I Feel the Earth Move Under My Feet

Activities Illustrating Why and How Earthquakes Occur
for Grades 3-6

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FOREWORD

On January 17, 1994, an earthquake of magnitude 6.8 struck southern California. During the weeks that followed, the earth continued to rock and roll with aftershocks. These events frightened many and reminded still more that the earth is alive.

Students and teachers alike sought information about what had happened and what might happen in the future . . . and why. The Minerals Management Service (MMS) responded to these queries with staff geologists visiting elementary schools and discussing the events of January 17 with the students and providing information about what causes earthquakes.

The geologists used a number of activities to illustrate the dynamic nature of the earth and the causes of earthquakes. These activities are provided in this booklet for you to use with your classes.

The MMS is the Federal agency responsible for the management of the Nation's offshore energy and nonenergy mineral resources and for collection and disbursement of revenues associated with mineral leases on Federal and Indian lands. Offshore California, the Federal Government jurisdiction extends seaward 3 miles from the coastline. Almost all the natural gas and oil operations one sees offshore Ventura County are in Federal waters and are thus managed by the Minerals Management Service.

As caretaker of the mineral resources on the Outer Continental Shelf (OCS), the MMS is committed to achieving a balance between the need to provide energy for the American people and the need to protect the unique and sensitive coastal and marine environments. The Pacific OCS Region Office, located in Camarillo, California, is responsible for meeting these goals for the entire west coast of the continental United States. To do this, we employ environmental scientists to study and assess the effects of offshore natural gas- and oil-related activities, geologists and geophysicists to evaluate potential locations of hydrocarbon resources, and engineers and geologists to ensure that the actual activities (such as drilling and producing the gas and oil) are designed and conducted in a safe and environmentally sound manner. Inspectors from the Pacific Region are offshore 365 days a year to inspect the facilities to ensure safe and pollution-free operations.

The MMS is pleased to act as a resource for educators and students in the region. Questions and requests should be directed to the Office of Public Affairs, (805) 389-7520.

ACKNOWLEDGMENTS

Staff and management at the Minerals Management Service's Pacific Outer Continental Shelf Region have been generous with their time and expertise in developing age-appropriate lectures following the 1994 Northridge Earthquake. The activities they have employed to communicate information about earthquakes are easy to execute and reproduce.

Special thanks to MMS staff geologists James Galloway, Allan Shareghi, Craig Ogawa, and Michael Brickey and to our seismologist, Dr. Ken Piper, for working with educators and students and for developing the material presented in this booklet. John Romero, Public Affairs Specialist, organized the classroom visitations where this information was presented by staff following the Northridge Earthquake, held the end of the slinky at times, and put together the Earthquake Planning Guide included in this booklet.

The Minerals Management Service also thanks the educators in Camarillo, Newbury Park, and Simi Valley who invited us into their classrooms and provided valuable feedback concerning the lessons and activities.

This booklet was prepared for the Ventura County *Earth Day 1994 Mini-Workshop for Teachers K-6* sponsored by the Ventura County Superintendent of Schools and the Ventura County Environmental and Energy Education Council. Our thanks to these sponsors for providing the Minerals Management Service an avenue to work with elementary school educators in providing information about geology and our area to Ventura County students.

EARTHQUAKES IN SOUTHERN CALIFORNIA

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AN OVERVIEW

Plate tectonics is the major culprit when it comes to earthquakes. The outer layer of the earth, the lithosphere, is made up of numerous, somewhat rigid, "tectonic plates" which are in constant motion relative to each other (figure 1). Along the boundaries of these plates (figure 2), depending on the relative motion, new lithospheric crust may be formed (divergent margin), older crust may be subducted under the surface (convergent margin), or the plates may slide past each other (transform margin). Most earthquakes occur in the vicinity of these plate boundaries. About 80 percent of all earthquakes occur within the circum-Pacific seismic belt, or "Pacific Ring of Fire," the latter name referring to the widespread occurrence of volcanoes around this same margin. Another 17 percent of earthquakes occur in a belt extending from Indonesia to Europe, and including the Himalayas and the Zagros Mountains of Iran.

California is located within the circum-Pacific seismic belt. The San Andreas fault (figure 3), probably the most famous and certainly the most studied fault in the world, extends along the western margin of the state from Cape Mendocino into the Salton trough. The San Andreas fault is a "transform fault"; that is, it is a transform margin where lithospheric plates are sliding past each other. However, the plate motion is not quite so simple as plates sliding past each other, and earthquakes are not confined to the San Andreas fault. The deformation and earthquake activity associated with the San Andreas transform margin is distributed over a wide part of the western United States and, in particular, over most of California.

A major complication to the plate boundary in southern California is the so-called "great bend" of the San Andreas fault. Because of the direction of relative plate motion and the orientation of the boundary in this region, the plates are obliquely converging, or pushing against each other. This has resulted in the uplift of the Transverse Ranges, which include the San Bernardino and San Gabriel Mountains, and the Western Transverse Ranges extending to Point Conception and including the northern Channel Islands. In this region, abundant reverse (often termed "thrust") faults occur, which allow the crust to be shoved upward and downward to accommodate the horizontal convergence. Most of the damaging earthquakes in the Los Angeles area have been due to faulting of this type.

The January 17, 1994, Northridge Earthquake was caused by movement along a reverse fault that was "previously unknown." That is, because it did not intersect the surface, it was unknown to the community of seismologists for whom the subsurface geology is largely unknown or inferred. Petroleum geologists often have a better knowledge of the subsurface geology. This is because of geophysical studies they conduct to identify prospective areas for petroleum development, and because they "see" into the rocks when they drill wells. This is why the seismologists at California Institute of Technology called upon former oil-company geologists to identify the fault or faults associated with this earthquake.

