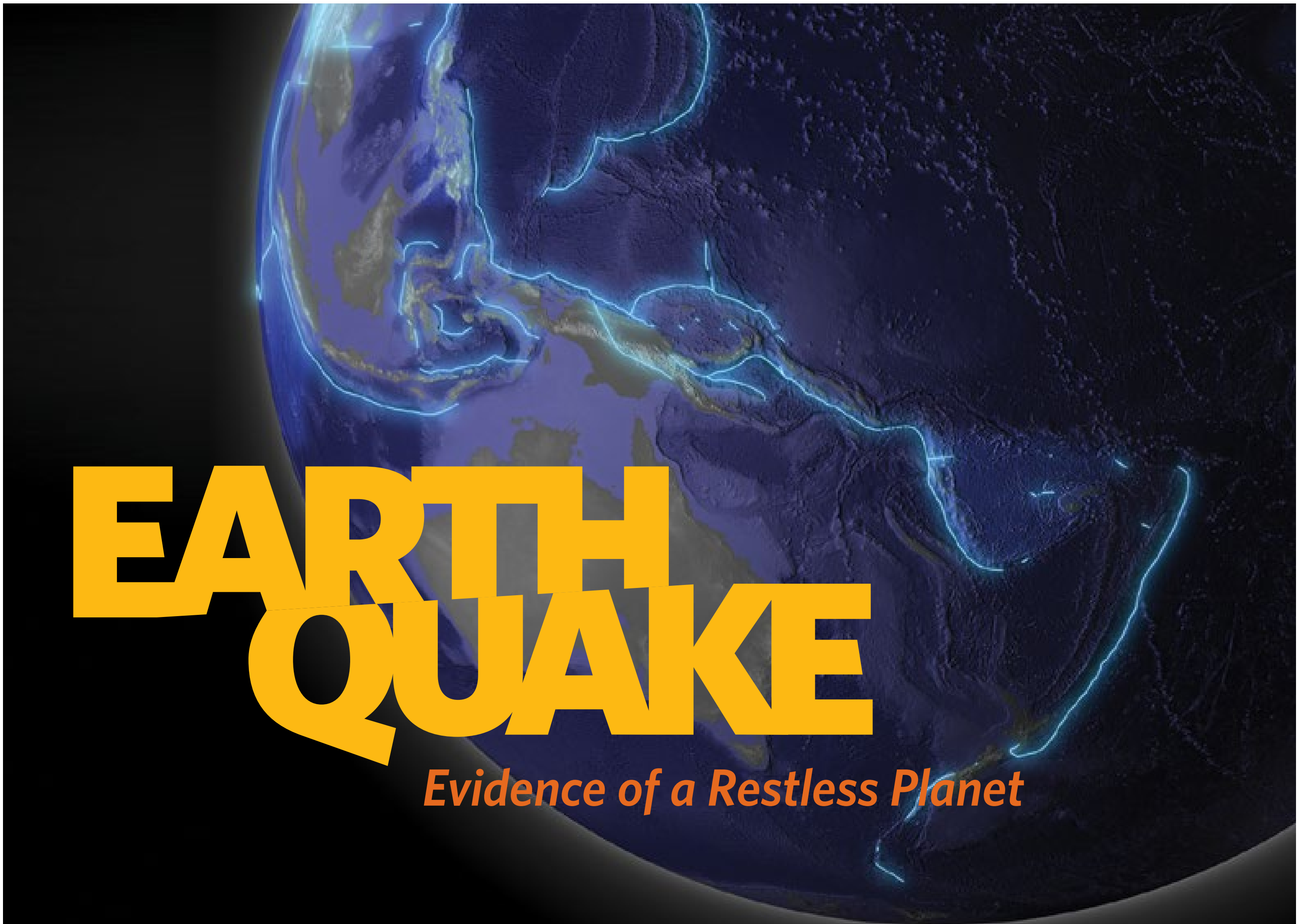


EARTHQUAKE

Evidence of a Restless Planet

Educator Guide

Grade 6 – Grade 12

What's Inside:

A. SHOW OVERVIEW

B. KEY CONCEPTS

C. VOCABULARY

D. RESOURCES

CALIFORNIA ACADEMY OF SCIENCES

Earthquakes provide dramatic evidence that we live on a dynamic planet.

Seismic activity affects lives around the world. It has shaped human culture and driven evolutionary change, acting on timescales from minutes to billions of years. Basic concepts covered in the show include:

- Earth is a dynamic planet that is always changing.
- The richness and diversity of life on Earth is affected by the movement of Earth's crust.
- Studying the movement of Earth's crust tells us where most earthquakes will occur, but cannot tell us when they will happen.
- Earthquakes affect people, and we can prepare to survive the next major one.

