A reason to study earthquakes: The *Jewel of the West* loses its lustre—by Glenn Dolphin

EXTRA THE DAILY NEWS EXTRA

HUNDREDS DEAD!

Fire Follows Earthquake, Laying Downtown Section in Ruins--City Seems Doomed For Lack of Water

KNOWN DEAD

AT MECHANICS' PAVILION

Max Fenner, policeman, killed in collapse Essex Hotel.

Niece of Detective Dillon, killed in collapse, 6th and Shipley.

Unidentified woman, killed at 18 7th st.

Two unknown men, brought in autos.

OTHER DEAD

Five killed, 2 injured, in collapse of building at 239 Geary.

Frank Corali, buried, beneath

At 126 Langton, 4 killed; Billy Sheehan, policeman, rescued 3 people.

Many injured at 117 6th st., Hotel Phillips.

Francisco Bay.

A building collapsed at Steiner and Haight sts. No report of loss of life.

Along Market st. from 5th toward Castro, the sidewalks are literally strewn with wreckage. In many places the sidewalks have collapsed, falling into the basements.

This is true on Market between 5th and 6th, between 6th and 7th, and between 7th and City Hall Square, on the west side.

https://sfbay.ca/2012/04/18/1906-hundreds-dead/

In the last half of the 19th century in the United States, the city of San Francisco, with the promise of gold, grew in prominence and population (Dalessandro, 2006; James, 1911). The city's location on the coast of the Pacific made it an attractive destination for those seeking wealth, and during those last years of the 1800s, the population doubled almost monthly. In fact, by the early 1900s, a full 25% of the US population living west of the Rocky Mountains, were located in or near the city limits of this coastal city. It was clearly thriving, with 17 cable car lines, 37 banks, and three opera houses. The city rivalled New York City for imports and exports, and was referred to as *The Jewel of the West*, and *Paris of the Pacific*.

Some noteworthy historical figures got also got their start there. A German immigrant saw the need for miners to have durable work clothes and began cutting cotton tarps and dying them blue. His name was Levi Straus. In the 1850s, Henry Wells and William Fargo founded a financial institution that today still bears their names. They conducted business by stagecoach and by ship, and by the early 1900s they maintained thousands of offices countrywide.

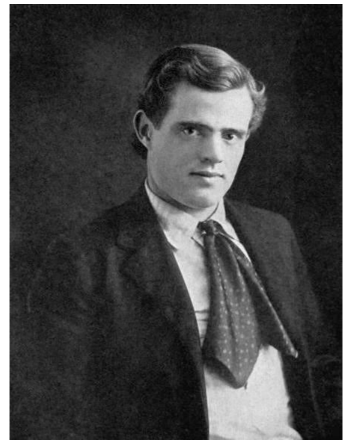
During the early morning hours of April 18th, 1906, most people were sleeping, though some were just heading home after a full night of revelry,when the earth began to shake violently and continuously for almost a minute. Later classified as a magnitude 7.8 earthquake, the shaking caused several buildings in the city to collapse and started dozens of fires. Most of these were due to underground gas lines that broke during the earthquake. As well, several water mains also broke, adding to the havoc in the city. Since two of the three major lines were damaged, fighting the fires through out the city was nearly impossible.

Cinematic Interlude: Watch *The Damnedest, Finest Ruins*. Find it here: https://www.youtube.com/watch?v=mvve8YiYGSo

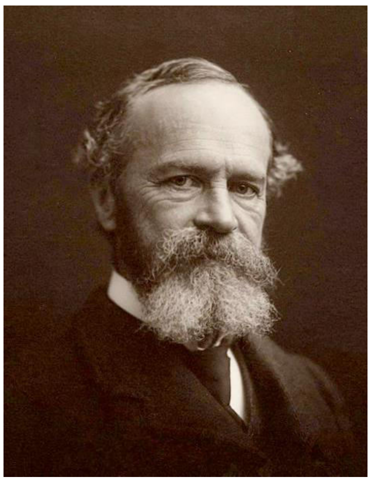
Two American authors were in San Francisco at the time of the quake and later wrote about their experiences. The backgrounds of these two gentlemen are clearly quite different and as you can imagine, their interpretation of the events of the morning of the 18th April, 1906 reflected their diverse backgrounds.