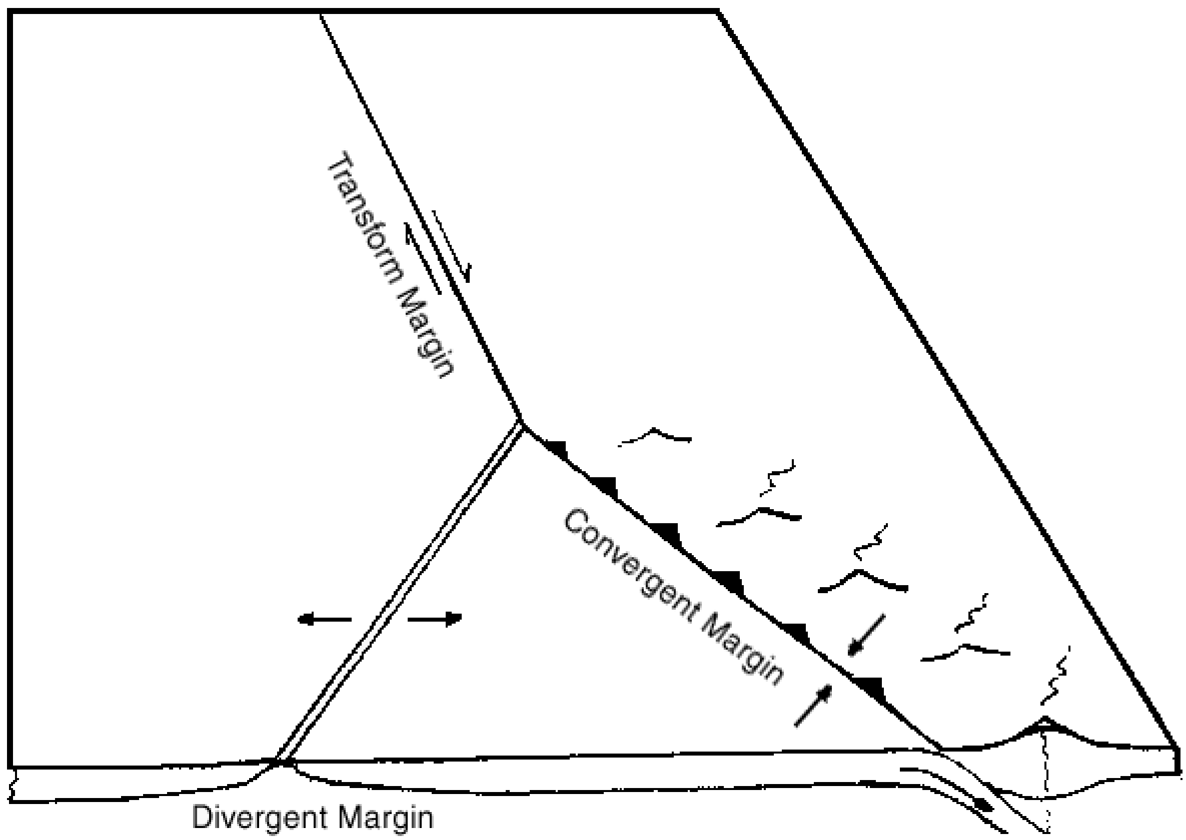


FIGURE 2

The Northridge Earthquake occurred on a south-dipping reverse fault under the San Fernando Valley. This fault was known by oil well information to be truncated by the north-dipping Santa Susana reverse fault (figure 4). Faults truncated in this manner were, until recently, thought by many geologists to be "locked" and therefore incapable of producing large earthquakes. The hypocenter (point of first rupture) occurred about 18 km (12 miles) below Reseda, the epicenter (the surface location directly above the hypocenter). The occurrence of the fault rupture surface further south and closer to the more populated areas explains the much more widespread damage within the Los Angeles area as compared to the 1971 San Fernando Earthquake. The 1971 epicenter was to the north, near the Antelope Valley Freeway. The near-surface displacement of the 1994 earthquake was west of that for the 1971 event, approximately along the trend of the Santa Susana Mountains.

Surface effects are dependent not only upon distance from the earthquake, but also upon near-surface geology. Oversteepened slopes, as result from roadcuts and "cut-and-fill" housing developments, often fail and result in landslides. And, obviously, fault rupture of the surface will cause damage beyond that of ground shaking. However, intensity of shaking is controlled more by the near-surface rock or soil type. Unconsolidated alluvium flooring the valleys shakes more intensely than rocks in the surrounding hills. Near-surface, water-saturated sediments occurring along the Los Angeles River in the southern San Fernando Valley shake even more and can be subject to soil liquefaction, whereby the soil becomes quicksand-like and buildings can sink or topple. These facts can help explain some of the heavily damaged areas in the southern San Fernando Valley and the Los Angeles basin.

Intensity and Magnitude Scales

Earthquakes are measured and described in two ways: intensity and magnitude. Intensity refers to the strength of earthquake ground motion at a particular location, and values are based on observable effects on man-made structures and the ground. Magnitude is determined by instrumental measurement and is proportional to an earthquake's energy and independent of the point of measurement.

The first intensity scale was developed in the 1850's by Robert Mallet as an attempt to measure the strength and distribution of ground motion resulting from an earthquake. The most commonly used modern intensity scale is called the Modified Mercalli Intensity Scale. It is normally displayed in Roman numerals ranging from I to XII. The intensity is measured by the destructive effects of an earthquake at a given location. With many measured locations, an intensity map can be made for a given earthquake. Because it measures how an earthquake was felt or the destruction to mostly man-made structures, the intensity depends on population and the type of construction.

In order for the magnitudes of earthquakes to be compared worldwide, a measure was needed that did not depend on the presence of people, structures, or type of structures. A strictly quantitative scale was originated in 1931 by Wadati in Japan and was developed by Charles Richter in 1935 in California. The idea was to use wave amplitudes as measured by seismographs. Because of the great variation in amplitudes, a logarithmic scale was developed. Richter originally defined the magnitude of a **local** earthquake as *the logarithm to base ten of the maximum seismic wave amplitude (in thousandths of a millimeter) recorded on a standard seismograph at a distance of 100 kilometers from the earthquake epicenter*. As the magnitude increases by one unit, the amplitude increases ten-fold. Over the years, variations on magnitude measurement have been developed to allow for measurements by different types of seismographs at varying distances from the event. Because of the various ways to measure magnitude, different recording stations will often give different measures of the magnitude of a given earthquake. Eventually, a **single** magnitude number is settled upon for a given event. (Table 1.)

MODIFIED MERCALLI SCALE

	Intensity	Description	Richter Scale Magnitude	Approximate Radius of Perceptibility
I	Instrumental	Detected only by seismology		
II	Feeble	Noticed only by sensitive people	3.5 to 4.2	2-15 Mi.
III	Slight	Like the vibrations due to a passing lorry (truck); felt by people at rest, especially on upper floors		
IV	Moderate	Felt by people while walking; rocking of loose objects; including standing vehicles	4.3 to 4.8	15-30 Mi.
V	Rather strong	Felt generally; most sleepers are awakened and bells ring		
VI	Strong	Trees sway and all suspended objects swing; damage by overturning and falling of loose objects	4.9 to 5.4	30-70 Mi.
VII	Very strong	General public alarm; walls crack; plaster falls	5.5 to 6.1	70-125 Mi.
VIII	Destructive	Car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed building damage	6.2 to 6.9	125-250 Mi.
IX	Ruinous	Some houses collapse where ground begins to crack/ pipes break open		
X	Disastrous	Ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes	7.0 to 7.3	250-450 Mi.
XI	Very disastrous	Few building remain standing; bridges destroyed; all services (railway, pipes, and cable) out of action; great landslides and floods	7.4 to 8.1	250-450 Mi.
XII	Catastrophic	Total destruction; objects thrown into air; ground rises and falls in waves	8.1 +	250-450 Mi.

TABLE 1

ACTIVITIES FOLDER

FOLDING, FAULTING, AND MOUNTAIN BUILDING

PLAY DOUGH DEMONSTRATION

Objective: Model layers of the Earth's crust and show how it becomes deformed by stress and strain.

Clay modeling has been used by geologists for more than a century to recreate earth processes in miniature. Clay models are particularly effective in demonstrating the processes of folding and faulting within the Earth's crust.

