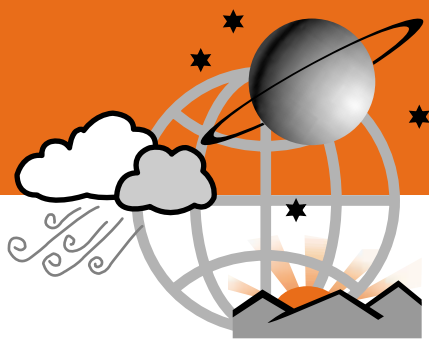

# Chapter 9
# Geologic Hazards

## WHAT IS A GEOLOGIC HAZARD?

People who live near the coast of southern California enjoy a location with mild temperatures and beautiful mountain scenery. The climate is usually dry, but rain and snow in mountains to the east provide freshwater and recreational opportunities. However, other aspects of life in California are not as favorable. If it rains hard, there can be flooding and landslides. This is because the mountains are young with steep, unstable slopes. In addition, the dry summer climate results in relatively few plants to hold back surface water and keep soil in place. This area also has more destructive earthquakes than any other part of the United States except Alaska.

Most residents of this part of California do not realize that the mild climate and mountain scenery are a result of active geological forces. The mild climate is enhanced by winds off the ocean that are stopped by mountain barriers. The San Andreas Fault and other faults along which earthquakes occur are responsible for the mountains. If it were not for earthquakes, the mountains would not be there. If it were not for the mountains, the climate would not be as mild. It all relates to geology.

Most geologic events, such as uplift, weathering, and erosion, take place over a long period of time. Such slow events are seldom a danger to people. But, some geologic changes happen quickly, such as earthquakes, volcanic eruptions, landslides, and avalanches. These rapid changes can cause hazards to humans. A **hazard** is an event that places people in danger of injury, loss of life, or property damage.

## Earthquakes

Some locations have more earthquakes than others. (See Figure 9-1.) The interaction between Earth's lithospheric plates makes plate boundaries the most active zones of change. Within the continental United States, our only plate boundary is the western edge of the North American Plate. The boundary between the Pacific and North American plates runs through California and then off the Pacific coast from Oregon to Alaska. Large earthquakes also can occur within the plates in places where the continental plates seem to be breaking apart. Two of the strongest seismic events in American history took place in the nineteenth century, one in Missouri and the other in South Carolina. Although large earthquakes are most common at plate boundaries, it appears that earthquakes can happen almost anywhere.

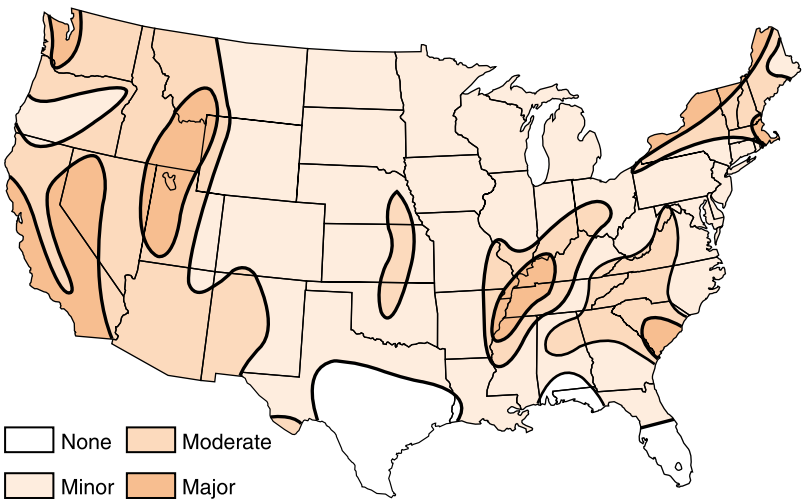


**Figure 9-1** Most predictions of earthquake hazards are based on historical records. Although earthquakes are less common in the central and eastern United States than they are along the Pacific Coast, there have been major earthquakes in all three regions.

