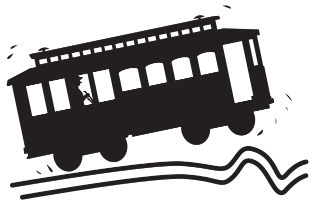


Earthquake Science—Feature 1 of 10

The Earthquake Machine:

What 1906 taught us about how earthquakes work

On April 18, 1906, the earth moved. Not only did the ground shake on the day of the Great San Francisco earthquake, but land on both sides of the San Andreas fault permanently shifted. Precise measurements of the amount of motion led scientists to discover why earthquakes happen.

Fences across the San Andreas fault ripped apart, and it was no longer clear who owned the land nearby. Surveyors went to mountain peaks to relocate the property boundaries. While the fences showed that ground had moved near the fault, the surveyors also discovered that much of northern California had moved and distorted during the earthquake. The movement followed a pattern with most of the motion near the fault and less motion far away.

Fence after 1906 earthquake.

At the time, nobody knew what caused earthquakes. The survey measurements led a scientist named H. F. Reid to propose one possible explanation. He hypothesized that strain built up in the earth's crust like the stretching of a rubber band. At some point, the earth would have to snap in an earthquake. The problem was that Reid didn't know what caused the strain to build up.

Scientists continued to survey after the earthquake and saw that motion continued throughout California, providing an important piece of evidence that the Earth's tectonic plates are in constant motion. This plate motion is Reid's missing cause of strain.

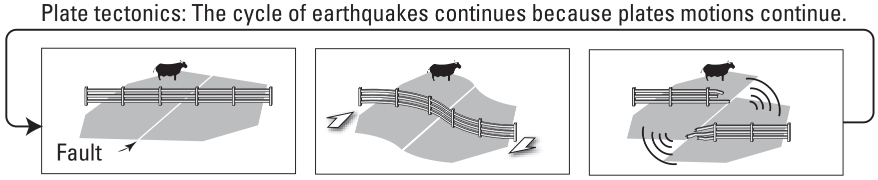
Two plates can get stuck together where they meet (at faults), but forces deep within the earth drag and pull the plates in different directions. Faults remain stuck together for many years as the nearby crust deforms and stretches, but eventually the strain is too much and the two plates shift suddenly in an earthquake.

Today, scientists monitor the buildup of strain near locked faults using satellite observations, and the pattern is much like Reid hypothesized 100 years ago.

By Dr. Matthew d'Alessio

U.S. Geological Survey
Earthquake Hazards Team

Plate tectonics: The cycle of earthquakes continues because plates motions continue.



A new fence is built straight across the fault at the boundary between two plates.

Over many years, plate motions cause strain to build up and deform the earth (and fence).

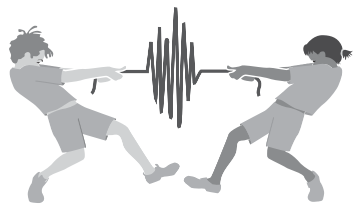
An earthquake is a sudden burst of motion that relieves the strain and causes shaking.

Resources: Demonstrate the earthquake cycle in your classroom (animations & "The Earthquake Machine"): http://quake.usgs.gov/research/deformation/modeling/teaching/

Putting Down Roots in Earthquake Country, a special insert in The Sunday Chronicle, Sept. 18, 2005, contains information about making your family safer in the next quake. Also online at: http://pubs.usgs.gov/gip/2005/15/

SAN FRANCISCO CHRONICLE IN EDUCATION

Newspaper Activity: Land features can change naturally over time, or more rapidly during an event such as an earthquake. Read and summarize an article in today's Chronicle that discusses natural or man-made changes in the land.



Earthquake Science—Feature 2 of 10

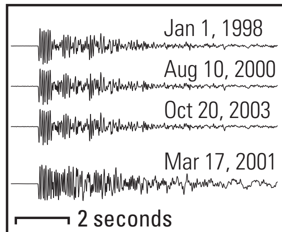
Seismograms: Earthquake Fingerprints

When a fault slips suddenly in an earthquake, it releases energy in the form of seismic waves. Captured by sensitive instruments, a seismogram is a recording of the shakes and jolts of these passing seismic waves. Seismograms are like the fingerprints of earthquakes with patterns that can be matched and decoded to learn about how earthquakes affect our world.