For precise and exact scientific modeling, the consistency, cohesion, and ductility of the clay are important factors. Readers are best referred to the technical literature (e.g. Sanford, A. R., 1959, "Analytical and experimental study of simple geologic structures," Bulletin of the Geological Society of America, Vol. 70, p. 19-52). However, to make static models which demonstrate the basic features of folding and faulting, commonly available products can be obtained inexpensively.

Materials: Play dough, 2 to 4 colors (available in 3 lb buckets)
Rolling pin
Knife
Wood blocks, 1" x 6" or 1" x 8" (best with one side beveled at a 45° angle)
Wax paper (optional)

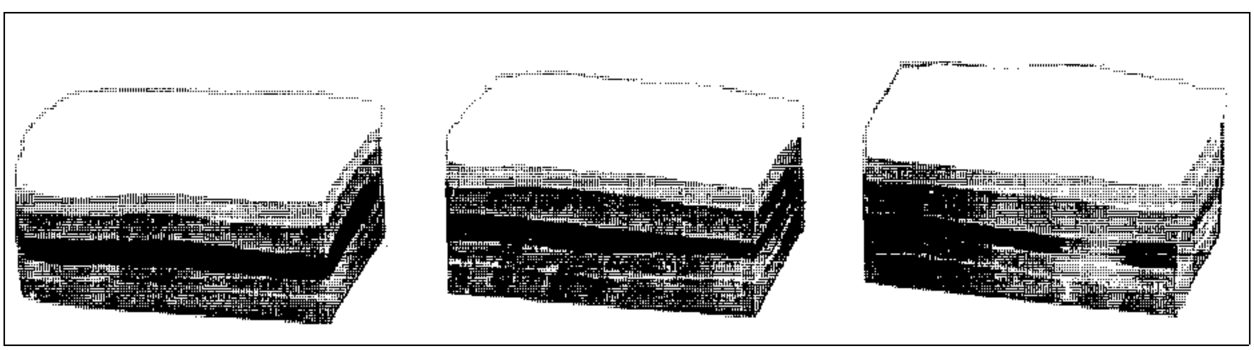
Procedure: To simulate strata within the Earth's crust:

1) Take a baseball-sized lump of play dough and roll flat into a pancake about ¼" to ½" thick.

2) Cut out a rectangular piece approximately 4" x 6" to 5" x 8" (the size of large postcards).

3) Repeat the process with as many colored layers as you have. If you only have a couple of colors, you can alternate. Try to make it at least 1½" thick.

4) Stack the layers one upon the other, optionally inserting wax paper for fold examples, cut to the same size as the play dough, between the layers.



You have now created a flat layered model of the Earth's crust. This model represented a part of the crust that has not been affected by geological forces, such a extension, compression, or translation. If you make three or four flat models, you can demonstrate the different processes without reworking the same material.

To show NORMAL faults:

1) Cut a plane with a 45° angle in your play dough, as show in the diagram below. (With Play Doh, a sharp, wet knife works best.)

2) Put the foot wall* block on a piece of wood, so that the hanging wall* block can drop to the table top. (If your wood block has a similar angle cut, so much the better.) Position so that the fault plane is evident in profile.

3) Notice the offset on the layered strata. Normal faults are caused when the Earth's crust is being stretched, or extended. They are often the result of extensional tectonics. The Basin and Range topography of eastern California and western Nevada, with fault-bounded high mountain and low valleys, is a good example of an area undergoing extension.

To show REVERSE or THRUST faults:

1) Same as above.

2) Lay the foot wall block down.

3) Turn the wood block base over so that it is in the hanging wall position and place it next to the foot wall.

4) Position the hanging wall block over the wood base so that the fault plane is apparent in profile.

5) Notice again the offset of the layers. Reverse faults are often formed in areas where the earth's crust is being compressed. Reverse faults, such as the Oakridge Fault or the San Cayetano Thrust, are common in Ventura County, where faulting, folding, and mountain building are active geologic processes.

* The terms "foot wall" and "hanging wall" are derived from mining terminology. In referring to NORMAL or REVERSE FAULT blocks, the foot wall and hanging wall always are in pairs. The easiest way to remember which one is which is to look at the REVERSE FAULT. The block which overhangs after movement is the hanging wall block; the other is the foot wall block. In a NORMAL FAULT, the down-dropped block is the hanging wall block. The foot wall block is the one where you could "stand on the plane of the fault," hence "foot wall." THRUST FAULTS are a special classification of low-angle reverse faults (see also "Types of Faults - Wooden Fault Models").

To show STRIKE-SLIP faults:

1) Lay a flat-layered block over two adjacent pieces of wood.

2) Cut the play dough layers vertically to coincide with the suture between the blocks.

3) To demonstrate strike-slip faulting, move the wooden blocks laterally along the suture. Don't separate the blocks - that's extension! Notice that the layers do not show any vertical separation.

4) Try this again with a twist. Make a deformed, or folded, play dough block. Give it some vertical relief like hills and valleys. Then repeat steps 1 through 3. Do you see offset valleys or ridges? That is one way to identify strike-slip faults from aerial photographs!

5) Can you think of any important strike-slip faults? If you said "San Andreas Fault" you are absolutely correct! The San Andreas Fault is certainly the most studied fault in the world.

To show FOLDING of the Earth's crust:

1) Starting with an undeformed, flat layered model, begin to compress the play dough compound along the long axis (the 6" to 8" direction). You can use your hands or the wooden blocks like a vise.

2) Deform slightly at first and notice how the play dough mass begins to thicken a little.

3) Continued pressure will cause the play dough to begin to "buckle." You will notice "highs" and "lows" begin to form. These are the folds. A concave downward fold is known as an "antiform" or "anticline." A concave upward fold is known as a "synform" or "syncline" (see figure 5).

4) If your modeling material is a little bit too dry, it may break rather than fold. What you have done instead is demonstrate faulting! Can you identify the type of fault by the stratal relationships? You may want to simply drape the clay over an object or two, such as a pencil. The important objective is to show the form of the fold.

Also, you might notice cracks in the top of the fold. These are tension gashes, rather than faults.

The folds demonstrated here are compressional features, much like those seen in the local mountains. But folds can form in extensional and translational regimes as well. Most folds are evidence of deformational forces working in the Earth's crust.

