moderate-size quake, meant structures were shaken by the force twice their weight.

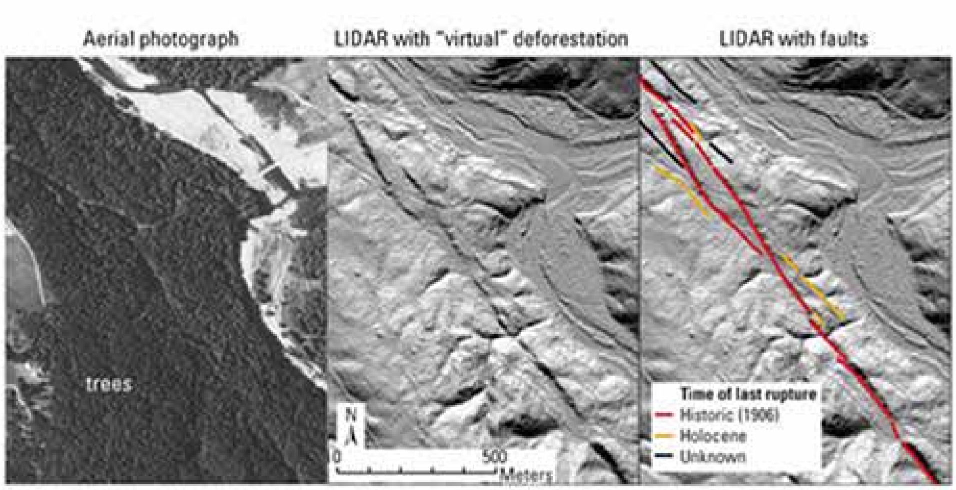
On the intensity scale, which quantifies the effects of an earthquake on the humans and man-made structures on a scale from I (not felt) to XII (total destruction), the Christchurch earthquake has a maximum IX intensity. By definition, intensity IX means that ground shaking resulted in general panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse; buildings shifted off foundations.

During the strong shaking, the simultaneous vertical and horizontal seismic shifts made it almost impossible for older masonry buildings to survive as shown in the photo below, where two-story masonry structures had severe damage to their facades and bearing walls.

Another factor, which contributed to the massive destruction, is widespread liquefaction, a phenomenon whereby a saturated soil substantially loses its carrying capacity when shaken, and thus undermines buildings and structures. It's similar to shaking a soda can—when the built up pressure is released, the fluid comes shooting to the surface, a sketch describing this phenomenon and its consequence during the Darfield earthquake are shown below. In and around the central business district of Christchurch, the soil types are dominated by fine sands, and ground water level is high, conditions that make this area particularly vulnerable to liquefaction. Strong ground shaking and liquefaction resulted in the demolition of 1,000 buildings within the CBD.

Other risks around the world

During the February earthquake two-story masonry structures suffered complete facade damage in the Christchurch historical district.
(photo courtesy of Walter Mooney)



(Left) A regular aerial photograph of an area of trees obscuring part of the San Andreas Fault zonein Sonoma County in California.
(Center) The same area in a computer rendering of LIDAR data to "virtually" remove the trees and other vegetation. Scarps and other landforms associated with the Quaternary-active fault are now much easier to see.
(Right) Fault strands traced onto the LIDAR.

(*Courtesy U.S. Geological Survey*)

Christchurch is just one of many cities at risk of amplified ground shaking and liquefaction. Many urban areas around the world, including the San Francisco Bay area, greater Los Angeles, and metropolitan Tokyo are built over soft sediments located in valleys or over basins. These urban areas sit atop geological features that may amplify earthquake ground motions, just as Christchurch experienced.

For example, the underlying basin structure in western Los Angeles would cause Manhattan Beach and its surroundings to experience up to 10 times the amount of amplification as nearby urban centers located on solid rock. In addition to residential buildings, Manhattan Beach houses many large-diameter oil tanks, all of which may be vulnerable to amplified ground motions during a large earthquake.

The challenge is how to account for such significant, higher-than-expected amplified ground shaking, as seen in Christchurch, when evaluating the design of existing and new structures in urban areas.

New Zealand's recent quakes demonstrated that resilience in urban areas requires not only accounting for possible amplified ground shaking and liquefaction but also identifying previously unmapped fault lines. The Greendale fault, on which the Christchurch and Darfield quakes nucleated, was unknown because of the historically low seismicity of the Canterbury region. Similarly, future ruptures of unknown faults may generate large magnitude quakes without any warning in other urban areas currently having low seismic activity.

Mapping previously unknown faults requires considerable field and lab work. In the San Francisco Bay area, after a century of study by geologists, many faults have been mapped, but not all faults are apparent at the surface. Some quakes still occur on previously unknown faults. A recent example of a damaging quake on a previously unknown fault occurred on September 3, 2000, in Yountville in California's Napa Valley. This magnitude 5.2 quake struck 10 miles northwest of Napa injuring 25 people, and causing at least $10 million in damage.

A more tragic example is the magnitude 7.0 earthquake that struck Port-Au-Prince, Haiti, in 2010, causing more than 200,000 casualties and leaving 1.5 million people homeless. This devastating earthquake was also generated by a previously unmapped fault.

