Appendix

A. Earthquake Background

B. Book of Legends

C. National Science Education Standards Matrices

Earthquake Background

Earthquake Legends

Ancient peoples experienced the same natural disasters that can affect each of us. Among these were hurricanes, tornadoes, droughts, floods, volcanic eruptions, and earthquakes. Because they did not have scientific explanations for such catastrophes, ancient peoples invented folk narratives, or legends, to explain them. Such legends are part of the literature that we have inherited from many cultures. An examination of legends gives a small insight into the location and frequency of occurrence of major earthquakes.

Defining an Earthquake

Earthquakes are an especially noteworthy type of catastrophe because they strike suddenly, without clear warning, and can cause much panic and property damage in a matter of seconds

An earthquake is a sudden, rapid shaking of the Earth caused by the release of energy stored in the Earth's crust. An earthquake occurs at a place, called the focus, which may be up to about 700 km deep in the Earth. The place on the Earth's surface that is directly above the focus is called the epicenter of the earthquake. It has long been known that earthquake epicenters often lie along narrow zones, or belts, of the Earth where mountain building and/or volcanic activity are also present. But earthquakes may also occur in seemingly "stable" areas like the central and eastern United States.

Plate Tectonic Theory and Earthquake Occurrence

According to the recently formulated (late 1960s) theory of plate tectonics, earthquakes occur because of the motion of the pieces of solid crust and upper mantle that form the 100 km-thick, outer rock shell of our planet. This shell, called the lithosphere, or rock sphere, is broken into major and minor pieces called plates.

There are seven to twelve major plates and a number of smaller ones. From a geophysical perspective the Earth is like a giant spherical jigsaw puzzle with its pieces in constant motion.

The reason for plate motion is unknown. Scientists speculate, however, that the internal heat of the Earth causes convection currents in the semimolten, mantle rock material beneath the plates. They suggest that this convective motion, driven by the Earth's internal heat, drives the plates. Such heat is believed to come from the decay of radioactive minerals in the mantle, which extends to a depth of 2,855 km below the Earth's surface.

Types of Plate Motion

The plates move, relative to one another, at between approximately 2 and 15 cm per year. Three types of plate motion are most important for understanding where and how earthquakes occur. Divergent plate motion occurs where the plates are moving apart. Such plate separation most often occurs along the mid-ocean ridges. As the plates separate, new ocean crust forms from mantle material by volcanic eruptions or fissure flows. Many shallow earthquakes result from separation of plates. Because these usually occur in the deep ocean, however, they are rarely of concern to humans.

Plates are moving toward each other in such places as around the Pacific Ocean basin, and the Mediterranean. This is called convergent plate motion. Where the leading edge of a plate is made of ocean crust and underlying mantle, the plate tends to sink under the edge of the opposing plate. Such motion is called subduction.

An oceanic trench is a common feature at plate boundaries where subduction is occurring, such as along the Pacific side of the Japanese or Aleutian island areas and the Pacific side of South America. As the subducting plate sinks into the mantle, it begins to melt. The resulting molten rock materials gradually rise toward the Earth's surface to form volcanoes and fissure flows of lava. Subduction results in many earthquakes with foci from near the Earth's surface to about 700 km below the surface. Some of these earthquakes are extremely violent.

Where the opposing plates are both made of continental material, their collision tends to raise mountain chains. The convergent motion of the continental masses of India and Southeast Asia began millions of years ago and continues into the present. The result is the Himalayan Mountains, which are still rising slowly and are being subjected to frequent earthquakes as the mountain building process continues.

The conservation of the area of the lithosphere is one of the important concepts that relates to the divergent and convergent activity of plates. That is, a worldwide balance exists between the creation of new lithosphere at the mid-ocean ridges and the destruction of the lithosphere along subduction zones. This allows us to picture the Earth as remaining relatively constant in size. Earlier explanations of folded and thrust-faulted mountain ranges incorrectly required that the Earth shrink in size as it cooled. The mountains were thought to rise as the lithosphere buckled, something like the shriveling of the skin on an apple as it ages.

In the third major type of plate motion, the edges of the plates slip past each other. This is called lateral (or transform) plate motion. The line of contact between the plates is a fault. The stresses involved in lateral plate motion actually cause rupturing and movement on faults some distance from the area of contact between the plates. Therefore, it is proper to speak of a fault zone when discussing rock movement caused by lateral plate.

One of the lateral faults best known in to North Americans is the San Andreas fault of California. The San Andreas and its associated faults extend from the Gulf of California to the Pacific coast north of San Francisco. Earthquakes occur frequently in the San Andreas fault zone. Some of them have caused loss of life and extensive property damage.

Mid-Plate Earthquakes

Many earthquakes occur at places far from plate boundaries. Some of them, like the New Madrid earthquakes of 1811-1812 and the Charleston earthquake of 1886, have been major historical disasters. Explaining such mid-plate earthquakes has been a challenge to the theory of plate tectonics outlined above. Recent research has shown, however, that the zones of instability within plates can produce earthquakes along intraplate fault zones which may be hidden at the Earth's surface. Because of the location of these fault zones and their infrequent activity, it is still difficult to assess the hazards they may pose.

