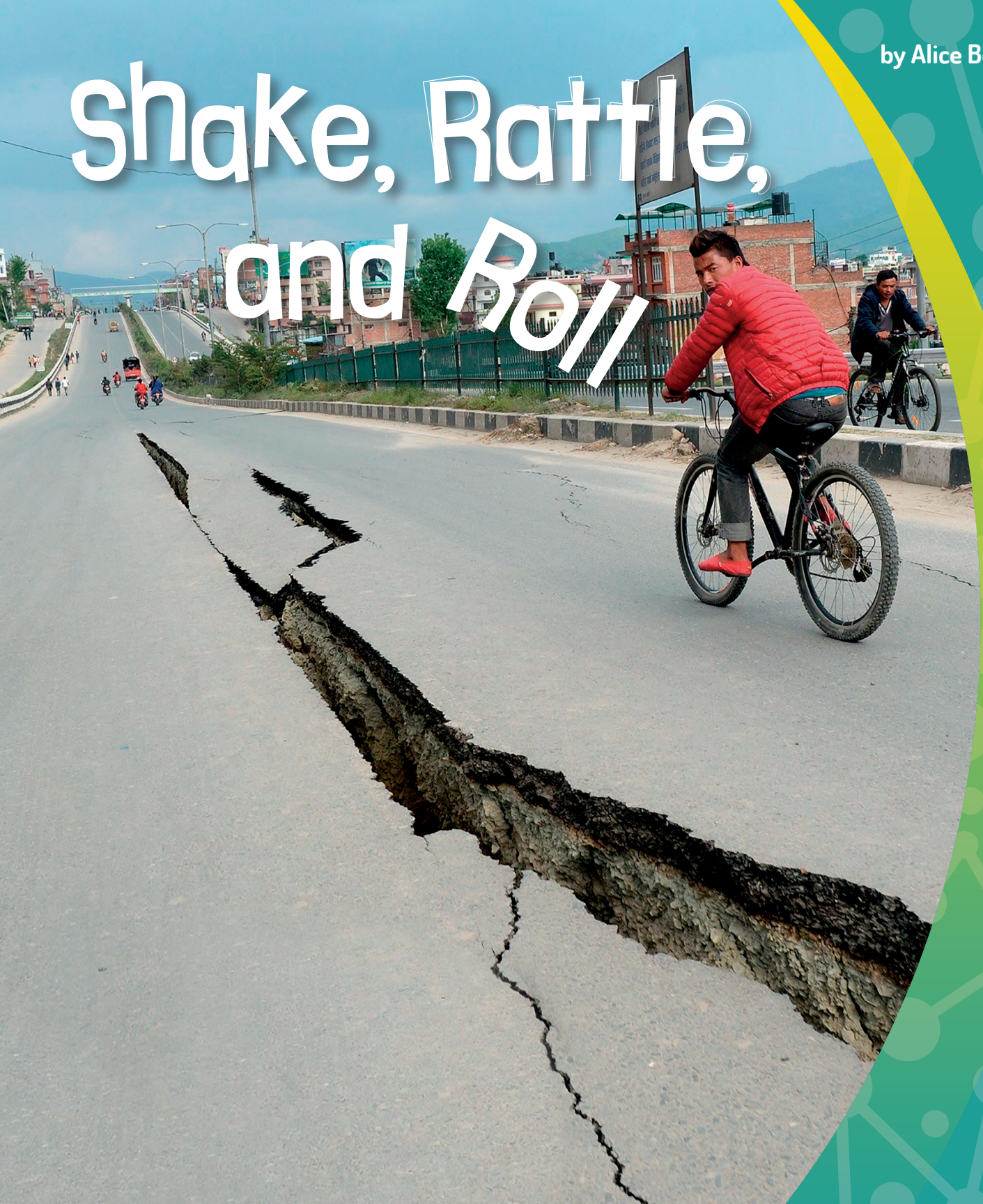
# Shake, Rattle, and Roll

by Alice Boynton



**Shake, Rattle, and Roll**
Author: Alice Boynton

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CHAPTER 1

# THE **CURIOUS** SCIENTIST

Today, the idea that loud noises can cause an earthquake makes us laugh. But long ago, people believed it could. In ancient times, people didn't have scientific explanations for what happened in the natural world. Still, they needed to make sense of natural disasters—like earthquakes—that could wipe out a whole town in a matter of minutes. So they came up with some pretty way-out explanations.



## ANCIENT MYTHS

Earthquakes can happen anywhere on Earth. So different cultures had different theories about what caused them.



### India

In India, people believed that four massive elephants held up the Earth. The elephants all balanced on the back of a gigantic turtle. This turtle balanced on the coils of a huge cobra. When one of the animals got tired and moved—you got it. Earthquake!

### Mexican Vaqueros, California

Mexican vaqueros, or cowboys, believed that El Diablo made earthquakes happen. When the evil god felt like causing trouble, he made a giant rip in the ground. Then he and his mischief-making followers could easily climb through. What a shortcut!



## West Africa

Some cultures believed that all earthlings lived on a giant's head. His hair was made of plants and trees. People and animals wandered around on his scalp. Whenever the giant sneezed or turned suddenly . . . OOPS! An earthquake occurred.

## Japan



## Greece

Poseidon, the Greek god of the sea, was nicknamed "Earthshaker." Why? When angry, he struck the ground with his trident. That caused an earthquake.

The Greek philosopher Aristotle (384–322 BCE) wasn't satisfied that these myths could explain earthquakes. He collected facts about earthquakes. He recorded where they occurred, at what time of day, and in what kind of weather. That meant he asked questions, made observations, and kept records of his **data**. Sound familiar? It should. That's what you do!

In time, Aristotle developed a theory. He based it on his observations, supported by evidence. His theory was that the movement of wind currents below the Earth's surface caused earthquakes.

Now hold on a minute! Before you dismiss Aristotle's conclusions, remember this. He didn't have today's scientific equipment and digital tools to test out his ideas. Yet despite this, Aristotle was one of the first scientists to come up with an explanation based on the observation of natural phenomena, not folklore.



"Aristotle. Philosopher and scientist. Authority on biology, botany, chemistry, physics, zoology, history, logic, poetry, and art." Wow, he was one smart guy!

