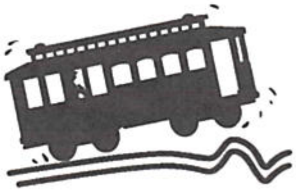


Earthquake Science—Feature 6 of 10

Liquefaction— When the ground *flows*

After the 1989 Loma Prieta earthquake, a fireman on Treasure Island (in the middle of San Francisco Bay) told me his earthquake experience. He saw water spurting out of the ground from many places, and his greatest fear during the earthquake was that he might drown.

As I listened, I was thinking how ironic this was. Only a few miles away in San Francisco, the same natural phenomenon that triggered the spurting water in the 1989 earthquake contributed to the fire that burned about 500 city blocks in San Francisco after the 1906 earthquake.

In both 1989 and 1906, buildings and streets had lots of damage where they were built on wet sand layers. This sand had been deposited not long ago either by rivers and creeks or by humans making new land by dumping sand into water bodies. Normally such sandy soil provides excellent support for buildings, but earthquake shaking jiggles the sand and squeezes the water trapped between the grains so much that the layer begins to act like a muddy liquid. We call this process liquefaction.

In 1989, the fireman on Treasure Island witnessed one effect of liquefaction, as muddy water spurted from the ground like the violent squeezing of a sponge. In 1906, the liquefied sandy soils flowed down hill slopes and snapped buried water pipes. With so many water pipes broken, firefighters in San Francisco did not have enough water to douse the fire. It raged out of control for three days. Firefighters even blasted buildings with dynamite to try to form fire breaks.

Today, many neighborhoods around San Francisco Bay are built on sandy soils. Geologists are busy mapping soil types to identify areas that might be at risk for liquefaction. They push probes more than 100 feet down into the soil, measuring how the probes slide into the earth. This tells them how much sand is present and how firmly it is packed together. Engineers and planners can use this information to make our community safer for the next time an earthquake shakes the Bay Area.

The fire that destroyed 500 city blocks after the 1906 quake raged out of control because **liquefaction** broke water pipes that were needed by firemen to fight the fire.

By Dr. Thomas Holzer

U.S. Geological Survey
Earthquake Hazards Team

Newspaper Activity: This feature recounts a fireman's observations of liquefaction. Read today's Chronicle to find an article in which a personal experience was used to discuss a fact or theory. Write a summary of the article you chose.

Liquefaction in your classroom: Take a large rubber dish pan and fill it about one-quarter full with tap water. Then add sand with the texture of table salt until the sand surface reaches the water level. Stir the sand as you pour it into the water to remove bubbles and level the sand surface. Gently place a brick on the sand so that it stands up on its end like a skyscraper. Tap the side of the pan with a mallet with a series of quick taps. What happens to the brick?

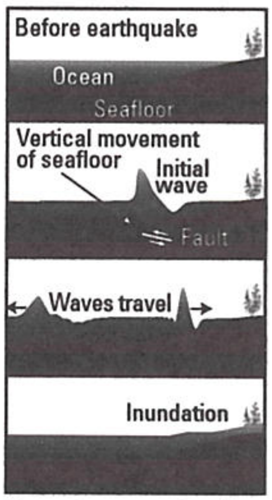
SAN FRANCISCO CHRONICLE IN EDUCATION

Related activities: See Lesson 6 of http://teachingboxes.org/earthquakes for an explanation and liquefaction maps.

Earthquake Science—Feature 7 of 10

Bay Area Tsunamis: Are we at risk?

The infamous 1906 San Francisco Earthquake began when a tiny section of the 1300 km-long San Andreas fault began to rupture. That initial break-known as the hypocenter-occurred just offshore of San Francisco. Although most of the movement was strike-slip (with blocks of crust moving horizontally) there was a small amount of vertical movement. When the ocean floor moved down, it created a tsunami.



Tsunamis occur when the ocean floor moves vertically.

Luckily for San Franciscans already suffering the effects of a major earthquake, the 1906 tsunami wasn't a large one. In fact, it measured only 10 centimeters high when it arrived at the San Francisco tide gauge station near Crissy Field.

Does that mean there's no tsunami danger in the Bay Area? Not exactly! Our greatest tsunami danger comes from subduction zones similar to the one that generated the 2004 Indian Ocean tsunami, where one tectonic plate dives beneath another. When an offshore earthquake occurs along a subduction zone, a large section of ocean floor moves vertically, generating a tsunami. Tsunamis from subduction zone earthquakes as far away as Alaska or Japan, for example, can hit Bay Area shores. In 1964, a large earthquake in Alaska caused waves 6 meters high in northern California, killing 11 people. Today, the West Coast/Alaska Tsunami Warning Center would alert authorities in time to evacuate coastal regions. Although San Francisco Bay is sheltered by its narrow entrance at the Golden Gate, tsunamis can still enter the bay and result in strong currents.

We have tsunami danger from another source as well: a local earthquake could trigger coastal or underwater landslides, potentially leading to dangerous waves. If you feel shaking, be sure to leave the beach, even if no official alerts you!