It is helpful to realize that when seismic waves pass from solid rock into loose sediment, the shaking is intensified. A major earthquake in Mexico in 1985 did more damage in Mexico City than in Acapulco, even though Acapulco was closer to the epicenter. Acapulco is built on or close to solid rock. On the other hand, Mexico City is built on sediments of an ancient lake bed. Not only do thick sediments amplify the shaking of an earthquake, they also provide a less secure foundation on which to construct large buildings.

Seismologists sometimes say, that Earthquakes do not kill people, buildings do. People are rarely hurt by motion of the ground. The collapse of buildings is the major cause of death and injury in most earthquakes. This is especially true if the buildings have no reinforcement to hold them together. Adobe is a building material made by mixing mud with straw, placing the mixture into molds to form blocks, and drying the blocks in the sun. Adobe blocks are stacked to make walls of the house and wooden rafters are placed across the tops of the walls to support a roof. This is a common form of construction in some third-world countries. Most adobe homes do not have any frame to hold the bricks together. Adobe structures are reasonably good at withstanding vertical motion, but horizontal motion can cause the walls and roof to collapse on anyone unfortunate enough to be inside. Wood frame houses are among the best buildings at withstanding earthquakes. In this kind of house, walls are held in place by adjoining walls. The foundation, floors, walls, and roof of the home can be secured with bolts. Wood frame structures absorb energy by bending and can still go back into their original shape. Steel frame buildings are also good absorbers of ground motion.

Fires often follow earthquakes in populated areas. The fire that followed the San Francisco earthquake of 1906 caused far more damage than was caused by the collapse of structures. The ground broke and shifted as much as 6 meters, causing gas lines to rupture. Damaged and sparking electrical lines ignited the highly flammable natural gas escaping from broken gas lines. Water pipes, which could have provided water to fight fires, were also broken, making it impossible to save burning buildings. The fire burned for several days, destroying most of the city.

Fortunately, builders have learned from their mistakes. Events in San Francisco and other cities that have experienced major earthquakes have helped engineers understand how to avoid damage. When the Alaska oil pipeline was constructed in the 1970s, special bends and joints were added where the pipeline crosses known fault lines. Should an earthquake occur causing movement along the fault, these bends should prevent the pipeline from breaking.

Earthquakes can also trigger ground failure. Near Anchorage, Alaska, 75 houses were lost in the 1964 earthquake. The houses were part of a development built on a high bluff of sediment overlooking an arm of the ocean. Shaking caused the sediments and the houses built on them to loosen and then collapse into the bay.

Sediments that hold groundwater pose another hazard. Saturated sediments can turn into a material like quicksand in a process known as **liquefaction**. This is caused by strong shaking that allows water to surround the particles of sediment, changing the sediment into a material with properties of a thick fluid. Buildings can sink where the ground is weakened by liquefaction.

Dam failure is also a hazard associated with earthquakes. The shaking of the ground or a landslide can break dams. If a reservoir of water is held back by the dam, people who live downstream will be in danger from flooding. Table 9-1 lists some of the world's greatest earthquakes as well as nearby seismic events.

Earthquakes sometimes cause a giant series of waves called a **tsunami** (sue-NAHM-ee). Although tsunamis are sometimes called tidal waves, these waves have nothing to do with the twice-daily rise and fall of ocean tides. That is why scientists prefer to use tsunami, a Japanese term that means harbor wave. The most destructive tsunamis are probably caused by a sudden motion of the ocean bottom or an underwater landslide released by an earthquake. In the open ocean, tsunamis may travel 1000 km/hr as a gentle swell that would be hard to notice on board a ship. At this speed, a tsunami can cross a major ocean in a few hours. When a tsunami moves into an open but shallow bay, its energy becomes more concentrated and the water can build high waves. Some tsunamis