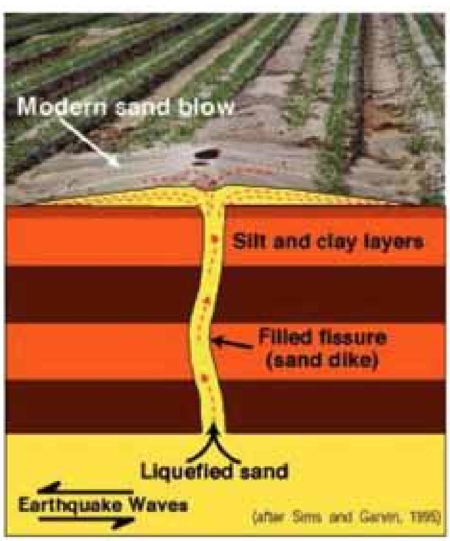
Another surprising event was the magnitude 5.8 quake near the town of Mineral, Virginia, on August 23, 2011. The quake, the largest in the eastern United States since the 1886 magnitude 6.9 Charleston, South Carolina earthquake, also occurred on a previously unmapped fault.

Identification techniques

Today, scientists use modern techniques, which were not available in the past, to identify and map fault lines. One of the newest tools for mapping faults obscured by extensive vegetation is Laser Imaging Detection and Ranging (LIDAR). LIDAR uses laser light projected from an airplane to make a detailed image of the ground surface. It provides a picture of the ground hidden beneath, using a sophisticated computer program that produces an image of the land stripped clean of all its trees, bushes and greenery.

This technology has been used to make a detailed map of the San Andreas Fault along the Sonoma and Mendocino County Coast in California. The figure below shows how LIDAR can help reveal active faults in this area.

Around the world, increasing population contributes to the creation of high-density developments, which place residential and commercial buildings, and infrastructure at more elevated risk than traditional low-density development on equivalent hazard-exposed land. The Christchurch quake



is raising a very sobering alarm to other major, high-density metropolitan areas, which may be under the potential threat of unknown fault lines. For resilience of urban areas against future earthquake hazards, it is crucial to find traces of active faults and to identify their potential to rupture and create strong shaking.

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Resources

Below are brief descriptions of some of the resources on hazards and disasters that have recently come to the attention of the Natural Hazards Center. Web links are provided for items that are available free online. Other materials can be purchased through the publisher or local and online booksellers.

All of the material listed here is available at the Natural Hazards Center Library. For more information contact librarian Wanda Headley at wanda.headley@colorado.edu

ALL HAZARD

The Disaster Experts: Mastering Risk in Modern America. By Scott Gabriel Knowles. 2011. ISBN: 978-0-8122-4350-5. 280 pp. $45 (hardcover). University of Pennsylvania Press. **www.upenn.edu/pennpress**.

"When it comes to mastering risk," writes Scott Gabriel Knowles, "knowledge is not usually the problem." Instead, the problem is converting knowledge into action.

Knowles begins his exploration of converting expertise into action with the research response to the September 11, 2001, World Trade Center attacks. Then he expands further into an examination of the hazards in post-industrial urban America. Portions of the book draw heavily on the groundbreaking work of Henry Quarantelli, Russell Dynes and Eugene Haas, research that is familiar to everyone who works in the disaster field.

He also quotes Natural Hazards Center director Kathleen Tierney who set out the proactive research agenda for the next generation of disaster researchers. Tierney said work ahead needed "a critical perspective on risk that focuses on the ways in which risk and power are related. Such an approach would recognize that political and economic power determine the ability to impose risks on others, shape public discourse about risks, sponsor and conduct research that presents risks in particular ways, and lobby for particular positions on the acceptability of risk."

The book tracks the history of disaster expert opinion in clear and lively prose.

North by 2020: Perspectives on Alaska's Changing Social-Ecological Systems. Amy Lauren Lovecraft and Hajo Eicken, eds. 2011. ISBN: 978-1-60223-142-9. 736 pp. $70 (softcover). University of Alaska Press. **www.alaska.edu/uapress/**

This book takes a deep and varied look at the social issues facing Alaska in the coming decade, which are "complex, culturally sensitive, and potentially divisive," as Virgil (Buck) Sharpton, chair of the U.S. Arctic Research Commission, says in his foreword.

The framework for the volume is a thematic, holistic look at the changes overtaking Alaska in only a generation. These themes are wide-ranging. They cover: socio-ecological research methods; indigenous knowledge; freshwater systems; coastal systems; marine resources; marine infrastructure; energy development; and artistic expression.

The volume is to a certain extent focused on the changes brought about by global warming. Higher latitudes are warming more dramatically than mid- and low-latitude regions. In an interesting and innovative section entitled "Expressions of climate change in the arts," this book looks at how artists interpret these changing surroundings and their consequences.

Behind the Backlash: Muslim American's After 9/11. By Lori Peek. 2011. ISBN: 978-1-59213-983-5. 230 pp. $26.95 (softcover). Temple University Press. **www.temple.edu/tempress**.

Someone was to blame for the attacks in the United States on September 11, 2001, and the easiest people to blame were the generic "Muslims." Lori Peek's fascinating book listens to the voices of 140 Muslim-Americans who were subjected to discrimination and harassment both before and after the attacks.

Two women describe their frustration with the stares they encountered: "Right after 9/11, I was scared of looking into people's eyes in the subway. That's why I was always looking down. I didn't want to see that they were staring at me. Now I'll look around a little more. When I'm studying for class, I can see they try to see what I'm studying. They'll look at my books."

And Mohammed, born in Morocco, but living in the