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Making Waves: A Study of Earthquakes and Tsunami

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by Chrissy Bieler

Unit Objectives

The unit, "Making Waves: A Study of Earthquakes and Tsunami" is designed for a twelfth grade environmental studies curriculum. The goal of the unit is to provide students with a comprehensive understanding of plate tectonics and how they affect the occurrence of earthquakes and tsunami around the world. Students will be made aware of how the Earth is divided into tectonic plates and how the plates move in different directions and at different speeds. They will familiarize themselves with the locations of plate boundaries and the effects that the different movements of these plates have on the occurrence of earthquakes and tsunami.

In studying these phenomena, students will need to become familiar with both seismic and ocean waves and how they are measured. Students will differentiate between the types of waves that cause earthquakes and tsunami. In addition, they will examine why these waves travel at different speeds. Students will also investigate how the measurement and detection of waves are used to understand and mitigate disasters. To compare the severity of specific disasters that have occurred during our lifetime, students will perform case studies on a number of the earthquakes and tsunami that have occurred around the world, examining the causes and effects of each.

In teaching the unit, I plan to incorporate a variety of teaching strategies to effectively engage my students. Students will be introduced to the content presented in this unit through a mixture of instructional modes. A textbook will be used to provide students with background information on each specific topic. Students will complete hands-on laboratory activities to investigate the concepts of seismic waves and tsunami. Videos and newspaper articles will be used to represent actual accounts of the phenomena students will be researching. Maps will be used to keep track of all of the disasters studied throughout the unit.

The conclusion of this unit will require each student to independently report on an earthquake or tsunami that has happened over the past four hundred years. They will construct a newspaper in which they compile pictures and articles pertaining to their specific incident. It is my expectation that students will uncover a greater awareness of the natural disasters that occur on Earth on a daily basis and will also gain a deeper understanding of these events and the effects they have on common people like themselves.

Rationale

I have the privilege of teaching science to both eleventh and twelfth graders at New Haven Academy, a small magnet high school in New Haven, Connecticut. This setting allows not only for great diversity among the student body but a tight-knit community that exists between students and faculty. The class to which I expect to teach this unit next year is 67% female and 33% male. Of these students, 40% are black, 40% are Hispanic, and 20% are white. As a result of our small class sizes the students in this class are a close-knit group. While this leads to some excellent scientific conversations on some days, it can lead to excessive social conversations on others. The students continuously need to be kept on task and reminded of the objective that they are currently aiming to complete. They also need a variety of instructional modes during a class period. In my planning, my goal is to teach in a specific instructional mode for no longer than 20 minutes at a time to keep the students engaged as much as possible. Each class period is either 60 or 70 minutes at New Haven Academy; therefore, in each class period I attempt to use at least 2 modes of instruction to teach the main objectives of the lesson. In addition, the students are generally more interested and engaged when working together, therefore I try to incorporate pair or group work as often as possible.

Knowing the specific needs of my students is of great assistance to me in developing a curriculum unit. This unit is designed with the intentions of engaging and educating this specific group of students. In the future I will likely need to adjust the teaching methods and strategies as necessary to sufficiently address the needs of each particular group of students. I will also need to adjust the unit specifically for each student in my class as they all have different individual learning needs. While none of the students in my class are identified by an Individualized Education Plan (IEP) they all have different learning strategies and strengths. Some students work best individually while others are better served in a small-group setting; some need to be challenged while others need some hand-holding; some need guided questioning from me while others can form valid conclusions on their own. I am fortunate to have such small class sizes as it enables me to recognize these differences clearly and address them fully.

It is my hope that throughout this unit students will further develop their scientific inquiry and literacy skills. Students will be encouraged to speak, read, write, interpret, and present scientific information on a daily basis. I also look forward to challenging their analytical and creative thinking as they examine, predict, and describe the earthquakes and tsunamis that will be studied in this unit. I will also focus on the higher levels of Bloom's Taxonomy and strive for students to improve their critical thinking skills through interpretation, investigation, analysis, comparative thinking, prediction, and persuasive writing.