**TABLE 9-1. Selected Historic Seismic Events**

| Location | Date | Magnitude | Notes |
|---|---|---|---|
| Shensi, China | 1556 | Unknown | Worst natural disaster known; 830,000 deaths. |
| New Madrid, MO | 1812 | ~8 (est.) | Few deaths due to sparse settlement. Flow of Mississippi River briefly reversed. |
| San Francisco, CA | 1906 | ~8.3 (est.) | Most damage caused by uncontrolled fires. Water lines broken. |
| Massena, NY | 1944 | ~6 (est.) | Largest in NY state. Chimneys destroyed; water lines broken. |
| Lebu, Chile | 1960 | 9.6 | Largest event measured with seismographs. Occurred in the Pacific Ocean. |
| Anchorage, AK | 1964 | 9.3 | Extensive tsunami. Damage to buildings extensive; 131 deaths. |
| Haicheng, China | 1975 | 7.5 | Predicted by scientists. City evacuated; only ~130 deaths. |
| Tengshan, China | 1976 | 7.6 | Prediction failed. Worst modern natural disaster; ~650,000 deaths. |
| Mexico City, Mexico | 1985 | 8.1 | Worst damage in city far from epicenter that was built on fill; ~9,000 deaths. |
| North Ridge, CA | 1994 | 6.7 | $10 billion in damages; 61 deaths. |
| Kobe, Japan | 1995 | 7.2 | Destroyed the port built on landfill; 5,500 deaths |
| Izmit, Turkey | 1999 | 7.4 | More than 12,000 dead and 34,000 injured. Lateral offsets of 2.5 m (9 feet). Largest event in a modern, industrialized area since San Francisco quake in 1906 and Tokyo quake in 1923. |
| Au Sable Forks, NY | 2002 | 5.1 | Felt throughout NY state. Caused damage to local roads. |

grow to 10 to 20 meters high, sometimes higher. These waves may appear first as a giant wave or as a sudden drop in sea level. People have been drawn to the shore by the sudden withdrawal of the sea. They may not realize that they are observing a sign that a giant wave is coming that could sweep them away. Tsunamis are rare, but they cause great damage and loss of life in coastal locations. The city of Hilo in Hawaii has experienced several destructive tsunamis. The United

States now has a tsunami early warning system to alert people who live in coastal areas of approaching danger.

## Earthquake Preparedness

Reducing the risk of injury or loss of property is especially important in places that have a history of damaging earthquakes. There are things people can do to prevent injuries and property loss. The following measures can be split into two categories: preparing for an earthquake and what to do during an earthquake. The following are examples of advanced preparations.

- Select a home built on or close to solid bedrock.
- Select a homesite that is not near a steep hill, open and shallow bay of the ocean, or downstream from a reservoir.
- Be sure your home meets local building codes.
- Know how to shut off gas, electricity, and water.
- Avoid storing heavy objects on high shelves.
- Store some food and freshwater in your home, as well as a battery-operated radio.
- Keep emergency telephone numbers in handy locations.
- Know where to find medical supplies and the location of the nearest doctor or hospital.
- Learn how to help any family member with special needs.
- Plan and rehearse what to do in case of an earthquake.

After a major earthquake, your help may be needed.

- Assist official emergency services as requested, but do not get in their way.
- Until help arrives, respond to the needs of people who are injured.

- Prevent further injuries by identifying unsafe structures, broken objects, chemical spills, and similar hazards.
- If possible, turn off gas, water, and electric supplies.
- Listen to the radio for information and instructions.
- Find safe shelter, undamaged food supplies, and clean water.

In a strong earthquake, your best protection depends on where you are. If you are outside, it is best to stay away from buildings or trees, since they may fall. If you are in a building, the best protection is probably under a strong object, such as a desk or a table, that can protect you from falling debris. Doorways are also good places in which to stay because the walls might be able to protect you if the ceiling collapses. While it would probably be safer to be outside, you may not have time to reach an exit before the earthquake is over. Most earthquakes last less than a minute. Do not use an elevator to leave a building during or after an earthquake. Elevators can be damaged by the original event or by aftershocks, trapping people inside. Stairways are a safer way to leave. Remember that aftershocks often occur following a major earthquake.