We know the earthquake's magnitude from the height of the waves, and we can figure out when and where the earthquake happened from the times the waves arrive at different places. The exact pattern of the wiggles is shaped by the individual earthquake: how deep it was, which direction the fault moved, and what kinds of rocks the waves passed through.

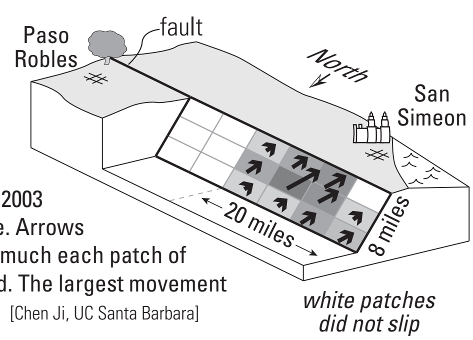
Most earthquakes have unique seismograms, like people have unique fingerprints. Some groups of small earthquakes have almost identical seismograms, which means that these earthquakes are repeats of exactly the same motion in exactly the same direction in exactly the same place.

We can find out even more about big earthquakes by breaking them down into smaller parts. For example, a magnitude 6.5 earthquake that hit Paso Robles in December 2003 released built-up strain over a fault area 20 miles long and 8 miles from top to bottom. You can think of this area as being like a quilt divided into individual patches. The movement of each patch has its own unique fingerprint. The seismogram of a large earthquake is then the combined fingerprints of all the patches. We use a computer to match patterns in the large earthquake's seismogram to figure out which patches of the fault moved and by how much.



Seismograms from magnitude 2 earthquakes on the San Andreas fault. The same patch of fault slipped 3 separate times, producing nearly identical seismograms (top 3). A different patch slipped and has a different fingerprint (bottom). [R. Nadeau, UC Berkeley]

Some patches of the fault did not slip much, so we can expect future earthquakes sooner there. Patches that slipped a lot already won't move again until plate tectonics causes the strain to build back up.



View into the Earth along the fault of the December 2003 earthquake. Arrows show how much each patch of fault moved. The largest movement was 9 feet. [Chen Ji, UC Santa Barbara]

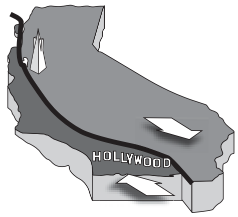
By Dr. Jeanne Hardebeck

U.S. Geological Survey Earthquake Hazards Team

Resources: Recent earthquake locations: http://quake.usgs.gov/recenteqs/latest.htm • Listening to Seismic Waves (activity to introduce seismic waves): http://quake.usgs.gov/info/listen/ • Virtual Earthquake (online activity to locate earthquakes using seismic waves): http://cdl-flylab.sonoma.edu/eec/Earthquake/

SAN FRANCISCO CHRONICLE IN EDUCATION

Newspaper Activity: Advances in technology have helped scientists better understand earthquakes. Read today's Chronicle to find an article about other advances in technology. How could these advances change your life?

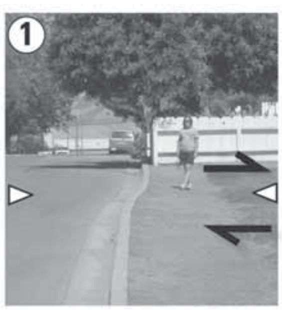


Earthquake Science—Feature 3 of 10

Find the Fault:
Recognizing Active Faults

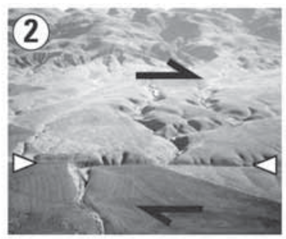
Faults are where large blocks of the Earth's crust move past each other. At plate boundaries, they are most often stuck tight, but at times they lurch several feet in a great earthquake. Living near faults is a fact of life for many Californians, but how do you recognize an active fault?

Some faults, called creeping faults, move very slowly all the time. Structures like bridges, sidewalks, and buildings built astride these faults will be offset as the faults slowly move (up to a half inch each year). You can find these faults by looking for bent or offset curbs and sidewalks (Photo 1). Not every offset curb is a fault, but if you find several features that all line up, you may have found a fault.



