The Government of the Republic of Trinidad and Tobago

MINISTRY OF EDUCATION

NIHERST

UWI SEISMIC RESEARCH CENTRE

Seismology in Schools Programme

Trinidad and Tobago

Geography Workbook

"Nature uncovers the inner secrets of nature in two ways: one by the force of bodies operating outside it; the other by the very movements of its innards. The external actions are strong winds, rains, river currents, sea waves, ice, forest fires, floods; there is only one internal force — earthquake."

Mikhail Vasilyevich Lomonosov
About the Layers of the Earth and other Works on Geology (1757),
trans. A. P. Lapov (1949).

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Introduction

Seismology is the study of seismic waves, most commonly experienced as earthquakes. Earthquakes occur when strain energy accumulates slowly within the Earth's crust due to tectonic plate motion and then is released suddenly at fractures in the crust called faults. This workbook aims to help students grasp fundamental concepts covered by the Caribbean Secondary Examination Certificate (CSEC) syllabus for Geography by exploring real-world applications of these concepts using basic principles of seismology. Activities presented in this workbook are linked to specific objectives detailed in the syllabus which will hopefully assist teachers in implementing the curriculum's module concepts and objectives through a hands-on and practical approach geared to reinforcing theoretical concepts.

The workbook covers a range of topics including: the earth's internal structure, global seismicity, the propagation of seismic waves and how these waves are used to locate earthquakes. Students will be able to learn about the many applications of seismology and are challenged to develop knowledge and skills unique to the earth sciences.

Seismologists use earthquake data to monitor plate boundaries and prepare seismic hazard maps for earthquake-prone countries. They also analyse seismic waves to determine characteristics of earthquakes such as their location and magnitude. This workbook offers students a resource to better understand the science of earthquakes and their impact on students' own lives.

Seismology in the Classroom

Seismology can be used to demonstrate aspects of plate tectonics and the structure of Earth which are outlined in the Caribbean Secondary Entrance Certificate (CSEC) Geography syllabus. The SIS Geography workbook is specifically designed to aid in the teaching of the aforementioned topics through a series of practical experiments and activities which are supported by the SIS kit box and the SEP seismometer. This workbook can be used to reinforce the objectives of these broad topics, as students are encouraged to consider and discuss the following:

- What is an earthquake?
- What are some of the concepts used in analysing earthquakes?
- What are some of the geographical processes that occur because of earthquakes?
- What are the different wave parameters associated with earthquakes?
- What are some preparations that can reduce the impacts of an earthquake?

The SEP Seismometer System

This is a basic seismometer utilising a ‘garden gate’ design that oscillates from side to side when the ground beneath its rigid frame is disturbed either by local activity or seismic activity. The seismometer’s design and operation can be used to illustrate basic concepts in Geography and general seismology. This workbook can be used to reinforce specific syllabus objectives listed. Students are encouraged to explore topics such as: earthquakes and plate tectonic theory, plate boundaries and faults, seismic waves, aspects of seismometer design, and detection & location of earthquakes using seismometers. This is all done using real earthquake data from local SEP seismometers (Figure 1) and stations around the world, as well as software known as jAmaSeis.

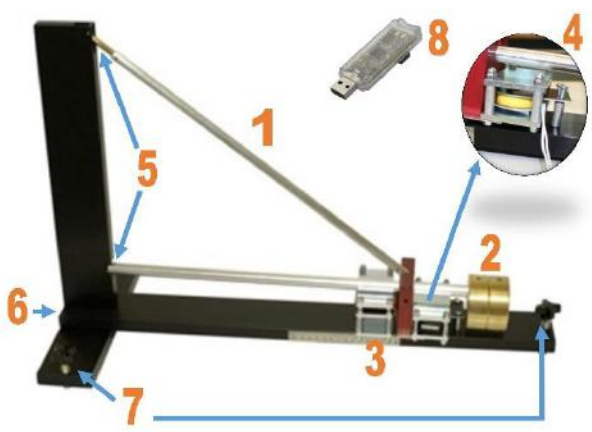


Figure 1: The SEP Seismometer

Key

1. Rigid suspension arm or moving boom
2. Brass mass
3. Magnetic eddy current damping -
4. Magnetic and coil velocity transducer - Uses electromagnetic induction to detect ground motion (velocity) and eddy current damping.
5. Pivot points – To allow the moving boom to oscillate freely.
6. Rigid Frame (Long base part, short base part and upright part)
7. Levelling screws – To adjust the horizontal level of the rigid frame and boom which must be centred.
8. USB Digitizer – To connect to your computer with jAmaSeis.