Overview and Strategies

Earthquakes

The unit will begin with background information on earthquakes. Students will first be asked to complete a chart about earthquakes in which they provide details about what they already know about earthquakes and what they want to know about earthquakes by the completion of this unit. The information provided by the students will be compiled and will be displayed in the classroom for the duration of the unit. It is the goal of the unit to address any misconceptions that the students have about earthquakes and to provide additional information on other points they wish to further investigate.

Following this activity, students will take part in a hands-on investigation to simulate how earthquakes are caused. They will attach a Slinky to a damp sponge and place the sponge on a lab table, pushing down on it so it sticks to the surface of the table. Students will then be instructed to pull on the Slinky to create stress on the sponge. They will continue to pull the Slinky until the sponge 'pops' off the table. This demonstration will show how the release of stress causes earthquakes and can also be adjusted by adding objects on top of the sponge to show the change in stress as the sponge is freed from the tabletop. Students will be asked to describe their observations and will discuss their responses as a group.

Students will then be provided with notes about earthquakes to supplement their initial understanding of the phenomenon. The information provided to them will include a definition of an earthquake, where they occur, how they are caused, the types of faults that exist, and how earthquakes are measured and recorded.

What is an earthquake and where do they occur?

In order for students to understand the phenomenon of earthquakes, they must first become familiar with the structure and composition of the Earth, the workings of the Earth's tectonic plates, and the convection in the mantle. The Earth is divided into three layers based on the composition of each layer. These three layers are the core, the mantle, which is the middle layer; and the crust, or outer layer. The core is made up of the densest elements, mostly nickel and iron, and has a radius of about 3,400 km. The mantle is made up of elements and rocks of medium density and is approximately 2,900 km thick. This layer is also responsible for 64% of the Earth's total mass. The crust is made up of the lightest elements and is the thinnest layer of the Earth with a maximum thickness of approximately 70 km. The crust is responsible for less than 1% of the Earth's total mass (Arms, 2006, 60).

In addition to the differences that exist among the composition and masses of each layer are differences in temperature. As you travel from the crust through the mantle to the core, temperatures increase drastically. The temperature of the inner core is approximately 4.000oC to 5,000oC (Arms, 2006, 61). The dramatic temperature difference between the layers enables convection to occur. Convection is the movement of matter caused by changes in temperature (Arms, 2006, 679). In terms that students can understand, convection causes cold matter to fall and warm matter to rise. As related to earthquakes, the cold mantle near the surface sinks into the warmer mantle, which is the driving force behind plate tectonics.

Earthquakes are caused by the breaking or shifting of plates within the Earth to release stress. The plates are large pieces of rock that make up the Earth's lithosphere, or the colder, stiffer, outermost layer. There are twelve major plates that the lithosphere is separated into. The movement of plates causes waves to travel through the Earth, which causes the vibrations that are felt by humans when an earthquake happens. Most earthquakes occur along fault lines, which are fractures in the Earth's crust. These fractures are typically located along the edges of major plates.

Causes of Earthquakes

The cycle of plate tectonics is most frequently used to describe how earthquakes occur. In this process, the Earth's plates are continually moving and interacting. They can separate apart, grind past one another, or push against each other. Plates separate from each other during seafloor spreading at divergence zones and produce small earthquakes. Plates slide past one another at transform or strike-slip faults and release energy in the form of large earthquakes (i.e. San Andreas Fault). Plates also push against each other at convergent plate boundaries. At these locations, the cold, more dense plate is either pulled into the mantle (subduction) or continents are pushed together (continent-continent collision). Both types of earthquakes produce high energy and are of very large magnitude (Abbott, 2004, 56).