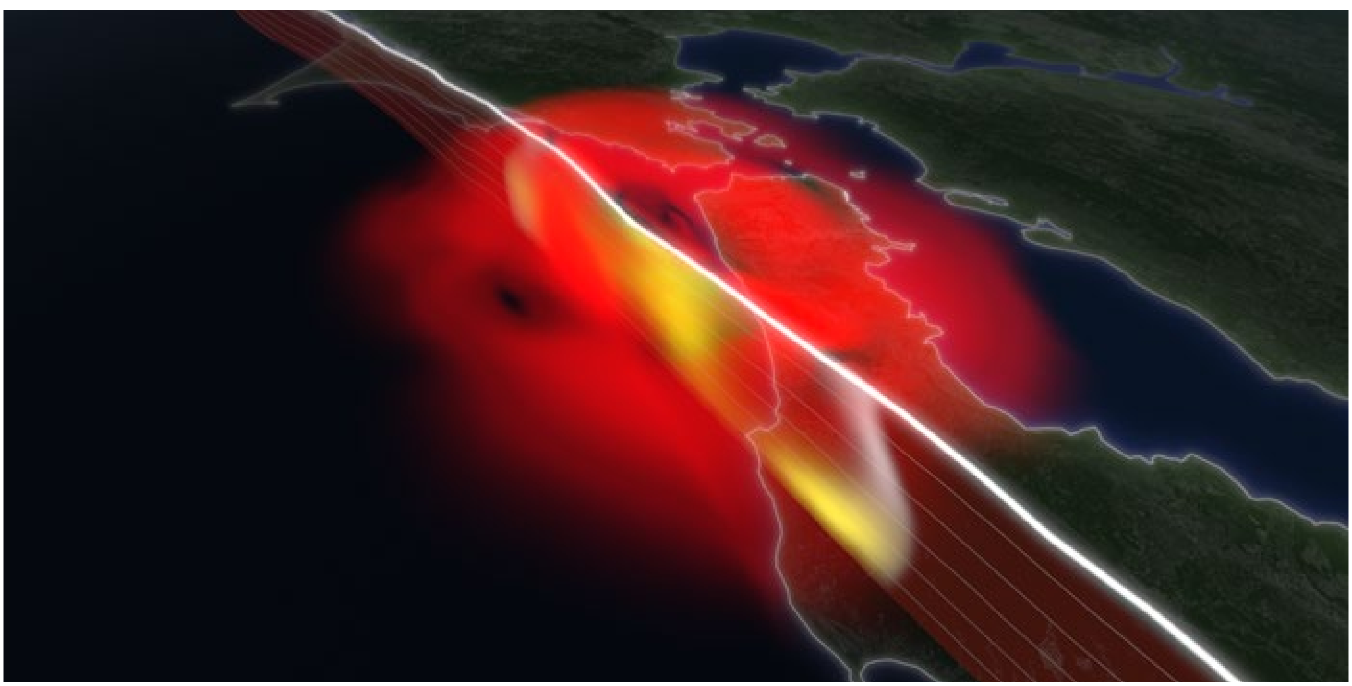
We begin our journey on the California Coast, where geological formations tell a story of gradual change: sand that has eroded from the surrounding terrain over a period of centuries and 10 million year-old granitic rock that has travelled hundreds of miles to where it stands today. Although Earth's surface is moving and changing over geological time, we rarely see it happening before our eyes in human time, except when we experience an earthquake.

Point Reyes is one of the many places in Northern California where land has been sculpted by tectonic forces. The famous San Andreas Fault, the boundary between the Pacific Plate and the North American Plate, reveals differences in vegetation along the boundary, due to the differences in rock and soil composition. As we lift off for an aerial view of the narrow San Andreas Fault, we trace this boundary toward the city of San Francisco to relive a time when these two plates, building pressure over time, moved suddenly and catastrophically.

Sometimes geological time, human time, and historical time intersect. Jumping back to the year 1906, we see an accurate representation of the city of San Francisco at the turn of the century. We view the Ferry Building in the early morning of April 18, 1906, traveling up Market Street to witness approximately 20 seconds of the 1906 Earthquake (which actually lasted about 90 seconds). In the aftermath of the earthquake, fires erupted and destroyed 500 city blocks—more than 30,000 buildings. Approximately 3,000 people died in the 1906 earthquake and fire. The tragedy motivated Californians to study earthquakes in greater detail, giving birth to modern earthquake science.

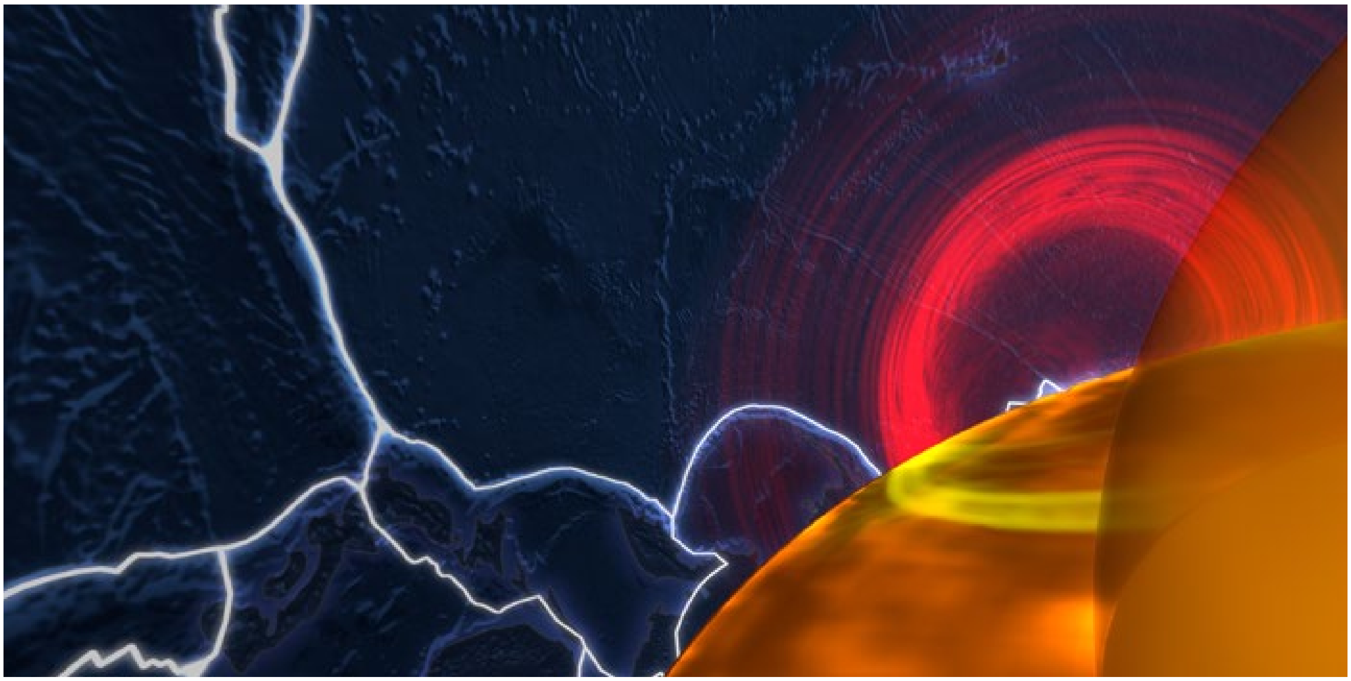
Data from computer simulations now allow us to analyze the historic quake. Our best estimates indicate that the earthquake started nine miles (14.5 kilometers) to the west of San Francisco, six miles (about 10 kilometers) beneath the ocean floor. The earthquake released stored energy, causing intense surface shaking shown in red in the image below. The area in yellow illustrates the overall slip along the fault—as much as 21 feet (7 meters) in some places. Together, the area of the rupture and the amount of slip determine the total energy released by the earthquake—what we call its magnitude. The energy of the quake travels along the surface and through Earth's interior in the form of seismic waves.

