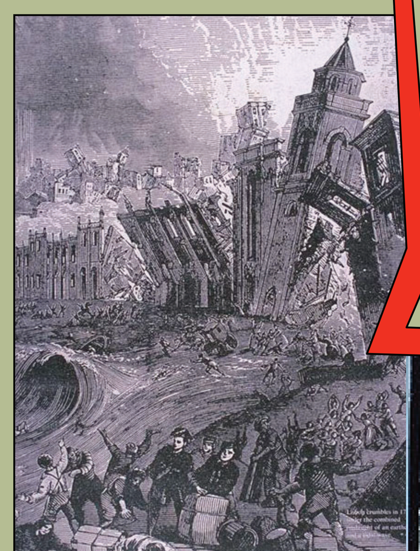
TRIM LINE

THE HISTORY OF SEISMOLOGY

Robert Hooke, CEIIOSSOTTUU

In 1676 the English Physicist published a treatise entitled the **True Theory of Elasticity or Springiness** with the anagram above on the title page. The solution to the puzzle is *Ut Tensio, Sic Uis*, or "as the extension so the force". Today we state this as "stress is proportional to strain" and call this Hooke's Law. This is the first fundamental mathematical formulation in modern Seismology.

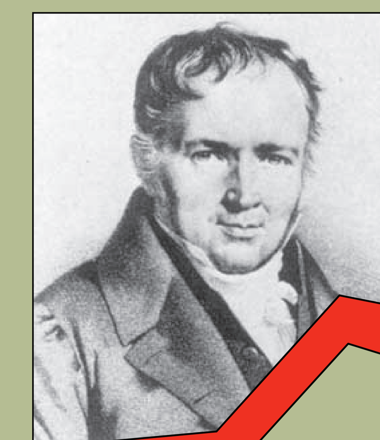


November 1, 1755

Lisbon, with a population of more than a quarter of a million was one of the largest cities in Europe. About 9:30 a.m. a great earthquake occurred 200 km to the southwest beneath the Atlantic ocean. The city shook for nearly 10 minutes and ~30 minutes after the event a tsunami swamped the Targus river which runs through the center of the city. The Lisbon Earthquake was the first event to be studied scientifically. J. Mitchelle proposed the shaking was caused by wave propagation from a distant source, and that the waves were very similar to those produced by sound in air.

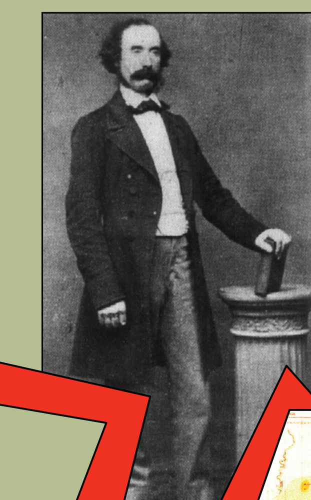
1830 Discovery of P and S waves

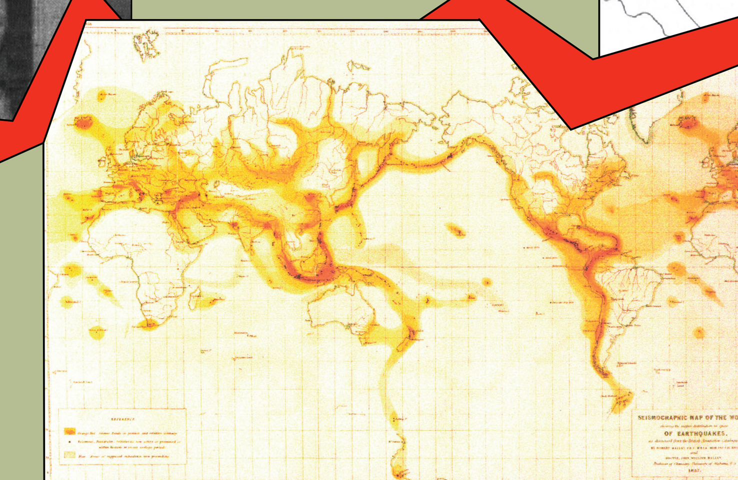
The early part of the nineteenth century was an extraordinary time for mathematics. French mathematicians Navier and Cauchy developed equations for elasticity. Then, in 1830 Poisson published a paper showing that there were two fundamental elastic waves: P and S waves. Poisson's Ratio, which is a measure of the S to P velocity, is widely used in seismology today.