To assist students in differentiating among the different types of fault movements, a video clip from United Streaming video will be shown. Students will also visually observe and draw pictures to clarify the different movements of faults. I expect that students will have the most difficulty comprehending how the movements at subduction zones occurs. A demonstration will be performed by the teacher to show how density changes from heating and cooling cause fluids to convect and overturn. This can be done simply by adding cream to a hot cup of coffee. Students will be able to observe the movement of the cream in the coffee as it makes its way to the bottom of the cup (since it is colder and denser). This will hopefully provide enough background as to why one plate (the colder, more dense one) will be pulled underneath another (the warmer, less dense one) at convergent plate boundaries.

Types of Faults

There are four different types of faults that students will be made aware of: normal, reverse (thrust), strike-slip, and dip-slip. At a normal fault, the plate boundaries separate and the Earth's crust stretches. When this happens, the plate on one side of the fault slides down below the other. At a reverse, or thrust, fault, plates collide with each other causing one side of the fault to be pushed up and over the other. At a strike-slip fault the plates slide against each other horizontally. A dip-slip fault is where a strike-slip fault combines with either a normal or reverse fault. When this happens, one plate moves sideways and the other moves downward (National Geographic, 2006).

From describing the types of faults it is relatively easy to determine the activity that occurs at each. Normal faults exist mostly at divergence zones, reverse faults exist mostly at convergent boundaries, and strike-slip faults exist primarily at transform fault boundaries.

Plate Boundary Locations

To illustrate that most earthquakes occur along plate boundaries, a map of earthquake epicenters from 1980-1990 will be shown (Berkeley, 1996). Students will be familiarized with some of the most common plates, including the Pacific plate. This plate has all three types of plate boundaries and is one of the fastest and biggest of the twelve major tectonic plates (Abbott, 2004, 45). The Arabian plate is also an important plate to study as its movement helps students visualize the different types of earthquakes that can occur.

Earthquake Case Studies

For students to become more familiar with the different types of earthquakes and the locations in which they most often occur, several case studies will be performed. These case studies will serve to provide a strong foundation about the disasters that have occurred over the years and will also guide them in their own case study research of tsunami, which will occur at the end of the unit.

The following earthquakes will be researched for these case studies: Lisbon, 1755; San Francisco, April 1906; Tangshan, China, 1976; Kobe, Japan, 1995; Alaska, 1946; Chile, 1960; Alaska, 1964; World Series (Loma Prieta) Earthquake, 1989; Sumatra, 2004. As each earthquake is studied, students will identify the location on a large map that will hang in the classroom for the duration of the unit. They will also have to identify the type of earthquake, the type of fault, and the magnitude of the earthquake. Other notable information will be recorded, i.e. if the earthquake caused a tsunami.

Waves

In order for students to fully grasp how earthquakes are 'felt', they need to understand the concept of waves. A review lesson on waves will be taught which serves to refresh students on the basic concepts of wave motion and measurement. This will include discussion of such terms as amplitude (height), wavelength (distance between two consecutive peaks or troughs of waves), period (amount of time between two waves), and frequency (the number of waves to pass a point in one second). Students will also identify reasons that waves are important to us, such as carrying energy and information. They can easily relate to the importance of their cell phones, iPods, or their own voices, which cannot function without utilizing waves. Once the necessary terms are discussed and reviewed and the importance of waves is addressed, the topic of seismic waves will be introduced. Seismic waves are produced when energy is released in an earthquake (Abbott, 2004, 70).

Particles moving in a wave can oscillate, or move back and forth, in different directions. Waves are classified by the way a particle in the wave is displaced in relation to the direction of wave propagation. In transverse waves the particles are displaced perpendicular to the direction of wave propagation. The particles move up and down in relation to where they began; they do not travel with the wave. A transverse wave can be simulated by a string. When the string is held at both ends and one end is moved up and down, the motion that occurs mimics a transverse wave. Longitudinal waves are different from transverse waves in that their particle displacement is parallel to the direction of wave propagation. However, they are similar to transverse waves in that their particles also do not travel with the wave but oscillate about their initial positions (Russell, 2001). A Slinky can be used to reproduce the motion created by a longitudinal wave. When the Slinky is laid on a table and is held firmly at one end, abruptly pulling or pushing the Slinky at the other end will produce a longitudinal wave. Sound waves are longitudinal (compressional) waves.