Seismic waves help scientists decipher Earth's interior structure. The layers of the inner Earth include the thin crust, the rocky mantle, and superheated metal core. The heating and cooling of the mantle drives the constant movement of tectonic plates. These plates float atop the denser mantle and interact with



Simulation of the 1906 Earthquake. Data courtesy of Lawrence Livermore National Laboratory.

one another: some plates spread apart allowing the formation of new crust, some move towards each other, and others, like the plates in California, grind against each other moving side by side in opposite directions. The movement of tectonic plates continues to transform the surface of Earth.



Visualization of seismic waves viewed from within the Earth. Data courtesy of Lawrence Livermore National Laboratory.

Seismic waves help scientists decipher Earth's interior structure. The layers of the inner Earth include the thin crust, the rocky mantle, and superheated metal core. The heating and cooling of the mantle drives the constant movement of tectonic plates. These plates float atop the denser mantle and interact with one another: some plates spread apart allowing the formation of new crust, some move towards each other, and others, like the plates in California, grind against each other moving side by side in opposite directions. The movement of tectonic plates continues to transform the surface of Earth.

Leaping back in geological time to a point 200 million years in the past, the continents looked very different from today. India and Antarctica were neighbors. Buenos Aires and Cape Town were much closer than they are today. And Morocco and New York City were separated by a thin strait, which eventually expanded into the Atlantic Ocean. The formation of the Atlantic occurred as new crust formed along the underwater Mid–Atlantic ridge, driving the breakup of Pangaea. By speeding up geological time, we can witness the movement of the plates and the break up of larger landmasses into the continents we recognize today.

Earthquakes have affected our human ancestors since the time the early hominins evolved along the East African Rift, in a region shaped by plate tectonics. Early civilizations may have settled in tectonically active areas for the benefits accrued near rainy mountain ranges and volcanically–enriched soils. The island of Cyprus offers another example: oceanic crust lifted to the surface by tectonic activity exposed veins of copper that provided raw materials during the Bronze Age.

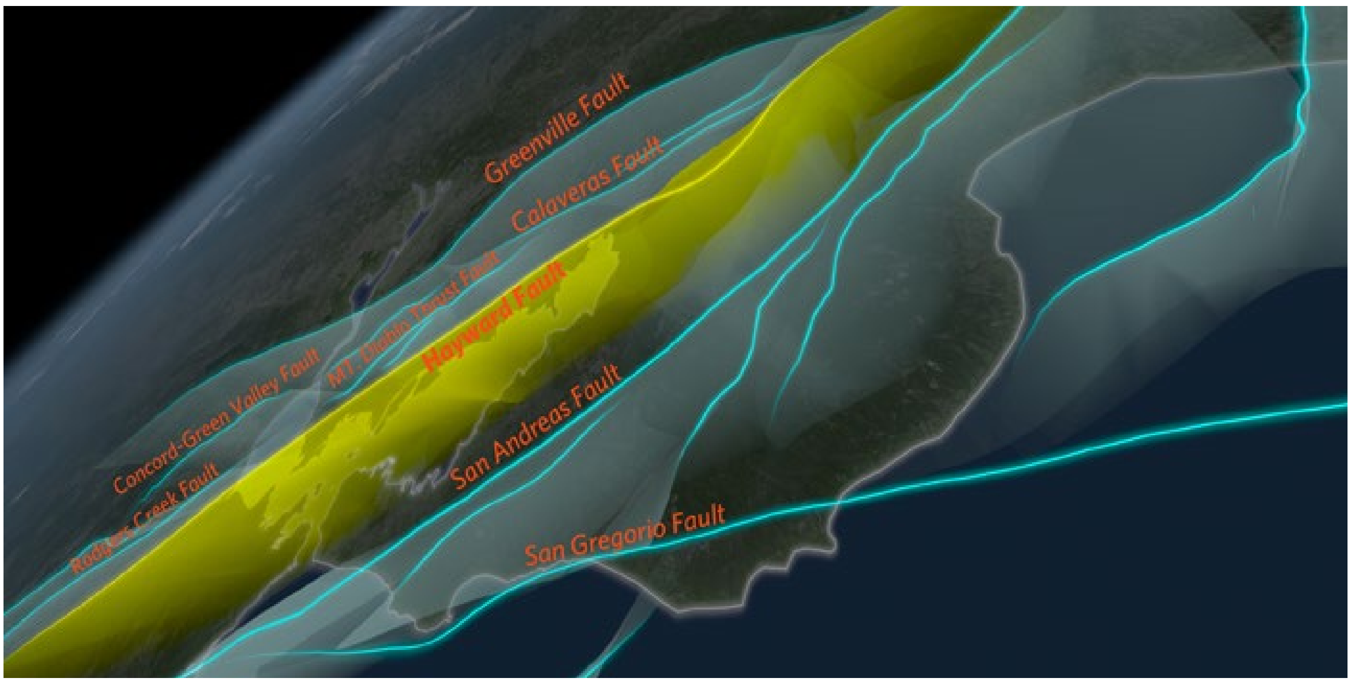
Perhaps in the past, plate tectonic activity could have led to the demise of entire civilizations, leaving behind only archeological remains to puzzle out prehistoric events. Historical records have yielded information on ancient quakes, helping scientists piece together more recent events. But only in the last century have humans developed precise instruments to monitor seismic events.

The Indian plate's northward movement pushes it into (and under) the Eurasian plate, causing tremors in Assam, India, that produced two massive earthquakes in 1897 and 1950. The concentration of populations in urban centers in seismic active areas has increased tremendously over the past century, which increases the probability of lethal earthquakes. In the worst such event every recorded, Tangshan, China, experienced near total destruction in 1976, and a quarter million people died.