Robert Mallet

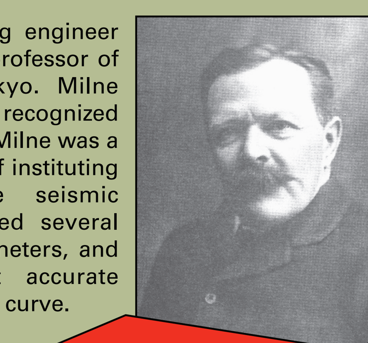
Not only the inventor of the word seismology, Robert Mallet was considered the "first" seismologist. Born in Ireland, he was an engineer of considerable skill and his contributions to seismology mark the birth of the science. He constructed the first comprehensive earthquake catalog and world seismicity map. In the late 1840's Mallet used explosions to produce seismic waves and investigate the idea that seismic waves travel at different speeds in different rock types. Following the 1857 Neapolitan earthquake, Mallet traveled to Italy and using the orientation of cracks and fallen masonry produced an isoseismal map for the event. The map identified areas of similar intensities of shaking.

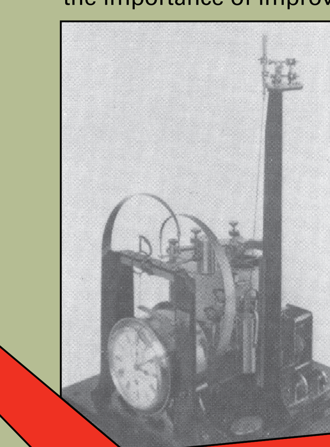


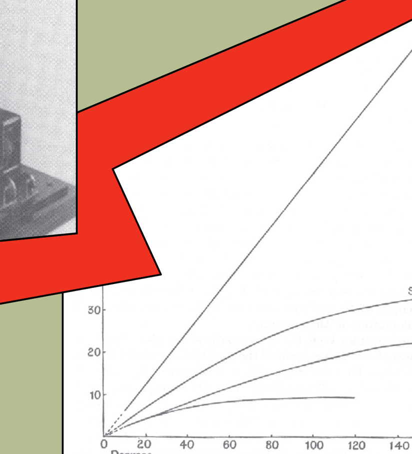


John Milne

In 1875 a 25 year old mining engineer named John Milne was invited to become a professor of geology at the Imperial University of Tokyo. Milne organized a seismic survey of Japan and soon recognized the importance of improving the seismogram. Milne was a great promoter of instituting a world wide seismic network, designed several types of seismometers, and made the first accurate global travel time curve.

