THE BIGGEST ONE

Fifty years ago this month, a massive earthquake in Chile broke new ground in seismic science. **Roff Smith** looks back at the largest quake ever recorded.

Castro, Chile, a few days after the great 1960 earthquake.

W.J. SMITH/AP

When a massive earthquake rocked southern Chile early one Saturday morning in May 1960, those residents who were lucky enough to rise from the rubble could have been forgiven for thinking that they'd just come through the worst that nature could deliver. The force of the earthquake that had just levelled their villages would later be estimated at magnitude 8.1 — the largest shock Earth had produced in more than a year.

As authorities in Santiago scrambled to send aid to the stricken region, they could not have foreseen that such a monumental earthquake was merely a drum roll for the main event. The following afternoon, on 22 May, the earth convulsed so violently that it wobbled the planet and sent it ringing for days on end. In the decades afterwards, seismologists would pore over their printouts trying to understand just how incredibly strong that earthquake was. They would go on to devise a whole new way to measure seismic tremors and assign the 1960 event a value of 9.5 on the logarithmic magnitude scale — to this day the most powerful earthquake on record.

With an energy more than 20,000 times greater than the bomb that destroyed Hiroshima, the earthquake killed at least 1,500 people in Chile and spawned a tsunami 25 metres high that obliterated coastal villages and threw ships at anchor more than a kilometre inland. The tsunami raced across the Pacific Ocean, taking 61 lives in Hilo, Hawaii, before hammering an unsuspecting Japan and killing about 140 people there, 17,000 kilometres away from the quake's epicentre.

"This was a planetary monster," says Tom Jordan, director of the Southern California Earthquake Center in Los Angeles. "An earthquake in South America that killed people in Japan."

Half a century after the event, the monster continues to fascinate and intrigue, even in the face of recent, deadlier quakes, such as January's disastrous shock in Haiti. This month, the American Geophysical Union will hold a conference on giant earthquakes and tsunamis in Valparaíso, Chile, with many delegates making a 50th anniversary pilgrimage to the site of the 1960 quake to marvel at the seismic scars in the landscape and the sediments deposited by the tsunami that followed.

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"Here is the benchmark, the superlative event in recent seismic history," says Brian Atwater, of the US Geological Survey's Earthquake Hazards Team in Seattle, Washington, who is a convenor of the conference.

It was a benchmark in the history of seismology as well. The Great Chilean Earthquake of 1960 provided seismologists with their first unambiguous evidence of the planet's free oscillations — the harmonic vibrations that ring the planet like a bell after it has been hit by a major jolt. Over the intervening years, researchers have learned how to use those free oscillations like a planetary CAT scan to discern the inner structure of Earth.

Lifesaving legacy

In the decade after 1960, the Chilean quake and the magnitude-9.2 Alaska earthquake of 1964 would both become persuasive arguments in support of the radical theory of plate tectonics — providing textbook examples of subduction zone earthquakes, in which one tectonic plate is forced under another.

Beyond teaching basic lessons about the planet, the quake also left a legacy that has saved lives. It spurred nations around the Pacific to set up an international tsunami warning system in the 1960s. The tsunami deposits left by this event give geologists a model for identifying other spots that might be prone to giant earthquakes, such as the Cascadia subduction zone

off the western coast of North America.

In many ways, however, the Chilean monster was a quake before its time, coming as it did just on the cusp of a technological and theoretical revolution in Earth sciences. "Had this earthquake happened only ten years later, we could have learned so much more from it," says Seth Stein, a seismologist at Northwestern University in Evanston, Illinois. In 1960, with the concept of plate tectonics still in the future, researchers did not understand how to place the quake in a geophysical context. And the global network of seismometers that could have provided so much information would not be in place for another three years.

The 1960 event happened when a fault zone running down Chile's coastline ruptured along about 1,000 kilometres of its length (see map). The tectonic plates on either side of the fault slipped 20–30 metres past each other — releasing centuries of accumulated energy in several terrifying minutes.

The earthquake was not only the biggest ever recorded, at 9.5 it approaches the upper limit of what the planet is likely to ever produce in a single event. "This is not to say a bigger quake couldn't eventually happen," says Richard Aster, a geophysicist at the New Mexico Institute of Mining and Technology in Socorro and president of the Seismological Society of America. "It could. But you wouldn't get one much bigger. Faults are only so big and so strong."