## ACTIVITY 9-1 DEVISING AN EARTHQUAKE PREPAREDNESS PLAN

Work with your family or classmates to devise an emergency plan to use in the event of a damaging earthquake. Brainstorm with them to take into account unique characteristics of where you live and the needs of people around you. Create a list of things you can change to make your home more earthquake-safe.

**PREDICTING EARTHQUAKES** There have been many attempts to predict earthquakes. Such signs as bulging of the ground, unexplained changes in the water levels in wells, or even unusual animal behavior have been used to predict seismic

events. Places along major faults that have not experienced ground movement as often as surrounding areas are considered likely places for future earthquakes. For example, seismologists might be able to predict that over the next 20 years there is a 60 percent chance of a magnitude 7 earthquake along a particular part of the San Andreas Fault.

Chinese scientists predicted a major earthquake and evacuated the city of Haicheng in 1975. A large earthquake did occur at that time and the death toll was remarkably light. However, a year later they missed a larger earthquake in the city of Tengshan where more than half a million people lost their lives.

In spite of a few successes, predictions of earthquakes that successfully specify a particular time and place are rare. Government agencies are reluctant to issue warnings when most earthquake warnings have been incorrect. If they issue many false warnings, the public will no longer respond to them.

## Volcanic Eruptions

Before it erupted in 1980, Mount St. Helens in the state of Washington was a nearly perfect volcanic cone almost 3000 meters high. The mountain was known to be an active volcano. In fact in 1975, scientists from the United States Geological Survey predicted that it would probably erupt before the turn of the century.

Signs of activity began in late March of 1980 with numerous small earthquakes generated by underground movement of magma. A bulge in the northern slope of the mountain grew to about 100 meters. On May 18, it broke loose and rushed down the northern slope of the mountain in a great, gas-charged cloud. The loss of pressure within the mountain resulted in a blast of hot ash and volcanic gases that filled Spirit Lake, a popular fishing resort on the north side of the mountain. About 1 cubic kilometer of the mountain was lost, and ash fell several centimeters deep hundreds of miles away. The mountain lost nearly a quarter of its height, and 60 people lost their lives. In fact, a number of the scientists who came to observe Mount St. Helens were burned to death or suffocated in

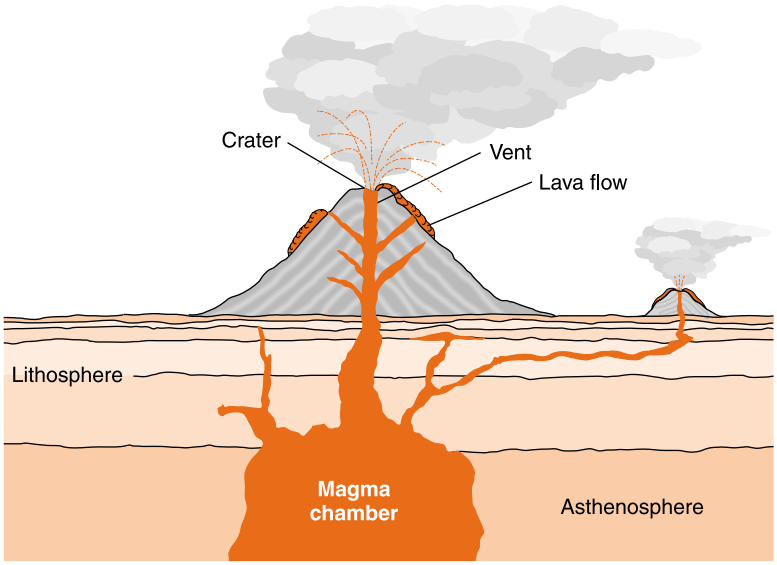


**Figure 9-2** A volcano is a place where magma escapes from Earth's interior. Sometimes the eruption builds a mountain; other eruptions cover large, nearly flat areas with fluid lava. (Not drawn to scale.)

the ash cloud. Since the 1980 eruption, a small dome has grown inside the new crater. This dome could grow to the original height of the mountain, or it could lead to another eruption in the future.