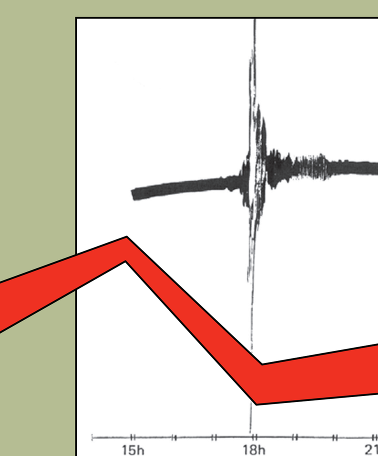






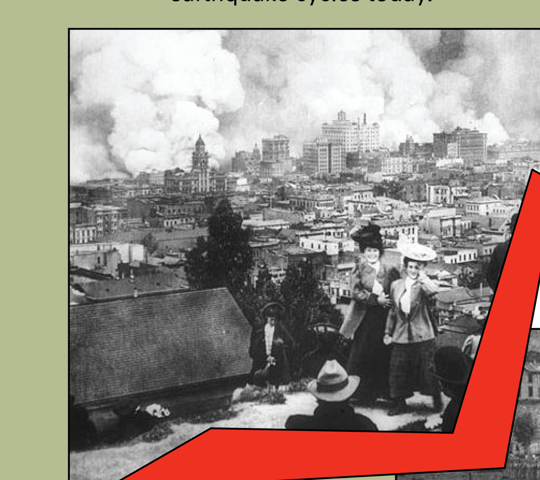
1889, The First Teleseism

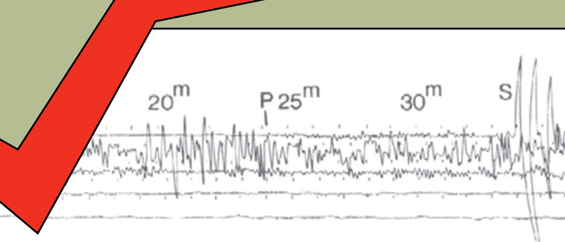
The first time a seismogram was correlated with a distant earthquake was in 1889. The record shows a deep Japanese earthquake as recorded in Potsdam, Germany.

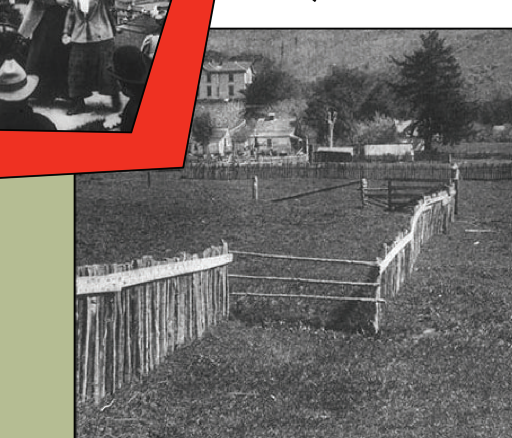


April 18, 1906

At the turn of the century San Francisco was a bustling port city with a population of 400,000. Early on the morning of April 18 a major earthquake occurred on the San Andreas Fault, and the "City by the Bay" was devastated. A nearly 400 km long section of the fault slipped with offsets as great as 8 meters. Many of the structures in the city were destroyed, but much of the damage was caused by the ensuing fires that burned out of control for days. The state of California set up a commission, headed by H.F. Reid and G.K. Gilbert, to study the earthquake and the resulting report laid out the theory of "elastic rebound" which forms the core of understanding earthquake cycles today.