Jack London

Jack London (1876–1916) was considered by many as the greatest novelist in the US. He was a native of San Francisco, and grew up both poor and an orphan. He was a self-taught man who spent many years on various seafaring vessels, and wrote stories that were often about challenges of nature. He eventually ran for Mayor of Oakland (a neighbouring city of San Francisco) under the socialist party. You can read his 1906 account of the earthquake here: http://www.sfmuseum.net/hist5/jlondon.html Further description of Jack London's life can be found here: http://london.sonoma.edu/jackbio.html



https://en.wikipedia.org/wiki/Jack_London
Jack London
1876-1916



https://en.wikipedia.org/wiki/William_James
William James
1842-1910

William James

William James (1842–1910), a philosopher and psychologist, was only visiting San Francisco at the time of the earthquake. In fact, he had written about the hope of experiencing one. In contrast to London's humble origins, he was born in New York City and educated by tutors and in private schools, and often travelled to and from Europe. He attended Harvard School of Medicine, but interrupted this studies to head to Europe for medical reasons, including severe depression and suicidal thoughts. He did eventually receive his MD, but never practised medicine. You can read his 1911 account of the earthquake here: http://grammar.about.com/od/classicessays/a/WJamesEarthquake.htm More information about William James can be found here: http://plato.stanford.edu/entries/james/#1

Activity 1: Personal accounts of the 1906 San Francisco earthquake— Read the two personal accounts of the 1906 San Francisco earthquake by Jack London and William James, at the links noted above. On the Venn diagram provided, record the similarities and the differences between how each of them perceived the events during and after the earthquake.

Think Question: Briefly describe the similarities between how Jack London perceived this event with how William James perceived the event.

Think Question: Discuss why these authors may have differed in their perceptions of the same event?

"The ground had broken open for more than 270 miles along a great fault—the San Andreas rift. The country on the east side of the rift had moved southward relative to the country on the west side of the rift. The greatest displacement had been 21 feet about 30 miles northwest of San Francisco" (William Rubey, 1969).

Outside the ctiy of SanFancisco

http://loc.gov/pictures/resource/ppmsca.05595/
A panorama of the destruction to San Francisco

1. Investigating earthquakes

The devastation to the city increased as the Mayor of San Francisco ordered military and law enforcement personnel to use dynamite to try to extinguish burning areas. After nearly a week of trying to contain the disaster, the fires eventually did subside, but about 80% of the city had either burned down or been blown up, and some 3,000 people were dead. The total cost of the disaster came to about 400 million US dollars, a price tag equivalent to the entire national budget at that time.

While people of the period had plenty of experience with earthquakes, no one really knew what they were or what caused them. Given the huge cost of this particular event, not to mention the loss of life and the tremendous disruption in commerce, the Governor of California, George C. Pardee, appointed Andrew C. Lawson as the head of the State Earthquake Investigation Commission (later known as the Lawson Commission). Lawson, a professor from the University of California, Berkley, had with him eight scientists from other institutions—such as various observatories, the University of California, Johns Hopkins University and the still quite young United States Geological Survey. Theirs was a historic mandate, as it was the first time the government had commissioned a scientific investigation. Though the state government did not have the money to fund the investigation (see below), this government-commissioned investigation was the origin of such well-known present day institutions as the National Science Foundation, and the National Institutes for Health, which now do fund scientific investigations with public (taxpayer) money. Until this occurrence, scientific investigations had been primarily directed and subsidized by private funds.

> **Think Question:** If you were Lawson, and need money to support investigation of this huge disaster, where would you go to get money? How would you justify your expenses?

> **Think Question:** What kinds of strategies would you employ to investigate this massive earthquake?

In his book, *California Earthquakes: Science, Risk, and the Politics of Hazards* (2001), Carl-Henry Geschwind (2001) wrote about the findings of this commission. The details are startling in their clarity and insight into the cause and implications of this unexpected and massive geological event:

> *The commission's study of the earthquake progressed rapidly. Within two weeks of the quake, parties of geologists and students sent out from Berkeley were noting earthquake damage in Sonoma, Marin, and Monterey counties and the East Bay area, thereby completing the work of Branner's assistants on the San Francisco Peninsula. These parties soon found that damage was particularly concentrated along the San Andreas Fault. In 1893, Lawson had first defined and mapped this feature as an abrupt boundary between different geological strata that extended for 20 miles on the San Francisco Peninsula. In later writings Lawson and his students had downplayed its importance, claiming it to be an insignificant geological feature. But in 1906 Branner found abundant evidence that during the recent quake the two sides of the San Andreas Fault had moved past each other by about 8 feet on the peninsula. Roads had been disrupted, and fence posts that formally had been aligned in a straight line were now offset. Gilbert found similar evidence of up to 20 feet of movement along an extension of the fault in Marin County north of San Francisco. To the south, Lawson noted horizontal displacement near Salinas. After piecing together this information, members of the earthquake commission concluded that there had been horizontal slipping along the fault extending for at least 100 miles along the California coast and that this slipping had produce the seismic waves of the San Francisco earthquake. The San Andreas Fault thus was both much longer and much more important than geologists had realized.*
>
> *Acting upon the suggestion made by Branner, the earthquake commission on May 31 submitted a preliminary report embodying its early conclusions to Governor Pardee, who quickly approved it for publication. The report, after describing the commission's origin and early actions, documented the earthquake fault from point Arena in Mendocino County all the way to Mount Pinos in Ventura County, 375 miles to the south. The report also outlined the area in which damage had been severe and noted that the amount of damage was correlated both with distance from the fault and with the nature of the ground on which structures had been erected, with those on loose alluvial sediments or artificial fill along the waterfront experiencing much more damage than those on hard rock. Finally, the preliminary report provided some general recommendations for strengthening buildings against earthquakes, focusing mostly on the need for solid foundations. On the important question of the recurrence, that is, how soon (if at all) another destructive shock could be expected, the report was silent. (pp. 34–35)*