While movement on a fault causes earthquakes and tsunami, waves can result from the sudden movement on a fault as well. When a block on a fault suddenly moves, the block ahead of the motion is compressed and the block behind the movement is decompressed, producing longitudinal waves. Any blocks that are on either side of the movement are shaken and produce transverse waves.

Seismic Waves

Seismic waves can be divided into two categories: body waves and surface waves. Body waves are those that pass through the Earth while surface waves only move near the Earth's surface. These waves travel at different speeds, body waves being the faster of the two. There are two types of body waves: P waves, or primary waves, and S waves, or secondary waves. P waves are faster than S and they are longitudinal waves. The speed of a P wave depends on the density of the material it travels through. The denser the material, the faster the wave is; the less dense the material, the slower the wave is. P waves can travel through any type of material, even air, and are therefore are the same as sound waves. Secondary, or S, waves are slower than primary waves and can only travel through solids. Their particle motion is transverse to wave direction and they travel both up and down as well as side to side. The shape of an S wave is similar to that of a wave on a string or a sine wave.

Even though surface waves are slower than body waves they have larger amplitudes. The two types of surface waves that exist are Love waves and Rayleigh waves. Love waves have a similar shape to an S wave but they travel horizontally rather than vertically. This causes the particles in a Love wave to have a side-to-side motion rather than an up-and-down motion. They are also like S waves in that they can only travel through solid materials. However, Love waves cause considerably more earthquake damage than P or S waves. Rayleigh waves have particle motion that is circular and up and down. These waves have long periods and can travel long distances (Abbott, 2004, 72).

To help students understand the motion of these waves a few demonstrations will be performed. A Slinky and a jump rope will help to simulate the motion and shape of the P and S waves, respectively. Studies can also be conducted with these materials to show how the speed of a wave is altered depending on the density of the material it travels through.

It is also important for students to be introduced to the concept of resonance for them to further investigate how earthquakes occur. Resonance involves the relationship between a wave and the natural frequencies of the system through which the wave travels (Hsu, 2003, 204). This can be explained to them in terms of a swing on a playground. Resonance occurs when the person on the swing is kicking their legs in sync with the swing, adding energy to the swing in the same direction at each passage of the swing. If the person were to kick her legs on the way down instead of the way up this resonance would not occur. When resonance occurs in an earthquake and the oscillations of a shaking building interact with the seismic wave of the earthquake, the waves are amplified further and the damage becomes more serious (Abbott, 2004, 78). Resonance can be demonstrated in the classroom by shaking a bowl of Jell-O. Students will be able to observe how the waves formed in the Jell-O move differently as the teacher's movements and the Jell-O's movement become resonant with each other. Students will be provided with an example of how resonance is involved in earthquakes by studying the Mexico City earthquake of 1985.

Case Study: Mexico City, 1985

The Mexico City earthquake of 1985 was a subduction zone earthquake. It occurred as the Cocos plate subducted and caused three separate shocks, the first being the largest with a surface wave magnitude (Ms) of 8.1. Many people died as a result of this earthquake mostly because of building damage. Many buildings collapsed from this earthquake due to wave resonance, or site amplification. The seismic waves from the quake, the waves that were created in the soft foundation underneath the buildings, and the waves from the shaking building created resonance that was stronger than the effects of the earthquake alone (Abbott, 2004, 101).

Case Study: World Series (Loma Prieta) Earthquake, 1989

The World Series earthquake of 1989 was a transform fault earthquake that occurred in the San Andreas fault zone. The Pacific and North American plates that had been pushing against each other for some time ruptured and shifted, causing an earthquake with a magnitude of 6.9 on the Richter Scale. The quake caused much death and destruction. Part of the upper level of the Bay Bridge collapsed onto the lower level and an immense fire broke out in the Marina District of San Francisco. Sixty-three people died and 3,700 were injured as a result, and the financial damages reached approximately $8 billion. It has been speculated that more deaths and casualties would probably have occurred had the World Series not been going at the time. More people would likely have been traveling on the major roads and bridges at the time instead of watching the game (California Department of Conservation, 2002).