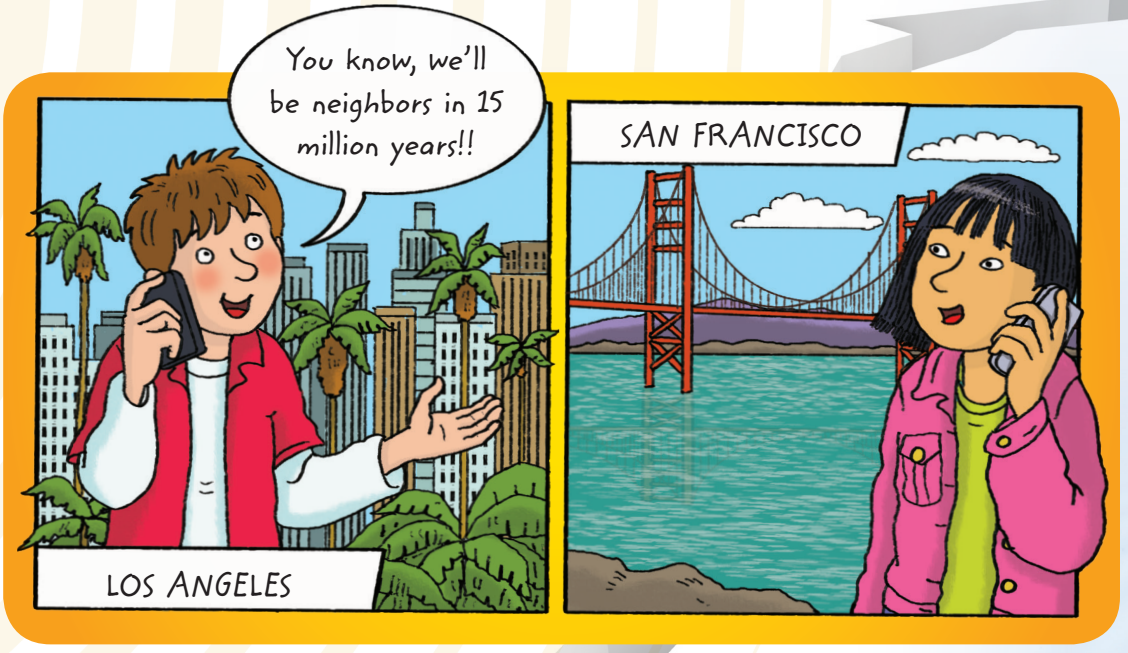


Okay, so now we know what doesn't cause an earthquake. Time to find out what does.

But first things first . . .

It may come as a surprise to you that the Earth's surface, called the **crust**, is not one solid piece. It's broken up into humongous segments, or pieces. Each segment is called a **tectonic plate**. Some plates are land above sea water. Others are underwater.

The place where two tectonic plates meet is called a **fault line**. And get this—those plates move constantly. Luckily for us, they move very, very s-l-o-o-o-o-w-l-y.



The plates, those gigantic slabs of rock, don't move in sync, either. Nothing like *"All together now. Let's move east."* No. Sometimes the plates slide apart from each other. Sometimes they bump into each other. At times, one of the plates slides on top of the other. They may even get stuck. Locked together. If the slabs break free, energy is released. That energy moves through the rocks in waves, called seismic waves. These are like the ripples in a pond that move outward when you drop a stone into the water. The result? EARTHQUAKE!

Get the picture?

So now you know. An earthquake is a natural process. It's a shaking of the Earth's surface caused by the movement of tectonic plates. Since the plates are always moving, this is going on under our feet all the time. Every day, thousands of earthquakes take place. Multiply that by 365 days. Incredible!

You may be thinking, *how come we don't feel all those earthquakes?* Most of the quakes are too weak, too far below the Earth's surface, or too deep in the sea for us to feel. But sometimes an earthquake occurs that releases huge amounts of energy. Those are the ones that shake, rattle, and roll the land above them, causing terrible destruction.

**QUESTION:**

What did one earthquake say to the other?

**ANSWER:**

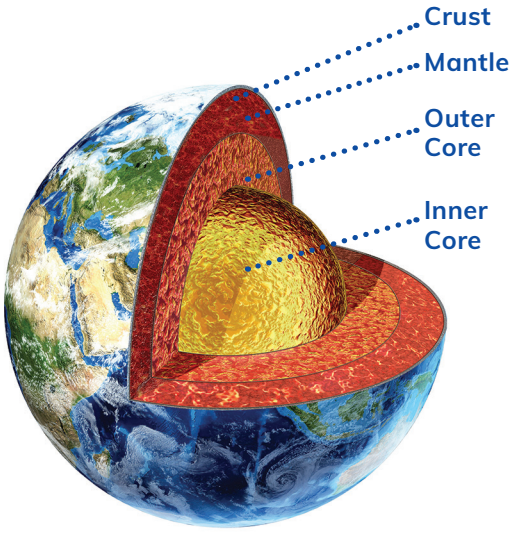
Hey, it wasn't my fault!



## DIG DEEPER

What else is under our feet? If you had superpowers, you could dig through the Earth. Here's what you would find.

- The Earth has four layers.
- The crust is the outer layer—the one we live on.
- The mantle, the widest layer, is made up of semi-molten and molten rock called magma.
- The outer core, extremely hot, is a liquid layer.
- The inner core is the hottest part of the Earth. It's a solid.