A **volcano** is an opening in Earth's surface through which molten magma erupts. The source of magma is somewhere within the planet where the temperature is above the rocks' melting temperature. The temperature at which rock melts depends on its mineral composition and pressure on it. Felsic rocks melt at a lower temperature than mafic rocks. As pressure increases, so does the melting temperature. Fluid magma moves toward the surface through cracks or zones of weakness in the overlying rock. When the magma reaches the surface and releases gases into the atmosphere, it is called lava.

Figure 9-2 shows a cross section, or profile view, of a volcano. In this diagram you can see the magma chamber with vents that lead to the surface. Note the layering of ash and lava inside the mountain, which was built up by successive eruptions. Explosive eruptions of some volcanoes leave a bowl-shaped depression at the top of the mountain called a **crater**.

Some volcanoes erupt quietly. Kilauea on the island of Hawaii has continuously vented rivers of lava for several

**Figure 9-3** The teardrop shape of this volcanic rock shows that it hardened from lava as it was thrown into the air. It is known as a volcanic bomb.

decades. The basaltic lava that feeds Kilauea is very hot and contains little gas, making its lava very fluid. But other volcanoes such as Mount St. Helens vent lava that is more felsic in composition. These lavas are recycled continental rocks. They contain more silicate minerals as well as dissolved gases such as water vapor, carbon dioxide, and sulfur dioxide. As felsic lava comes to the surface, decreasing pressure causes the gases to expand explosively like the soda in a bottle that has been shaken. Such volcanic eruptions release large quantities of volcanic ash and toss larger objects known as blocks and bombs into the air. These are considered the most dangerous eruptions. Figure 9-3 shows a volcanic bomb from a volcano in California.

**TYPES OF VOLCANOES** The cooling of magma at the surface builds volcanic features around the **vent** where the lava comes to the surface. Scientists recognize four types of volcanoes based on their shapes: shield volcanoes, cinder cones, composite volcanoes, and lava plateaus.

Repeated eruptions of hot, fluid, basaltic magma build a broad structure with gently sloping sides known as a shield volcano. The Hawaiian Islands contain shield volcanoes as much as 100 km across. Cinder cones are usually small fea-

**Figure 9-4** Sunset Crater in Arizona is a cinder cone produced by an eruption approximately 1000 years ago.

tures built by cooler lava that was blown into the air, fell back to Earth, and hardened into a pile around the vent. (See Figure 9-4.) Composite volcanoes are mounds built up by alternating lava flows and layers of ash. Mount St. Helens is a good example of a composite volcano. The eastern part of the state of Washington is covered by hundreds of meters of flat layers of successive fluid lava flows that created lava plateaus. The lavas that formed these plateaus were so hot that they flowed over the surface almost like water before they hardened into basalt.

Some volcanoes form a **caldera**. This is a large bowl-shaped depression formed when the top of the volcano collapsed into the emptied magma chamber. Crater Lake in Oregon is a caldera that has filled with water, making a large, round lake where the top of the mountain used to be.

## Volcanoes as Hazards

How likely you are to suffer injury or loss of property from a volcanic event depends on where you are. If volcanoes erupted in your location in the past, you are probably in a place that could have future eruptions. The more recent the past eruptions, the higher the likelihood of future eruptions. Volcanoes are sometimes classified as active or dormant. If scientists see evidence of recent activity or if they see steam rising out of a volcano, it is considered active. However, dormant volcanoes can suddenly erupt, showing how difficult it is to classify them accurately.

## ACTIVITY 9-2 ADOPT A VOLCANO

Select a famous volcano. Be sure that your teacher approves the volcano you have chosen. Prepare a report about your volcano's activity. Please give your source(s) of information in the form of a bibliography.