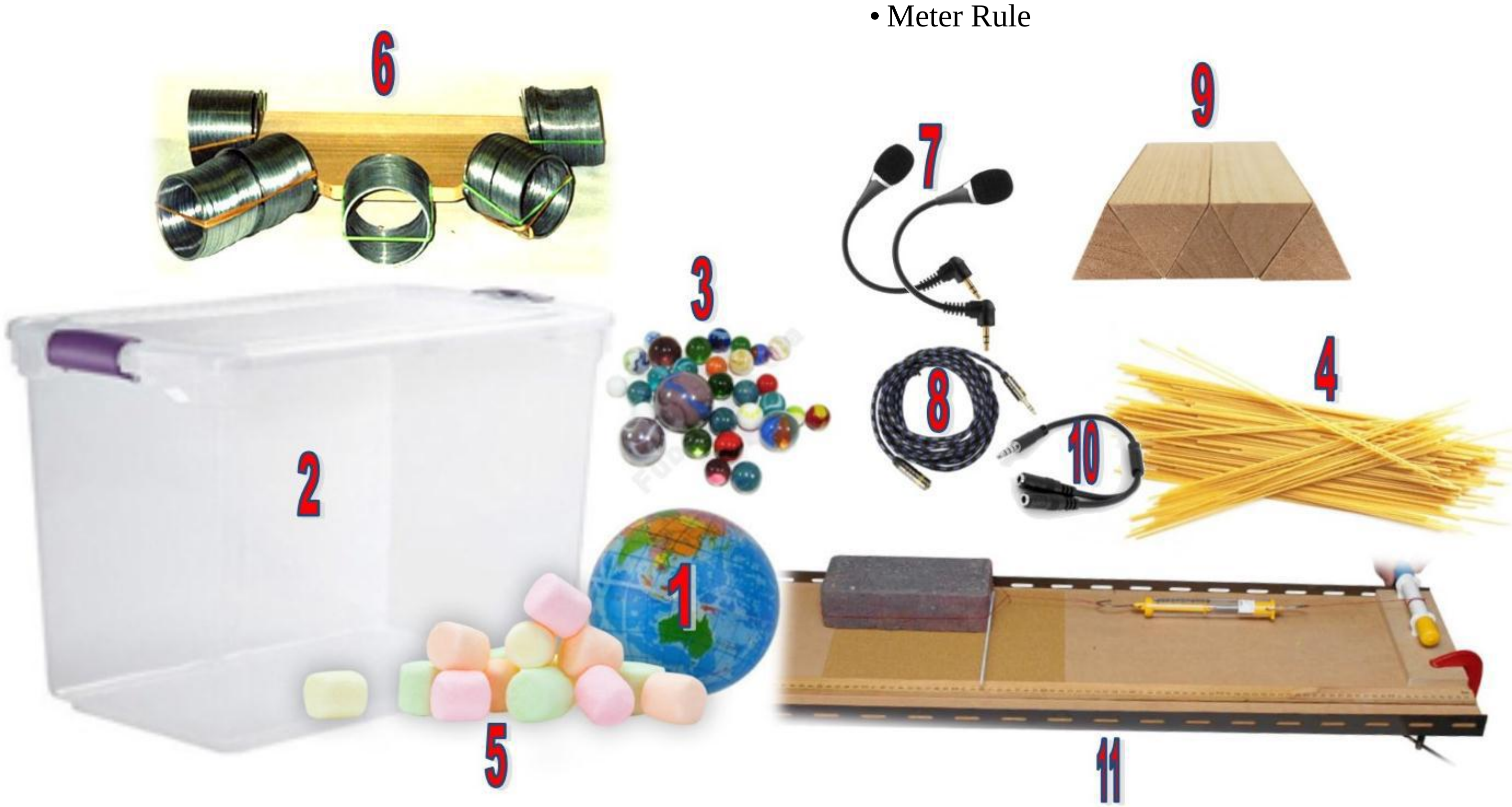
The Seismology Kit Box

This workbook is designed to be used with the equipment in the seismology kit box, but several of the activities can be implemented without the kit box equipment. Teachers and students can adapt the activities uniquely for different teaching needs. The activities have been designed to cater to a wide range of ages (approximately 8-18) and different stages of learning. The activities are designed to be as interactive and informative as possible, and to prompt engagement within the classroom.

The Contents of the Seismology Kit Box

Key

1. Geophysics foam Earth
2. Plastic container
3. Marbles of various sizes
4. Spaghetti sticks
5. Marshmallows
6. Slinky model
7. Microphones
8. 3.5mm audio jack combiner
9. 3 types of wooden fault block models
10. Auxiliary extension cable
11. Earthquake simulator model
    - Concrete brick
    - String
    - Newton meter
    - Pulley
    - Sandpaper board
    - Meter Rule



Teacher Preparation

To make the best use of this resource, teachers are required to be comfortable with concepts of plate tectonics and the structure of the Earth, in addition to having a working knowledge of the jAmaSeis software. The IRIS website is a great tool for accessing real time earthquake data, and the British Geological Survey is one of the leading geological survey websites. All resources can be found at the website links below.

- Incorporated Research Institutions for Seismology: http://ds.iris.edu/
- The British Geological Survey: http://www.bgs.ac.uk/
- jAmaSeis Software Download: http://www.iris.edu/hq/jamaseis/

Additionally, teachers can contact the SIS Team directly if further assistance is needed in the interpretation and delivery of the activities or lesson plans in this workbook via the Facebook page 'Seismology in Schools – Trinidad and Tobago' and the Edmodo platform at the following links:

1) Facebook page:
   https://www.facebook.com/Seismology-in-Schools-Trinidad-and-Tobago
2) Edmodo page:
   https://www.edmodo.com

Instructions for Edmodo.com

- The Online Learning Community can be accessed from the following website: http://www.edmodo.com/home
- If you already have an Edmodo account, **Login** and **Join** using the Group code **(ce5ags)**
- If you **don't** have an Edmodo account, to sign in, Click on **I'm a teacher**
- Type in group code **(ce5ags)** and **fill out the requested information**
- Copy your username and password and click **sign up**
- The next time you enter the website type in your username and password and click **login.**

CARIBBEAN SECONDARY EDUCATION CERTIFICATE (CSEC)

CURRICULUM SPECIFICATIONS AND CLASSROOM ACTIVITIES

Curriculum Links and Activities

Curriculum Specification	**Seismology Activities**
CSEC Geography Syllabus 2015	
Section I: Practical Skills and Field Study	
1. (b) Locate places, using four and six-figure grid references 4. (a) (i) Identify the main lines of latitude and longitude; and (ii) Locate a place from its latitude and longitude (b) Name and locate countries in the Caribbean (at high risk from the hazard of earthquakes).	Activity 1
Section II: Natural Systems	
1. Describe the internal structure of the earth	Activity 2
2. Explain the theory of plate tectonics	Activity 3, 5 & 6
3. Describe the consequences of the movement of plates;	Activity 4 & 5
4. Explain the formation of intrusive and extrusive volcanic features	Activity 5
28. Distinguish between a natural hazard and a natural disaster. 29. Describe the impact of earthquakes in the Caribbean. 30. Explain the responses of individuals in the Caribbean to reduce the effects of earthquakes.	Activity 12-13

Additional Seismology Activities

Topic Covered	**Seismology Activity**
1. Forces and earthquakes	Activity 7
2. Types of waves: Wave demonstration to understand P and S-waves	Activity 8
3. Evaluating travel time using slinky model	Activity 9
4. Understanding a Seismogram	Activity 10
5. Exploring jAmaSeis	Activity 11
6. Earthquake-proof structures	Activity 12
7. Disaster kits	Activity 13

Section I: Practical Skills and Field Study

ACTIVITY 1 - Mapping Earthquakes

OVERVIEW

In this activity, students will develop their map reading skills using actual earthquake location information and the provided sample map. Students are given information for specific earthquake events and are asked to plot its locations using lines of latitude and longitude.

OBJECTIVES

1. Determining the location of earthquakes using lines of latitude and longitude.

MATERIALS

- Large wall-sized world map with lines of latitude and longitude can be used. However, a print out of a sample map is also provided in this workbook[1].
- Push pins or pencils for plotting the earthquakes.
- Rulers

PROCEDURE

Part A

1. For this activity the class can use both the small and the large world maps in tandem to plot earthquakes by location.
2. Earthquake data can be accessed online at the Incorporated Research Institution of Seismology (IRIS)[2].
3. This link should take you to a listing of the latest earthquake events with latitudes and longitudes. Feel free to browse the online globe feature and observe what happens as you zoom in and out of an area. The number of stations should change depending on the number of earthquake events in that area.

Part B

This diagram conveys lines of latitude and longitude that are used to locate a detected earthquake event from a seismic station. Students should familiarise themselves with this diagram before trying to locate an earthquake.

[1] Refer to Figure 3 on page 12.
[2] Link to IRIS's website: http://geoserver.iris.edu/events/download/13710.