Measuring Seismic Waves

The Richter Scale is one of the methods used to measure the magnitude, or size, of earthquakes. This scale is based on the theory that the bigger the earthquake, the greater the resulting tremble, and therefore the larger the amplitude that is recorded on a seismometer. The scale starts at zero and has recorded earthquakes up to a magnitude of about 9.5. The lower the magnitude of the earthquake the more frequently they are known to occur (Abbott, 2004, 75). The body wave and surface wave scales can also be used to measure the amplitudes of P- and Rayleigh waves, respectively, to obtain a reading of the earthquake's effects (Abbott, 2004, 76). The Mercalli Scale can also be used to measure the intensity of earthquakes. This scale is based on what is 'felt' during an earthquake. It was used most often in the early 1900s when the Richter scale had not yet been invented. It takes into account the magnitude of the earthquake, the distance the earthquake travels from its point of origin, the composition of the ground in the area, and styles of buildings in the affected area, and the length of the tremble that the earthquake causes (Abbott, 2004, 80). The scale ranges from I to XII and is gauged by the amount of damage the earthquake caused. For example, a level V earthquake on the Mercalli Scale is one that causes some broken glassware and windows, rings small bells, sways tall objects, and can affect the workings of a pendulum clock (Abbott, 2004, 79).

It is important to note that these scales measure the size of the earthquake but not the waves that are produced as a result of the quake. A seismograph is used to measure these waves, or the movements that take place in the earth. A seismograph contains a seismometer, or a ground motion detector, and a recording device. A seismometer can be visualized by picturing a weight hanging from a spring. As the earth moves it causes the stationary weight to bob on the spring, providing a measure of vertical motion from the ground. A recording device on this type of instrument could involve a pen attached to the weight and a rotating drum attached to the base of the seismograph. As the weight bobs, the pen records the movement on the drum, producing a seismogram that can be used to study the history of ground motion. Seismometers are currently electronic and are very sensitive to movement therefore they can be used to detect both small and large earthquakes (Incorporated Research Institutions for Seismology).

To help students understand the scales further, as each case study is performed students will plot the magnitude of each quake on a line ranging from 0 to 10 as measured by the Richter Scale. This data will also be correlated to plate location.

Tsunami

A tsunami is a large wave that hits a shoreline and causes tremendous damage. They are caused by a large vertical displacement of water. This displacement can be created by fault movements, volcanic eruptions, landslides, and meteorite impacts. They most commonly occur as a result of a severe earthquake, most specifically those that occur at subduction zones (Abbott, 2004, 87). Subduction involves vertical motion as the overriding plate moves upward and the subducting plate moves downward (Abbott, 2004, 47).

Tsunami waves are not normally identified in the middle of the ocean. It is not until they reach the shore where the water shallows that the water piles up and creates the large wave that we speak of. The water piles up near the shore because tsunami waves travel faster in deeper water than they do in shallow water. Therefore, when moving up a slope the back of the wave which is over deeper water travels faster travels faster than the front of the wave, which is over shallow water. This causes the back of the wave to crash into the front of the wave. Tsunami are also most usually seen as a series of waves, not just a single wave. As tsunami waves become compressed near the coast, the wavelength is shortened and the wave energy is directed upward, increasing their heights considerably (United States Department of State, 2005). Tsunami waves can reach heights close to 30 m. These waves are mostly seen in the Pacific Ocean and affect places like Japan, Indonesia, Hawaii, and Alaska. Detectors around the Alaska coast, in Hawaii and other various islands, and around the west coast of the United States help to track tsunami. NOAA and the National Weather Service have developed a forecasting system that estimates the amplitude of the tsunami and the approximate arrival time for potential affected areas (Denbo, 2006). Scientists use information from the detectors to determine the speed at which the wave is traveling and can help to warn people of the emergency that lies ahead (Hsu, 2003, 545).