To illustrate the size of this quake, Aster has added up the seismic energy of all the world's earthquakes throughout the twentieth century, including the monster in Chile, and the 9-plus quakes in Kamchatka in 1952 and Alaska in 1964. He threw in the magnitude-9.2 Sumatra quake of 2004 for good measure and imagined all this energy unleashed in a single cataclysmic event. That would equal a magnitude-9.95 earthquake. "You're just not going to get a 10," says Aster.

And yet of that mountain of energy — the entire planet's seismic release for more than 100 years — one-quarter of it can be attributed to the single catastrophic event centred near Cañete, on the southern Chilean coast. It was twice as powerful as its nearest rival, the 1964 Alaska quake.

Groundbreaking behaviour

Among those who will be attending the anniversary commemoration at Valdivia is Hiroo Kanamori of the California Institute of Technology in Pasadena, one of the doyens of seismology who helped create the moment magnitude scale to accurately measure the size of great earthquakes. He has spent the past year re-examining the 50-year-old data from the 1960 earthquake, intrigued not only by the quake's sheer size and scale, but also by its unique behaviour.

Kanamori, who recalculated the size of the earliest earthquake in the sequence says "who would have imagined that you could have an 8.1 as a foreshock? And yet this is just the beginning of a spectacular foreshock sequence." In the 33 hours before the main event, there were about 6 quakes larger than magnitude 6, and one with an estimated magnitude 7.8 coming just 15 minutes before the big one itself, he says. "As far as I am aware there has never been a foreshock sequence like this."

"Who would have imagined that you could have a magnitude-8.1 earthquake as a foreshock?"

Perhaps even more curious are some strange, long-period vibrations recorded by a seismogram at Pasadena less than 15 minutes before the main earthquake, says Kanamori. Those readings suggest the big one might have been preceded by a powerful, slow earthquake deep underground, which helped catapult what might otherwise have been 'merely' a giant earthquake into a category all its own. There are some hints that other great earthquakes, such as the 1944 Tonankai shock in Japan, may also have had these slow precursors, which on their own do not produce damaging vibrations. But as with the Great Chilean Earthquake, the fragmentary evidence tantalizes more than reveals.

Unfortunately, the violence of the foreshocks in Chile obscured the readings on the handful of other high-quality seismometers that were working at the time, so there is no independent confirmation for the curious readings at Pasadena. But local eyewitnesses also hint that something unusual happened in the moments preceding the magnitude-9.5 main shock. Two geophysicists in Concepción, about 200 kilometres from the quake's epicentre, recalled that the quake began with a gentle rocking sensation rather than an abrupt jolt that typically heralds the start of a giant shock.

"One of them noticed parked cars rolling back and forth on the street," Kanamori says. "This is a very unusual description of the beginnings of a great earthquake, but these were trained seismologists so you have to take them seriously."

If there was indeed such a deep, slow precursor event, it could make the Great Chilean Earthquake of 1960 of wider relevance. "This is very similar to how many scientists believe a great subduction-zone earthquake would start along the Cascadia plate boundary," says Kanamori. That region has bouts of slow earthquakes about every 14 months or so, which prompts some researchers to suspect that the subduction zone there might share similarities with the one off Chile.

There are no written records of great earthquakes happening in the Pacific Northwest, but Atwater and other geoscientists have become convinced that quakes in the magnitude-9 range have pummelled that region in the past. In fact, sand deposits left by the 1960 Chilean tsunami helped Atwater and others discover that giant waves once pounded the coasts of western North America and Japan from a Cascadian earthquake centuries ago.

Giant jolts such as these make difficult subjects for scientists to study because they strike only once every 300 years — or even less frequently. But the globe is now wired up with hundreds of sensitive and readily accessible seismometers. So when the next monster strikes, whenever and wherever it may be, says Kanamori, "we will be able to understand it far better than we did for the 1960 Chile earthquake". ■

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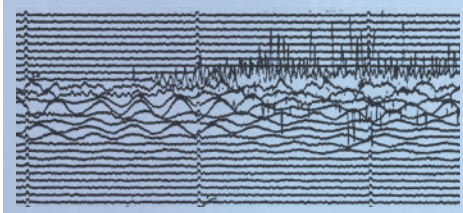
SOURCE: USGS

THE GREAT CHILEAN EARTHQUAKE OF 22 MAY 1960

The magnitude-9.5 earthquake happened along a subduction zone, where a part of the Pacific Ocean floor — the Nazca plate — slipped beneath the South America plate. The two plates are converging at about 8 metres per century and an earthquake estimated at magnitude-8.5 struck the same region in 1575.



Seismic recording of the 1960 quake made in Berkeley, California.