In 2011, a rupture that released 60 times the energy of San Francisco's 1906 Earthquake occurred beneath the eastern coast of Japan. The locked Pacific Plate snapped free uplifting a massive quantity of water that formed a destructive tsunami. This tsunami spread across the entire Pacific Ocean, eventually reaching California's coast: a clear demonstration of how earthquakes connect the entire world.

Today earthquake scientists collect real-time data through instruments that record and share data about current seismic events. The degree to which plate motion deforms Earth's surface is recorded through satellite Global Positioning Systems (GPS).

The Bay Area encompasses an extensive network of fault fractures. The Hayward Fault, running parallel to the more famous San Andreas Fault, has shifted only slightly since 1868. Computer simulations help scientists test possible scenarios, to see the impact of a Hayward Fault quake on the Bay Area. Information such as the proximity of mountains, type of soil, and other factors are used to calculate shaking intensity. This information, combined with historical data, allows engineers to design safer structures for earthquake prone areas.



The San Francisco Bay Area Faults. Data courtesy of the u.s. Geological Survey

Engineers also use computational models to simulate shaking of building materials, and real-world tests are conducted on large shake tables using accurate seismic data. Engineering designs, including the isolation bearings used to support a structure, enable buildings such as San Francisco's City Hall to experience less damage when the ground shakes. Alternatively, a building can be strengthened to resist ground motions, such as San Francisco's iconic Ferry Building, which survived the 1906 earthquake but has also benefited from recent engineering improvements to prevent damage during future quakes.

Seismic monitor stations across the Western United States indicated in yellow. Data courtesy of USGS.

INTERNATIONAL REGISTRY OF SEISMOGRAPH STATIONS. INTERNATIONAL SEISMOLOGICAL CENTREON-LINE BULLETIN - WWW.ISC.AC.UK INTERNATL SEIS CENT, THATCHAM, UNITED KINGDOM, 2010

We can plan for a safer tomorrow, not only by designing more resilient buildings, bridges, and other infrastructure, but also by making decisions about preparedness in our daily lives. Although we do not know when the next earthquake will occur, we do know that human time and geological time will eventually intersect once again.

The California Academy of Sciences recognizes Bruce A. Bolt for his pioneering contributions to seismology and public safety.

Heat and Gravity

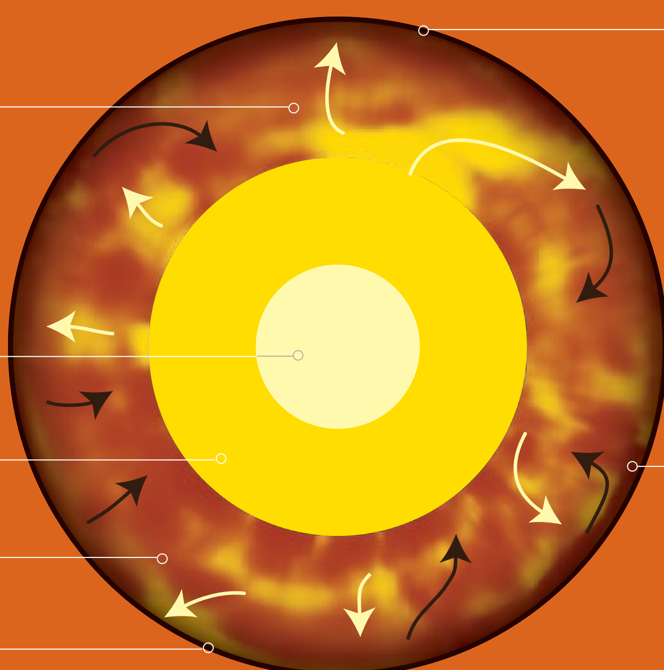
A constant heating and cooling cycle in the mantle drives plate movement on the Earth's surface. Heat combined with the effects of gravity causes irregular pieces of Earth's crust, called tectonic plates, to move.

Main ideas:

» Heat rising from Earth's **core** puts pressure on the bottom of the rigid outer mantle and crust (**lithosphere**) causing it to fracture and move.

» Heat left over from Earth's formation, combined with warmth of decaying atoms, softens the mantle rock, allowing it to flow slowly.

Take a closer look!



Reading Earthquakes

Earthquakes provide evidence of Earth's structure, which includes the core, mantle, and crust. Much of what we know about Earth's interior comes from waves generated by earthquakes.

Main ideas:

» The energy earthquakes release travels in the form of waves called seismic waves. Each earthquake produces three basic types of **seismic waves**.

» Each seismic wave has a different type of motion and travels through the earth at different speeds.

» Surface waves ripple across the crust, while body waves travel through Earth's interior in all directions. The faster primary P waves are always detected before slower secondary S wave. The farther away from the epicenter, the greater the time interval between the arrival of P and S waves.

» Scientists know about the structure and composition of Earth's interior by studying how seismic waves move through the Earth.

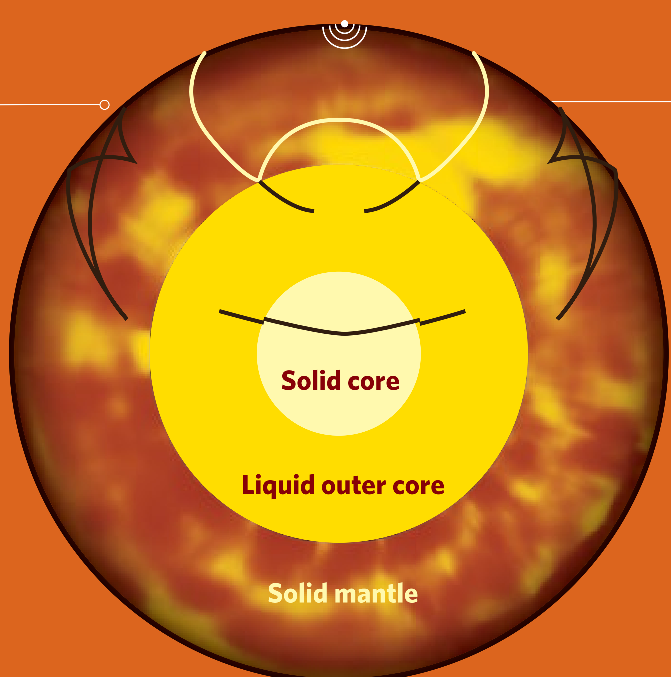
Seismic Waves

P-waves

Travel up to 46,800 km/h (29,000 mph).