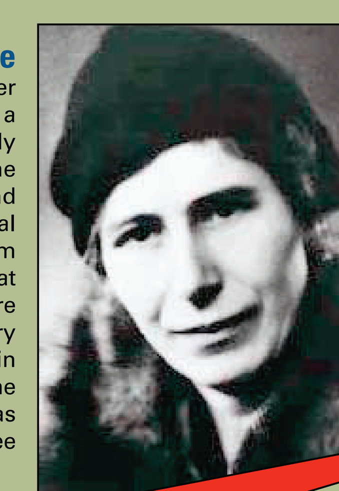


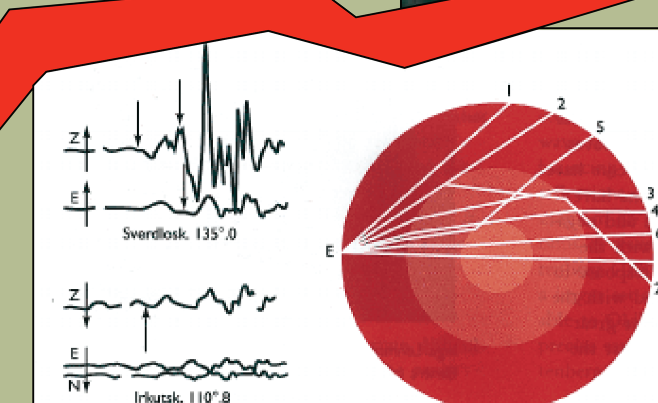
September 1, 1923: Tokyo

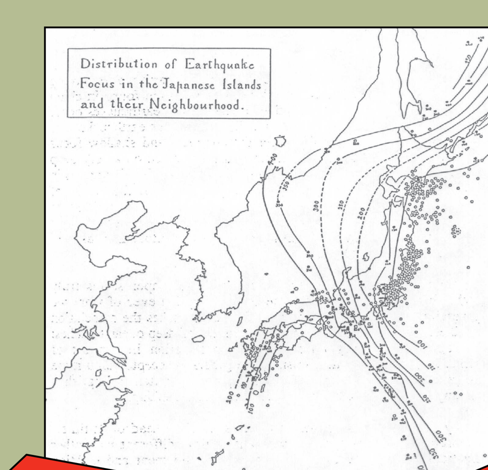
One of the deadliest earthquakes of this century struck the heavily populated Kwanto province in east-central Japan. The death toll in Tokyo exceeded 100,000, and nearly 2 million people were left homeless. Seismology was a developed science in Japan in the first part of the 20th century. Professor Fusakichi Omori had studied earthquakes in Japan and in 1922 concluded the region around Tokyo was "seismically quiet" and predicted that an earthquake would strike the region in the future. After the 1923 earthquake the Imperial Earthquake Investigation Committee was formed and produced five volumes of scientific and engineering studies which dramatically improved building practice in Japan.

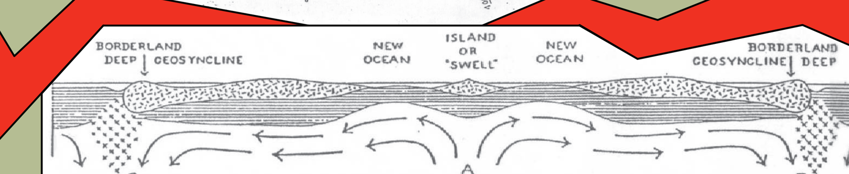
Lehmann: The Inner Core

Inge Lehmann discovered the inner core, a zone of solid material at a depth of 5150 km in the early 1930s. Lehmann worked at the Copenhagen Observatory and carefully measured the arrival times of seismic phases from distant earthquakes. She noted that the only way to explain the core phases was to have a boundary within the core with an increase in velocity. She hypothesized that the inner core was solid, which was later proved on the basis of free oscillations.







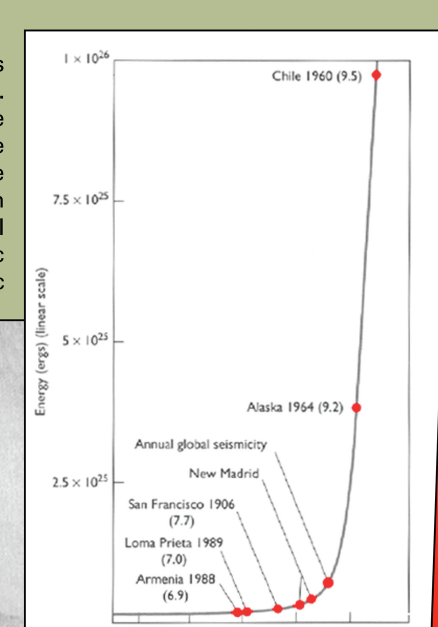


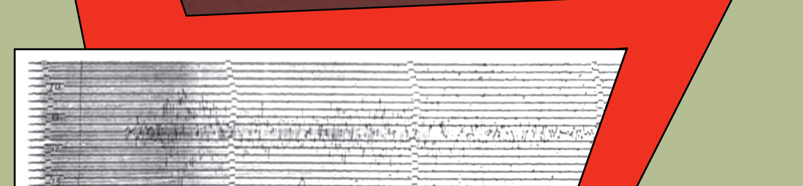
Wadati: The Discovery of Deep Earthquakes

Kiyoo Wadati noted that earthquakes with the same epicenter had very different patterns of P and S wave arrival times. Wadati reasoned that this phenomenon was due to different focal depths (depth below the surface of the Earth) for the earthquakes. Wadati proved conclusively that deep focus earthquakes occurred, and showed that the depths of these events formed an inclined zone beneath Japan, which we now recognize as subduction zones. Wadati's observations had a profound effect on Arthur Holmes, who in turn, produced the first 2-D picture that suggests plate tectonics in 1933.