A number of tsunami have occurred in recent times. Students will be introduced to the disasters that have occurred by studying as a class the tsunami that occurred as a result of the earthquake in Chile in May 1960. This incident will serve as a case study model for the students to follow as they complete several other case studies throughout the unit.

Case Study: Chile, May 1960

In May 1960 a powerful subduction zone earthquake occurred in Chile. This quake caused three separate tsunami waves that resulted in the deaths of more than 1,000 Chileans. The tsunami also affected people in Hawaii and Japan, causing deaths in both locations. While there was a tsunami warning system in place, which was fairly accurate in its prediction of when the tsunami would reach neighboring coastlines, people died anyway (Abbott, 2004, 90).

Case Study: Indian Ocean, 2004

As a result of its recent occurrence students will probably be most familiar with the tsunami that was generated in the Indian Ocean in 2004. This tsunami occurred on December 26, 2004 as an earthquake created a crack in the ocean floor off northern Sumatra. The rupture in the sea floor happened 10 miles below the sea floor and caused the floor to raise by tens of feet. This rise in the sea floor pushed a surge of water outward from that point to the rest of the Indian Ocean. Large waves, or tsunami, rippled throughout the Indian Ocean and killed approximately 245,000 people in thirteen countries (Abbott, 2006, 7).

Other Tsunami Case Studies

Using the Chile May 1960 and Indian Ocean 2004 incidents as a guide, students will be asked to research other tsunami to increase their understanding of the nature of the waves. Students will be divided into small groups and will be designated a specific tsunami to research together. The tsunami to be studied will include the 1964 tsunami in Alaska, the 1992 tsunami in Nicaragua, the 1993 tsunami in Japan, the 1998 tsunami in Papua New Guinea, and the 2004 Indian Ocean tsunami. For each case study students will answer the following questions:

1. What geologic events triggered the tsunami?

2. Where did the tsunami originate and what path of destruction did it follow?

3. What characteristics did the tsunami display while in mid-ocean?

4. What characteristics did the tsunami display as it hit the coastline?

5. What damage was caused by the tsunami?

6. Was a warning system in place at the time this tsunami occurred? What role did it play? Was it effective?

They will be asked to draw a map to show the areas that were affected by the tsunami they research. The map showing the tsunami travel time from the 1960 Chile Earthquake will be used as a guide (Abbott, 2004, 91). They will also present their research to the class.

Lesson Plans

The following lessons can be utilized in conjunction with the overview and strategies provided in this unit.

Lesson One - Plate Movement

In this lesson students will be given several materials and be asked to model the types of movement at each of the plate boundaries described during class lecture and discussion. Some materials that can be used include sponges, cardboard, modeling clay, and phonebooks. Students will work in pairs to demonstrate as many of the plate movements as they can with the materials provided. They will need to use the appropriate terms as introduced in the class lecture. Some of these terms may include convergent plate boundaries, divergent plate boundaries, subduction zones, transform plate boundaries, strike and dip faults, dip-slip faults, and strike-slip faults.

Lesson Two - Wave Properties

This activity is designed to help students learn the components of a wave as well as discussing the effects of wave height, wavelength, and wave period on the size of the wave. To begin students will collectively help to design a word wall in which they define some important terms that relate to waves and wave properties. Each student will be given one or two words to define. They will do so by taking an 8 ½ " by 11 " sheet of paper and folding it in half (either way is fine). On the front of the flap they have created they will write the vocabulary word that was assigned to them. On the inside of the flap, they will write the definition of the word. After students have written all the words and definitions they will be asked to go around the room and read their definitions. All words will then be placed on a word wall that can be accessed by students at anytime during the unit. The following list is a recommended vocabulary list for the word wall for this unit.

Vocabulary: amplitude, constructive interference, crest, destructive interference, harmonics, longitudinal wave, natural frequency, period, resonance, standing wave, transverse wave, trough, wave height, wavelength.