Move with a back and forth motion.

Travel through both solids and liquids.



S-waves

Move at about half the speed of P-waves.

Move with an side-to-side motion.

Travel through solids but not through liquids.

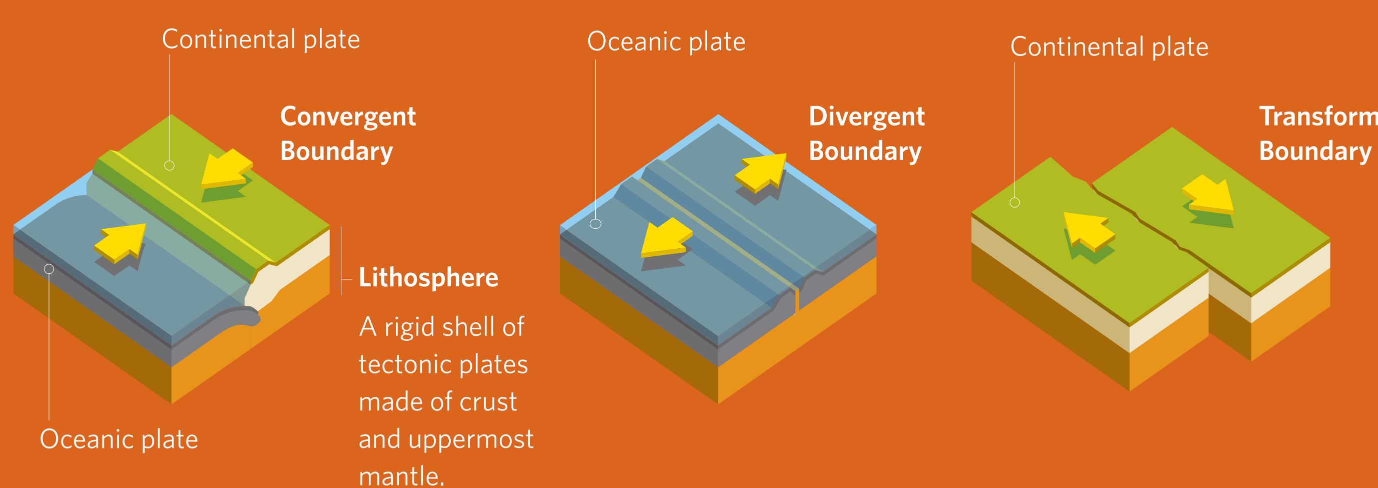
Earth Shakes Where Plates Meet

Movement in narrow zones along plate boundaries is the cause of most earthquakes. Earthquakes are not evenly distributed across the planet. Most seismic activity occurs at three types of plate boundaries: convergent, divergent and transform.

Main ideas:

- Earth's surface is fractured into irregular plates that are constantly in motion and most earthquake activity occurs in narrow zones along the boundaries of these moving plates.
- 80% of earthquakes—and the most powerful ones—occur where plates are pushed together, called **convergent boundaries**.
- Small earthquakes occur at mid-ocean ridges on the sea floor called **divergent boundaries**, where new crust causes plates to move away from each other.
- Large earthquakes that can happen at **transform boundaries** are caused by the periodic release of built-up stress caused by the friction of plates grinding past each other.

Coming Together, Spreading Apart, and Sliding Past



California Spans Three Shifting Plates

California lies within an active seismic zone. Earth's surface has changed dramatically over time due to the movement of plates. While significant on a human scale, the San Francisco earthquake in 1906 was just small a small blip in the continuous cycle of plate movement.

Main ideas:

- Most of the ocean-continent convergences take place along the Pacific Rim, but there is a lot of plate movement elsewhere, too.
- Plates are still moving today. The southern two-thirds of California straddle the Pacific and North American plates, which are grinding past each other.
- When stress, caused by moving plates, exceeds the strength of surrounding rock, the rock breaks and the released energy is felt as an **earthquake**.
- Ruptures along the San Andreas fault caused the great San Francisco earthquake in 1906 and the Loma Prieta event in 1989

California Plates

Subduction zone
This subduction zone is creating the most active seismic region in the state. Here, earthquakes up to 9.5 on the moment magnitude scale (Mw) can occur.

San Andreas Fault
This transform fault slices through California. The potential maximum size of its earthquakes is 8.0 (Mw).

Tsunamis
Transform faults like the San Andreas rarely cause tsunamis, but earthquakes in subduction zones often do.

Tectonic Plates Move

Tectonic plate boundaries cut across continents and oceans alike. Discover which boundaries are most seismically active and where in the world earthquakes have recently occurred.

Main ideas:

- We know where most earthquakes will occur, but not when they will occur.
- Many active faults in California are capable of creating major earthquakes.
- Earthquakes happen all the time, but most are too small to be felt.

Earth's Crust

Plate types
The North American Plate is a continental plate with a crust thickness of 35 to 70 km (22-44 mi). The Pacific Plate is an oceanic plate with a crust thickness of 7 to 10 km (4-6 mi).

Plate size
Fourteen large plates and 38 smaller ones make up Earth's crust. The Pacific and North American Plates are the largest.

Mid-ocean ridge
A continuous ridge of volcanic mountains down the center of the Atlantic Ocean. Hot mantle rises to form new oceanic crust as the seafloor is pushed apart.

The Impact of Earthquakes on Human Development

Widespread and powerful, earthquakes can have dramatic effects on people. Their effects can be short-term and superficial or much longer-lasting, influencing the course of cultural development by both building and destroying whole civilizations.

Main ideas:

- Our ancestors established many civilizations along plate boundaries: volcanoes enrich topsoil, making it better for growing crops, and mountain ranges can affect local climate to increase the availability of fresh water.
- Tectonic activity has also exposed precious metals to upper layers of Earth's crust: for example, in Cyprus, plate movements lifted up a portion of the sea floor, exposing veins of copper that provided raw materials for the Bronze Age.
- Aside from their local effects, earthquakes can cause tsunamis, or seismic sea waves, which can have effects on communities thousands of miles away: most recently, Japan's 2011 Tohoku earthquake reached across the Pacific Ocean to the west coast of the United States, with tsunami waves and debris that washed up in the Pacific Northwest.