This curb is offset by about one foot due to creep on the Calaveras Fault. The white triangles point along the fault.

However, most faults don't creep, so geologists look for effects faults have on the landscape. Natural features like streams, valleys, and ridges can be offset from repeated earthquakes if they cross the fault (Photo 2).



The stream in this photo is offset by movement along the San Andreas Fault. As the fault continues to move, the two parts of the stream will get farther apart. Also, a straight ridge, or "scarp" runs along the fault.

Active faults also make their own landscape features. If one side of the fault moves up or down, it creates a long, straight ridge called a "scarp." As faults move along in repeated earthquakes, the rock along the fault is broken and ground down. This shattered zone is more easily eroded than the surrounding rocks, so long valleys can form along the fault (Photo 3). So faults can cause both ridges and valleys to form. Faults also can disrupt the movement of underground water, forcing it to the surface to form springs and ponds.

Crystal Springs Reservoir lies within the long, straight valley broken up by the San Andreas Fault.

A lot of these features are easiest to spot from the air. Our newest tool to find faults is Laser Imaging Detection And Ranging (LIDAR), which uses laser light from an airplane to make a detailed image of the ground surface that can even see through trees in a forest. Being able to read the landscape allows us to pinpoint the exact location of dangerous faults.

By Dr. John Solum and
Dr. Russell Graymer

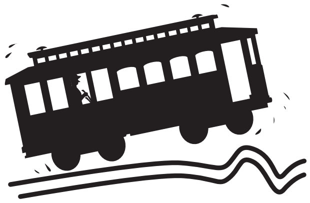
U.S. Geological Survey
Earthquake Hazards Team

Resources: Visit the San Andreas Fault: A Geology Fieldtrip Guidebook To Selected Stops On Public Lands, http://pubs.usgs.gov/of/2005/1127/

SAN FRANCISCO CHRONICLE
IN EDUCATION

Newspaper Activity: Using the Bay Area map on today's Weather Page, look for features that could indicate a fault. Which cities are closest to these features? Which bodies of water?

Want to know more? Visit http://education.usgs.gov



Earthquake Science—Feature 4 of 10

Looking into the Past With Earthquake Trenches

Do earthquakes tend to repeat at regular intervals? If so, that may tell us when to expect the next one. Many earthquakes happened long before recorded history; how can we discover what happened so long ago?

Geologists look for evidence in the ground below us. Layers of earth get added, one on top of the other, over time. Like the pages of a history book, each layer records what was happening at that time. A layer of round rocks can indicate an ancient river, while a layer of mud can be from an ancient flood. Layers also record earthquakes. The ground can shift several feet or more during an earthquake, disrupting the layers (and "tearing" the pages of Earth's history book). In the years after an earthquake, new layers of rock and soil may blanket the area and bury the broken layers below.

Scientists dig trenches across active faults to look for evidence of ancient earthquakes.

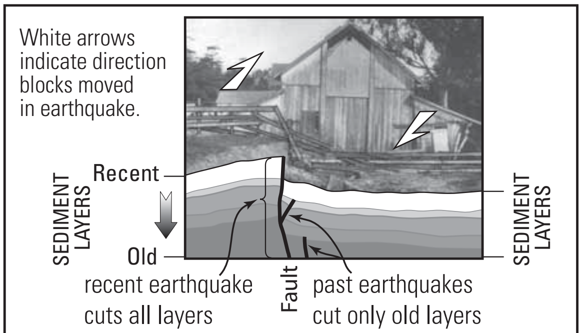
To go back in time, geologists dig trenches up to 20 feet deep and 10 feet wide and then walk in to observe the layers. If there has been a large quake, the sediment will be disrupted at the fault. Any layers that are not disturbed and that rest on top of the faulted layers were laid down after the earthquake.

Then, if we can figure out when the layers formed, we can figure out when the earthquake hit. Geologists look for plant or animal remains, like sticks or bones, in the buried layers and date them using the same tools used by archeologists.

With the information gathered in the trenches, geologists can tell how often earthquakes occur and even how large past quakes were. The more scientists know about a fault's past, the better they are able to suggest what may happen in the future.