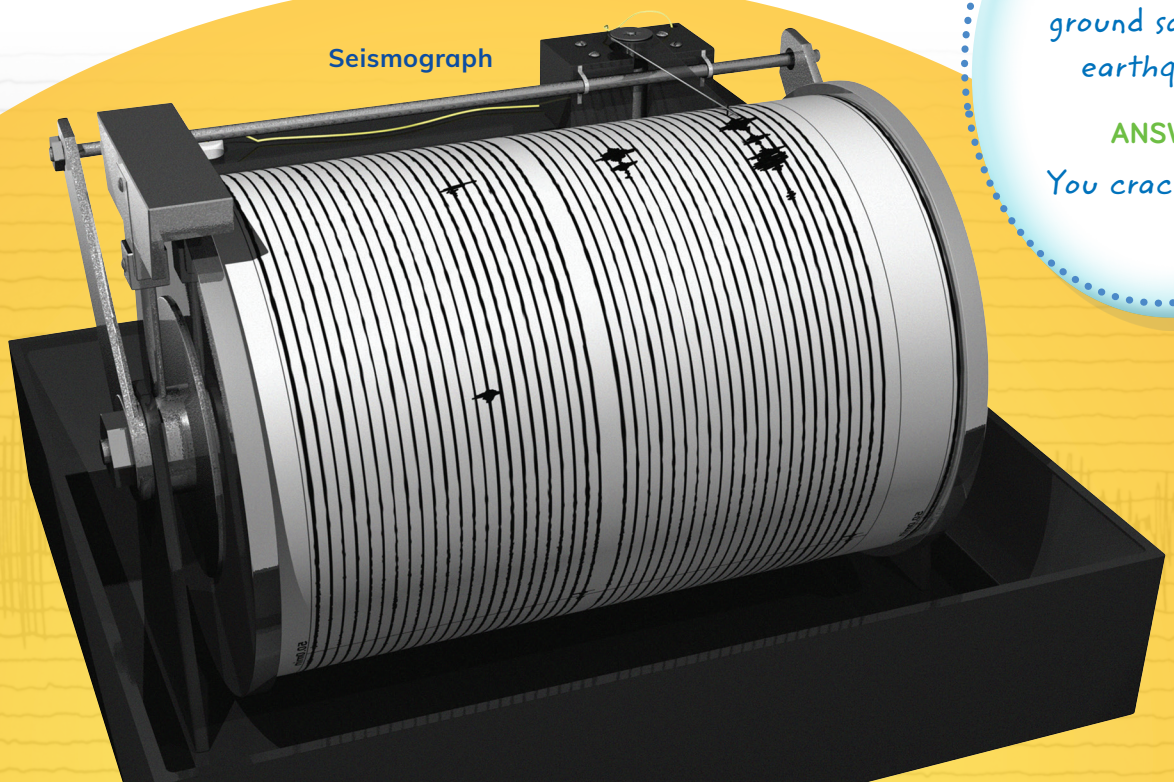



## TOOLS OF THE TRADE

A **seismograph** measures the strength of an earthquake. Scientists express the strength of the quake as its **magnitude**. That's the amount of energy released by the seismic waves.

**QUESTION:**
*What did the ground say to the earthquake?*

**ANSWER:**
*You crack me up!*



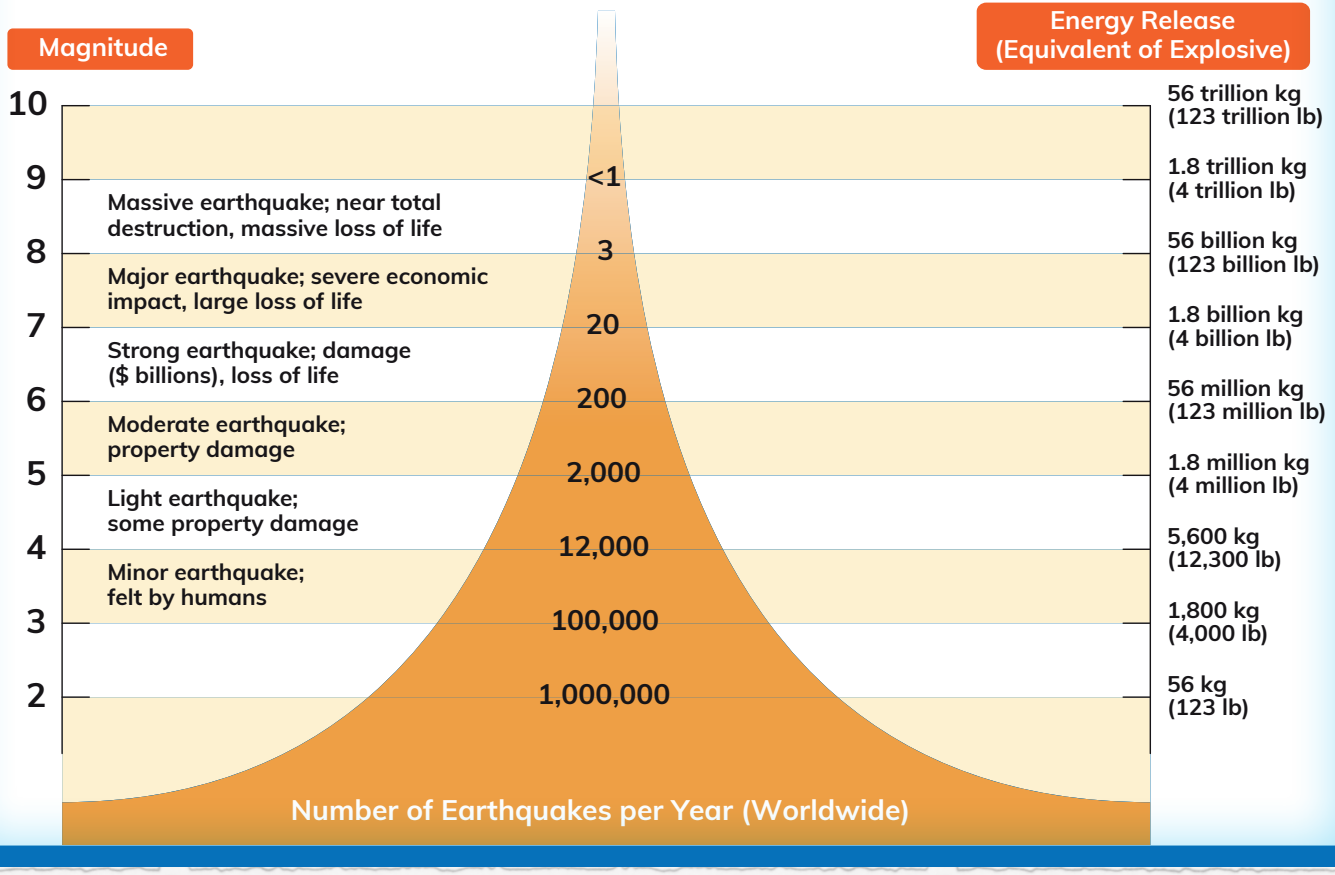
The Richter scale is the brainchild of Charles Richter. He was a seismologist and physicist. The scale ranks earthquakes according to their force. Today, different scales are also used. These include the moment magnitude scale and the Modified Mercalli Intensity scale.