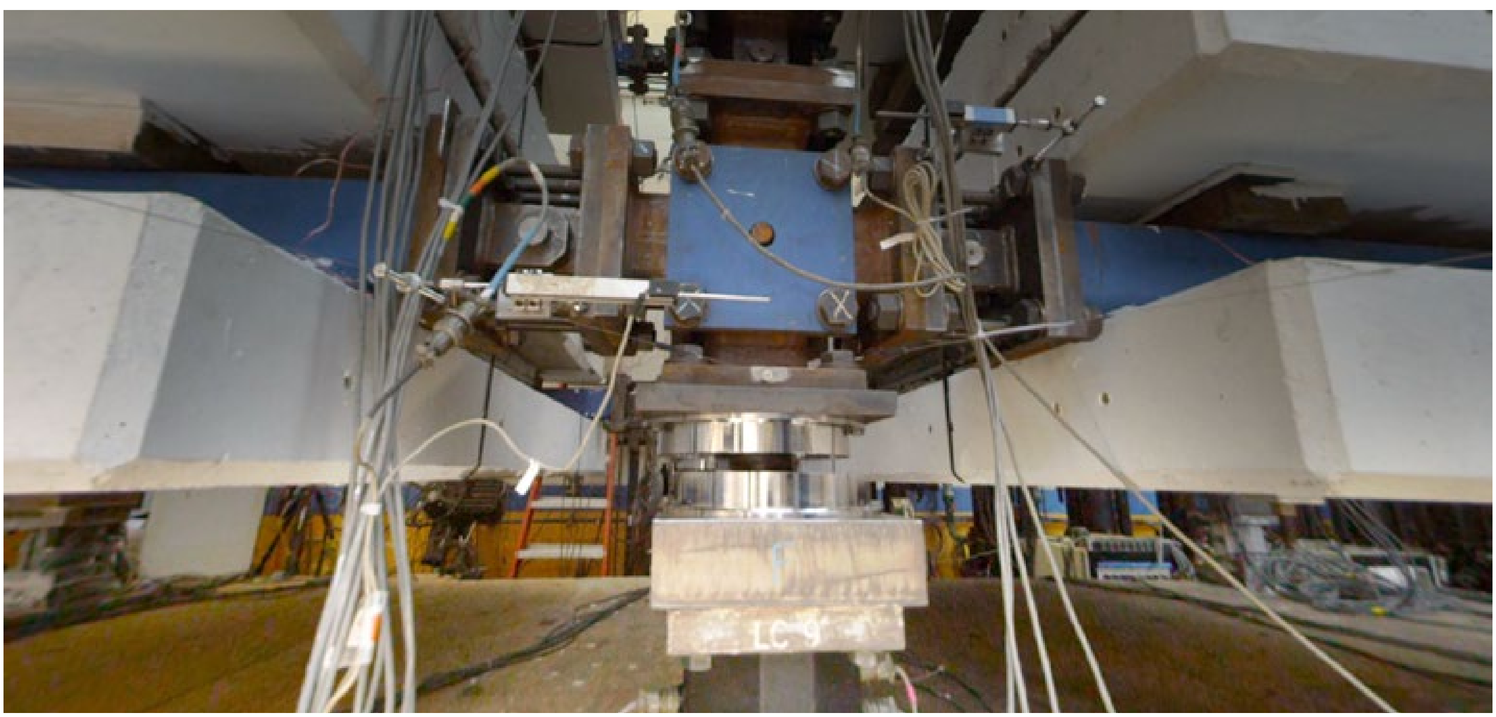
Images showing destruction from the 1897 earthquake in Assam, India.

Engineering for Safety

Earthquakes can do a lot of damage to cities and property, but strong building codes can help protect communities' infrastructure.

Main ideas:

- » As human population has grown, increasing numbers have settled in regions that experience seismic activity, which increases the likelihood of destructive earthquakes.
- » Studying earthquake activity and how structures respond to it helps scientists and engineers learn how to make buildings safer and more resistant to earthquake damage, protecting lives and saving millions of dollars worth in property. Applying this knowledge in the form of building standards can protect entire communities.
- » Making structures seismically safe requires a long-term commitment, since earthquakes can occur at long and irregular intervals.
- » Not only major buildings but ordinary homes can benefit from seismic strengthening.



Pacific Earthquake Engineering Research Center, University of California, Berkeley

How We Can Prepare

Get prepared—earthquakes happen without warning. We don't know when the next major earthquake will happen, but we can take action now to prepare to survive it and minimize impact. Preparedness starts with a plan. Here's what you and your students can do:

Six Steps to Stay Safe

Make a plan

Gathering your family will be top on your list. Choose a meeting place and an out-of-area contact person to relay messages.

Drop, cover and hold on

When a quake starts, drop down where you are, and cover your head. If you're near heavy furniture, take cover underneath and hold on tight.

Secure your home

Make sure your house is as shakeproof as possible by retrofitting weak spots, strapping down heavy furniture and securing loose objects.

Check for hazards

When the shaking stops, check for injuries and for damage to home electrical wires, gas lines, walls, floors and water pipes.

Get a kit

Store supplies to get your family through at least the first three days after a quake.

Stay connected

Surviving a quake is a community effort. Get to know your neighbors now, and work together with local organizations to prepare.