1935: The Richter Scale

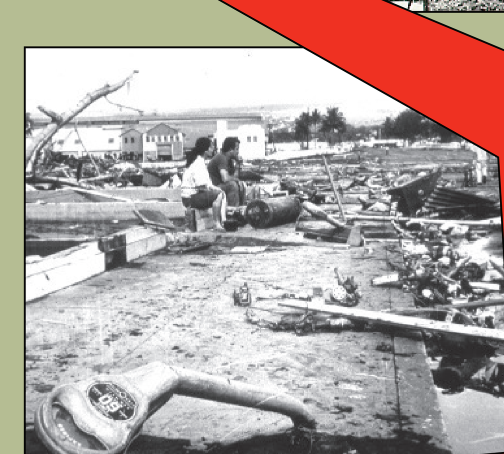
In the early 1930s Charles Richter was amassing a catalog of California earthquakes. Richter wanted to publish the catalog with the "size" of the earthquakes instead of the intensity. He developed a measure of earthquake size based on two fundamental principles: the level of shaking experienced at a distant site will depend on the size of the earthquake, and the level of shaking will decrease the farther the distance traveled by the seismic waves. Richter used these principles to develop a logarithmic scale (each unit of the scale corresponds to a 10-fold increase in shaking) which became known as the "Richter Scale". Although Richter's early work was only applicable to southern California, it served as the basis for modern magnitude scales.





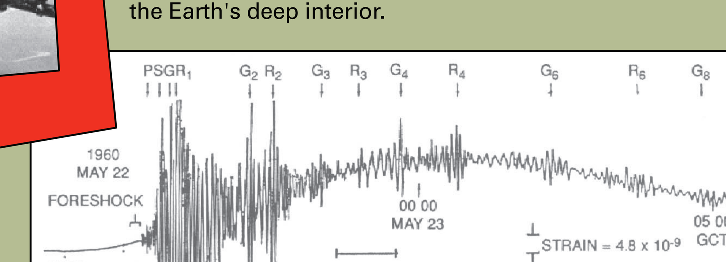
July 16, 1945

At 5:30 a.m. the USA detonated the first nuclear weapon in central New Mexico. The test, code named TRINITY, had an explosive yield of approximately 15 kt (equivalent to 15 thousand tons of TNT). The closest seismic station was in Tucson, and the seismologist Beno Gutenberg used the record to determine the origin time of the explosion. The ability to seismically record this and other explosions gave rise to the field of "Verification Seismology".



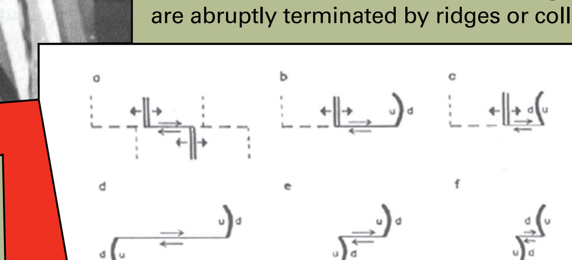
May 22, 1960

The largest earthquake in recorded history occurred in southern Chile in 1960. The earthquake, which had a magnitude of 9.5, ruptured a 1000 km section of the subduction zone where the Nazca plate descends beneath Chile. The event triggered a tsunami that not only devastated the coast of Chile, but killed 61 people in Hilo, Hawaii. The Hilo tsunami height was measured to be over 10 meters. The Chilean earthquake was the first event to produce free oscillations of the Earth. Free oscillations are vibrations of the entire planet, and can be used to detail the structure of the Earth's deep interior.



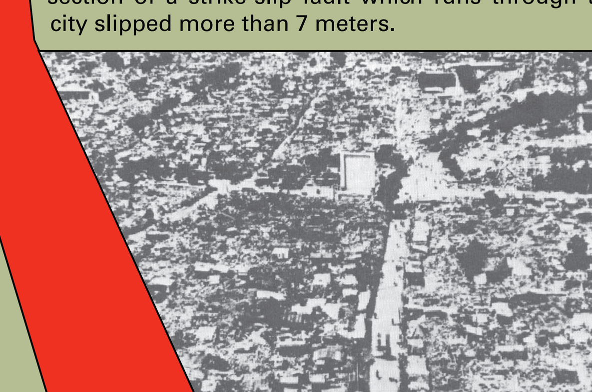
1965: J. Tuzo Wilson and Transform Faults