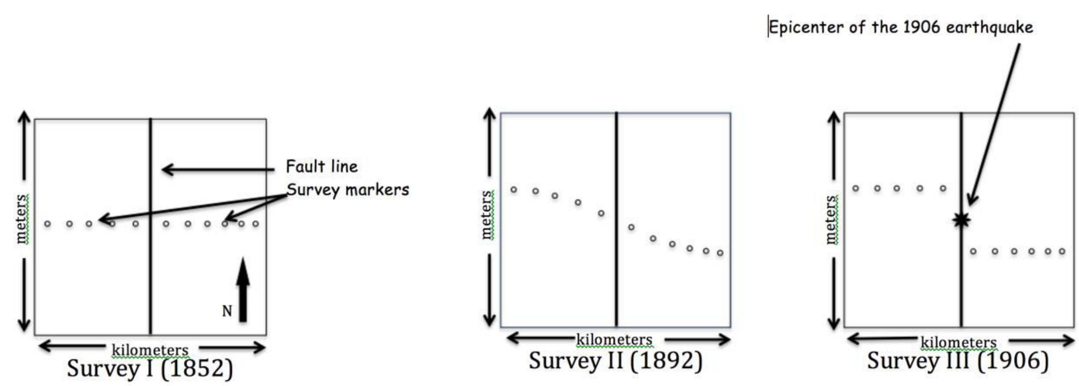
Think Question: Given the preliminary results from this report, if you were Governor Pardee, what would be some of the issues you would want to start considering to ensure the safety of the citizens of California?

Elastic rebound theory

One of the commission's members was Harry Fielding Reid (1859–1944), a professor from Johns Hopkins University in Baltimore, Maryland. While Reid had been born in Baltimore, he was schooled in Switzerland where he took an interest in the science of glaciers. In 1886, after completing his PhD in geophysics from Johns Hopkins, he became a professor of mathematics in Chicago. However, he soon got another appointment at Johns Hopkins, first as a physics professor and soon thereafter as a professor of geological physics. He turned to his interest in glaciers and went on to develop much of the knowledge we currently have today about glaciers. His interests changed again after being appointed to the Lawson Commission as he began to make great contributions to the discipline of seismology—that is, deformation of the earth's crust.

https://en.wikipedia.org/wiki/Harry_Fielding_Reid
Harry Fielding Reid
1859-1944

In his research, Reid looked at survey data from the previous several decades. During a survey from 1851–1865, markers were set from west to east across the San Andreas fault. These survey markers were again measured in a second survey, that took place around 1890. After the 1906 event, the commission again measured these markers. In essence, what Reid found was that there was relative displacement of about 4 metres on each side of the San Andreas fault where the earthquake happened, which could be measured for several kilometres away. See "Survey III (1906)" in Figure 1 below. Enigmatically, however, is Reid's observation that the survey markers in survey II (Figure 1) show a gradation of displacement, from no displacement where the survey line crossed the fault, gradually increasing to a couple of metres several kilometres away.



Here are three schematic drawings of survey markers at three different times. Survey I (1852) showed markers (fixed points on the ground) in a straight line across the fault. Survey II (1892) found a displacement of the survey markers and a distortion of the survey line. Survey, III (1906), after the San Francisco earthquake, found the markers to be displaced (to the north on the west side of the fault), but the survey line was no longer distorted.