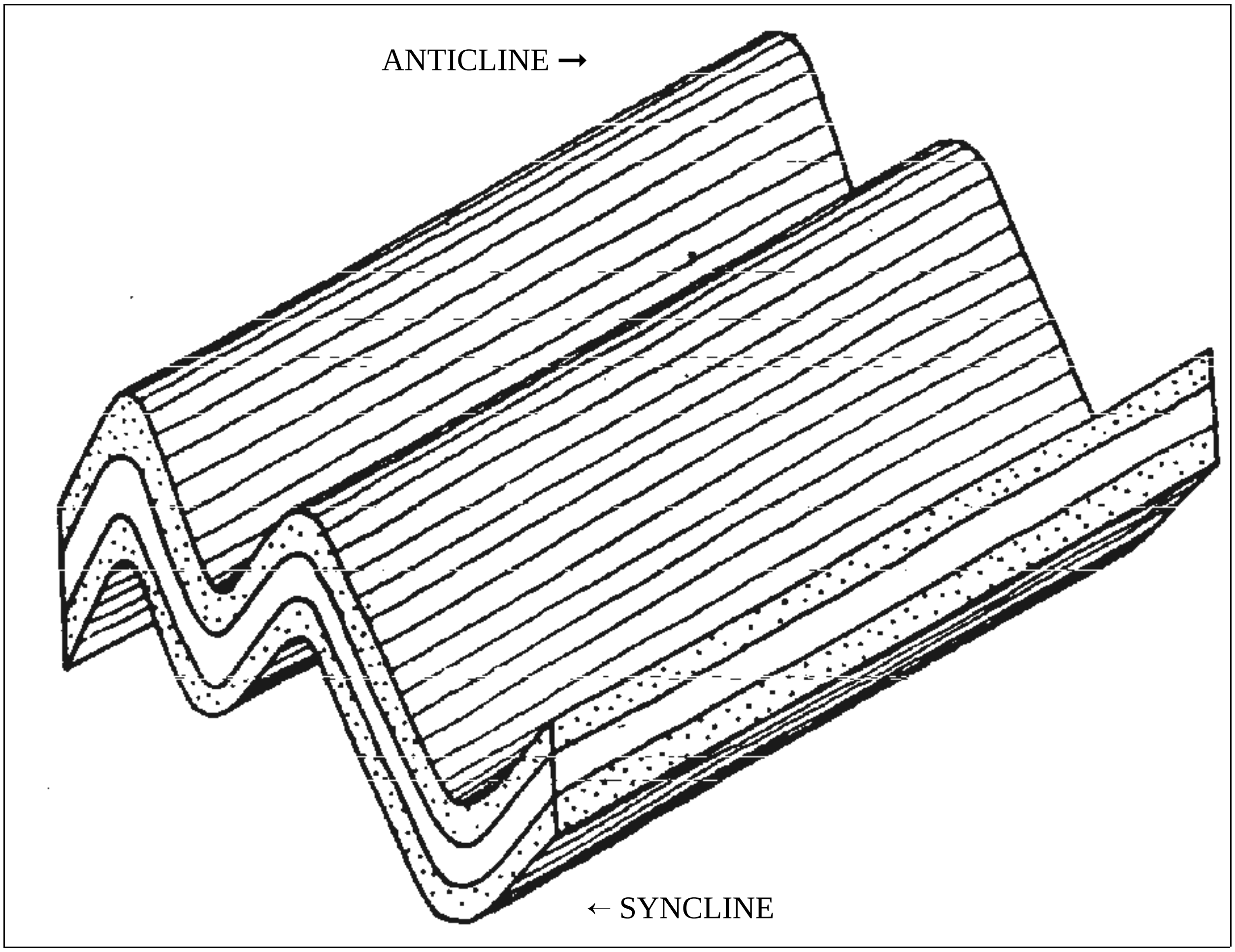
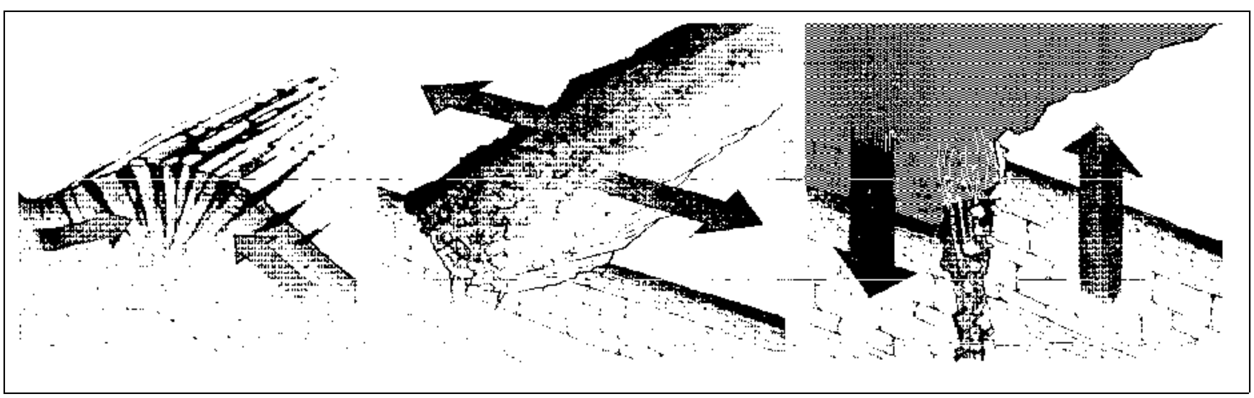


FIGURE 5



A COMPRESSION **B** TENSION **C** SHEAR

Questions:

1. Do folds cause faults, or do faults cause folds?

   Folding and faulting are both the result of stresses which exist throughout the earth. These are large-scale features in the crust. Whether a rock mass folds or faults depends on the physical properties of the rock material. Some material, although hardened into rock ("lithified"), remains somewhat "ductile" (plastic) and will, or is able to, deform without breaking. Other materials, when stressed, will react in a "brittle" manner, and break. The zone where the breakage, or failure, occurs is called a fault.

2. How big can folds become?

   Some folds in the Ventura County area are more than 4 miles wide and continue for over 50 miles. Big folds like these are often called "fold-trends" Other folds are small enough to be contained in hand-held rock samples.

3. Is it possible to fold a fold or a fault?

   Yes! As a matter of fact, there is a fold near Ojai, called the Matilija Overturn which has folded so much that the layers are now upside-down. Of course, this has taken millions of years to happen. Sometimes too, faults which have become dormant have been subsequently folded by new stresses.

4. Can faults change their location?

   Not really. Once a fault has formed that's where it will stay. A fault forms where there is a weakness in the rock mass. However, some faults form wide areas called "fault zones," in which only part of the zone is active at one time or another. It is also normal for changes in the stress field of the crust to cause a fault trace to be abandoned, and a new fault formed at another weak point. This is why some faults have become dormant and other faults show constant seismic activity.

5. Can more than one fault break during an earthquake?

   Yes. It is widely thought that this phenomenon occurred during the recent Northridge Earthquake. Scientists are studying this possibility from recorded seismic data. In fact, this type of earthquake may be more common than previously thought.

TYPES OF FAULTS

WOODEN FAULT MODELS

Objective: Dramatize movement along faults.

Material: Wood blocks cut at 30° to 45° angle.

Procedure:

1. Select a thick block of wood or several thin pieces of pine. If using layers of wood (to depict various layers of the Earth's surface), glue the layers together with a good carpenter's glue. Put weight on top of the wood, applying pressure to the glue. Let it sit overnight to dry.
2. Cut diagonally through the wood block at 30° to 45° angle.
3. After the cut is made, use a fine to medium sandpaper to smooth the blocks.
4. Paint the blocks to represent different layers of the Earth's crust.
5. Slide the blocks along the slanted surface to model (figure 6):
   - ☛ **a reverse fault (thrust fault);**
   - ☛ **a normal fault; and**
   - ☛ **a lateral fault (strike-slip fault)**

Questions:

1. How did you move the blocks to model each type of fault?

   Lateral fault (strike-slip fault): The hanging wall and the footwall move horizontally either to the right or left as the blocks are moved against one another side by side.