Figure 9-5 shows that volcanoes, like earthquakes, tend to occur near plate boundaries. Notice the way that active volcanoes nearly surround the Pacific Ocean. That region is called the Ring of Fire. Many of these volcanoes occur inland near ocean trenches. Subduction zones are especially dangerous because this is where granitic (felsic) rocks are pulled into Earth's interior. With their low melting temperature, low-density, high-viscosity magma, and considerable gas content, subduction zone volcanoes are the most dangerous kind of volcano.

In the real estate business it is said that the value of a property depends on three factors: location, location, and location. The same factor(s) will determine your vulnerability to volcanic hazards. The first question is, Are there volcanoes in your area? If not, the likelihood of danger is low. If there is local evidence of volcanoes, the second location factor comes


**Figure 9-5** Most of the world's active volcanoes are at or near plate boundaries.

in. How close are you to a volcano that is or could become active? If the volcano is within a few tens of kilometers, the next question comes into play. Is your home, school, or place of work in a valley connected to the volcano?

Volcano damage can come in several ways. Sometimes, lava flows out of a volcano and runs downhill into valleys destroying anything in its path. However, most lava flows are slow enough that people can usually escape them. A greater threat is gas-charged flows of hot ash that can descend from a volcano at 100 km/hr or more. This was the kind of activity that killed observers and flattened forests around Mount St. Helens in 1980. Some volcanoes discharge poisonous gases that can suffocate people and animals in nearby lowland areas. Meltwater from the snow that covered Mount St. Helens before eruption was the greatest cause of damage in 1980 when the water quickly flowed into rivers already clogged with ash. Eruptions can also emit poisonous gases and choking dust, while they trigger landslides and mudflows that cause loss of life and property.

Volcanoes sometimes show signs of an impending eruption. The best way to protect yourself from their dangers is to move far enough away to avoid direct effects such as lava flows and gas clouds, and high enough to escape floodwaters.

## Mass Movement

Gravity is the force that pulls all matter toward Earth's center. As tectonic forces build mountains, erosion powered by gravity wears them down. Nearly all erosion starts with earth materials at a high elevation and moves them to a lower elevation. Wherever the ground is too steep for friction to hold rock and soil in place, there is danger that it will move downslope. **Mass movement** is the motion of soil or rock down a slope without the influence of running water, wind, or glaciers.

Some soil movement happens slowly such as the slow downhill creep that caused the trees in Figure 9-6 on page 234 to bend or the slumping of a block of soil shown in Figure 9-7 on page 234. These slow movements are most com-