Seismic . . . seismograph . . . seismologist . . . get it?

## It's a Fact!

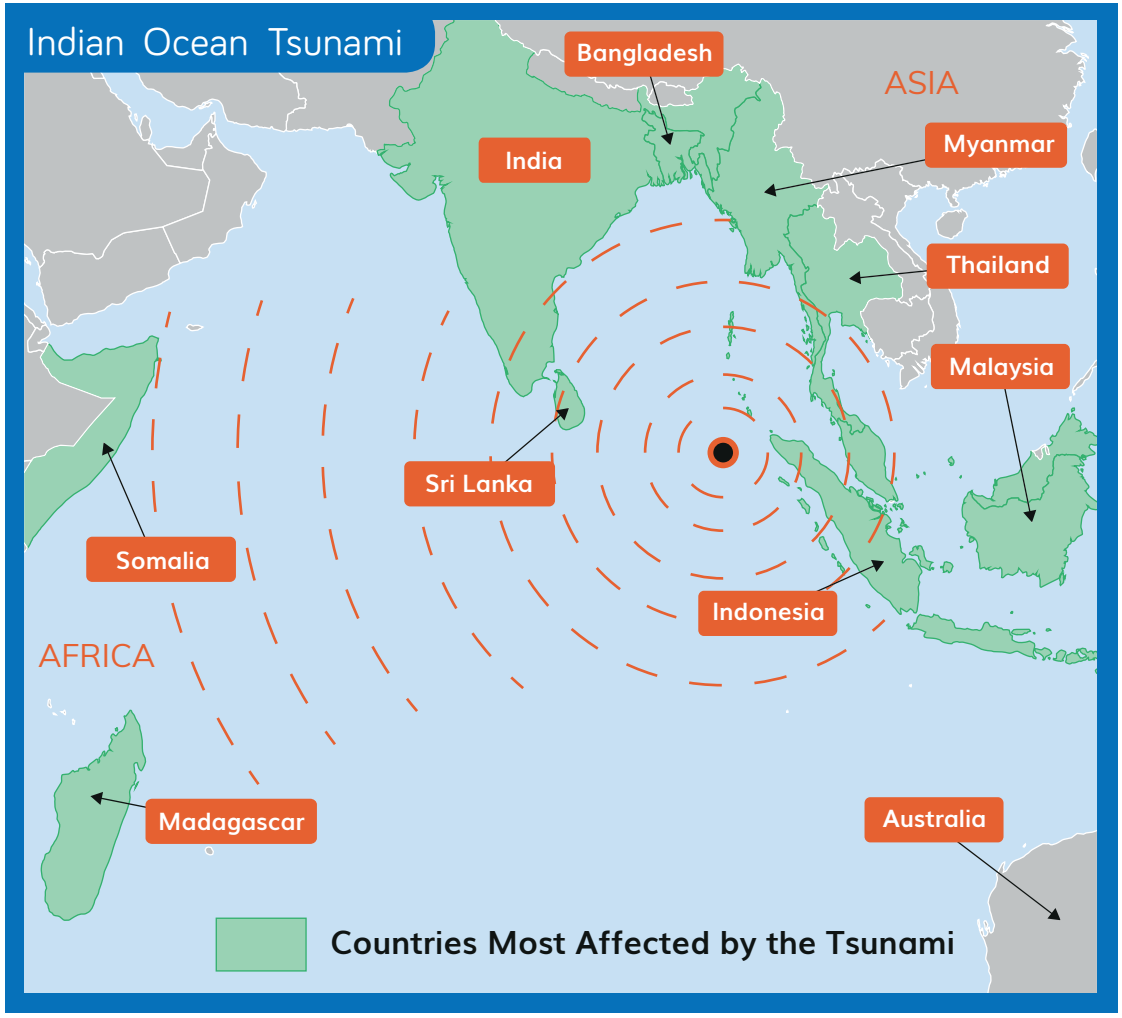
In 1964, the energy from a 9.2 earthquake in Alaska caused fishing boats in Louisiana to sink. Can you figure out why?

## The Moment Magnitude Scale



## MAKING WAVES

Earthquakes with a magnitude of 9.0 or more are rare. Unfortunately, they do happen. In 2004, a 9.1 magnitude earthquake originated under the Indian Ocean. It unleashed different natural disasters—tsunamis. Tsunamis are killer waves caused by earthquakes on land or under the sea. From where they originate in the sea, the waves travel outward in all directions—remember that stone dropped into the water? As they hurtle toward land, the waves move at the speed of a jet. They can build up to heights of 100 feet.




The Indian Ocean tsunami traveled 3,000 miles. It slammed into the coastline of 11 countries. By the end of the day, 150,000 people were dead. Millions were homeless.

## RUN FOR YOUR LIFE!

Here is how a lucky survivor described his nightmare.