Plate Tectonics, Faulting, and Topography

From the previous discussion, the origin of major topographic elements of the ocean floor become more apparent. Among these are the world-circling, 60,000 km-long mid-ocean mountain ranges, or mid-ocean ridges, and the trenches, whose depth below the ocean floor exceeds any chasm found on land. Plate motion also causes the folding and faulting of continental rocks and their uplift into mountains. Thrust faulting may accompany such mountain building. A thrust fault is one in which the upper block of rock slides over a lower block which is separated from it by the fault. Earthquakes occur at and near the fault surface, as the blocks of rock move relative to one another.

Normal faults occur where rock units are pulled apart allowing movement vertically under the influence of gravity. The result of normal faulting, on a continental scale, is the creation of long, deep valleys or the lowering subsidence of large pieces of coastal topography. A normal fault is one in which the upper block moves downward relative to the lower block which is separated from it by the fault. As in thrust faulting, earthquakes occur at and near the fault surface as the blocks of rock move relative to one another.

Lateral faults occur where plates are sliding past each other. A lateral fault is one in which the blocks of rock move in a predominantly horizontal direction past each other with the vertical, or near-vertical, fault surface separating them. In the ideal case, lateral faults do not cause much change in the elevation of the opposing blocks of rock. Rather, they move the existing topography to different locations. Earthquakes occur at and near the fault surface as the blocks move relative to one another

Detecting Earthquakes

When rock units move past each other along normal, thrust, or lateral fault surfaces, or zones, the result is often an earthquake Vibrations arise at the earthquake focus and travel outward in all directions. The vibrations travel through the upper part of the lithosphere and also penetrate the deeper shells of the Earth's structure. The waves that travel through the upper part of the lithosphere are called surface waves. Those that travel within the Earth are called body waves.

The two main varieties of surface waves are Love waves, which travel sideways in a snake-like motion, and Rayleigh waves, which have an up-and-down motion. Surface waves from a large earthquake travel for thousands to tens of thousands of square kilometers around the earthquake epicenter. They are primarily responsible for the shaking of the ground and damage to buildings that occur in large earthquakes.

Body waves are either P- (for Primary) waves or S- (for Secondary) waves. Regardless of the nature of the material through which they travel, P-waves are always faster than S-waves. The difference in the arrival times of the two types of body waves allows seismologists to locate the focus of an earthquake.

Instrumental Measurement of Earthquakes

One way to describe an earthquake is in terms of the amount of energy it releases. That energy is indicated by the strength of the surface and body waves that travel away from the earthquake focus. As simple as this principle may seem, it was not until the late 1800s that a machine (seismograph) to detect and record earthquake waves was invented by British scientists working in Japan. The most famous of these early seismographs was invented by John Milne, who returned to Great Britain to establish the field of seismology.

In modern observatories, seismograph instruments can measure the north-south, east-west, and vertical motion of the ground as the various types of seismic waves travel past. Each machine sends an electrical signal to a recorder which produces a highly amplified tracing of the ground motion on a large sheet of paper. This tracing is called a seismogram. Modern seismographs record data digitally, increasing the speed and accuracy of earthquake measurements

The American seismologist Charles Richter used the amplitude of the body waves shown on seismograms to measure the amount of energy released by earthquakes. The scale which he created in 1935 is called the Richter Scale in his honor. It uses Arabic numerals to rate earthquake magnitudes. The scale is logarithmic and open-ended. That is, there is no lower or upper limit to the magnitude of an earthquake. However, the largest earthquake ever recorded had a Richter magnitude of 8.9. The Richter magnitude of an earthquake also can be measured from the amplitude of its surface waves.

In recent years seismologists developed a new magnitude scale called moment magnitude. The moment of an earthquake is a physical quantity (e.g., area of fault slip) which is related to the total energy released in the earthquake. Moment magnitude can be estimated in the field by looking at the geometry of the fault, or by looking at the record of the earthquake (seismogram). Moment magnitude is now preferred because it can be used to measure all earthquakes—no matter how large, small, close, or distant—at the same scale.

Intensity Measurement of Earthquakes

Even before seismographs came into common use, the effort to classify earthquakes by the damage they produce reached success through the work of the Italian seismologist Giuseppe Mercalli and other European scientists. The 1902 Mercalli scale was modified in 1931 by two American seismologists, H.O. Wood and Frank Neumann. In the Modified Mercalli scale, Roman numerals from I to XII are used to rate the damage, ground motion, and human impact resulting from an earthquake.

The intensity assigned to an earthquake is a relative measure. That is, the Modified Mercalli intensity at a given place depends on the distance from the earthquake epicenter as well as the geological structure of the area. For example, houses built on bedrock will receive less damage than similar houses built on sediment at the same distance from the earthquake epicenter. Poorly built structures will receive more damage than those reinforced to withstand earthquakes.