Following the word wall activity the teacher will draw a wave on the board. Students will be asked to identify the crest, trough, wave height, and wavelength of each wave. The concept of wave period will also be introduced at this point (the amount of time it takes for two adjacent crests to pass the same point is one cycle).

In pairs, the students will be able to investigate the properties of waves on the internet using a wave simulator. An excellent wave simulator can be found on the National Geographic Xpeditions website www.nationalgeographic.com/xpeditions/lessons/06/g912/waveproperties.html.

On this site students can adjust the wave height, wavelength, and wave period to determine the individual and combined effects they have on a boat that is at rest in an area without current. Students will be asked to record their observations and share them with the class.

Lesson Three - Final Project: Tsunami Case Study

To end the unit, students will perform individual case studies similar to those they performed in small groups. They will be free to choose any tsunami that has occurred over the past 400 years. They will be encouraged to answer the same six questions from their first case studies and to provide additional information as they see necessary. Rather than presenting their research to the class in the form of an oral presentation, students will construct a 'mini-newspaper' in which they present their material. This will require some creativity! Also, this assignment lends to some interdisciplinary study, for students will be required to write not only about the tsunami but will be asked to report on other occurrences from that time such as earthquakes and the historical or social impact of the tsunami.

Implementing District Standards

Content Standard 4.0 Earth Science

4.1 Students will have a basic understanding of energy in the earth system.

Content Standard 6.0 Ecology

6.4 Students will develop a basic understanding of environmental quality.

6.5 Students will be aware of natural and human-induced hazards.

6.6 Students will be aware of the roles of science and technology in local, national, and global challenges.

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United States Department of State, The US Tsunami Relief Effort 2005. http://www.usinfo.state.gov, 2005.

Teacher Resources

Books

Abbott, Patrick L. Natural Disasters. 4th ed. New York: McGraw-Hill, 2004. This textbook includes information on plate tectonics, seismology, earthquakes, and tsunami, among other natural disasters. It also includes case histories and historical perspectives.

Abbott, Patrick L. Natural Disasters. 5th ed. New York: McGraw-Hill, 2006. This textbook includes information on plate tectonics, seismology, earthquakes, and tsunami, among other natural disasters. It also includes case histories and historical perspectives.

Arms, Karen. Environmental Science. Orlando, FL: Holt, Rinehart and Winston, 2006. This is an excellent textbook for use in an Environmental Science class. The teacher edition of this book includes great teaching tools such as discussions, debates, activities, and demonstrations.

Hsu, Tom. Foundations of Physical Science with Earth and Space Science. 1st ed. Peabody, MA: CPO Science, 2003. This textbook provides information about waves, waves in motion, and natural frequency and resonance. It is commonly used for teaching a ninth grade science curriculum.

Kious, W. Jacquelyne, and Robert I. Tilling. This Dynamic Earth: the Story of Plate Tectonics. Washington, D.C.: United States Government Printing, 1996. This book provides a historical perspective of plate tectonics, provides background of the plate tectonics theory, discusses the movements that occur along plate boundaries, and provides specific examples of locations where these phenomena can be studied.

Websites

California Department of Conservation. "News Room." California Department of Conservation. 2002. 17 July 2007 http://www.consrv.ca.gov/index/news. This site provides environmental and geological information about California including recycling programs, mine reclamations, land resources and management of states' natural resources.

Denbo, Donald, K. McHugh, J. Osborne, P. Sorvik, and A. Venturato. "NOAA Tsunami Forecasting System." National Oceanic and Atmospheric Administration. 2006. 17 July 2007 http://www.ams.confex.com. This site shows a diagram of the tsunami forecasting system and provides detailed information about the goals, architecture, implementation and future of such a system.

Incorporated Research Institutions for Seismology. "How Does a Seismometer Work?" 2006. 17 July 2007 http://www.iris.edu. IRIS is a research program dedicated to monitoring the Earth and exploring its interior. The website has a variety of one page descriptions in their Education and Outreach Series that provide information related to these topics.