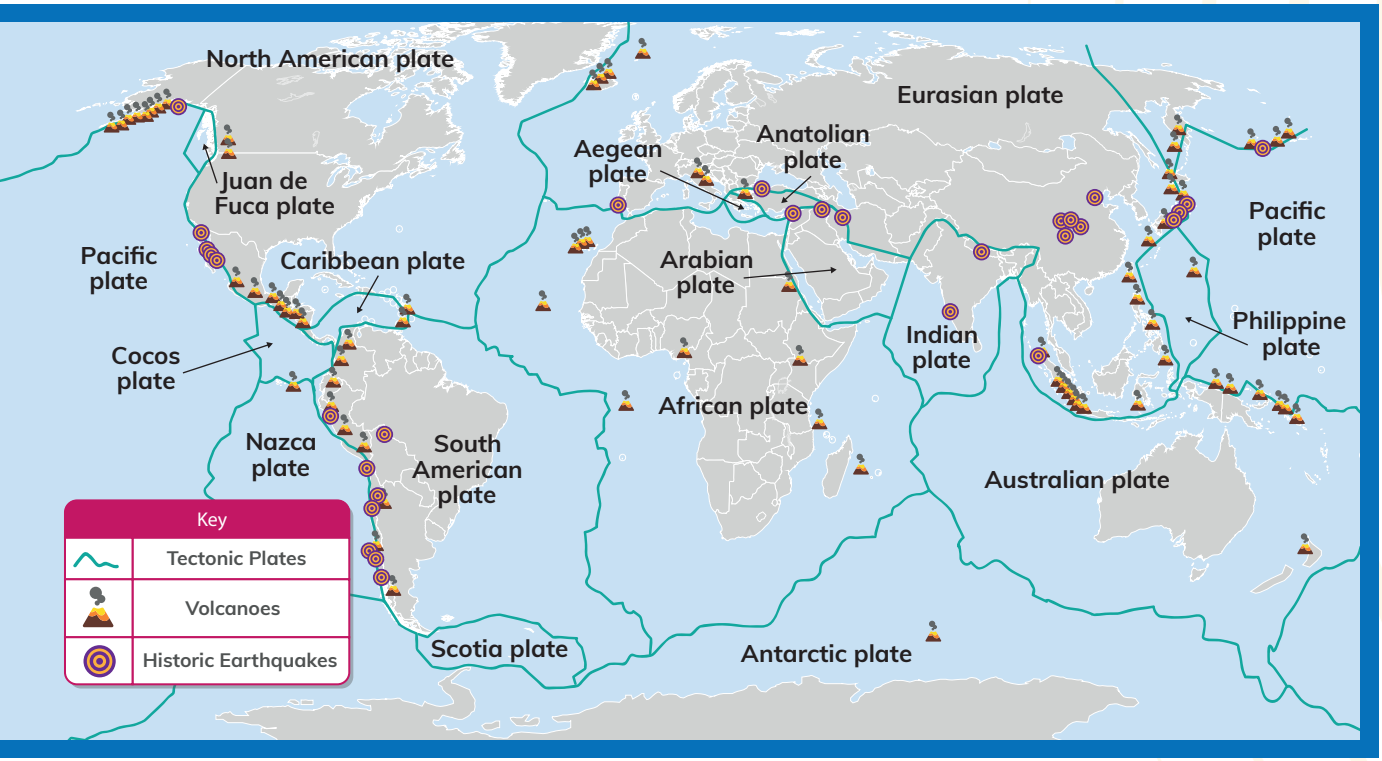
## FINDING PATTERNS

This world map shows the tectonic plates. It also has two other features. The circles show locations of major earthquakes in the past 30 years. The triangles indicate where the Earth's active volcanoes are found.

Take your time and study the map carefully. What patterns do you see?

Here's another test of your powers of observation. Study the map again. Which plate has the greatest concentration of earthquakes and volcanoes?

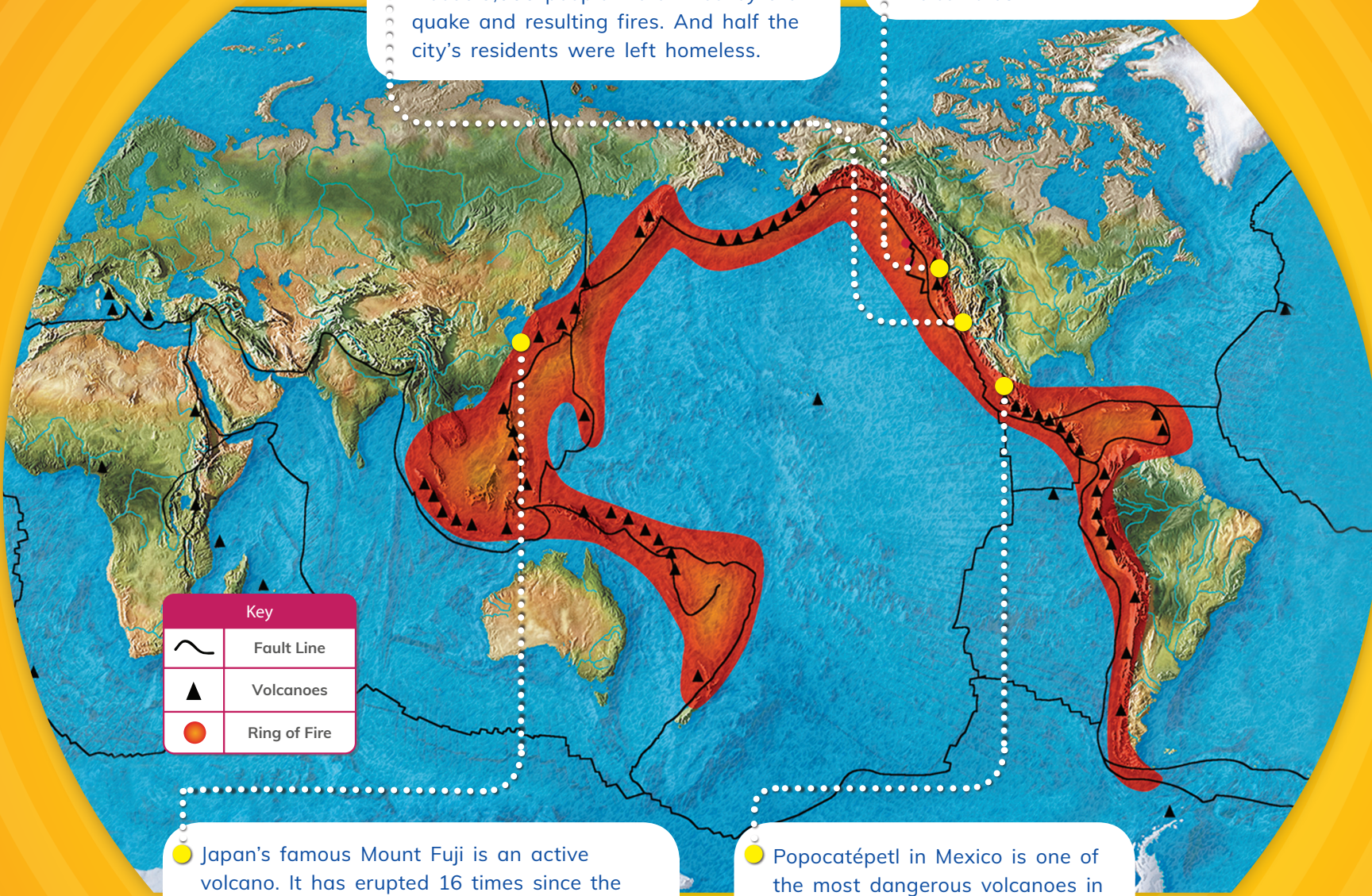
If you said the Pacific plate, you rank right up there with Sherlock Holmes. The Pacific plate has more erupting volcanoes and strong earthquakes than any other place on Earth. That's why it's known as the Ring of Fire. Although, it's actually shaped more like a horseshoe. It's where 80% of the planet's earthquakes take place.