Earthquake Magnitude—The Size of an Earthquake

m_L = *Local magnitude*, devised by Richter and Gutenberg to describe local (Southern California) earthquakes. This is the *Richter magnitude* reported often in newspapers.

m_b = *P-wave* or *body* magnitude, determined using P-wave amplitude.

m_s = *Surface-wave* magnitude, calculated using Rayleigh wave amplitude having a period approximately 20 seconds. The m_s is commonly-reported magnitude, superseding that of m_L.

m_w = *Seismic moment* magnitude. Determined by taking into account rupture area, displacement, and rock strength. These values are obtained by analysis of seismograms, including wave amplitudes; and field observations.

Location and Earthquake Risk

Earthquakes tend to occur where they have occurred before. There also appears to be some periodicity to the recurrence of earthquakes, that is, some more or less regular interval between major quakes. Unfortunately, human memory and written records do not go back far enough to allow us to predict earthquakes accurately along any known fault. Of course, some faults lie hidden beneath sediment or rock cover and have not been active in recorded time. When an earthquake occurs on such a fault, it may come as a surprise to everyone.

Scientists are developing and refining techniques, such as measuring the change in position of rock along a fault, that may eventually result in an ability to predict the magnitude and date of an earthquake on a known fault. Meanwhile, it is prudent to assume that an earthquake could occur on any fault at any time. Even if an earthquake occurs on a fault that is tens or hundreds of kilometers away, the resulting vibrations could inflict serious damage in your local area.

What Should Be Done To Prepare for an Earthquake?

Weaker structures are more prone to damage than structures built to resist earthquake shaking. Luckily modern houses built with wooden framing are fairly resistant to serious damage in small to medium earthquakes. Most modern commercial buildings are now designed to resist wind forces and earthquake shaking.

Since earthquake shaking is possible almost everywhere in the United States, earthquake safety should be practiced by everyone, whether at home, at school, at work, or on the road.

After personal safety in an earthquake has been attended to, it may be necessary to lead, or join, citizen action groups that are concerned with the safety of the community infrastructure during and after an earthquake. Will the "lifelines" -- water, gas, electricity, phone and sewer lines -- survive the anticipated earthquake? Will the hospital and other emergency services be operating and adequate to handle emergencies created by the earthquake? Even California, where individuals and governments are sensitive to these questions, the answer seems to be "not completely." What is the status of earthquake preparedness where you live?

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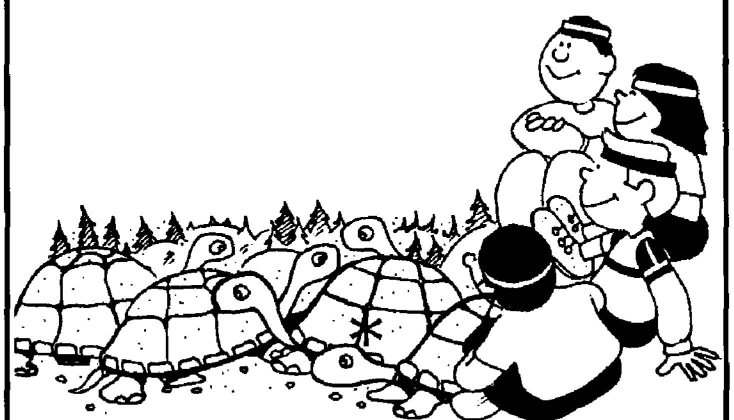
Earthquake Legends



1. India

The Earth is held up by four elephants that stand on the back of a turtle. The turtle is balanced in turn on a cobra. When any of these animals moves, the Earth will tremble and shake.

*

20. West Africa

A giant carries the Earth on his head. All the plants that grow on the Earth are his hair, and people and animals are the insects that crawl through his hair. He usually sits and faces the east, but once in a while he turns to the west (the direction earthquakes come from in West Africa), and then back to the east, with a jolt that is felt as an earthquake.

*

19. Romania

The world rests on the divine pillars of Faith, Hope, and Charity. When the deeds of human beings make one of the pillars weak, the Earth is shaken.

*

2. Assam

(between Bangladesh and China)

There is a race of people living inside the Earth. From time to time they shake the ground to find out if anyone is still living on the surface. When children feel a quake, they shout "Alive, alive!" so the people inside the Earth will know they are there and stop the shaking..

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3. Mexico

El Dia, the devil, makes giant rips in the Earth from the inside. He and his devilish friends use the cracks when they want to come and stir up trouble on Earth.

*

18. Central America

The square Earth is held up at its four corners by four gods, the Vashakmen. When they decide the Earth is becoming overpopulated, they tip it to get rid of surplus people.

*

17. East Africa

A giant fish carries a stone on his back. A cow stands on the stone, balancing the Earth on one of her horns. From time to time her neck begins to ache, and she tosses the globe from one horn to the other.

*

4. Siberia

The Earth rests on a sled driven by a god named Tuli. The dogs who pull the sled have fleas. When they stop to scratch, the Earth shakes.

*

5. Japan

A great catfish, or namazu, lies curled up under the sea, with the islands of Japan resting on his back. A demigod, or daimyojin, holds a heavy stone over his head to keep him from moving. Once in a while, though, the daimyojin is distracted, the namazu moves, and the Earth trembles.

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16. New Zealand

Mother Earth has a child within her womb, the young god Ru. When he stretches and kicks as babies do, he causes earthquakes.