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National Weather Service. "Tsunami: the Great Waves." National Weather Service. 10 Apr. 2007 http://www.nws.noaa.gov/om/brochures/tsunami.htm>. This brochure is intended to educate and increase awareness about tsunamis.

Russell, Dan. "Longitudinal and Transverse Wave Motion." Kettering University Applied Physics. 2001. 29 May 2007 www.gmi.edu/~drussell/Demos/waves/wavemotion.html>. This site shows animations of longitudinal, transverse, water, and Rayleigh surface waves and provides descriptions of each.

United States Department of State. "The US Tsunami Relief Effort 2005." United States Department of State. 2005. 17 July 2007 http://www.usinfo.state.gov. This site provides general information on foreign policy, international trade, and other worldwide topics of interest. It covers several regions of the world including Africa, the Americas, East Asia, the Pacific, Europe, Eurasia, the Middle East, North Africa, and South and Central Asia.

USGS. "The USGS and Science Education." United States Geological Survey. 2006. 10 Apr. 2007 http://education.usgs.gov>. This site contains USGS educational resources for teachers, students, and parents in all grade levels. Resources include classroom activities, computer activities, maps, videos, and printed articles.

Visuals

Continents Adrift: An Introduction to Continental Drift and Plate Tectonics. Rainbow Educational Media. 1995. unitedstreaming. 22 May 2007. http://www.unitedstreaming.com
This video clip provides information on the location of tectonic plates, the different ways that tectonic plates can move, and how the energy from these movements is released.
Map of Earthquake Epicenters 1980-1990. Regents of the University of California. 1996. ucmp.berkeley. 22 May 2007. http://www.ucmp.berkeley.edu
This map shows the occurrence of earthquakes and the location of tectonic plates.

Student Resources

Books

Abbott, Patrick L. Natural Disasters. 5th ed. New York: McGraw-Hill, 2006. This textbook includes information on plate tectonics, seismology, earthquakes, and tsunami, among other natural disasters. It also includes case histories and historical perspectives.

Hsu, Tom. Foundations of Physical Science with Earth and Space Science. 1st ed. Peabody, MA: CPO Science, 2003. This textbook provides information about waves, waves in motion, and natural frequency and resonance. It is commonly used for students in a ninth grade science class.

Kious, W. Jacquelyne, and Robert I. Tilling. This Dynamic Earth: the Story of Plate Tectonics. Washington, D.C.: United States Government Printing, 1996. This book provides a historical perspective of plate tectonics, provides background of the plate tectonics theory, discusses the movements that occur along plate boundaries, and provides specific examples of locations where these phenomena can be studied.

Websites

Denbo, Donald, K. McHugh, J. Osborne, P. Sorvik, and A. Venturato. "NOAA Tsunami Forecasting System." National Oceanic and Atmospheric Administration. 2006. 17 July 2007 http://www.ams.confex.com. This site shows a diagram of the tsunami forecasting system and provides detailed information about the goals, architecture, implementation and future of such a system.

Incorporated Research Institutions for Seismology. "How Does a Seismometer Work?" 2006. 17 July 2007 http://www.iris.edu. IRIS is a research program dedicated to monitoring the Earth and exploring its interior. The website has a variety of one page descriptions in their Education and Outreach Series that provide information related to these topics.

National Weather Service. "Tsunami: the Great Waves." National Weather Service. 10 Apr. 2007 http://www.nws.noaa.gov/om/brochures/tsunami.htm>. This brochure is intended to educate and increase awareness about tsunamis.

Russell, Dan. "Longitudinal and Transverse Wave Motion." Kettering University Applied Physics. 2001. 29 May 2007 www.gmi.edu/~drussell/Demos/waves/wavemotion.html>. This site shows animations of longitudinal, transverse, water, and Rayleigh surface waves and provides descriptions of each.

USGS. "The USGS and Science Education." United States Geological Survey. 2006. 10 Apr. 2007 http://education.usgs.gov>. This site contains USGS educational resources for teachers, students, and parents in all grade levels. Resources include classroom activities, computer activities, maps, videos, and printed articles.

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