What about that 10 centimeter 1906 tsunami? To scientists it was important; that single tide gauge record helped them to decipher how the offshore portion of the San Andreas fault moved during the Great 1906 Earthquake.

Eric Geist and
Anne Rosenthal

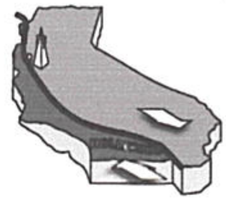
**U.S. Geological Survey
Coastal and Marine Geology Program**

Newspaper Activity: Tsunami is a word of Japanese origin meaning harbor wave. American English has adopted many words of non-English origin. How many non-English words can you find in today's Chronicle?

Tsunamis in your classroom: Take a glass baking dish (9" x 13" or larger) or clear rubber tub and fill with enough water to at least cover the bottom. Tip one end up and gently let the dish down to rest on the counter to generate waves. Use a ruler and stop-watch to calculate the speed at which waves move. Add more water and make new waves. How does the speed of the waves vary with the depth of water in the dish? The same is true for tsunamis! Tsunamis travel at different speeds in the deep Pacific Ocean than they do in the shallow San Francisco Bay.

SAN FRANCISCO CHRONICLE IN EDUCATION

Find out more: 1906 tsunami simulation: http://walrus.wr.usgs.gov/tsunami/1906.html



Earthquake Science—Feature 8 of 10

An Earthquake Scientist in Action: Jessica Murray

I'm a geophysicist working with the Earthquake Hazards Team at the U.S. Geological Survey in Menlo Park. Although my father is a geologist, I didn't know I wanted to become an earth scientist until I took an introductory geology course in college. I was fascinated with understanding how different types of rocks are formed and change through various processes, especially the tectonic forces that cause earthquakes.

As an earth science major in college I took courses in many different aspects of geology. When I graduated I knew I wanted to pursue a career in the field, but wasn't sure in what to specialize. I did know that my favorite courses had been about "structural geology" which is the way in which rocks are slowly folded to form mountains or broken by faults like the San Andreas. I also knew that I wanted to do scientific investigations that were important for society in general – not just other geologists.

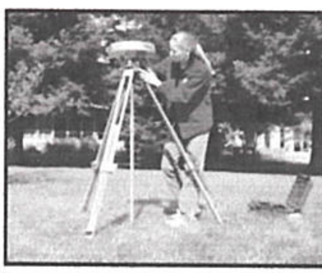
For those reasons I chose to attend graduate school to study a branch of geophysics called "crustal deformation." I learned to make and use measurements that tell us how the Earth's crust is distorted, or deformed, around faults and volcanoes. With this information we can determine where strain is building that may be released in an earthquake, or recognize that a volcano is inflating and may erupt soon.

One of the ways we monitor the slow movement of the Earth's surface is with Global Positioning System (GPS) instruments. These instruments are similar to what people use while camping or boating,

but are specialized for scientific applications. We can tell exactly where a location on Earth is to within about half the diameter of a dime.

A great thing about being an earth scientist is the opportunity to travel all over the world to investigate unique geological features. I get to work in a wide range of environments. Many of us do "field work" at least part of the year. This involves going to different locations, like near a fault or a volcano, and making measurements or taking samples.

For me, the best part is that I know the work I do will help us better understand the earthquake cycle and the hazards from large earthquakes.



Precise measurements using this GPS instrument help Dr. Jessica Murray monitor the motion of active faults.

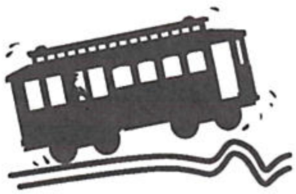
By Dr. Jessica Murray

U.S. Geological Survey
Earthquake Hazards Team

Newspaper Activity: Dr. Murray describes why she is a geophysicist and what a geophysicist does. Look through today's Chronicle for articles mentioning different jobs and classified job listings for jobs that you might like to have. Write a paragraph about each of the jobs that interest you.

SAN FRANCISCO CHRONICLE IN EDUCATION

Related Resources:
http://www.earthscienceworld.org/careers/
http://earthquake.usgs.gov/4kids/become.html
http://education.usgs.gov/common/careers.htm



Earthquake Science—Feature 9 of 10

How do we make buildings and roads safer?

Bay Area residents and visitors observe gigantic construction projects along our roads and bridges each day. Many of these projects are "seismic retrofits." A retrofit is a change in design and construction so that there are improvements; seismic retrofit means changes are made to a structure to reduce or eliminate loss of life and property during an earthquake.

We retrofit buildings and roads that were built using older techniques with designs that are less safe. Generally, it is cheaper and less disruptive to retrofit before hand than try to repair a structure damaged by an earthquake.

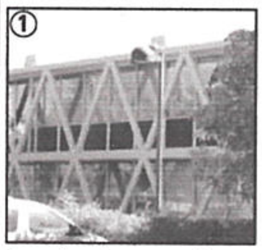
There are many ways a structure can be retrofitted, but two main ideas are most common. Sometimes, the best approach is to make a building stronger. Walls and foundations are designed to support the weight of the rest of the building pushing down on them. Earthquake shaking, however, pushes buildings side-to-side—a direction that they are not always designed to withstand. Shear walls and cross bracing (Pictures 1 and 2) provide strength and stiffness to resist future earthquakes. Shear walls can strengthen individual houses the same way they do for large buildings.