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15. Scandinavia

The god Loki is being punished for the murder of his brother, Baldur. He is tied to a rock in an underground cave. Above his face is a serpent dripping poison, which Loki's sister catches in a bowl. From time to time she has to go away to empty the bowl. Then the poison falls on Loki's face. He twists and wiggles to avoid it, and the ground shakes up above him.

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6. Mozambique

The Earth is a living creature, and it has the same kinds of problems people have. Sometimes it gets sick, with fever and chills, and we can feel its shaking.

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7. Greece

According to Aristotle, (and also to Shakespeare, in the play called Henry IV, Part I) strong, wild winds are trapped and held in caverns under the ground. They struggle to escape, and earthquakes are the result of their struggle.

*

14. Colombia

When the Earth was first made it rested firmly on three large beams of wood. But one day the god Chibchacum decided that it would be fun to see the plain of Bogota underwater. He flooded the land, and for his punishment he is forced to carry the world on his shoulders. Sometimes he's angry and stomps, shaking the Earth.

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13. Latvia

A god named Drebkuhls carries the Earth in his arms as he walks through the heavens. When he's having a bad day, he might handle his burden a little roughly. Then the Earth will feel the shaking.

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8. Belgium

When people on Earth are very, very sinful, God sends an angry angel to strike the air that surrounds our planet. The blows produce a musical tone which is felt on the Earth as a series of shocks.

*

9. Tennessee, USA

Once a Chickasaw chief was in love with a Choctaw princess. He was young and handsome, but he had a twisted foot, so his people called him Reelfoot. When the princess' father refused to give Reelfoot his daughter's hand, the chief and his friends kidnapped her and began to celebrate their marriage.

The Great Spirit was angry, and stomped his foot. The shock caused the Mississippi to overflow its banks and drown the entire wedding party. (Reelfoot Lake, on the Tennessee side of the Mississippi, was actually formed as a result of the New Madrid earthquake of 1812.)

12. India

Seven serpents share the task of guarding the seven sections of the lowest heaven. The seven of them a take turns holding up the Earth. When one finishes its turn and another moves into place, people on Earth may feel a jolt.

*

11. Mongolia

The gods who made the Earth gave it to a frog to carry on his back. When this huge frog stirs, the Earth moves directly above the part of him that moves: hind foot, head, shoulder, or whatever.

*

10. West Africa

The Earth is a flat disk, held up on one side by an enormous mountain and on the other by a giant. The giant's wife holds up the sky. The Earth trembles whenever he stops to hug her.

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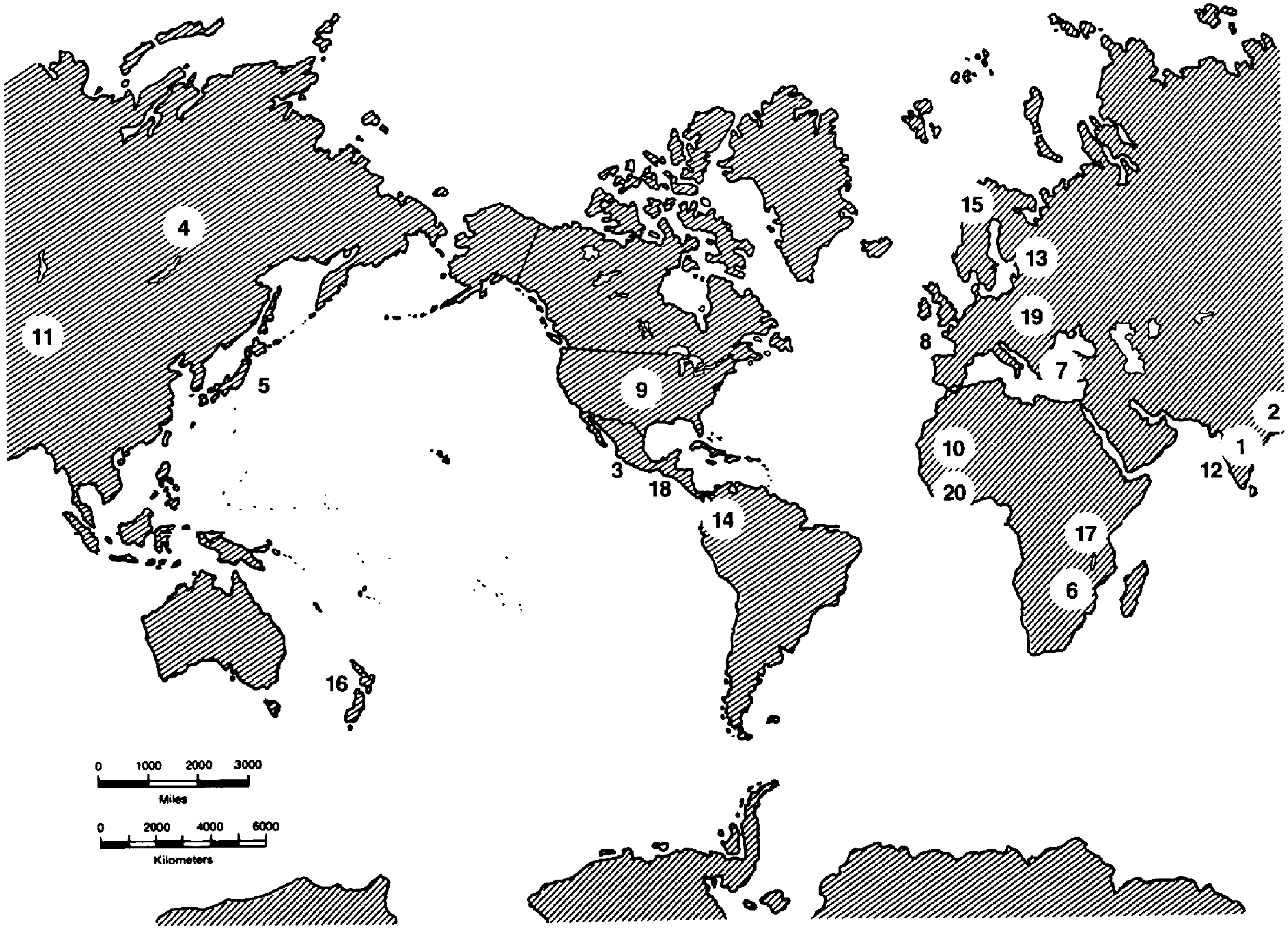
World Map with Legend Sites