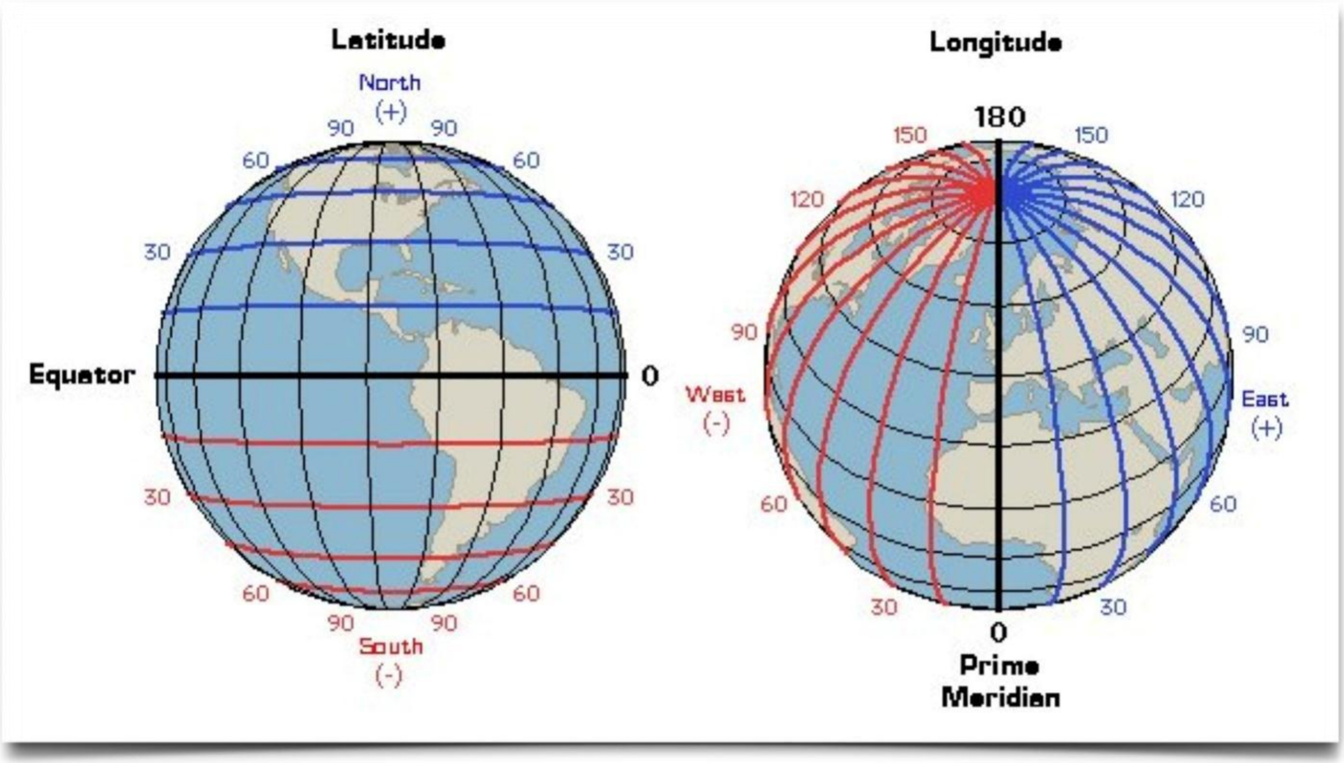


Figure 2: Lines of latitude and longitude on the Earth's surface

Note that each consecutive line increases or decreases by 30^0 in a specific direction. But this can vary according to the scale of the map.

Below is earthquake data taken from IRIS's website. Ask students to determine their locations on the World Map.[3]

Earthquake A

Date and Time:
2016-04-20 10:51:39
Magnitude:
5.6
Latitude / Longitude:
13.20 / -55.89
Depth (km):
10

Earthquake B

Date and Time:
2016-01-12 18:27:22
Magnitude:
4.2
Latitude / Longitude:
54.45 / -117.03
Depth (km):
5

Earthquake C

Date and Time:
2016-06-25 21:49:23
Magnitude:
4.7
Latitude / Longitude:
53.81 / -35.29
Depth (km):
10

Earthquake D

Date and Time:
2016-05-20 18:14:04
Magnitude:
6
Latitude / Longitude:
-25.56 / 129.88
Depth (km):
10

[3] Solutions are provided in the Additional Resources on pages 44-45.