# RING OF FIRE

The San Andreas Fault runs about 800 miles long and 10 miles deep. It cuts through the western part of California. Movement along the fault caused the April 1906 San Francisco earthquake. It devastated 500 blocks of the city. About 3,000 people were killed by the quake and resulting fires. And half the city's residents were left homeless.

Washington's Mount St. Helens is an active volcano. It lies on a weak section of the Earth's crust. Eruptions are always a possibility. The one in 1980 lasted 9 hours. It covered the nearby areas in dark volcanic ash.




Japan's famous Mount Fuji is an active volcano. It has erupted 16 times since the year 781 CE. The last eruption took place in 1707. However, Japan has had many severe earthquakes in modern times. An earthquake off the coast in 2011 triggered a tsunami that killed about 20,000 people.

Popocatépetl in Mexico is one of the most dangerous volcanoes in the Ring of Fire. It has erupted 15 times since 1519. Because it lies close to Mexico City, an eruption would threaten the 21 million people who live there.

## BE SMART, BE PREPARED

Fortunately, scientists have now mapped out a lot of the world's fault lines. They know where people are under the greatest threat of earthquakes and volcanic eruptions. Unfortunately, it's hard to predict when and where the next catastrophe will happen. So knowing what to do if disaster strikes is really important.



All over the world, at-risk communities practice emergency procedures. In Hawaii, people practice what to do if there's a volcanic eruption. In California, earthquakes are a serious threat. If you're wondering why, check out the map on page 13. In fact, the state has declared April as Earthquake Preparedness Month. Here's the drill.




**DROP** to the ground.

**COVER** your head and neck with one hand and get under a desk or table.

**HOLD ON** to the desk or table leg so that the desk or table will stay over you.

If you're in a wheelchair or unable to walk, do this.

The better prepared you are, the better your chances of staying safe.



CHAPTER 2

STEM CAREER

# MEET A SEISMOLOGIST



Dr. Rebecca Bell

Many different kinds of scientists study the Earth's activity in and around the Ring of Fire. **Volcanologists** study volcanoes. **Seismologists** study earthquakes. They look at movements, or energy waves, in the Earth's crust. Let's find out more from seismologist Dr. Rebecca Bell.

What does a seismologist do?

We are like detectives. We look for clues about the past in rocks. We study seismic waves. We do experiments and examine data to discover the source, size, and cause of seismic waves. They cause earthquakes.

Where do you do your work?

We spend a lot of time in the lab. We study rocks. We create and test computer models of earthquakes. I interpret images of what the Earth looks like below the surface. These images have been produced with sound waves. They show me where faults are located. These faults could cause earthquakes. I also use information from drilling into the ground to learn about how the ground might respond in an earthquake.



Can you predict earthquakes?

Although we can predict where earthquakes are likely to occur it is impossible to predict when they will occur. The best we can do is look for patterns. We look to see if earthquakes in any places occur at regular intervals. We need a lot of data to do this. Volcanic eruptions are easier to predict. There are signs that a volcano is becoming active and might soon erupt. For example, earthquake swarms are an important sign. That's when lots of little earthquakes occur near a volcano. Larger earthquakes take a long time to build up energy, in some cases hundreds of years. So we might have no record of an earthquake on that fault line before. That means we have very little data that we can use to spot patterns. It's hard to predict a large earthquake within 50 years. But with volcanic eruptions we have more data so we can often determine when an eruption is imminent and evacuate the area.

Is your job dangerous?

We often travel to places that experience big earthquakes and tsunamis to learn more about them. So in this way, maybe the job is a little dangerous. However, many millions of people all over the world live in areas at risk of earthquakes and tsunamis. To conduct experiments we sometimes drive to remote areas in off-road vehicles. Then we dig holes to deploy seismometers, which are powered by large batteries of solar panels. And when we work in areas that are very hot or cold there are some risks.

How do you protect yourself from these dangers?

Before we do any experiment we perform a full risk assessment. This helps us decide what are the risks and how we can reduce them. We make sure we wear appropriate clothing for either the hot or cold conditions. We wear strong boots and wear gloves when we are digging holes and making fences. We wear high visibility vests when working close to roads. Whenever we go to an area where earthquakes might happen we familiarize ourselves with the evacuation procedures.



What do you like about your job?

We know that our work will someday make people safer. We need to learn more so we can get better at predicting volcanoes and earthquakes. We won't be able to prevent them but we can help people prepare for them. This can even save lives. This makes us proud of what we do.

How can I learn more about earthquakes?

There are lots of websites where you can see where earthquakes have happened in the last few days. Sometimes earthquakes will happen in areas that will surprise you.

# SEISMOLOGIST'S COOL TOOLS

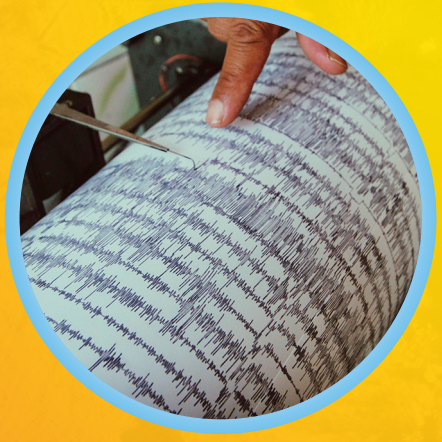
A seismologist uses these tools on the job.



**GPS stations** can be used to measure how much the land moves over time.



**Strainmeters** are buried underground and measure if the ground moves.



**Seismometer** measures earthquakes.



**Theodolites and surveying instruments** can also be used to measure ground movement.

# EARTHQUAKE BLOCKS

Learn how energy is stored and released during an earthquake.