National Science Education Standards Matrices

Tremor Troop
Link to National Science Education Standards

Unit/ Grades	Science as Inquiry	Physical Science	Earth & Space Sci.	Science & Technology	Sci. in Personal & Social Perspectives	History & Nature of Science	Unifying Concepts & Processes
I.1	D	D	D	D	I	I	D
I.2	D	D	D	D	I	I	D
I.3	D	D	D		D	D	D
II.1	I	D	D	I			D
II.2	D	D	D	D		I	D
II.3	I	D	D		D		D
III.1	I	D	D	I	I		D
III.2	D	D	D		I		D
III.3	I	D	D			I	D
IV.1	D	D	D	D	I		D
IV.2	D	D	D	D	I		D
IV.3	D	D	D	D	I	I	D
V. Part 1		D	D	I	D		D
V. Part 2	I	D	I	I	D		I
V. Part 3				I	D		I
V. Part 4				I	D		

D = Direct Connection
I = Indirect Connection

National Science Education Standards

Tremor Troop: Earthquakes	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology
I.1 People Explain Earthquakes Students explore their personal experiences with earthquakes and observe a simulated earthquake by building an earthquake model. They also learn about earthquake legends and suggest possible causes of earthquakes and the structure of the Earth's interior.	**Abilities related to scientific inquiry** Understanding about scientific inquiry	**Position and motion of objects**	Properties of Earth materials **Changes in the Earth and sky**	**Understanding about science and technology**
I.2 People Explain Earthquakes Students explore personal experiences with earthquakes and communicate their thoughts about the causes of earthquakes. They identify and compare cultures that developed legends explaining earthquakes and learn what scientists believe cause earthquakes.	**Abilities related to scientific inquiry** Understanding about scientific inquiry	**Position and motion of objects**	**Changes in the Earth and sky**	**Understanding about science and technology**
I.3 Energy Waves Cause Earthquakes Students conduct investigations to simulate earthquakes and explain how they relate to events on Earth. They identify and compare locations of earth-quakes and relate earthquake sites to legends and cultures.	**Abilities related to scientific inquiry** Understanding about scientific inquiry	**Motions and forces** **Transfer of energy**	**Structure of the Earth system** **Earth's history**	

National Science Education Standards

Tremor Troop: Earthquakes	Science in Personal and Social Perspectives	History and Nature of Science	Unifying Concepts and Processes	
I.1 People Explain Earthquakes Students explore their personal experiences with earthquakes and observe a simulated earthquake by building an earthquake model. They also learn about earthquake legends and suggest possible causes of earthquakes and the structure of the Earth's interior.	Personal health Changes in Environments	Science as a human endeavor	Systems, order, and organization **Evidence, models, and explanation**	
I.2 People Explain Earthquakes Students explore personal experiences with earthquakes and communicate their thoughts about the causes of earthquakes. They identify and compare cultures that developed legends explaining earthquakes and learn what scientists believe cause earthquakes.	Personal health Changes in Environments	Science as a human endeavor	**Systems, order, and organization** **Evidence, models, and explanation**	
I.3 Energy Waves Cause Earthquakes Students conduct investigations to simulate earthquakes and explain how they relate to events on Earth. They identify and compare locations of earth-quakes and relate earthquake sites to legends and cultures.	Personal health **Natural hazards** Risks and benefits	Science as a human endeavor Nature of science **History of science**	Systems, order, and organization **Evidence, models, and explanation**	