   Reverse fault (thrust fault): The hanging wall has moved upward relative to the footwall as the hanging wall block is moved upward.

   Normal fault: The hanging wall has moved downward compared to the footwall by dropping the hanging wall down.

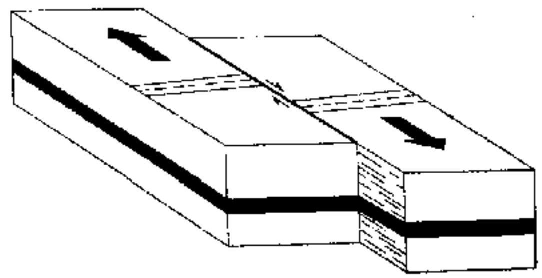
2. What forces cause the movement of the Earth along each fault?

   Strong shear forces can push one block sideways past the other (lateral or strike-slip fault). Strong compression forces can cause one block to push up over the other and produce a reverse (thrust) fault. A normal fault results from tension forces. These forces pull the block apart. Then, gravity pulls the hanging wall down along the fault.

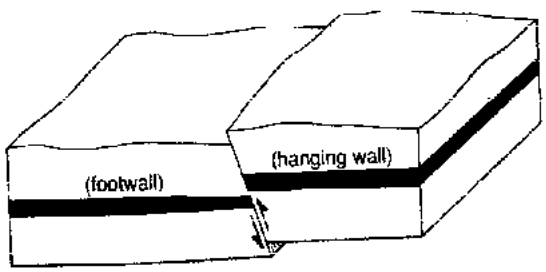
Strike-Slip Faults

The movement along a **strike-slip fault** is approximately parallel to the strike of the fault, meaning the rocks move past each other horizontally.

The San Andreas is a strike-slip fault that has displaced rocks hundreds of miles. As a result of horizontal movement along the fault, rocks of vastly different age and composition have been placed side by side. The San Andreas fault is a fault zone rather than a single fault, and movement may occur along any of the many fault surfaces in the zone. The surface effects of the San Andreas fault zone can be observed for over 600 miles (1,000 km).

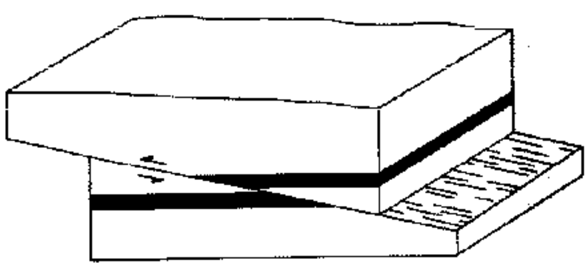


STRIKE-SLIP FAULT

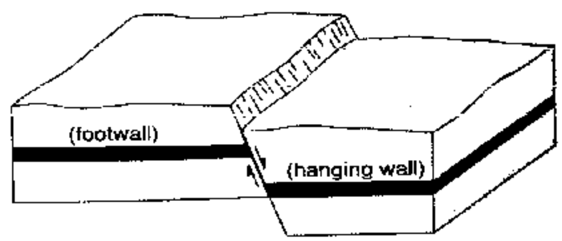


REVERSE FAULT

A **thrust fault** is a reverse fault with a gently-dipping fault surface. Thrust faults are very common in the Klamath Mountains of northern California.



THRUST FAULT



NORMAL FAULT

FIGURE 6

ROCKING AND ROLLING

SLINKY

Objective: Demonstrate P-WAVES and S-WAVES

The energy released in earthquakes is transmitted in the form of wave energy. Fundamentally, three types of waves are observed in any earthquake: compressional, shear, and surface waves.

Compressional waves can be transmitted through any medium (solid, semisolid, liquid, or gas). Sound waves, for instance, are compressional waves. The compressional wave released in an earthquake is called the "primary", or P-WAVE. It has the fastest velocity of the three types of waves, generally about 15,000 to 20,000 feet per second (5 kilometers per second), although velocity varies with the density of the medium. P-WAVES arrive first at the observer.

Shear waves, also called S-WAVES, can only propagate through a medium that has shear strength. Generally, that means a solid material. Shear waves travel somewhat slower than compressional waves in the same medium. Their velocity again varies with the density of the medium, and averages about 10,000 to 12,000 feet per second (or about 3 to 3½ kilometers per second).

Surface waves, sometimes referred to as L-WAVES, or "long waves," travel along the land-air or water-air interface. They result from refracted P-WAVE and S-WAVE energy, and can cause violent shaking; however, they also dissipate rapidly. Good examples of surface waves are those caused when one throws a pebble into a pond. The result of imparting energy at the surface of the water (as well as through the air and into the water) causes a ring of waves to expand outward from the impact point. This can be likened to the L-WAVES in the earthquake expanding from the epicenter.

Materials: Slinky, original metal type preferable
Flat desk or table top, about 3-5 feet long
Butcher paper, marking pen, masking tape (optional)

Procedure: This is a demonstration of P-WAVES and S-WAVES. Note that in the demonstration, a particular loop in the Slinky, which represents a particle in the Earth, does not travel very far as the wave propagates. Rather, the energy is transferred from particle to particle as the wave propagates.

1) Tape down butcher paper (white, glossy) on demonstration table, or floor.

2) Mark a loop by wrapping it with a small piece of tape.

3) Have two students stretch the Slinky out about 3 feet (1 meter) over the paper, firmly holding both ends.

4) Mark with pen on paper the location of the taped loop mark.

For P-WAVES:

5a) One student should "push", or cause a "pulse" to be sent straight through the Slinky toward the other student. (A few practices may be necessary.)

6a) Notice how the loops compress as the wave is propagated down the length of the Slinky. With enough force, you will also notice a reflected wave return. This also happens in real quakes!

For S-WAVES:

5b) One student should move his/her end of the Slinky in a back- and-forth motion, moving about 4-6 inches to the left or right, then returning to the original position.

6b) Notice the sine wave, or "S" shape of the wave as it propagates down the length of the Slinky. It, too, will reflect if enough force is imparted.

If you have optionally marked locations for a particular loop, have a student stand above the Slinky and watch to see the motion of the tape-mark. The student can then mark the farthest movement of the "particle" from its original location and see if it returns to the starting point. You can observe that the P-WAVE causes particle motion in the direction of the wave. The S-WAVE causes particles to travel "sideways," or normal, to the direction of the wave propagation.

Questions:

1. Can you tell how far away an earthquake was from you by using the arrival times of the P-WAVES and S-WAVES?

   By using the arrival times for the various wave types, as gauged at a number of seismograph stations, you can determine the epicenter of the earthquake and your distance from it. A good rule of thumb is at 20 miles distance, the P- and S-WAVES will be about 4 seconds apart.

2. What does it means when the P-WAVES and S-WAVES arrive at the observer almost together?

   It means you are very close to the epicenter.

3. How else can you use the waves to measure an earthquake?

   The amplitude of the waves, as measured on a seismograph, are used to determine the "Richter magnitude" of the quake.