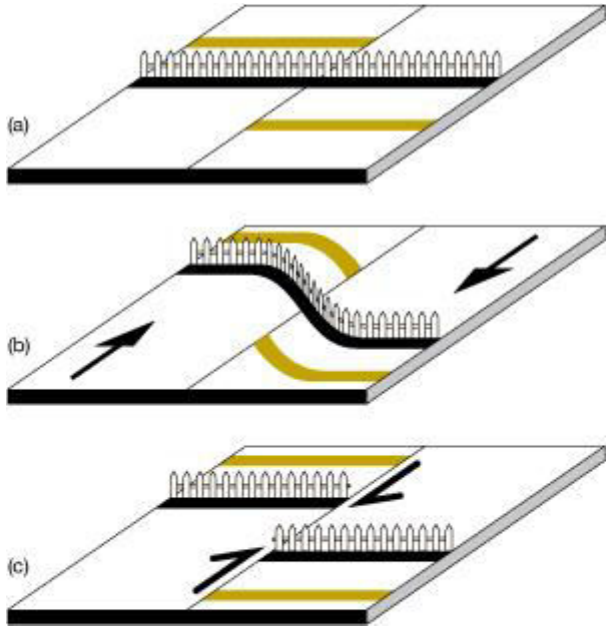
Based on the survey data across all of the three dates in for which it was collected, including the 1906 earthquake, Reid (1910) made a number of claims. They were as follows:

- The strain, or deformation of the bedrock (seen by the curved path of the survey markers in survey II) decreased farther east and west of the fault line.
- The displacement in the path of survey markers observed in survey III decreases north and south along the fault, away from the epicenter.
- The displacement occurred suddenly, ruling out a gradual compressional or extensional force to cause this pattern of deformation.
- Because displacement was horizontal, the force could not be gravitational. Gravity would be responsible for vertical displacements.
- The Farallon Islands, far west of the event, showed the 6 metres of displacement, but none of the strain.

Think Question: Given the data and the reasoning of Reid (above), develop an explanation for the great earthquake of 1906.

Activity 2: The earthquake machine

Reid's interpretation of the data assumed a time when there was no displacement across the fault, as shown in (a) in the graphic below. After the first survey, the ground deformed in response to horizontal displacement; west of the fault the ground moved in a northerly direction, and east of the fault it moved in a relatively southern direction. The deformation accommodated the gradual build up of strain, represented as (b) below; this deformation was like bending a large stick that would bend back to its original configuration once the stress was removed. Eventually, the strain build-up became too much for the strength of the rock and the rock broke along the fault. When the rock broke, the energy in the rock, stored as strain, was released as the rocks *elastically* rebounded to their normal, unstrained structure, shown in (c). Based on much of these findings, Reid developed his ideas into a very important explanation of seismic activity, which he called *elastic rebound theory*. This theory remains the cornerstone in seismology for understanding how and why earthquakes happen.



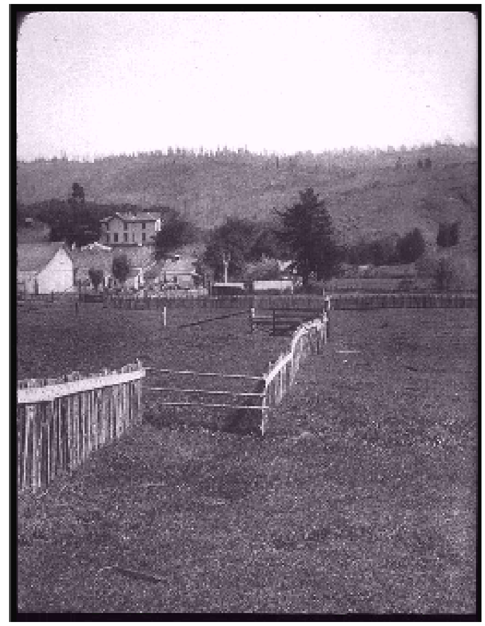


Diagram showing Reid's idea of gradual strain (b), causing deformation in the crust, until it broke and rock on each side of the fault *rebounded*, releasing stored elastic energy. Source: http://www.iris.edu/hq/gallery/photo/1530
The picture on the right shows actual offset of a fence crossing the San Andreas Fault. Source: http://earthquake.usgs.gov/regional/nca/1906/18april/reid.php

Think Question: According to Reid's theory of elastic rebound, what is an earthquake? What causes earthquakes to happen? Where do earthquakes get energy?

Think Question: Reid's life in Switzerland is credited for the development of his interest in the physics of glaciers. How might his experiences with glaciers and their dynamics have influenced Reid's understanding of the relationship between the deformation in the earth's crust and the cause of earthquakes?

Think Question: How could Reid's theory of elastic rebound actually be further tested? Where would be the best places to do such testing?

Think Question: What are the possible implications of this new understanding about earthquake triggers and processes? How could this information benefit those who find themselves living in seismically active areas?

Think Question: Based on the methods and findings of the Lawson Report, where should seismologists concentrate their future research efforts? What types of new investigations should they begin? What data should they start collecting and how should they do this?

You can find a biographical memoir about Reid at:
http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/reid-harry.pdf

In discussing the history of the San Francisco earthquake of 1906, Lubick (2006) wrote the following:

> *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. (864)*

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