National Science Education Standards

Tremor Troop: Earthquakes	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology
II.1 Inside Planet Earth Students name, identify, and observe a model of Earth's layers and plates and construct representations of each.	Abilities related to scientific inquiry Understanding about scientific inquiry	Properties of objects and materials **Position and motion of objects**	Properties of Earth materials **Changes in the Earth and sky**	Understanding about science and technology
II.2 Plates Going Places Students describe, name, and identify the interior and layers of the Earth. They construct models the Earth that demonstrate the way the surface is affected by interior movements.	**Abilities related to scientific inquiry** Understanding about scientific inquiry	Properties of objects and materials **Position and motion of objects**	Properties of Earth materials **Changes in the Earth and sky**	**Understanding about science and technology**
II.3 Layers, Plates, and Quakes Students construct models of the Earth's layers and describe the composition of the layers and the effects of activity at plate boundaries. They investigate convection as a model of plate movement.	Abilities necessary to do scientific inquiry Communicate scientific procedures and explanations Use mathematics in all aspects of scientific inquiry	**Motions and forces**	**Structure of the Earth system** **Earth's history**	

National Science Education Standards

Tremor Troop: Earthquakes	Science in Personal and Social Perspectives	History and Nature of Science	Unifying Concepts and Processes	
II.1 Inside Planet Earth Students name, identify, and observe a model of Earth's layers and plates and construct representations of each.			**Systems, order, and organization** **Evidence, models, and explanation**	
II.2 Plates Going Places Students describe, name, and identify the interior and layers of the Earth. They construct models the Earth that demonstrate the way the surface is affected by interior movements.			**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	
II.3 Layers, Plates, and Quakes Students construct models of the Earth's layers and describe the composition of the layers and the effects of activity at plate boundaries. They investigate convection as a model of plate movement.	**Natural hazards** Risks and benefits	History of science	**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	

National Science Education Standards

Tremor Troop: Earthquakes	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology
III.1 Earthquakes Shape Our Earth Students demonstrate two types of faults and construct a model of a rural community to demonstrate the effect of an earthquake.	Abilities related to scientific inquiry Understanding about scientific inquiry	**Position and motion of objects**	**Changes in the Earth and sky**	Understanding about science and technology
III.2 Landscape on the Loose Students describe land features that result from earthquake activity and construct models of fault types. They demonstrate the formation of land features and events from earthquakes.	**Abilities related to scientific inquiry** **Understanding about scientific inquiry**	Properties of objects and materials **Position and motion of objects**	Properties of Earth materials **Changes in the Earth and sky**	
III.3 Building Up and Breaking Down Students describe and construct models of major landscape features. They relate these models to actual locations and demonstrate underwater activity that relates to earthquakes.	Abilities necessary to do scientific inquiry Communicate scientific procedures and explanations	**Motions and forces**	**Structure of the Earth system** **Earth's history**	

National Science Education Standards

Tremor Troop: Earthquakes	Science in Personal and Social Perspectives	History and Nature of Science	Unifying Concepts and Processes	
III.1 Earthquakes Shape Our Earth Students demonstrate two types of faults and construct a model of a rural community to demonstrate the effect of an earthquake.	Personal health Changes in Environments		**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	
III.2 Landscape on the Loose Students describe land features that result from earthquake activity and construct models of fault types. They demonstrate the formation of land features and events from earthquakes.	Personal health Changes in Environments		**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	
III.3 Building Up and Breaking Down Students describe and construct models of major landscape features. They relate these models to actual locations and demonstrate underwater activity that relates to earthquakes.		History of science	**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	

National Science Education Standards

Tremor Troop Earthquakes	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology
IV.1 Earthquakes Great and Small Students demonstrate earthquake simulation of different strengths and compare damage of each. They also demonstrate the length of time associated with earthquakes.	**Abilities related to scientific inquiry** **Understanding about scientific inquiry**	**Position and motion of objects**	**Changes in the Earth and sky**	**Abilities of Technological Design**
IV.2 Different Shakes for Different Quakes Students demonstrate simulations of various earthquake strengths and describe tech niques for measuring earthquakes. They demonstrate a technique for recording earthquake movement and a method used to measure earthquakes.	**Abilities related to scientific inquiry** **Understanding about scientific inquiry**	**Position and motion of objects**	**Changes in the Earth and sky**	**Abilities of Technological Design** **Understanding about science and technology**
IV.3 Sizing Up Earthquake Waves Students simulate earthquake waves and construct a model for measuring earthquake waves They also identify events associated with earthquakes and interpret data about intensity of earthquakes	Abilities necessary to do scientific inquiry Communicate scientific procedures and explanations	**Motions and forces** **Transfer of energy**	Structure of the Earth system **Earth's history**	**Abilities of Technological Design** Communicate the Process of Technological Design

National Science Education Standards

Tremor Troop: Earthquakes	Science in Personal and Social Perspectives	History and Nature of Science	Unifying Concepts and Processes	
IV.1 Earthquakes Great and Small Students demonstrate earthquake simulation of different strengths and compare damage of each. They also demonstrate the length of time associated with earthquakes.	Personal health Changes in Environments		**Systems, order, and organization** **Evidence, models, and explanation** **Constancy, change, and environment**	
IV.2 Different Shakes for Different Quakes Students demonstrate simulations of various earthquake strengths and describe techniques for measuring earthquakes They demonstrate a technique for recording earthquake movement and a method used to measure earthquakes	Personal health Changes in Environments		**Systems, order, and organization** **Evidence, models, and explanation** Constancy, change, and environment	
IV.3 Sizing Up Earthquake Waves Students simulate earthquake waves and construct a model for measuring earthquake waves They also identify events associated with earthquakes and interpret data about intensity of earthquakes.	Natural hazards Risk and benefits	Science as a Human Endeavor Nature of science	**Systems, order, and organization** **Evidence, models, and explanation** **Constancy, change, and environment**	