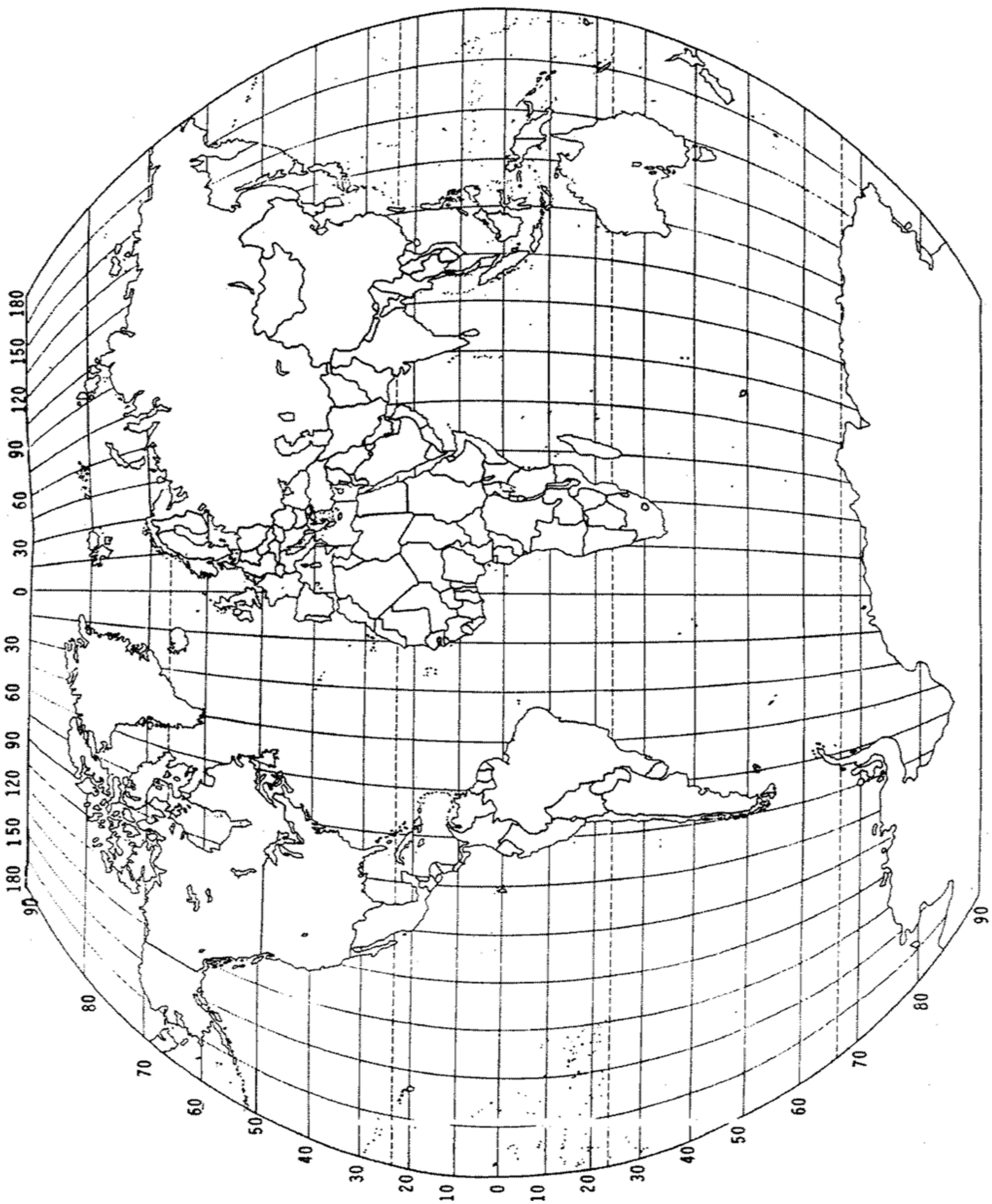


Figure 3: World map with latitudes and longitudes

1. Students can now take turns locating and marking these earthquakes on the wall map while others find and mark the approximate location on their individual maps.
2. Select more earthquake data for the class as needed.

Extension

3. Zoom into the Caribbean region and plot all the earthquakes for the year 2016 & 2017 (click on the "By Year' tab) listed on the website. After the students have plotted all locations, they should see patterns emerge.
4. Discuss and encourage them to make statements about where the earthquakes seem to be more frequently occurring and make hypotheses on why.
5. Can you identify some Caribbean countries that are high risk from hazards of earthquakes? Hazards will be further discussed in Activity 13.

DISCUSSION

By plotting a series of earthquakes over a period of time for the same region, students should have observed *hot spots* where earthquakes occur frequently. These are active earthquake zones, which also give an idea of the plate boundaries (which will be further explored in another activity). Students should have been able to identify the Caribbean plate based on the plotted earthquakes.

Historical data also shows that earthquakes occur in the same general patterns year after year, predominantly in three large zones of the earth.

Zone 1: The circum-Pacific seismic belt found along the rim of the Pacific Ocean, where about 81 percent of the world's largest earthquakes occur. It has earned the nickname "Ring of Fire". You should be able to zoom in to the Pacific region and observe this pattern of the earthquakes.

Zone 2: The second important belt, the Alpide, extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic. This belt accounts for about 17 percent of the world's largest earthquakes, including some of the most destructive.

Zone 3: The third prominent belt follows the submerged mid-Atlantic Ridge. The remaining shocks are scattered in various areas of the world. Earthquakes in these prominent seismic zones are taken for granted, but damaging shocks occur occasionally outside these areas.

Section II: Natural Systems

ACTIVITY 2 - Exploring the Internal Structure of the Earth

OVERVIEW

The Earth is divided into several distinct layers, each with their own properties. The Earth consists of concentric layers that include: the inner core, outer core, mantle and crust. The crust is made up of tectonic plates, which are in constant motion. Plates are large units of the earth's lithosphere that move relative to other plates and the interior of the earth.

OBJECTIVES

1. Understanding the internal structure of the earth.
2. Introducing students to plate tectonics.

MATERIALS

From the kit box:

- Geophysics foam Earth model (refer to figure 4)

PROCEDURE

Using the foam Earth model from the kit box separate the two hemispheres to reveal the layers within the earth and discuss with students the different layers described below:

1. **Crust (outermost blue layer):**
    a. Is the coolest and thinnest layer, is ~7km thick below oceans and 30 - 40km thick for the continents.
    b. Is hard and brittle, and when it deforms, earthquakes can occur.
    c. Is coolest at the surface, but can be 200 - 400^{o}C at the bottom of the crust.

2. **Mantle (orange layer):**
    a. Is very viscous, like honey, but millions of times thicker.
    b. Is very thick – over 2900 km (nearly half of the radius of the Earth)!
    c. Is much hotter than the crust, coolest at the top and warmer the deeper you go.

3. **Outer Core (red layer):**
    a. This is a molten metallic layer mostly made of iron and nickel (it behaves like a liquid).
    b. The Earth's magnetic field is generated by convection currents in this layer - this has links to dynamos which might be taught in Physics lessons covering magnetism.

4. **Inner Core (central yellow layer):**
    a. This is the hottest part of the Earth (>4300^{o}C).
    b. It is made of solid metal – iron and nickel.

Figure 4: Geophysics foam Earth model

Ideas for exercises/homework:

Using the thicknesses of the crust, mantle and inner and outer cores, work out the percentage thicknesses and volumes of each layer compared to the whole Earth. This can be achieved by providing the following information to the class:

Thicknesses: Continental Crust: 40km

Mantle: 2865km

Outer Core: 2260km

Inner Core: 1210km

Equation for volume of a sphere: $V = \frac{4}{3}\pi r^3$

Answers:

Radius of the Earth	6375 km	
Volume of the Earth	1.08×10^{12} km^3	
Percentage thickness	Crust Mantle Outer Core Inner Core	0.6% 44.9% 35.5% 19.0%
Volumes	Crust Mantle Outer Core Inner Core	2.03×10^{10} km^3 8.85×10^{11} km^3 1.68×10^{11} km^3 7.42×10^{9} km^3
Percentage Volume	Crust Mantle Outer Core Inner Core	1% 83% 15.3% 0.7%

ACTIVITY 3 - Exploring the Earth's Crustal Plates

OVERVIEW

This activity looks at the continents of North America, South America, Africa, Antarctica, Australia and Eurasia, and how they have moved over the last 200 million years. At that time, these six continents were all part of a single large super continent, called Pangaea. Starting about 180 million years ago, Pangaea began to break up and new diverging plate boundaries were formed within it. This eventually created the continents we see today. In this exercise, students will reconstruct Pangaea. They will use the fit of the continental crust to put Pangaea back together.

OBJECTIVES

1. Exploring the results of movement on the Earth's crust as a phenomenon of the theory of plate tectonics.
2. Understanding that the interior structure of the Earth is divided into separate regions, each with different physical properties.
3. Understanding the linkage between the location of earthquakes and plate boundaries.