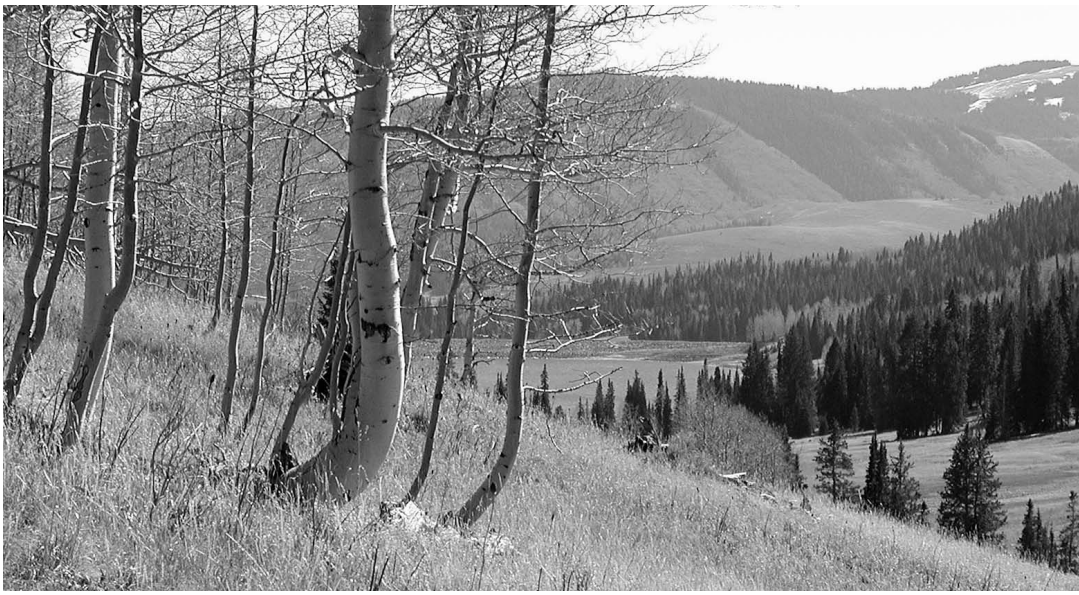

**Figure 9-6** Soil creep in Utah

mon in clay-rich soils, particularly when they become saturated with water. If roads or buildings are constructed along these slopes, the structures can lean and break apart as downslope motion stresses and carries them.

Sometimes there is the rapid, downslope movement of rock and soil known as a **landslide**. In unpopulated areas,


**Figure 9-7** Slumping at Half Moon Bay in California

mass movement is of little concern. But each year downslope mass movement breaks up or covers roads, causes damage to property, and occasionally causes injury or loss of life.

Landslides are often triggered by water seeping into the ground. Clay minerals in soil can absorb many times their dry weight in water. Clay also offers little resistance to gravitational force. If the soil is composed primarily of moist clay, it can even slide down relatively gentle slopes. A 55-acre area near the bottom of a valley south of Syracuse, New York, slid downhill, covering a road and damaging three homes in the spring of 1993. The slope above the slide was steep, but held in place by bedrock. However, the valley had been the site of a large lake that left deposits of soft clay. When the clay was saturated by groundwater it moved downslope.

An **avalanche** is the rapid, downhill movement of snow, similar to a landslide, that occurs on a steep slope. Large quantities of rock can be carried down by avalanches. Some mountain valleys show evidence of avalanches where trees have been uprooted by slides in the past

Like volcanoes, landslides usually occur in places where they have happened in the past. The best way to protect yourself and your property is to be aware of where landslides have occurred previously. Avoid building on or below steep or unstable land. Be aware of avalanche dangers when skiing or traveling in mountain areas in the winter or early spring. Figure 9-8 shows a structure built to protect a mountain road from avalanches and landslides.

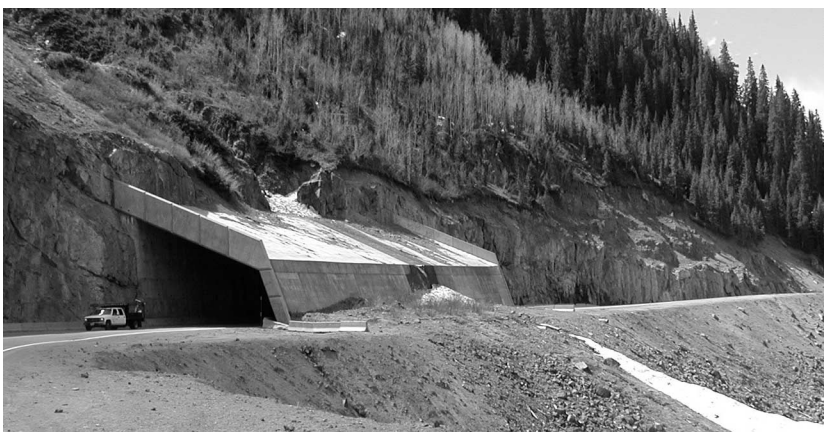

**Figure 9-8** This snow shed in the Rocky Mountains protects the road and people who travel on it from avalanches and landslides.