Related to Earthquakes

earthquake	a sudden rapid shaking of the ground caused by a rapid release of energy
epicenter	the point on Earth's surface that is vertically above the focus of an earthquake
fault	a break or fracture in a rock mass across which movement has occurred
focus (hypocenter)	the point of origin of an earthquake
intensity	the destructive effects of an earthquake on people and man-made things in a particular place. Intensity varies depending on distance from the focus, the nature of the surface materials, and the human development of an area.
magnitude	the amount of energy released by an earthquake; described by the Moment Magnitude Scale. The Richter scale is no longer used for official reporting.
seismic waves	shock waves in solid rock generated by earthquakes or underground explosions

Related to Plate Tectonics

convergent boundary	a boundary at which tectonic plates are pushing against each other
divergent boundary	a boundary at which tectonic plates are moving apart and the crust is expanding
lithosphere	the rigid outer layer of Earth, consisting of the crust and upper mantle. The lithosphere is broken into slowly moving tectonic plates.
plate tectonics	the theory that explains the movement and interactions of plates, which are segments of Earth's crust. The plates move slowly and continuously, and their interactions generate earthquakes, volcanoes, and mountains.
subduction	a geologic process in which one edge of a lithospheric plate is forced below the edge of another
transform boundary	a boundary at which tectonic plates slide past each other

Related to Earth's Structure

continental crust portions of Earth's crust that are thicker, more rigid and less dense than oceanic crust. Continental crust rises higher in the mantle than oceanic crust, and sheds water and sediments into the ocean basins.

core the innermost of Earth's layers, consisting of an outer core and an inner core. The molten outer core is composed mostly of iron and nickel and is located between approximately 2,900 and 5,200 km (1,802 and 3,231 miles) below Earth's surface. The solid inner core is composed of mostly iron and nickel and ranges from approximately 5,200 and 6,400 km (3,231 and 4,000 miles) below Earth's surface.

crust the outermost and thinnest of Earth's layers, with a thickness between 5 km (3 miles) (the oceanic crust) and 90 km (56 miles) (below the Himalayas). The average thickness of the crust is 35 km (22 miles). The crust is composed of brittle rocks that are high in silica and low in iron and magnesium.

mantle the thick layer of dense, rocky matter found below Earth's crust and surrounding Earth's core. Generally located from 35–2,900 km (22–1,802 miles) below Earth's surface, the mantle is ductile (flexible) and composed primarily of magnesium-iron silicate minerals such as olivine. It has an upper, partially-molten section, which is the source of magma and volcanic lava.

oceanic crust portions of Earth's crust that are thinner and more dense than continental crust. Oceanic crust has a lower elevation than continental crust, and water accumulates in these low-lying areas to form oceans.

Current Terminology

Vocabulary can change over time as our understanding of a concept is refined. Here are words and phrases currently used by earthquake scientists that replace some of the older terms you may see in textbooks.

Best term(s)	Old term	Explanation
Plate Movement, Movement of the Crust, or **Tectonic Plate Movement**	Continental Drift	Some scientists do not like using the term drift, when referring to motion of the plates, because it inaccurately describes the process that is causing the continents to move.
San Andreas Fault or **San Andreas Fault Plane**	San Andreas Fault Line	Faults describe the area of displacement between rocks. This area is a two-dimensional plane, not one-dimensional plane.
Heating and Cooling Cycle	Convection	The process that causes the mantle to move is more accurately described as a heating and cooling cycle, because actual "convection" cells are not formed in this process.
Moment Magnitude Scale	Richter Scale	When referring to the strength of an earthquake, the Moment Magnitude Scale measures the amount of energy released in an earthquake, while the Richter Scale measures the intensity of the shaking of an earthquake. Moment Magnitude is more consistent and fluctuates based on earthquake or rock type. The USGS uses the Moment Magnitude scale to report on the strength of earthquakes, not the Richter Scale.

Common Misconceptions

Many myths and misunderstandings exist about earthquakes. Here are the facts behind some common student misconceptions:

There is **no** relationship between earthquakes and weather.

- Earthquakes occur during all seasons, in all climate zones, during all types of weather, and at all times of day.
- While earthquakes are not influenced by weather, they can change climate over time by altering the elevation of land or by changing coastlines.

The ground **does not** open up during an earthquake.

- Shallow crevasses can occur during an earthquake, but faults do not open up and "swallow" buildings or people.

California **will not** break off of the continent and fall into the ocean.

- The San Andreas Fault divides the Pacific and North American Plates. Most motion along the fault occurs in a horizontal direction, with the Pacific Plate moving in a north-northwesterly direction at about 5 cm (2 inches) per year.
- Due to the horizontal nature of the movement, the West Coast will not separate from the continental United States. But if movement continues, land now located in Southern California will move towards Northern California.

Small earthquakes **do not** necessarily make a large earthquake less likely.

- So much pressure exists at the fault that small earthquakes do little or nothing to reduce it.
- Large earthquakes, however, do reduce the pressure at the fault.

Earthquake scientists **cannot** predict earthquakes.

- Current science does not have the ability to predict when the next major earthquake will occur or how big it will be.
- Based on past earthquakes and plate tectonics, scientist can tell where earthquakes are likely to occur, but not when.

CA Science Content Standards

Grade Six

Earth Sciences

1a: Evidence of plate tectonics

1b: Earth's layers

1c. Lithospheric plates

1d. Earthquakes

1e. Geological events

Grade Seven

Life Sciences

4a: Earth processes

4f. Plate movement

Grades Nine Through Twelve

Earth Sciences

3b. Principal structures at plate boundaries

3d. Earthquake intensity and magnitude

9b. Principal natural hazards and their geologic basis

Health Education

1.3.S. Analyze emergency preparedness plans

1.11.S. Identify ways to stay safe during natural disasters

Suggested Activities to Download

Download these activities from our website to enrich your field trip experience.

» **At-Academy Activity:** Earthquake Scavenger Hunt
www.calacademy.org/teachers/resources/lessons/earthquake-scavenger-hunt/
Through this scavenger hunt, students will explore key content found in the *Earthquake* exhibit, including evidence of plate movement and the structure of the Earth's interior.

» **At-Academy Activity:** The History of Geology and Life on Earth
www.calacademy.org/teachers/resources/lessons/the-history-of-geology-and-life-on-earth/
This scavenger hunt will take students all around the Academy to find life that is representative of different periods of Earth's evolutionary history. They will then use the *Earthquake* exhibit to help link the evolutionary timeline to what the Earth looked like at different points in time.

» **Anytime Lesson Plan:** Plotting Earthquakes
www.calacademy.org/teachers/resources/lessons/plotting-earthquakes/
In this activity, students will learn how to plot earthquakes on a map by exploring recent earthquake activity in California and Nevada.

Online Resources for Teachers

www.calacademy.org/teachers/resources/lessons

» **Connected experiences:**
Activity combinations that extend the museum visit into the classroom.