What you'll need:

- Two 2 × 4 pieces of wood (about 134 cm long)
- Eye bolt
- 10 thin rubber bands (looped and tied together to create a 16 cm length)
- Sandpaper (create a strip as shown)
- Tape measure





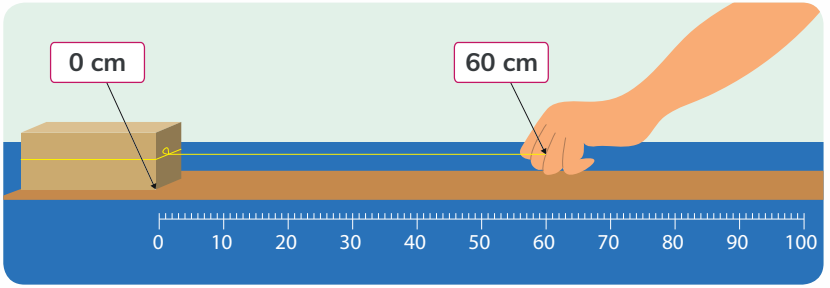
## SET-UP

- Glue some sandpaper to the bottom of the wooden block.
- Attach the rubber band string to the wooden block using an eye bolt.

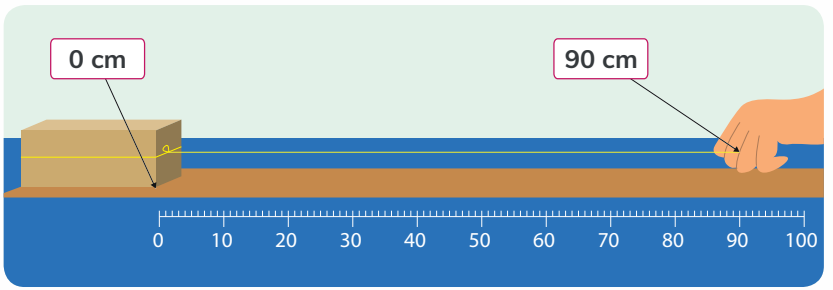
**Note:** The wooden block represents the tectonic plates. The rubber bands represent the forces acting on these plates. The sandpaper represents the contact between plates. Finally, the moving block represents an earthquake!

## DIRECTIONS

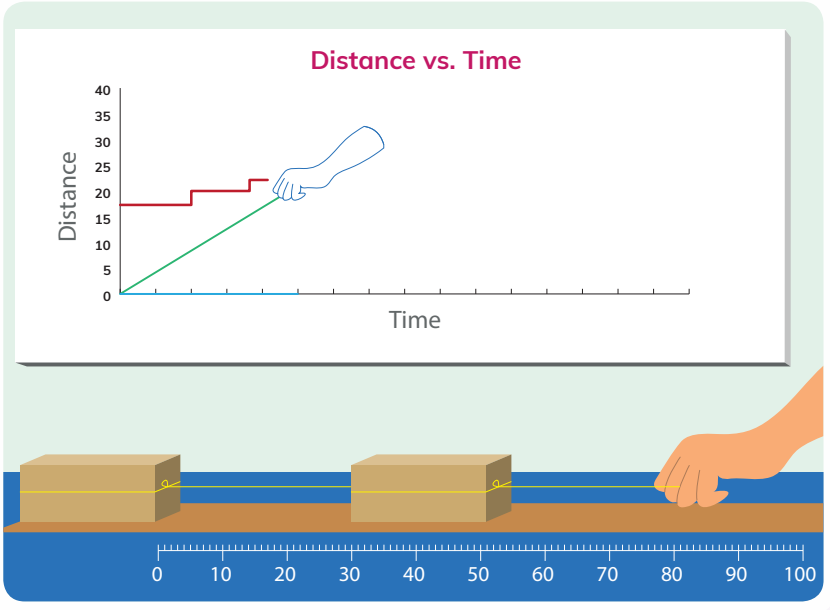
1. Set up the materials using the diagram to the right.




2. Experiment with the materials. For example, stretch the rubber band with your finger. Record when and how far the block moves with each stretch. Note how energy is stored and released. Then, place a pencil through the rubber band loop. Repeat and record your observations.




3. Add a second block, separated by a rubber band. How does this affect movement? Draw or graph your findings. Share these with classmates. How do they compare?



CHAPTER 3

# EARTHQUAKE PROOFING: WHAT'S THE COST?



When it comes to earthquakes, there's good news and there's bad. Remember those ancient myths? The good news is we've learned a lot about earthquakes since then. Scientists near you are putting this know-how to work.

## THINK LIKE A SEISMOLOGIST

By analyzing data, seismologists have identified patterns. They know where on Earth most earthquakes have taken place. And therefore where quakes will probably take place again. But when will an earthquake strike? As one geologist explains, "We don't know what makes an earthquake start today, instead of yesterday. We also don't know what makes it stop." That's the bad news!

Scientists can't prevent natural hazards like volcanic eruptions, tsunamis, and earthquakes. So they're doing the next best thing. They're trying to reduce the impact these natural disasters have. How? One way is by trying to better predict when an earthquake will happen. A heads-up would save lives and reduce damage.

Why is earthquake prediction so difficult? There doesn't seem to be an early signal. All's well. Then suddenly, the ground starts shaking.

Lab experiments and observations have led scientists to this conclusion: all earthquakes start small. But only some become big, bigger, and BIGGER. There are half a million earthquakes in the world every year—about 35,000 of them are recorded in California. We don't need to know about all of them. We don't even feel most of them. We only need to know about the one or two quakes that can do serious damage.

Finding the right spot for a building is important. Especially if it's a nuclear power plant! The Diablo Canyon Power Plant is a nuclear power plant in Avila Beach, California. It was built near four faults. Engineers had to make sure it could withstand a 7.5 magnitude quake.





A seismologist connects a solar panel to a seismograph in Oklahoma City.

Scientists have made some advances. Seismologists currently monitor the most active fault lines. One is the San Andreas Fault in California. A system called **nowcasting** is in place there. Instruments are buried deep underground. They measure tremors as they move along the fault lines. A tremor is a small seismic shaking, or earthquake. Small tremors often come before larger earthquakes.