MATERIALS

- Foam Earth model

- Pangaea jigsaw[4]
- Plate boundaries map
- Scissors
- Colouring pencils/crayons

PROCEDURE

1. Using the foam Earth model from the kit box and the Pangaea jigsaw, demonstrate the structure of the earth.
2. Review the composition of the plates with the class. Make sure the students understand that the continents make up the non-oceanic part of the crust.
3. Students should name and identify the different continents and explore the transformation of the Earth throughout years of history. Discuss with them that the edges of the continents look as if they may have fit together at one time.
4. Have students label, colour, cut out, and fit the continents together. Explain that the plates are moving, due to convection and gravity.
5. Explain that this movement causes stress within the plates, which generates earthquakes and volcanoes.
6. Ask students to label the continents in terms of their continental drift direction, using simple arrows/keys or markers to indicate direction.

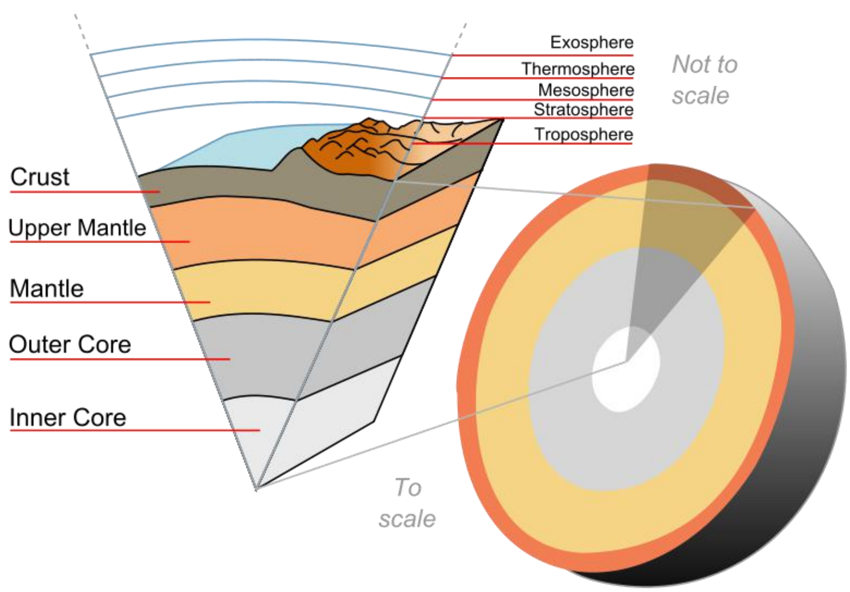


Figure 5: Structure of the Earth

[4] Provided in Additional Resources on page 44.

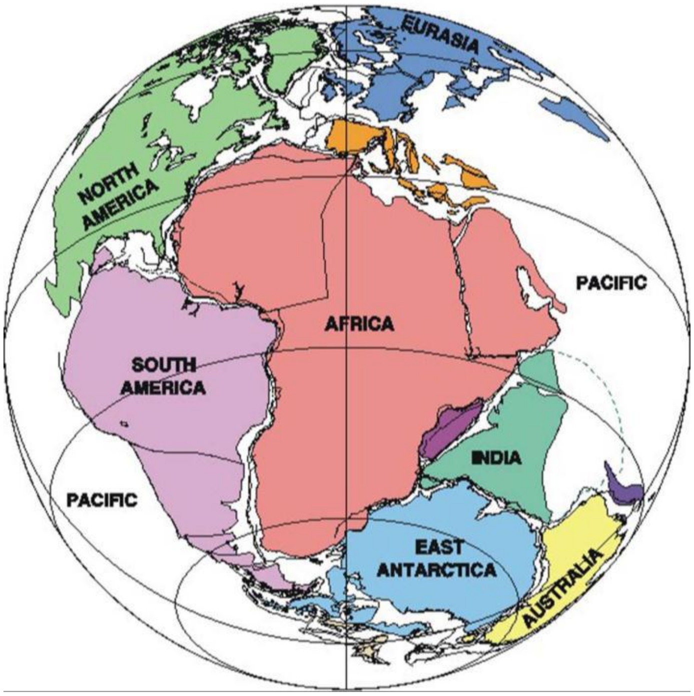


Figure 6: Continents arranged in Pangaea layout

ACTIVITY 4 - Basic Faults and Earthquakes

OVERVIEW

This simple activity involves Earth movement. It uses blocks to demonstrate the movement of the Earth's crust and how these movements generate earthquakes.

OBJECTIVES

1. Introducing students to the different fault types.
2. Teaching basic fault terminology.
3. Understanding the effects of fault movement.

MATERIALS

- Wooden fault block models

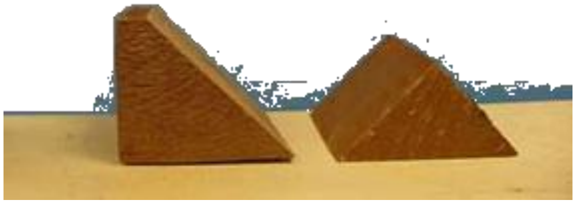


Figure 7: Wooden block fault models (left)

Part A

PROCEDURE

1. Begin by asking the students what they think causes earthquakes.

2. Using the wooden fault blocks (as seen in figure 7), explain that the crust of the Earth is made up of lots of different blocks.

3. Again using the fault blocks, demonstrate that forces moving in different directions cause these blocks to move and slide. Slide them apart, together, and sideways past each other.

4. Explain that the break between the two sections is called a fault.

5. Explain that there is a great deal of friction between the two blocks of wood and that the sudden release of pressure when the blocks slide past each other causes an earthquake. To enhance this learning experience, this activity could be linked with Activity 7 "Build-up of Forces" on page 25.

Part B

PROCEDURE

This practical should be used as an expansion of Part A – Basic Faults and Earthquakes

1. Explain the different types of faults:

    a. Normal faults – pulling blocks apart

    b. Reverse faults – pushing blocks together

    c. Strike-slip – sliding blocks past each other

2. Hand out the fault block model worksheets[5] along with scissors and glue sticks, and have students build the block models. The paper can be stuck onto Bristol board or card board for rigidity.