National Science Education Standards

Tremor Troop: Earthquakes	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology
V.Part 1: What Happens During an Earthquake Students identify areas of risk for earthquakes in the United States. They identify and describe events that occur during earthquakes, and they demonstrate safe behavior during an earthquake simulation.		Position and Motion of Objects **Motion and Forces** **Transfer of Energy**	Changes in the Earth and Sky **Structure of the Earth System** **Earth's History**	Abilities of Technological Design Understanding about Science and Technology
V.Part 2: Hunt for Hazards Students identify potential hazards in school and home and list possible ways to reduce hazards.	Abilities necessary to do scientific inquiry	**Properties of Objects and Materials**	Properties of Earth Materials	**Abilities of Technological Design** Communicate a Problem, Design, and Solution Understanding about Science and Technology
V.Part 3: Prepare and Share Students identify and assemble an emergency kit and communicate earthquake safety information to others.				Abilities of Technological Design Communicate the Process of Technological Design
V.Part 4: Evacuation Drill Students identify hazards during an evacuation and describe ways of helping others who are injured during earthquakes. They describe feelings and dangers associated with earthquakes.				Abilities of Technological Design Communicate the Process of Technological Design

National Science Education Standards

Tremor Troop: Earthquakes	Science in Personal and Social Perspectives	History and Nature of Science	Unifying Concepts and Processes	
V.Part 1: What Happens During an Earthquake Students identify areas of risk for earthquakes in the United States. They identify and describe events that occur during earthquakes, and they demonstrate safe behavior during an earthquake simulation.	**Personal Health** **Changes in Environments** Natural Hazards Risks and Benefits		**Systems, order, and organization** Evidence, models, and explanation Constancy, change, and environment Form and function	
V.Part 2: Hunt for Hazards Students identify potential hazards in school and home and list possible ways to reduce hazards.	**Personal Health** **Changes in Environments** **Science and Technology in Local Challenges**		Systems, order, and organization Evidence, models, and explanation Constancy, change, and environment Form and function	
V.Part 3: Prepare and Share Students identify and assemble an emergency kit and communicate earthquake safety information to others.	**Personal Health** **Types of Resources** **Changes in Environments** **Science and Technology in Local Challenges**		Systems, order, and organization Evidence, models, and explanation Constancy, change, and environment Form and function	
V.Part 4: Evacuation Drill Students identify hazards during an evacuation and describe ways of helping others who are injured during earthquakes. They describe feelings and dangers associated with earthquakes.	**Personal Health** **Changes in Environments** **Science and Technology in Local Challenges** **Natural Hazards** **Risks and Benefits**			

Glossary

aesthenosphere *(aestheno means to flow)* — The aesthenosphere is a part of the mantle below the lithosphere. The upper portion of the aesthenosphere is a region with a plastic, semi-solid consistency that bends and flows in response to pressure.

aftershock — An aftershock is an earthquake which follows a major earthquake, and is of lesser magnitude.

amplitude — Amplitude is the measurement of a wave determined by measuring the distance from the top of the wave to the bottom of the wave and dividing that amount by 2.

abyssal plain — a flat region of the deep ocean floor.

body waves — Body waves are earthquake waves that travel through the body of the Earth. They are of two types, P-waves and S-waves.

convection current — A convection current is a circular movement in a fluid in which hot material rises and cold material sinks.

continental drift — Continental drift is an outdated theory, first advanced by Alfred Wegener, that Earth's continents were originally one land mass, which split up and gradually migrated to form today's continents.

convergent plate boundary — A convergent plate boundary represents the collision of two plates moving toward each other. Such collisions may generate mountain ranges and volcanoes.

core — The core of the Earth consists of two sphere-shaped bodies; the inner core is like a very hot solid steel ball, surrounded by a liquid outer core. The core is the deepest part of the Earth, and is thought to be responsible for generating the Earth's magnetic field.

crust — The crust is the very thin uppermost layer of the Earth's lithosphere.

culture — A culture is the special way of life that holds a group of people together and makes it different from all other groups.

divergent plate boundary — A divergent plate boundary represents the separation of two plates moving apart. This divergent movement is in response to forces in the Earth's mantle. Features formed at divergent boundaries include mid-ocean ridges and rift valleys.

earthquake — An earthquake is a sudden, rapid shaking of the Earth caused by the release of energy stored in rocks.

earthquake intensity — Expressed as Roman numerals on the Modified Mercalli scale, earthquake intensity is a measure of ground shaking based on damage to structures and changes felt and observed by humans.

earthquake magnitude — Earthquake magnitude is a measure of the amount of energy released by an earthquake. Expressed in Arabic numerals, it is based on several widely-used logarithmic scales.

earthquake waves — Earthquake waves, or seismic waves, are waves caused by the release of energy in the Earth's rocks during an earthquake.