## TERMS TO KNOW

| | | | |
|---|---|---|---|
| **avalanche** | **hazard** | **mass movement** | **vent** |
| **caldera** | **landslide** | **tsunami** | **volcano** |
| **crater** | **liquefaction** | | |

## CHAPTER REVIEW QUESTIONS

**1.** Which city is most likely to have a destructive earthquake in the next 100 years?

(1) New York City
(2) Los Angeles
(3) Houston
(4) Chicago

**2.** Sometimes one destructive natural event is caused by another event. Which of the following is most likely?

(1) a thunderstorm caused by a landslide
(2) a tsunami caused by an earthquake
(3) a hurricane caused by a landslide
(4) lightning and thunder caused by an earthquake

**3.** Some people refer to tsunamis as tidal waves. Why do scientists seldom use the term "tidal wave?"

(1) Most scientists speak Japanese.
(2) Tsunami is easier to spell
(3) Tsunamis are not caused by tides.
(4) Tsunamis occur more often than tides.

**4.** A homeowner removed all heavy objects from high shelves in her home as a safety measure. That action would probably be most important in preparing for which of the following events?

(1) a landslide
(2) a hurricane
(3) an earthquake
(4) a volcanic eruption

**5.** Where is the safest place to build a home if your area has many earthquakes?

(1) on the bank of a river
(2) at the base of a weathered cliff
(3) on a thick layer of sediment
(4) on solid bedrock

**6.** Why is a wood frame house a good type of building to live in if your region has large earthquakes?

(1) Wood cannot burn.
(2) Wood is more dense than stone or brick.
(3) Wood frame houses often hold together when shaken.
(4) Wood does not conduct heat energy as well as stone or brick.

**7.** How do cities and other communities now protect citizens from earthquake hazards?

(1) They can require buildings that resist damage from shaking.
(2) The can pass laws to make earthquakes illegal.
(3) They can reinforce the ground to prevent lithospheric plates from moving.
(4) They can tell people exactly when earthquakes will occur and make them leave the area.

**8.** How would the magma that produces a cinder cone differ from lava that contributes a new layer to a lava plateau?

(1) The cinder cone magma comes out at the surface more slowly.
(2) The lava plateau magma is cooler and more liquid.
(3) The cinder cone magma crystallizes rapidly.
(4) The lava plateau magma does not reach Earth's surface.

**9.** Which location is most likely to have volcanic eruptions?

(1) near the North Pole
(2) near a large lake
(3) near plate boundaries
(4) near the centers of continents

**10.** A volcano whose top was covered by large glaciers and snowfields erupted. Which of the following is likely to cause the most property loss, injury, and deaths?

(1) flooding
(2) thunder
(3) violent shaking of the ground
(4) people falling into cracks in the ground

**11.** What kind of rock is likely to be found on the Hawaiian Islands?

(1) sandstone
(2) limestone
(3) gneiss
(4) basalt

**12.** What ocean is surrounded by a zone of frequent earthquakes and active volcanoes?

(1) Atlantic
(2) Pacific
(3) Indian
(4) Arctic

**13.** Where and when is a landslide likely to happen?

(1) on bedrock that is wet
(2) on bedrock that is dry
(3) on clay sediments that are wet
(4) on clay sediments that are dry

**14.** Which natural event usually occurs without warning and usually lasts less than a minute?

(1) a tsunami
(2) an earthquake
(3) a hurricane
(4) a volcanic eruption

**15.** Which natural disaster is most likely to include solid objects falling from the sky?

(1) floods
(2) earthquakes
(3) tsunamis
(4) volcanoes

## Open-Ended Questions

**16.** Students read an article in a local newspaper stating that a major earthquake can be expected to affect that region within the next year. The students plan to stay in the region. As a result, the students decide to help prepare their home and family for this expected earthquake.

State three specific actions the students could take to increase safety or reduce injury or damage from an earthquake.

**17.** An Earth science class is creating a booklet on emergency preparedness. State one safety measure that should be taken to reduce injury or deaths during a nearby volcanic eruption.

**18.** What is one form of evidence that might indicate that your area is in danger from volcanic eruptions?

**19.** Volcanoes' shapes and surface features can often be used identify them. State one way in which a volcano is likely to look different from other mountains.

**20.** Why are earthquakes, volcanoes, and landslides considered hazards?