[5] Handout can be found in Additional Resources on pages 47-49

3. Using the fault block models, have the student explain how movement along faults affects stratigraphy and other geological features.[6]

4. Explain fault terminology such as:

   a. Fault plane

   b. Throw

   c. Fault dip

   d. Foot wall

   e. Hanging wall

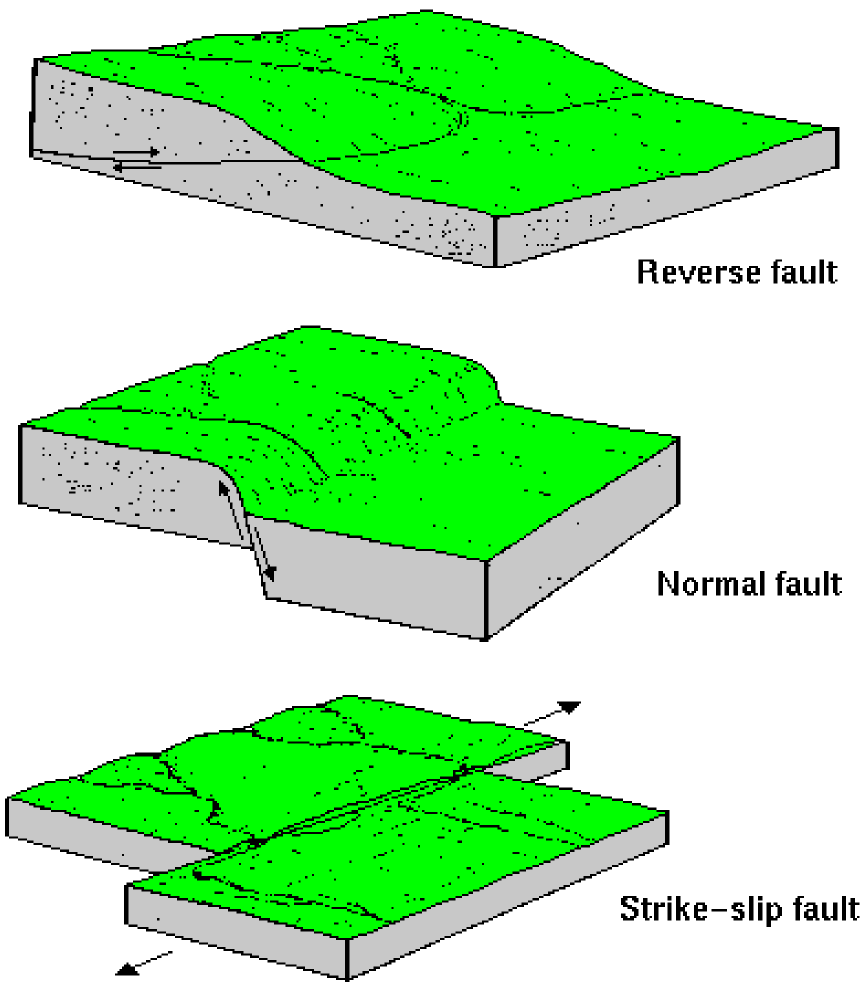


Figure 8: Types of faults

[6]Additional information : http://earthsci.org/education/teacher/basicgeol/deform/deform.html

ACTIVITY 5 - Plate Boundary Exploration

OVERVIEW

The previous activity introduced students to Earth's structure. Students should have a basic understanding of how the continents were formed and how they have moved over the years. This activity further builds on this knowledge by exploring the types of crustal plates (oceanic and continental) and the interactions that take place at their borders.

OBJECTIVES

1. Identifying types of crustal plates (oceanic and continental) and their characteristics
2. Understanding plate tectonics and describing the movement at the three types of plate boundaries.

MATERIALS

- Geophysics foam Earth model
- Completed Pangea jigsaw
- World map

PROCEDURE

1. Prompt the students to reiterate the idea that the Earth's crust is divided into separate regions commonly known as plates as mentioned in the previous activity.
2. Identify the two types of crustal plates:

Oceanic Crust vs Continental Crust

Oceanic Crust

- Thinner, more dense and tends to have oceans above them.
- Oceanic crust is mainly based on basalt minerals.
- Extends 5-10km beneath the ocean floor.
- The oldest area of the ocean crust is nearer 270 million years old.

Continental Crust

- Thicker, less dense, and makes up most of the land we live on.
- Continental crust is mainly composed of types of granite.
- The most abundant minerals in this crust are aluminium and silicate.
- Although less dense than oceanic crust, continental crust extends to 70km deep.

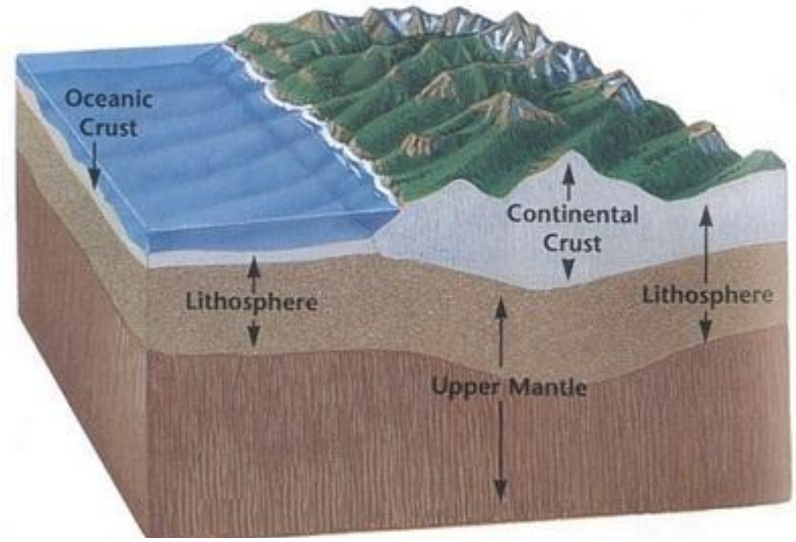


Figure 9: A visual representation of continental and oceanic crust.

3. Using the foam Earth model, point out examples of both continental crust (e.g. Eurasian plate, South American plate, African plate) and oceanic crust (Pacific plate, Caribbean plate, Nazca plate). Hand it around the class so the students can try to locate some themselves. These plates move extremely slowly, just a few centimetres a year, but over millions of years this can completely change the layout of the continents.

4. To display this, place the Pangaea jigsaw pieces in the present day configuration on a world map. Then move the pieces to represent their positions in Pangaea. Alternatively, place the pieces in their Pangaea positions and then move them slowly to their present day positions.
5. Explain what happens when the plates meet.

Depending on the directions and types of plates involved there are 3 main types of plate boundaries:

i. **Divergent** – This occurs when two plates move away from each other. The crust is extremely thin here, and molten magma erupts, rising to the surface, creating new oceanic crust. It is common to find small earthquakes along these boundaries. This is how continents break apart – a good example is the Mid-Atlantic Ridge, which is producing new oceanic crust and increasing the distance between the Americas and Europe by a few centimetres every year.

ii. **Convergent (Continental)** – This occurs when two plates move towards each other. If the two plates involved are both continental crust, they collide and deform, pushing up large mountain ranges – e.g. The Himalayas - where the Indian plate collided with the Eurasia plate. Large earthquakes are common. See if the students can locate any other large mountain ranges on the foam Earth model from past continental collisions e.g. Rocky Mountains on the North American plate.