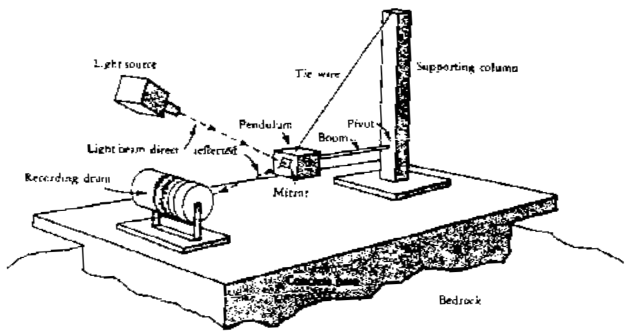
DELICATE INSTRUMENTS RECORD THE EARTH'S VIOLENCE

Any attempt to record earthquake movement is handicapped by the necessity of resting the measuring instrument (seismograph) on the very earth that is moving. Because the base must be anchored in rock, there is no way of setting up an instrument that can operate completely independent of earth movement. However, there are ways of establishing a steady mass that will remain *relatively* inert when the earth moves beneath it, thereby creating a significant, measurable difference between its motion and that of the earth. This mass is usually a pendulum. We are accustomed to watching a pendulum move while the earth is at rest; but in a seismograph, the opposite is true. The pendulum is suspended either vertically or horizontally as shown below. The weight is joined to a supporting pillar by only a wire and a boom resting in a universal joint, so that the delicately-suspended mass will tend to hold its original position even though the support vibrates considerably during an earthquake. Thus, even large earth movements result in only minute shifts of the pendulum.

These small movements must then be converted into a visible record. The recording device may be either a very sensitive pen that is attached directly to the pendulum, or a beam of light that is reflected off a mirror, as shown below. The recording medium is blank paper or, in the case of light beam recording, photographic paper that is attached to a rotating drum. Time segments are marked on the paper, so that the arrival time of the earthquake waves can be accurately pinpointed.

A seismograph of this type can record only one type of motion, at right angles to the length of the pendulum. So to obtain a truly accurate record, each recording station must have three seismographs—one each for north-south, east-west, and vertical motion.

Recent improvements in seismographs have made them more valuable in recording very weak motion, and in determining the exact nature and direction of the various wave forms. Most modern seismographs use an electrical pickup of pendulum movements, and transfer this current through a magnifying galvanometer. With this arrangement, slight motion can be magnified many times to make a more legible record.



The record written on a seismograph is called a seismogram. It is a continuous line that fluctuates according to the pendulum movements. The greater the earth movement, the greater the variation in the record. The degree of amplitude is the basis for assigning a Richter magnitude to the shock. The arrival time of the P, S and L waves enables seismologists to fix the distance between epicenter and the recording seismograph. By comparing the records taken at several different stations, the source of the waves can be accurately pinpointed in both direction and distance.

The seismogram shown below was taken at the University of California Seismographic Station in Berkeley. Source of the waves was an earthquake of magnitude 6½ that originated in the Aleutian Islands, 2,550 miles from Berkeley, shortly after noon on July 13, 1959.

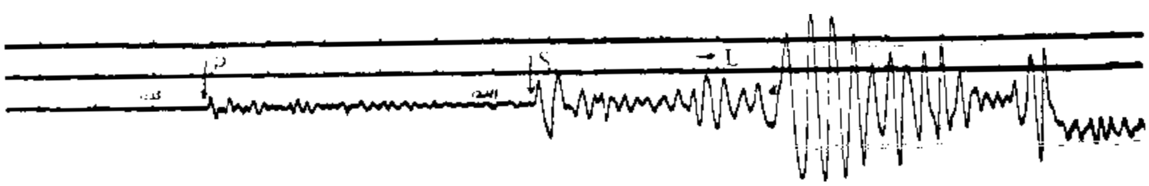


FIGURE 7

STRESS AND STRAIN IN THE EARTH'S CRUST

HANDS

Objective: Demonstrate the great pressures inside of the earth and how difficult it is to move blocks of the crust.

This demonstration is more appropriate for grade three and younger. The concept that earthquakes begin at great depths, and at those depths tremendous pressures exist, is often difficult for younger students to grasp.

The most recent data available suggests that the hypocenter (the hypothetical starting point of the earthquake, which is directly below a point on the surface known as the epicenter) for the Northridge Earthquake was at a depth of greater than 55,000 feet. The 1987 Whittier quake had a hypocenter of about 35,000 feet.

The hypocenter is sometimes called the focus. Occasionally, the terms "deep focus" or "shallow focus" will appear in the newspapers or in quotations. These terms refer to the level in the crust where the quake originated. Deep focus quakes (greater than 200 miles, or 300 kilometers, beneath the surface) occur in places where crustal material is being subducted beneath continental crust, such as beneath the Andes Mountains. Recent southern California earthquakes have been of the shallow focus variety because they have occurred shallower than depths of 60 miles, or 100 kilometers.

Materials: Just two hands

Procedure: This demonstration is best when the students hands are not sweaty from recess or lunch break.

1) Place hands together, flat with fingers closed, in front of body (much like a unclasped prayer position).

2) Push hands tightly together with as much strength as the student can muster.

3) While pushing hard together, ask student to try to move one hand over the other, still pushing all the time.

4) With dry hands this should result in a jerky, grating movement between the hands. Sometimes, too, the hands will suddenly release.

What have we demonstrated here? The analogy to the crust of the earth is this: Deep within the crust great pressures exist on the rocks. Tremendous stresses build up as the crustal blocks collide or try to shift past each other. Each hand in the demonstration represents a crustal block.

When the forces become great enough, movement of the blocks can no longer be contained by internal deformation. Therefore, some sort of translation along a weak boundary takes place. That is the fault, which is represented by the "boundary" between the hands. That is where the blocks (hands) are offset.

Does the movement (earthquake) take place smoothly, or do the blocks (hands) shake, grind, and shutter? In most cases the simulated earthquake is a shaky one. But there also exists a natural phenomenon call fault creep. The best example of that occurs in the Hollister, CA, area (near the San Juan Bautista Mission). There, the San Andreas Fault exhibits small, almost continuous movement. Roads, homes, fences, etc., which cross the fault show clear offset over the course of many years.

Questions:

1. How many earthquakes are there in southern California on an average day?

   There are about 20-30 measurable earthquakes epicentered in southern California on a normal day. But after a significant earthquake, there can be hundreds of quakes, most of which are aftershocks to a larger recent quake. Sometimes, activity can continue for years afterward.

2. How many earthquakes like the Northridge quake happen in the world each year?

   Statistical studies of past quakes indicate that in an average year there will be about 120 quakes in the Richter magnitude range of 6.0 - 6.9. These are classified as "destructive quakes." There will be about 20 "major earthquakes" of a range between 7.0 - 7.9. There will also be 1 "great quake" of 8.0 or greater.

3. What is the likelihood of a "great quake" in southern California anytime soon?

   Studies of the San Andreas Fault suggest that there is about a 50% probability of a great quake within the next 30 years. The last great quake in this area happened in 1857. The last destructive quakes occurred in 1992 (Landers, 7.2) and 1952 (Kern County, 7.7).