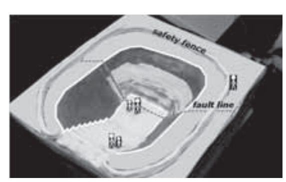
By Heidi Stenner

U.S. Geological Survey
Earthquake Hazards Team



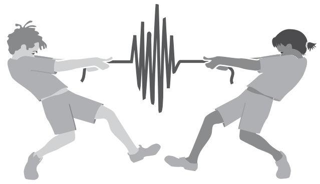
Newspaper Activity: Look through today's newspaper for pictures of items that you think should be included in an earthquake preparedness kit. Write a paragraph describing how you made your choices. What is the total price of the items?

In April 2006, visitors will walk below ground level to experience an active fault in downtown Fremont. They'll see evidence of an earthquake in 1868 — known as "The Great San Francisco Earthquake" until the even larger and more damaging 1906 quake.
http://quake.usgs.gov/research/geology/paleoseis/



SAN FRANCISCO CHRONICLE IN EDUCATION

Classroom Activity about trenching:
http://www.data.scec.org/Module/s1act09.html



Earthquake Science—Feature 5 of 10

When will the next big one hit? How do we know?

Plate tectonics causes stress to build up in the Bay Area, which will eventually be released by an earthquake. By measuring the rate of stress buildup and the largest stress that the Earth can sustain, we can predict how many earthquakes will occur during a decade. If we could predict exactly when one will occur, people could be better prepared for the disaster. But does the earth give any warning signs that an earthquake is coming? If it does, we could record those signals on scientific instruments.

Scientists have made hypotheses about several ways faults might signal that they are about to rupture. For example, faults might start moving very slowly before they lurch violently in a big earthquake – a lot like a car starting up at a stoplight. This slow start could take place over a whole year or a fraction of a second. So far, it looks like the earth starts slipping too quickly to give us any warning, but it's possible that our instruments aren't sensitive enough to detect this motion.

Scientists have successfully observed one type of warning sign that helps them predict earthquakes – other earthquakes. Sometimes, one earthquake can trigger another one. Imagine that an earthquake is like having one leg of a table break – if the objects on the table are too heavy for the remaining three legs to support, another leg will eventually snap under the stress. This is why aftershocks occur after a large earthquake. Scientists have detected patterns in aftershocks and can now predict how many large aftershocks there will be. This information helped San Francisco decide how many firefighters to keep on duty during the days after the 1989 earthquake.

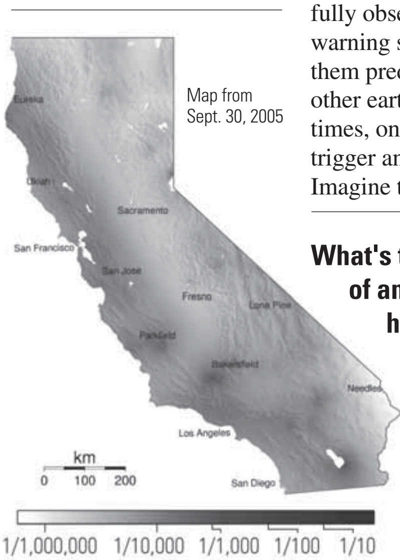
Sometimes an aftershock can even be bigger than the first earthquake. When a small earthquake occurs, scientists predict the odds that the earthquake is a warning sign that a larger earthquake will hit soon. These odds are based on the earthquake's magnitude and the seismic history of the fault on which it occurred. If the chance is large enough, the government issues a warning.

There are lots of unanswered questions, and we are always looking for new, creative ways to measure what the Earth is doing.

By Dr. Matthew d'Alessio

U.S. Geological Survey
Earthquake Hazards Team

Map from
Sept. 30, 2005



Probability of Exceeding MMI VI Shaking

What's the probability of an earthquake happening today?

An earthquake is more likely to happen in the dark areas.

See today's map at: http://pasadena.wr.usgs.gov/step

SAN FRANCISCO CHRONICLE IN EDUCATION

Newspaper Activity: Earthquake scientists have tried to use Earth's clues to predict earthquakes. Using today's Chronicle, read the headlines of a few articles to try to predict what the articles are about. Were your predictions correct?