Another way to protect a building is to isolate it from the ground—a lot like adding shock absorbers to its foundation. The ground can move back and forth during shaking, but the building stays still (Pictures 3 and 4).

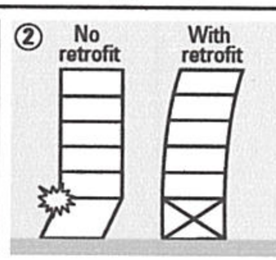
Because each building has unique architecture and a unique setting, there is a different retrofit solution that's right in each case. Earthquake engineers are people who come up with creative new ways to make these buildings safer than ever before.

By Dr. Mehmet Çelebi

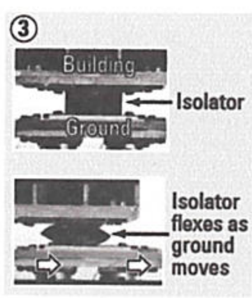
U.S. Geological Survey
Earthquake Hazards Team



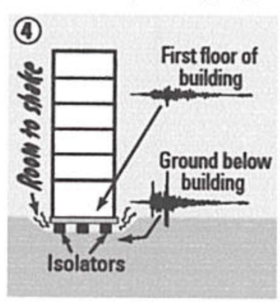
Cross-bracing strengthens the walls of this office building at the USGS in Menlo Park. Bracing can also be added inside walls.



During earth movement, even though the upper floors look fine (above left), the weak first floor could snap; strengthening it (above right) allows the whole building to flex gently.



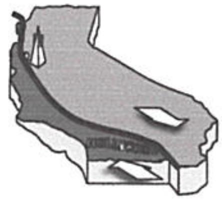
Base isolation allows the building to shake a lot less than the ground beneath it.



Engineers install instruments that record shaking to test if their retrofit designs worked.

SAN FRANCISCO CHRONICLE IN EDUCATION

Newspaper Activity: This feature uses photos and graphics so readers can visualize the information in the text. Read today's Chronicle to find an article without a photo or graphic. Draw a picture and write a caption to accompany the article you chose.



Earthquake Science—Feature 10 of 10

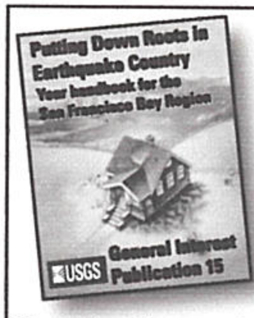
Putting Down Roots in Earthquake Country

If you live in the Bay Area, you live in earthquake country. Earthquakes have helped sculpt the Bay Area's natural beauty – from it's dramatic ocean shoreline to the steep slopes of the East Bay hills and Santa Cruz mountains. Slight curves and bends in plate boundary faults cause the peaks to grow as plates slide past one another.

Most of the time (when faults are locked tight), the mountains stay still. When an earthquake happens, the mountains rise suddenly in a dramatic growth spurt that may push them a few inches or a few feet higher. These violent events that shape our landscape make the Bay Area a beautiful place to live, but also pose a hazard to people living here.

Large, damaging earthquakes will likely strike the Bay Area during your lifetime. Building codes and innovative construction techniques make structures a lot safer in the Bay Area than in many other parts of the world, so we don't expect the next large earthquake to claim as many lives as the recent earthquakes in Asia. However, many buildings in the Bay Area were built before modern building codes. Depending on when your home was built, it may be a good candidate for a seismic retrofit.

Earthquakes may seem a little frightening, but you can do a lot to prepare yourself. Start by knowing what to expect: a major earthquake will have a huge impact. The power will go out as power stations are damaged, water may stop flowing as pipes break, some roads and bridges may be unusable, and phones may not function in your neighborhood.



Want to know how to make your family safer? Order a free earthquake preparedness handbook online:
http://pubs.usgs.gov/gip/2005/15

Being prepared for these events will make your family safer. The box to the right shows five quick and inexpensive things you can do now to get prepared.

By Dr. Matthew d'Alessio

U.S. Geological Survey
Earthquake Hazards Team

Try not to be scared of earthquakes – instead, be prepared!

1. Prevent things from falling on your head during earthquake shaking by moving heavy objects away from high places — especially above your bed or desk.

2. Create a family disaster plan. Discuss where you will meet, and don't expect to rely on phones (cell, landline, or Internet) to get in touch after a quake. It may be easier to reach a friend outside California, so know her phone number and have your family use her as a central contact point.

3. Create a disaster kit. Have enough food and water for the entire family for at least three days.

4. When you feel an earthquake, drop to the ground, take cover, and hold on. Shaking makes it hard to move around, so don't try to run.

5. After a quake, be ready to help others in your neighborhood.

SAN FRANCISCO CHRONICLE
IN EDUCATION

Newspaper Activity: Using the Weather Page of today's Chronicle, mark on the Bay Area map the locations of your family members during week days. Then determine a meeting location during a disaster. What form of transportation will your family members use to get there? How far will they travel?