BREAKING NEW GROUND

In 1906, a great earthquake destroyed San Francisco, and galvanized US seismologists. Naomi Lubick looks back at the event that changed the country's geological scene.

The Great Earthquake and subsequent fire that destroyed San Francisco in 1906 began at 5:12 a.m. on 18 April. More than 3,000 people are thought to have died following the magnitude-7.9 tremor. The metropolis of San Francisco, built on gold-rush fortunes, was almost utterly destroyed in three days of fire, and officials spent years playing down the possibility of another 'big one'. Yet the earthquake also jump-started seismology in the United States, inspiring it to catch up with countries such as Britain, Japan and Germany.

The US scientific community had already encountered several major earthquakes. Three tremors of magnitude 8 or more racked the New Madrid region in the US Midwest in 1811 and 1812. And the city of Charleston, South Carolina, was seriously damaged during an 1886 earthquake.

But the 1906 earthquake happened in the right time and place to act as a catalyst for science. Chance brought together several ingredients: the right people, the right technology, key ideas in need of testing — and a huge earthquake delivering the data. "It took that large an event to make seismology a national priority," says Jack Boatwright, a seismologist at the US Geological Survey (USGS) in Menlo Park, California.

Around the world, the discipline of seismology began to coalesce in the late nineteenth century, as non-specialists interested in earthquakes began to work together. In India, Richard Dixon Oldham identified primary (P) and secondary (S) waves, the main components of seismic waves. In Germany, engineers developed precision techniques to make seismometers more accurate. British geologists teaching in Japanese universities became interested in the tremblings beneath their feet. And in 1891, when the great Nobi earthquake hit, Fusakichi Omori of Tokyo's Imperial University was primed to lead his colleagues in documenting the event.

> "There weren't any seismologists in the States before 1906."
> — Jack Boatwright

The Japanese view the magnitude-8 Nobi earthquake in much the way that Americans see the 1906 San Francisco event, says Thomas Jordan, director of the Southern California Earthquake Center in Los Angeles. Thousands of people died, and supposedly 'modern' structures were shaken apart. In tracking the subsequent tremors, Omori made critical observations that led to his eponymous theory on how aftershocks decay with time. And he brought his ideas with him to San Francisco, where he did field work after the 1906 earthquake.

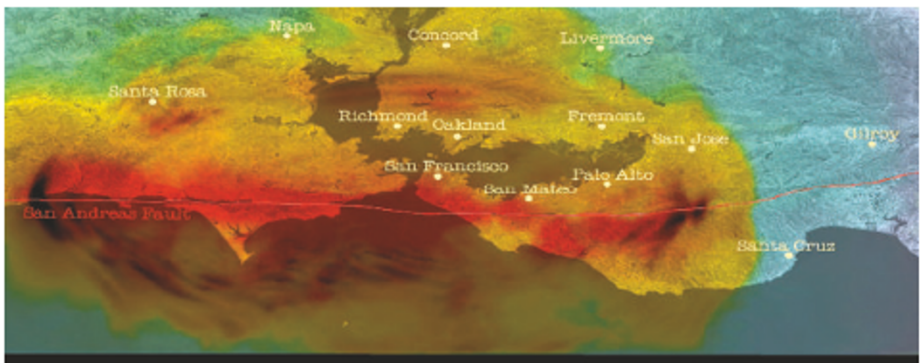
Omori's expertise was rare in the city. "In my estimation, there weren't any seismologists in the United States before 1906," says Boatwright, "there were geologists." That soon changed. Immediately after the tremor, Andrew Lawson, a professor of geology at the University of California, Berkeley, assembled a troupe of scientists, who fanned out across the affected area. The group became a kind of seismic SWAT team, collecting evidence north towards Oregon and south almost to Mexico.

Ground forces

For the first time, scientists began to recognize the extent of the San Andreas fault. This 1,300-kilometre gash marks the boundary between two sections of Earth's crust: the Pacific plate and the North American plate. California geologists knew of the fault's existence, but until 1906 they had little idea of the power it could unleash. They did, however, realize that such faults cause earthquakes — a theory that came in part from Omori's documentation of the Nobi disaster.

Hours after the earthquake rattled San Francisco, geologists saddled up, got into automobiles — recently introduced to the region

G. K. GILBERT/USGS



The 1906 earthquake after 24 seconds: ground in the red areas was moving at 60 cm a second.

CREATED BY USGS FOR 100TH ANNIV. EARTHQUAKE CONF.

Crack shot: Grove Karl Gilbert's photo of a rupture is part of a 1908 report on the 'big one'.

— or simply walked to sites along the San Andreas fault. "It was a really remarkable group of people," says Boatwright. Participants ranged from the respected geologist François Matthes, who avoided talking to anyone, to the sociable Grove Karl Gilbert, a USGS legend who spent a lot of time chatting to people who lived along the fault and recording their personal experiences. Gilbert quickly picked up evidence of the fault's movement, noticing fences, houses and roads that had been offset by up to 6 metres in some places.