Convergent (Subduction) – If an oceanic plate meets a continental plate, the more dense oceanic crust is subducted beneath the less dense continental crust. As the subducted crust goes deeper into the mantle, it melts, which can cause volcanism when the magma reaches the surface (E.g. Japan and island arc volcanoes such as the Lesser Antilles). This is where oceanic crust is destroyed, and large earthquakes are common.

iii. **Transform –** This occurs when two plates slide past each other. Crust is neither created nor destroyed. The plates often get 'stuck' when sliding past each other, causing pressure to build up. When the pressure has built up enough to overcome the friction that stopped them from sliding past each other, large earthquakes can occur. Examples include the San Andreas Fault and where the Caribbean plate is sliding past the South American plate on its southern boundary.

6. To understand the location of the different types of plate boundaries and how they are linked to different geographic features, give students a copy of the plate tectonics map[7]. Ask students to allocate a colour to each of the different plate boundaries and make a key on the side of the map. Get students to colour in the different plate boundaries. As a class, discuss the locations of various topographic features, (mountains, volcanoes etc.) and how they link to where different boundary types are located.

DISCUSSION

1. How is continental crust formed?
2. What happens to subducted oceanic crust?
3. Is there anywhere in the world where rifting (continents splitting) is occurring today?

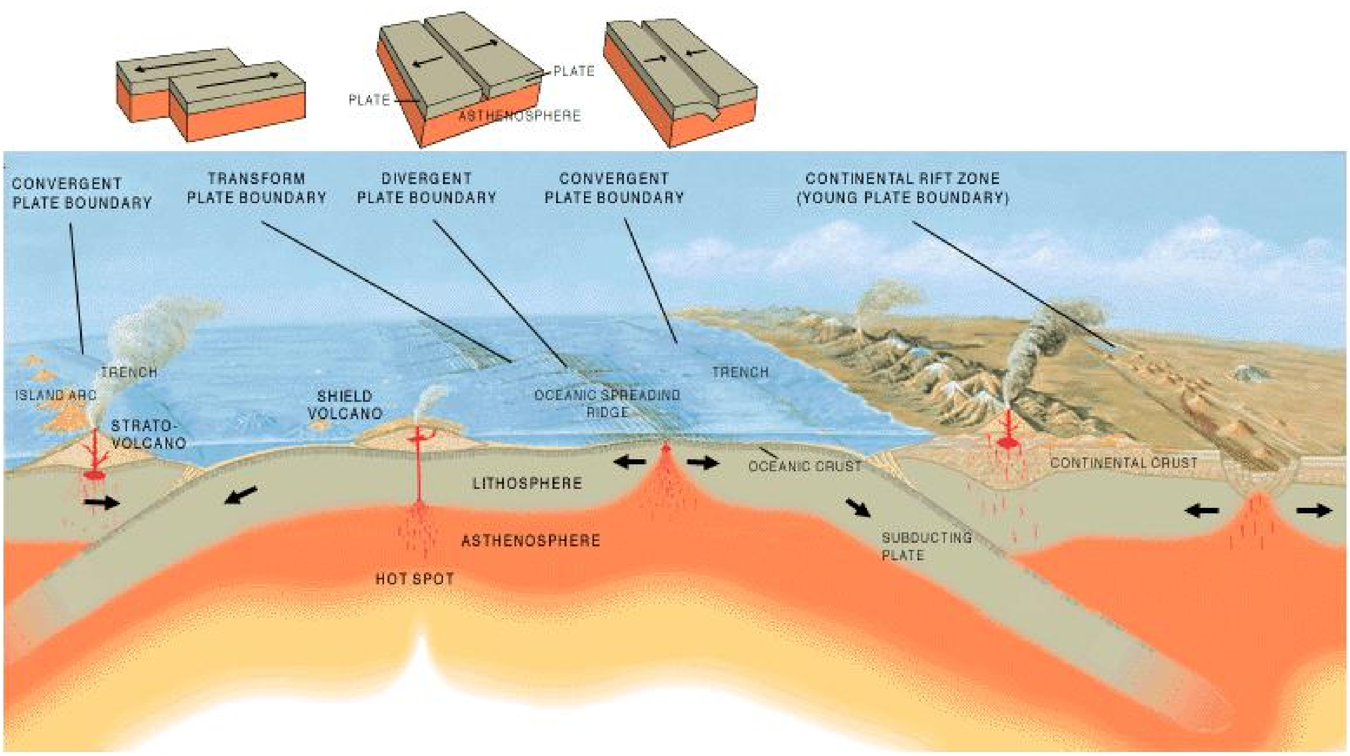


Figure 10: Types of plate boundaries

[7] Location of the World Plate Boundaries can be found in Additional Resources on page 50.

ACTIVITY 6 - Bending Sticks and Earthquakes

OVERVIEW

Students will learn about elastic and brittle deformation and how the earth moves to create earthquakes. This is an introduction to the physical principles of earthquakes. These activities demonstrate to students how the earth moves and creates earthquakes using the simple analogy of sticks. Dried spaghetti can be used as an alternative to sticks.

OBJECTIVES

1. Using a real life analogy to illustrate how the structure of the earth is dynamic.
2. Understanding how the earth moves, deforms and creates earthquakes.
3. Understanding the concepts of elastic and brittle deformation.

MATERIALS

- Dried spaghetti

PROCEDURE

Either use one stick as a demonstration at the front of the class or hand one out to each student.

1. Start by applying a small amount of pressure to either end of the stick so it begins to bend slightly. This is how the earth initially deforms in a plastic manner when forces build up.
2. If you release the pressure the stick returns to its original shape, like the Earth if the forces were removed.
3. Continue to apply force to the two ends whilst explaining that as pressure builds up it continues to bend plastically until it snaps much like an earthquake, where the break is a fault. The sound of the 'snap' is heard because of the waves that are released. These sound waves can be compared to seismic waves that are released during an earthquake. This activity can be linked to the Activity 9 "Wave Generation using the Slinky Model" on page 31 to explain waves. This is an example of brittle deformation.
4. Variations in thickness can be compared to variations in rock strength, with thicker sticks comparable to stronger rocks. Try using macaroni for comparison.