   However, other smaller faults, both known and unknown, can cause significant damage locally with less than a 7.0 magnitude, as we have recently experienced.

4. What can we do in the event of another quake?

Earthquake preparedness should be a part of life for California residents. Included in this manual is an abbreviated listing of some things to consider. You are strongly advised to consult the "Earthquake Survival Guide" in the front of your telephone book. Also, literature is available from various organizations such as the American Red Cross and your local governments.

SOURCES
AND
SELECTED REFERENCES

SOURCES/SELECTED REFERENCES

The following resources are easily accessible to answer questions about earthquakes.

1. Scientific American, published monthly.

2. California Geology, published bimonthly by the California Department of Conservation, Division of Mines and Geology. Some issues contain "Teacher Features." A subscription costs $28 for 3 years. Back issues can be ordered for $2 each.

3. The U.S. Geological Survey has published a series of four pamphlets on earthquakes: Safety and Survival in an Earthquake (prepared jointly with the Office of Emergency Preparedness), Earthquakes, The San Andreas Fault, and Active Faults of California. These pamphlets, written in non-technical language, are available free upon request from U.S. Geological Survey, Washington, D.C. 20242.

4. Bolt, Bruce A. Earthquakes, revised and updated. New York, W.H. Freeman and Company, 1988.

5. Yanev, Peter I. Peace of Mind in Earthquake Country. San Francisco, Chronicle Books, 1991.

6. Earthquake Sounds. A tape cassette containing sounds recorded in various earthquakes is available with catalog (by K.V. Steinbrugge) for $13 from:

   Seismological Society of America
   6431 Fairmont Avenue, Suite 7
   El Cerrito, CA 94530.

7. The National Geophysical Data Center in Boulder, CO has slide sets of different geologic hazards such as earthquakes, volcanoes, and landslides. The slides cost $30-$40 per set. They can be ordered from:

   National Geophysical Data Center
   325 North Broadway
   E/GC1, Department 897
   Boulder, CO 80303-3328
   (303) 497-6277 or 497-6419

8. Local geological societies, such as the Coast Geological Society, may be able to provide assistance.

9. Some Automobile Association of America (AAA) maps show the San Andreas Fault Zone.

10. "Southern California from 438 Miles in Space." A satellite map (36" x 24") of southern California that identifies the San Andreas and many other faults in the area. The map costs $15 for a paper copy or $20 for a laminated version. They can be ordered from:

    Piedmont Pacific Trade Corporation
    76 Lakeview Avenue
    Piedmont, CA 94611
    (800) 398-0126

EARTHQUAKE PLANNING GUIDE

WHY SHOULD WE THINK ABOUT EARTHQUAKE PREPAREDNESS?

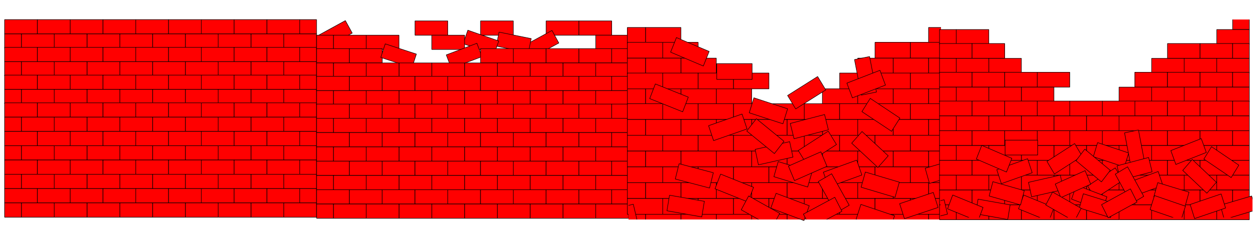
Disasters are a natural occurrence that often come without warning. Each year, people all over the world find themselves affected by such adverse events and the emergency situations that immediately follow. Preparedness for such anticipated disasters is a vital key to enhancing one's chances for survival.

The recent Northridge Earthquake and its many aftershocks have reminded southern California residents of the importance of being prepared. Many southland residents found themselves affected by the earthquake both during and after the initial shock occurred. From bracing oneself and riding out the shaking to coping with subsequent power outages and freeway snafus, the need for careful emergency planning is essential for quick decisive response measures and ensured survival.

Some people may feel uncomfortable thinking about potential earthquakes. These feelings of anxiety are normal. However, earthquakes themselves are seldom responsible for actual deaths or injuries. Most casualties are the result of falling objects, debris, or partially-collapsed structures.

Through active planning for future seismic activity, some levels of apprehension may actually decrease. Moreover, when an earthquake hits again, this preparation will serve as a conditioned response to assist in controlling panic reactions and promoting sound decision-making to strengthen one's chances for survival.

The Minerals Management Service Pacific OCS Region has compiled the following information and safety tips to assist you and your students in a quest toward understanding and living with California's rockin' and rollin' through strong earthquake preparedness.



DURING THE ROCKIN' AND A ROLLIN', HOLD ON TIGHT, AND REMEMBER THESE THREE SAFETY TIPS

1. DUCK — Duck or drop to the ground.

2. COVER — Get under a sturdy table, desk, or other piece of furniture. If this is not available, seek cover under a door jamb or against an interior wall. (Do not place your fingers between the door and the jamb!) Clasp your hands behind your neck, and cover your head with your arms. Stay clear of windows, shelving units, and hanging objects.

3. HOLD — If you find cover under a piece of furniture, hold on to it to brace yourself until the shaking stops.

NEVER RUN OUTSIDE DURING AN EARTHQUAKE! The greatest danger during an earthquake is from falling objects, particularly just outside doorways and along the outer walls of buildings. If you must exit a building during an earthquake, proceed with extreme caution.

IF YOU ARE OUTSIDE DURING AN EARTHQUAKE, STAY THERE! Be sure to stay clear of buildings, power lines, trees, lamp posts, and other objects that could potentially fall on you.

IF YOU ARE IN A CAR, STOP AS QUICKLY AS POSSIBLE AND STAY IN YOUR CAR! Be sure to stop your car away from highway overpasses, road signs, lamp posts, power lines, and other objects that could potentially fall on you.

ALWAYS REMEMBER TO REMAIN CALM DURING AN EARTHQUAKE . . .
AND TO DUCK, COVER, AND HOLD!

After the Ground Stops Grumblin', Stay Calm, and Remember These Safety Tips

1. DON'T PANIC - Try to relax and think about what to do next. If you are inside, carefully look around your immediate area for potential hazards like broken glass and damaged utility lines.

2. PUT ON HEAVY SHOES - Be sure you are wearing sturdy, thick soled shoes before you walk around. Most of the injuries sustained from the recent Northridge quake were the result of people stepping barefoot on broken glass!

4. USE FLASHLIGHTS INSTEAD OF CANDLES - Be sure to keep a working flashlight readily available for emergencies. Never light a candle immediately after an earthquake until you gauge damages to gas lines.