Stirring tale

In 1908, Gilbert, Lawson and their colleagues produced a large tome that included detailed descriptions of fault scarps, sag ponds and other evidence of the earthquake; it was accompanied by an atlas of maps and seismic profiles. The Lawson report was reprinted in 1969[1], and seismologists and geophysicists still use it today for its physical descriptions, maps and timetables of the 1906 event.

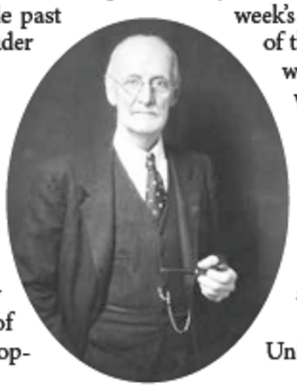
The scientists who created it didn't know what they were looking for, so they documented the earthquake observations very simply, in terms of factors such as building damage, fault movement and behaviour of the soil, says Dave Wald of the USGS in Golden, Colorado. In part, these extremely detailed descriptions are what makes the Lawson report so useful today.

Putting the whole picture together was not easy. At the time there was no overarching theory of plate tectonics — how parts of Earth's crust grind against each other. So geologists couldn't quite figure out how the San Andreas fault worked. "People didn't have a mechanism for large-scale deformation," says Carol Prentice of the USGS in Menlo Park.

Gilbert and others had already noted that faults could move horizontally, not just vertically. And geologists working on the Lawson report could clearly see that the fault had ruptured for at least 430 kilometres along its length, without significant uplift. Eventually, the San Francisco event helped geologists to recognize that the San Andreas is a strike-slip fault, in which two plates slide past each other rather than moving under or over one another.

All in store

In 1910, a second volume of the Lawson report was published, written by Harry Fielding Reid. It contained the 1906 event's greatest and most lasting contribution to seismology: the theory of elastic rebound. A professor of physics and geology at Johns Hopkins University in Baltimore, Maryland, Reid proposed that faults store up stress until they can no longer hold it, at which point they snap like a rubber band stretched too far. His meticulous synthesis came from field observations and information about the timing of shaking along the San Andreas fault.



Harry Fielding Reid posited that tremors come in cycles.

GREYSTONE STUDIOS/E. HAMBURGER ARCH., JOHNS HOPKINS UNIV.

Before the San Francisco earthquake, Reid had worked almost exclusively on glaciers, particularly on how they advance and retreat over time. Apparently, he saw a similar pattern in earthquakes. Elastic rebound implied that faults would gradually store stress over time, rupture in an earthquake and then begin the process all over again. And that, for the first time, suggested that earthquakes recur regularly on the same fault, in potentially predictable cycles.

The USGS estimates that an earthquake similar to the 1906 event is not likely in the near future, although earthquake risk remains high in the region — particularly on the nearby Hayward fault. San Francisco residents, city planners and emergency officials are currently bracing themselves for an earthquake of magnitude 6.7 or greater, which has a 62% probability of occurring in the San Francisco Bay area[2].

This preparation is a lesson that California has taken decades to learn. In a scenario that may seem distressingly familiar to disaster planners today, Lawson struggled after the earthquake to get funding for follow-up studies and to spread knowledge about seismic risks. Members of his team helped to found the Seismological Society of America in August 1906, modelling themselves on Japan's Seismological Society. But, says Duncan Agnew, a historian of seismology at the University of California, San Diego, "for a long time 1906 was one of the few well-documented earthquakes."

Landscape view

Even now, scientists are coming up with more analyses of the long-past earthquake. At next week's centennial anniversary meeting of the seismological society, Boatwright and his USGS colleagues will unveil a 'shake map' for the 1906 event. To produce a map of the intensity of shaking, they combed through the Lawson report to recreate the rupture as it would have been documented by seismometers placed along the fault.

Geologist Tina Niemi of the University of Missouri in Kansas City will present the meeting with a reconstruction of earthquakes along the section of the fault that jumped the farthest, in Marin County. She and her co-authors will report that large earthquakes recur on that part of the fault every 50 to 600 years, so some activity might be due soon.

On the same day, the few survivors from 1906 will gather, as is customary, at 5:12 a.m. at Lotta's Fountain in downtown San Francisco, to lay a wreath of remembrance and tell stories. Thousands are expected to attend, as San Francisco embraces the legacy of its most devastating day. ■

Naomi Lubick is a science writer in Washington DC.

1. *The California Earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission* (Carnegie Institution, Washington DC, reprinted 1969).
2. Working Group on California Earthquake Probabilities *Earthquake Probabilities in the San Francisco Bay Region: 2002–2031* (US Geol. Surv., 2003). http://pubs.usgs.gov/of/2003/of03-214