The information gathered can give us a warning. DANGER! EARTHQUAKE COMING! Even a few minutes allow us to protect ourselves:

- School kids and office workers have time to drop or lock, cover, and hold on.
- People in elevators can get out before the electricity goes off.
- Drivers can pull over.
- Critical computers can be shut down.
- People can dash out of unsafe buildings. That's important. Most earthquake-related deaths happen when buildings collapse. Just imagine the huge benefit of longer advance warnings.

It's important that new buildings be as safe as they can be . . . [The law] helps ensure our buildings are built on solid ground.

—*Los Angeles Mayor Eric Garcetti*

Why would one risk constructing multimillion-dollar investments on ground that is known to be of very high hazard, and place in jeopardy the lives of those who inhabit the building?

—*John Parrish, California geologist*

## THINK LIKE AN ENGINEER

In addition to better prediction, scientists are working to reduce the impact of earthquakes. Strong earthquakes cause structures to collapse. Lives are lost. About a million people have died in earthquakes in the last two decades alone. Many died from collapsed buildings. So one question is: Where is it safe to build?

In California, builders are required to first investigate the ground. Does a fault run under the proposed building site? Construction is banned on top of faults. It's the law! Sounds clear-cut, but there's a snag. Yes, geologists in earthquake-prone cities have identified many fault lines. But not all of them have been mapped yet.

Once a safe site is chosen, the next question is: What makes a structure earthquake-resistant? This is where **engineers** play a big part. They design buildings and bridges in a city that can stand up to earthquakes. Literally.

But can you really earthquake-proof a city? Many scientists think so, especially for newly-built buildings and bridges. Research in seismology means that scientists know where to build. And they also know how to prevent the collapse of buildings. Maybe in the near future we will be able to build earthquake-proof cities.

Some specific things we know:

- Certain building materials and structures are stronger than others.
- Increasing the number of horizontal beams that are holding up walls helps.
- Taller buildings are more stable—a building 100 stories tall can better withstand the swaying and shaking of an earthquake than a smaller building.



How do we know this? Building designers create models of their buildings. They then put the models on a "shake table." They test how their models perform against violent shaking. They use these tests to make buildings that can last through strong earthquakes. And last for hundreds of years!

This know-how not only saves lives, it saves money. It's expensive to earthquake-proof a city. But for every $1 spent preventing earthquake damage, $7 is saved later. How? It's saved in relief efforts and rebuilding collapsed buildings.

**It's a Fact!**

An engineer invented a new building material for a bridge in Seattle, Washington. If there's an earthquake, the new metal alloy bends. But afterward, it returns to its original shape.

A new San Francisco-Oakland Bay Bridge was completed in 2013. It was designed to withstand a strong earthquake. Its two roadways hang from cables. Four pillars make up the tower. Each cable is attached to one of these pillars. This allows the roadways and the pillars to sway when a quake hits. But they won't break, even through the strongest shaking. The bridge is also fitted with motion detection sensors. They will warn drivers of an earthquake.

## TESTING CONTINUES . . .

Engineers from Stanford University in California have built and tested a special new kind of house. In a very strong "test quake," this house shook. But it didn't fall. Why? The house sits on sliding "isolators." It skates back and forth along the shaking ground. The building moves with the motion of the earthquake, instead of collapsing.



Likewise in Japan, builders need to be extremely innovative. It has about 1,500 earthquakes a year! So engineers and architects constantly invent and test new and different earthquake-proof designs and materials. Some Japanese engineers asked: Can a curtain of carbon rods do the job? They tested it on a building. Thousands of rods anchor this building to the ground. Kind of like a tent. The rods are flexible. They're also extremely strong. When the ground starts to shake, it causes the building to move. But the rods stretch and pull it in the opposite direction. This prevents the building from breaking apart. It remains standing. What do you think about this method?



Inside the building, rods also reinforce the stairs and windows.

# WHAT'S NEXT?

Scientists have learned a lot about predicting earthquakes and making buildings safer. But there's still a lot we don't know. Below are some of the questions scientists are asking. Maybe someday you'll help discover the answers to these and other earthquake-related questions!

What building materials are best to earthquake-proof a home? A tall building? A bridge?

Can human activity trigger an earthquake? Can a geothermal energy project cause a quake? What about building a water reservoir?

Can animals sense an earthquake days before it occurs? Can we use their behavior to predict one?

What exactly happens inside the Earth during an earthquake? Scientists aren't sure. But they are trying to test their ideas. The challenge is to simulate, or imitate, mini-earthquakes in a lab. So far they haven't been able to do so.

Earthquakes tend to happen along fault lines. So why was there an earthquake of 7.0 in New Madrid, Missouri? The town sits right in the middle of the North Atlantic plate. No fault lines there.

# VISUAL GLOSSARY



**crust**
the outer layer of the Earth



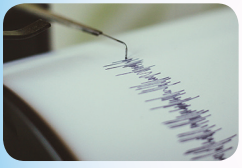
**data**
facts collected to analyze (look closely at)



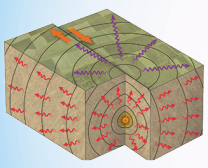
**engineer**
a person who designs and builds structures like buildings and bridges



**fault**
a crack in the Earth's crust along which movements occur



**magnitude**
the size or extent of something, such as an earthquake



**seismic waves**
waves in the Earth created by an earthquake



**seismologist**
a scientist who studies earthquakes and seismic waves



**volcanologist**
a geologist who studies volcanoes, past and present

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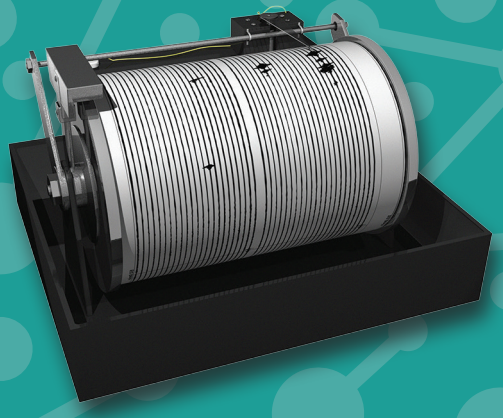
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