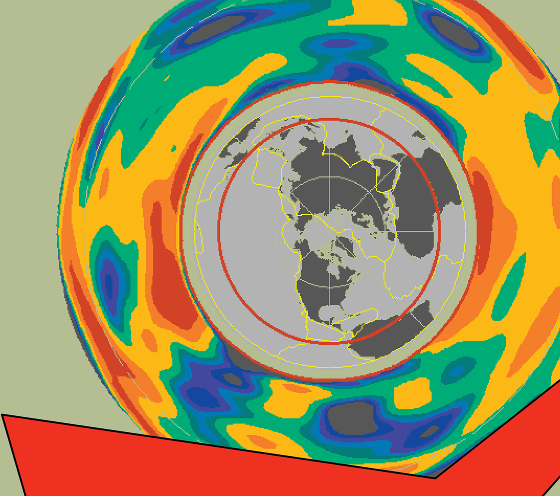
The spatial distribution of earthquakes was a fundamental in developing the theory of plate tectonics. J. Tuzo Wilson made a major contribution with the discovery of Transform Faults, which are shear faults with significant motion that are abruptly terminated by ridges or collision zones.



July 28, 1976

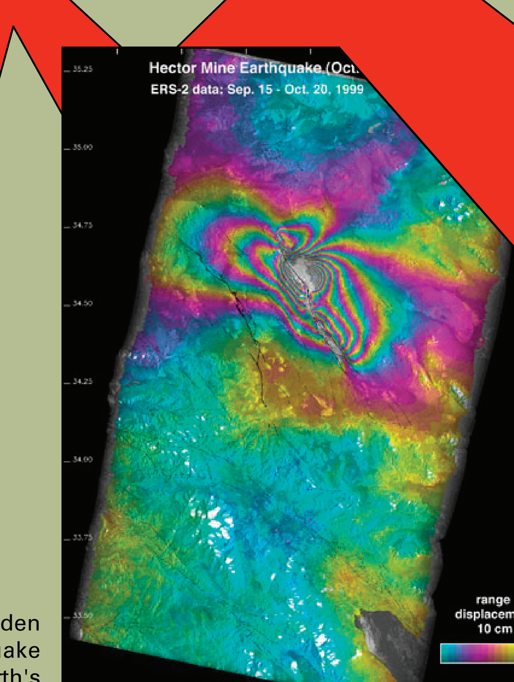
The deadliest earthquake of the 20th century struck the city of Tangshan, China on July 28, 1976. The death toll lay in excess of 500,000. The industrial city was totally destroyed when a 150 km section of a strike-slip fault which runs through the city slipped more than 7 meters.





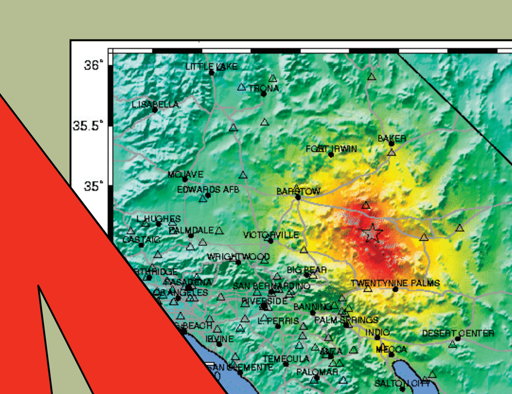
Earth Velocity Structure

Using a very large number of earthquakes it is possible to map changes in velocity throughout the interior of the Earth, known as tomographic slices. These slices can show descending slabs and the upwelling of hot material.



Seismology from Space

The sudden slip along a fault during an earthquake causes permanent deformation of the Earth's crust. This deformation can be measured from space by a technique called INSAR, or Interferometric Synthetic Aperture Radar. By comparing two radar images taken before and after the earthquake, it is possible to measure changes in the ground surface. This technique was used to produce a map (right) of crustal deformation following the October 16, 1999 Hector Mine earthquake, a magnitude 7.1 event in the Mohave Desert of California.



Shake Map

Real-time collection of seismic data allows for the construction of maps depicting shaking intensity within seconds of an Earthquake occurrence. Shake Maps can highlight areas of expected damage and help provide rapid emergency response as is shown on the left for the Hector Mine earthquake.

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Design and illustration: Jason Mallett