» **Anytime lesson plans:**
Full-period lessons to integrate into your yearly curriculum

» **Pre-, during-, and post-visit activities:**
Short, lively activities to focus your class trip.

Online Resources for Students

Want to find out more?

» **Quake Catcher Network**
http://qcn.stanford.edu/
This is the website for a citizen science project that uses computers to create a seismic monitoring network, which improves our understanding of earthquakes, raises awareness about earthquake safety and helps people learn about the science of earthquakes. Includes information on how to obtain a seismic monitor and lesson plans.

» **Animations for Earthquake Terms and Concepts**
http://earthquake.usgs.gov/learn/animations/
Developed by the U.S. Geological Survey, these short videos provide a visual explanation for various terms from "amplification" to "wavefront".

» **Earthquakes for Kids**
http://earthquake.usgs.gov/learn/kids/
Learn about historical earthquakes, current seismic activity and the science for predicting future events on this site created by the U.S. Geological Survey. Includes links to animations, puzzles, games and science fair project ideas.

» **Faultline: Seismic Science at the Epicenter**
http://www.exploratorium.edu/faultline/index.html
This interactive website includes an overview of earthquakes in San Francisco's history, earthquake science basics, links to information on current seismic activity and hands-on activities.

» **Kid's Hazards Quiz**
http://www.ngdc.noaa.gov/hazard/kqStart.shtml
Are you prepared for an earthquake? Find out how to prepare for this and other natural disasters by taking these quizzes created by NOAA (National Oceanic and Atmospheric Administration).

» **Tremor Troop: Earthquakes—A Teacher's Package for K-6. Revised Edition.**
http://www.fema.gov/library/viewRecord.do?id=1632
Developed through a partnership between FEMA and NSTA, this curriculum provides a series of hands-on activities related to the science of earthquakes and earthquake safety. The lessons are multi-disciplinary and aligned with the national science standards.

Guiding Questions and Answers

Use these questions to get the students thinking about earthquakes.

» **What are the different layers of the earth made of?**
The earth is made up of three basic layers: the crust, mantle, and core. Going from the outermost crust to the innermost core, the layers are exposed to increasing pressures and temperatures. The crust is made up of hard, solid rock. The mantle is made of rock and is solid at the outermost edges and becomes a thick liquid on its inner side. The core has two sections. The outer core is very hot and made up of liquid metal. The inner core is even hotter, and made of metals, but because it is under extreme pressure it is solid.

» **What evidence led scientists to the idea of plate tectonics?**
The evidence that supports plate tectonics includes the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.

» **How have moving plates affected Earth's surface? Are these changes fast or slow?**
Over millions of years, plate movement has created our continents and oceans. Plates coming together can form mountain ranges and plates moving away from each other can form basins that underlie oceans. Other changes happen much more quickly, like volcanoes erupting and earthquakes, which can form new landscapes and remodel existing ones.

» **A lot of energy is released in an earthquake. Where do you think this energy comes from? What do you think happens to it/where do you think it goes?**
Before an earthquake happens, energy is stored as rocks are pushed against each other along the boundaries of tectonic plates. When stress exceeds rock strength, the rock breaks and energy is released as an earthquake. The magnitude of an earthquake is a measurement of the amount of energy released. This energy is released as heat and waves of energy that travel through the earth and cause the shaking that we feel during an earthquake.

Guiding Questions and Answers

Use these questions to get the students thinking about earthquakes.

» **What are ways that you can stay safe at home during and following an earthquake?**
One way you can stay safe during an earthquake is by being prepared ahead of time. This can be done by encouraging your family to prepare a disaster plan and a household disaster kit. Your plan should include what you and your family will do before, during and after an earthquake. The kit should contain items that you will need following a severe earthquake including drinking water, emergency lights, food, etc. Another way you can stay safe during an earthquake is by identifying potential hazards in your home and minimizing those hazards before an earthquake occurs. This includes securing top–heavy furniture to a wall, anchoring hanging objects, and moving heavy items to lower shelves in your home. During an earthquake, you should drop, cover and hold on. Immediately following an earthquake, you can stay safe by checking for injuries and damage and continuing to follow your family's disaster plan.

Credits

Science Data and Simulations

1906 San Francisco Earthquake Broadband Ground Motion Simulation
U.S. Geological Survey
Brad Aagaard and Robert W. Graves

San Francisco 1906 Earthquake Simulation
Hayward Earthquake Simulation
Global Tomographic Model

Lawrence Livermore National Laboratory
Atmospheric, Earth and Energy Division,
  Physical and Life Science Directorate
Center For Advanced Scientific Computing,
  Computational Science Directorate
Information Management and Graphics Group,
  Computational Science Directorate

3D Geologic Block Model
San Francisco Bay Region, U.S. Geological Survey

Digital Model of Earth Plate Boundaries
Peter Bird, Professor Emeritus
Department of Earth and Space Sciences
  University of California, Los Angeles

Paleomap Animation Key Frames
Ron Blakey, Professor Emeritus NAU Geology
Colorado Plateau Geosystems, Inc.
www.cpgeosystems.com

Global Digital Elevation Model Topography and Bathymetry
NOAA
ETOPO1 1 Arc–Minute Global Relief Model
Amante, C. and B. W. Eakins
NESDIS NGDC-24

Centennial Earthquake Catalog
U.S. Geological Survey
Engdahl and Villaseñor, 2002

International Registry of Seismograph Stations
International Seismological Centre
Online Bulletin: www.isc.ac.uk
Internatl Seis Cent, Thatcham, United Kingdom, 2010

Cypriot Artifact Illustrations
Cyprus: Its Ancient Cities, Tombs and Temples
Second Edition
New York, Harper and Brothers, 1878
General Louis Palma Di Cesnola

Assam Photographs
Roger G. Bilham, University of Colorado, Boulder

A Production of
California Academy of Sciences Visualization Studio

Continue the story at www.calacademy.org/earthquake

EARTHQUAKE
Evidence of a Restless Planet

This production generously underwritten by
Ann L. and Charles B. Johnson

In tribute to Bruce A. Bolt for his contributions to seismology and public safety.