3. CHECK UTILITY LINES - If electrical outlets are sparking or smoking, immediately turn the power off at the main control panel and contact a professional to assess the damage. The same applies to gas lines. If you hear hissing and/or smell gas around your appliances, immediately shut the gas off at the gas meter, and contact the gas company for assistance.

4. LISTEN FOR DISASTER INSTRUCTIONS ON BATTERY-OPERATED RADIO - Since power outages often occur after an earthquake, be sure to maintain a working battery-operated radio for damage updates and disaster instructions.

5. USE YOUR PHONE ONLY IN EXTREME EMERGENCIES - After an earthquake a heavy burden will be placed upon phone lines in the affected areas. While some phone lines may be down, other must be kept open for reporting of emergency situations. Designate an out-of-state contact, if possible, to serve as your primary information point. This individual can relay information from you to friends and family without drawing upon telephone lines in quake-affected areas.

6. STAY HOME - If you are home when an earthquake hits, stay there. Do not go sightseeing outdoors as there will still be many hazards lurking shortly after the initial quake. If you are in school, the teacher should give clear instructions to the students.

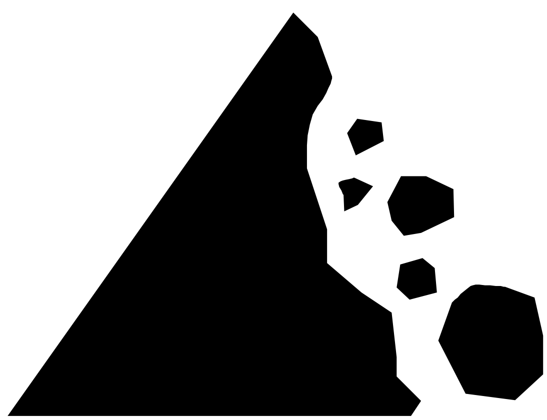
7. BE PREPARED FOR AFTERSHOCKS - Although aftershocks are smaller than the initial quake, they can still cause additional damage and perpetuate high levels of anxiety. Be sure to attend to frightened family members, particularly children and pets!

Earthquake Preparedness doesn't stop after the initial quake . . .
stay calm, assess the situation, and act sensibly.

DON'T LET THE RUMBLING CATCH YOU OFF GUARD, DRAFT YOUR OWN EARTHQUAKE PREPAREDNESS PLAN!

Reinforce earthquake preparedness by developing an individualized preparedness plan. Sit down with family members and develop an emergency plan to identify supplies, escape routes, and designated meeting areas. Once completed, be sure to rehearse the plan and update it every 6 months. A well-rehearsed plan will ensure that you'll keep your balance throughout the rockin' and a rollin'.

- ☐ SKETCH A FLOOR PLAN OF YOUR HOME.
- ☐ IDENTIFY TWO WAYS TO EXIT EACH ROOM.
- ☐ DESIGNATE INDOOR AND OUTDOOR EMERGENCY MEETING AREAS.
- ☐ IDENTIFY WHERE EMERGENCY FOOD/WATER RATIONS, AND FIRST AID KITS ARE STORED.
- ☐ IDENTIFY EXISTING HOUSEHOLD HAZARDS AND DESIGNATE A FAMILY MEMBER TO ADDRESS THE DANGER.
- ☐ IDENTIFY WHERE TO TURN OFF GAS, WATER, AND ELECTRICITY.



YOU CAN EVEN DRAFT AN EARTHQUAKE PREPAREDNESS PLAN WITH YOUR CLASS AT SCHOOL!

DON'T BE LEFT HELPLESS AND HUNGRY AFTER THE SHAKIN', PUT TOGETHER AN EARTHQUAKE SURVIVAL KIT!

After a major earthquake, household utilities may be interrupted and medical services delayed. Therefore, it is important to maintain an emergency supply of food, water, and first aid supplies to secure your safety and well-being until help arrives and/or power is restored. Here are some suggestions on what to include in your earthquake survival kit:

☐ **FOOD** - In your kit, maintain at least a 72 hour supply of non-perishable foods, such as: canned or dehydrated foods, canned juices, dried cereals, and unsalted nuts. **Be sure to include eating utensils and a non-electric can opener with your food supply!**

☐ **WATER** - In your kit, keep at least 3 gallons of bottled water for each person sharing the survival kit. Also include some water purification tablets and/or liquid chlorine bleach for use in disinfecting water.

Amount of Water	Amount of Chlorine to Add to Clear Water	Amount of Chlorine to Add to Cloudy Water
1 Quart	2 Drops	4 Drops
1 Gallon	8 Drops	16 Drops
5 Gallons	½ Teaspoon	1 Teaspoon

☐ **FIRST AID KIT** - Be sure to include basic first aid materials and an instruction booklet in your survival kit. You may even want to enroll now in basic first aid and CPR training to become better prepared. Also, remember to include any special medication or other medical items, such as eyeglasses, that you may need!

☐ **OTHER IMPORTANT ITEMS INCLUDE**:

- ☐ Flashlights with spare batteries
- ☐ Portable radio with spare batteries
- ☐ Pipe wrench for turning off gas and water valves
- ☐ Fire extinguisher
- ☐ Sanitation supplies, such as: toilet paper, plastic bags and twist ties, toothbrush/toothpaste, soap, shampoo, deodorant, etc.

BE SURE TO CHECK OVER ITEMS IN YOUR SURVIVAL KIT EVERY SEVERAL MONTHS,
ENSURE ITEMS ARE FRESH AND IN WORKING ORDER!

BEFORE THE EARTH STARTS A SWAYIN', IDENTIFY SOME EARTHQUAKE PREPAREDNESS RESOURCES!

Strengthen your preparedness efforts by keeping well-informed on emergency procedures. The following resources can provide you and your students with further information on earthquake preparedness.

1. YOUR LOCAL TELEPHONE BOOK - The **Emergency Procedures Section** is devoted entirely to earthquake preparedness!

2. VENTURA COUNTY FIRE DEPARTMENT
   EMERGENCY/MEDICAL SERVICES
   165 Durley Avenue
   Camarillo, CA 93010
   (805) 389-9777

3. VENTURA COUNTY SHERIFF'S DEPARTMENT
   DISASTER/EMERGENCY SERVICES
   800 S. Victoria Avenue
   Ventura, CA 93003
   (805) 654-2551

4. AMERICAN RED CROSS
   VENTURA COUNTY CHAPTER
   868 East Santa Clara
   Ventura, CA 93001
   (805) 643-9928

5. U.S. GEOLOGICAL SURVEY
   EARTH SCIENCE INFORMATION CENTER
   343 Middlefield Road
   Menlo Park, CA 94025
   (415) 329-4353

6. LAFFERTY & ASSOCIATES, INC.
   P.O. Box 1026
   La Canada, CA 91012
   (818) 952-5483
   Lafferty & Associates is a private consulting firm that produces various teaching aids on earthquake preparedness.

REMEMBER TWO STRATEGIES WHEN PURSUING YOUR PREPAREDNESS EFFORTS:

1. **KEEP INFORMED**

AND

2. **PREPARE NOW!**