elastic rebound theory — Elastic rebound was proposed by H. F. Reid in 1906 to explain earthquake generation. Reid proposed that faults remain locked while strain energy slowly accumulates in surrounding rock. When rock strength is exceeded and rocks fracture, the fault slips suddenly, releasing energy in the form of heat and seismic waves.

energy — Energy is the power to move or change things.

epicenter — The epicenter is the point on the Earth's surface directly above the focus. The focus is the place within the Earth where an earthquake's energy is released.

fault — A fault is a crack in rock or soil along which movement has taken place.

fault scarp — A fault scarp (cliff) is the topographic result of ground displacement attributed to fault movement.

fault creep — Fault creep is slow ground movement or slip occurring along a fault without production of earthquakes.

fault plane — A fault plane is a surface along which fault movement has occurred.

fissure — A fissure is an open crack in the ground.

focus — The focus, or hypocenter, is the place inside the lithosphere where an earthquake's energy is first released.

foreshock — A foreshock is an earthquake which comes before the main earthquake and is less severe.

hazard — A hazard is any object or situation which contains the potential for damage, injury, or death.

hypocenter — See focus.

lateral fault — See strike-slip fault.

legends - Legends are traditional narrative explanations of natural phenomena that evolve when scientific explanations are not available.

liquefaction — Liquefaction is the process in which soil or sand suddenly loses the properties of solid material (cohesion) and behaves like a liquid.

lithosphere *(litho means rock/stone)* — The lithosphere is the solid outer region of the Earth in which earthquakes occur. It contains the crust and the uppermost portion of the mantle.

Love waves — Love waves are surface waves that move in a back and forth, horizontal motion.

magma — Magma is liquid rock beneath the Earth's surface. When it erupts it is called lava.

mantle — The mantle is the layer of the Earth between the core and the crust. It has a semi-solid consistency and is capable of movement.

mid-ocean ridge — A mid-ocean ridge is a submarine mountain range along a divergent plate boundary, formed by volcanic activity.

mountain — A mountain is a portion of the Earth's surface that has distorted (folded, faulted, volcanic) rocks and is higher in elevation than surrounding regions.

normal fault — A normal fault is one in which an upper block of rock, separated by a fault from a lower block, moves downward relative to the lower block.

oceanic crust — Oceanic crust is the basaltic portion of the Earth's crust that is generated at mid-ocean ridges. Most of this crustal material makes up the ocean floor. Oceanic crust is thinner and greater in density than continental crust.

oceanic trench — An oceanic trench is a long, narrow depression in the seabed which results from the bending of an oceanic plate as it descends into the mantle at a subduction zone.

P-waves — P- (or Primary) waves are the fastest body earthquake waves, which travel by compression and expansion.

plain — A plain is a flat-lying geographic area.

plate, tectonic — A tectonic plate is a large, relatively rigid segment of the Earth's lithosphere; these plates move around in relation to other plates because they "ride" on the plastic aesthenosphere.

plate tectonics — Plate tectonics is a geological model in which the Earth's crust and uppermost mantle (the lithosphere) are divided into a number of relatively rigid, constantly moving segments (plates).

plateau — A plateau is an area of horizontal rocks that is higher than surrounding areas and usually has some areas of steep slopes.

potential energy — Potential energy is stored energy.

primary waves — See P-waves.

Richter scale — Richter scale is a type of measurement of earthquake magnitude. Charles Richter and Beno Gutenberg created this scale in 1935.

reverse fault — A reverse fault is one in which an upper block of rock slides over a lower block which is separated from it by the fault. A low-angle reverse fault is called a thrust fault.

risk, earthquake — Earthquake risk is the potential for loss (life, property) in the event of an earthquake.

S-waves — S- (or Secondary) waves are body earthquake waves which travel more slowly than P-waves, and create elastic vibrations in solid substances. S-waves do not travel through liquids.

secondary waves — See S-waves.

seismic sea wave — See tsunami.

seismic wave — An energy wave in the Earth generated by an earthquake or explosion.

seismogram — A seismogram is a recording of the Earth's motions produced by a seismograph.

seismograph — A seismograph is an instrument for recording the motion of the Earth in response to seismic waves.

seismologist — A seismologist is a scientist that studies the cause, measurement, and effects of earthquakes.

seismology — Seismology is the study of earthquakes.

strain, elastic — Elastic strain is the deformation or change in the shape of a body in response to stress.

stress, elastic — Elastic stress is a measure of the forces acting on a body.

strike-slip fault — Strike-slip fault is a fault along which motion is mostly in a horizontal direction.

subduction — Subduction occurs where the leading edge of a plate made of oceanic crust and underlying mantle sinks under the edge of an opposing plate made of continental crust and underlying mantle.

surface waves — Surface waves are seismic waves that travel only on the surface of the Earth.

transform fault — A transform fault is a lateral or sideways moving fault, generated along mid-ocean ridges.

thrust fault — See reverse fault.

tsunami — A tsunami is an ocean wave caused by movements of the ocean floor, such as from earthquakes and volcano eruptions.

turbidity current — A turbidity current is a dense current of sediment mixed with water that flows downslope in ocean regions. Turbidity currents are often started by earthquake shaking.

volcano — A volcano is a mountain of erupted volcanic material.