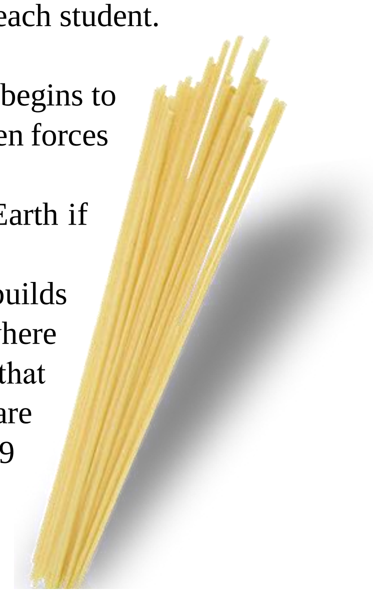


Figure 11: Spaghetti sticks

Section III: Additional Seismology Activities

Forces and Earthquakes

ACTIVITY 7 - Build-up of Forces

OVERVIEW

In these activities students will observe how the build-up of forces lead to the generation of earthquakes as demonstrated by slippage using brick and sandpaper. A brick being pulled along a surface covered in sandpaper will be used to model the behaviour of an earthquake: Turning the pulley to build up tension in the string is like the build-up of stresses at a fault, and the brick movement over the sandpaper is like the slippage that happens in an earthquake.This activity helps students understand that the relative size of an earthquake is related to how much energy is required to overcome friction at a fault. It also demonstrates how different faults require varying amounts of energy to overcome friction. Some can require varying amounts of energy to overcome friction: some have extremely large, infrequent earthquakes, while others just creep along at a constant speed.

OBJECTIVES

1. Demonstrating how slip rates are not constant for all earthquakes.
2. Demonstrating stick-slip properties of faults.
3. Illustrating that the size of earthquake depends on the force required to overcome the friction.

MATERIALS

- Earthquake simulator model
- Graph paper

Figure 12: The earthquake simulation model

PROCEDURE

1. Make sure the pulley is clamped onto the plank and attach the string from the pulley onto the force meter.
2. Use another string attached to the force meter to tie around the brick.
3. Stick or tape a ruler with a millimetre scale onto the plank and a pointer onto the brick: you should be able to measure the position of the brick against the scale to the nearest millimetre.
4. Start the brick at the end of the sandpaper furthest away from the pulley: make sure it is completely on the sandpaper.
5. **Wear eye protection**. Turn the pulley so it gradually increases the tension in the string (and the force on the brick) until the brick starts to move. Increase the tension slowly so that it takes several seconds before the brick slips.
6. Try this a few times. Watch what happens to the force meter reading: does the brick always begin to slip when the force reaches the same value?

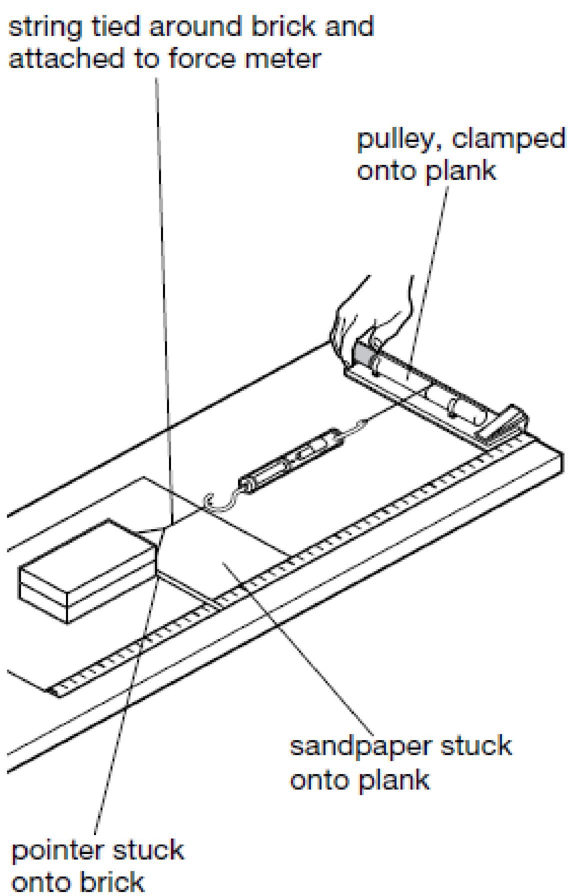


Figure 13: An illustration of how to use the earthquake simulator model

Optional

For better visualisation (refer to figure 14), a building can be constructed out of cardboard or heavy paper material and attached to the brick.

Figure 14: A paper building attached to the earthquake simulator model (left)

DISCUSSION

A typical plot of class data from the brick and sandpaper investigation will show that large slips occur much less frequently than smaller slips. Using the results of their investigation, students can then compare these with observed earthquake data on the following page.

While this model accurately simulates the strain energy that slowly accumulates in the rock material surrounding a locked fault, which is released in a sudden slip event (a process known as the elastic rebound theory), it is ultimately a simplification of a complex Earth system. Such simplifications must be understood to interpret the model accurately. Therefore the relationship between the model and reality should be clearly emphasised to students. This is particularly important for secondary school students, who often think of physical models as copies of reality rather than representations. For example, students should discuss how the fault plane of the model is horizontal due to the materials it is created from, and that such faults do not exist in nature.

Not only does the model provide a physical perspective on the generation of earthquakes, it also illustrates the concept of an earthquake's magnitude (Mw), and how the Mw can be calculated based on the physical features of the fault. In the model, the length and width of the fault section that slips during an event (represented by the dimensions of the block of wood) as well as the rigidity of Earth materials (represented by force meter) are constant for every event generated. The only factor that can vary is the displacement or slip of the fault. As a result, there is a direct correlation between the amount of slip of the block and the moment magnitude of the event. While aspects of the mathematical relationship may be premature for some students' experience, all students will physically see this relationship by noting how much the "building" on top of the block moves in relation to the amount the block slips. The further the block slips, the more energy is released, and the more violently the building shakes.

ACTIVITY 8 - Human Seismic Wave Demonstration

OVERVIEW

In Activities 8 and 9, students will observe how waves are created at a source and the subsequent propagation of these waves. The factors that affect various wave parameters and general wave properties will be investigated. To demonstrate how Primary (P) and Secondary (S) waves are generated during an earthquake and how they travel at different velocities, both a human seismic wave demonstration and a slinky model will be employed.

OBJECTIVES

1. Introducing waveforms as a physical concept.
2. Determining the differences between longitudinal (or P-waves), transverse (or S-waves) and surface waves.

PROCEDURE

To give students a better understanding and to demonstrate Primary (P) and Secondary (S) waves, students can be used to represent particles.

- For longitudinal waves, have a line of 10-12 students stand very closely together, shoulder to shoulder; a gentle push at one end of the line should be transmitted to the other end, making the end person step out. This demonstrates how P-waves travel.
- For transverse waves, have the same line of students stand side by side with arms linked; if the person at one end of the line bends forward, this will make the next person bend forward, and so on. Standing at the same separation but without arms linked does not transmit the effect when the end person bends forward: this is analogous to the way S-waves are transmitted through solids but not through liquids.

DISCUSSION

Unlike waves in water confined to the surface, waves from an earthquake can propagate through the entire interior of the Earth.

There are 3 main types of waves.

- Compressional waves, often known as Primary waves or P-waves
- Shear waves (often called Secondary waves or S-waves due to their arrival time)

- Surface waves, sometimes called Love or Rayleigh waves

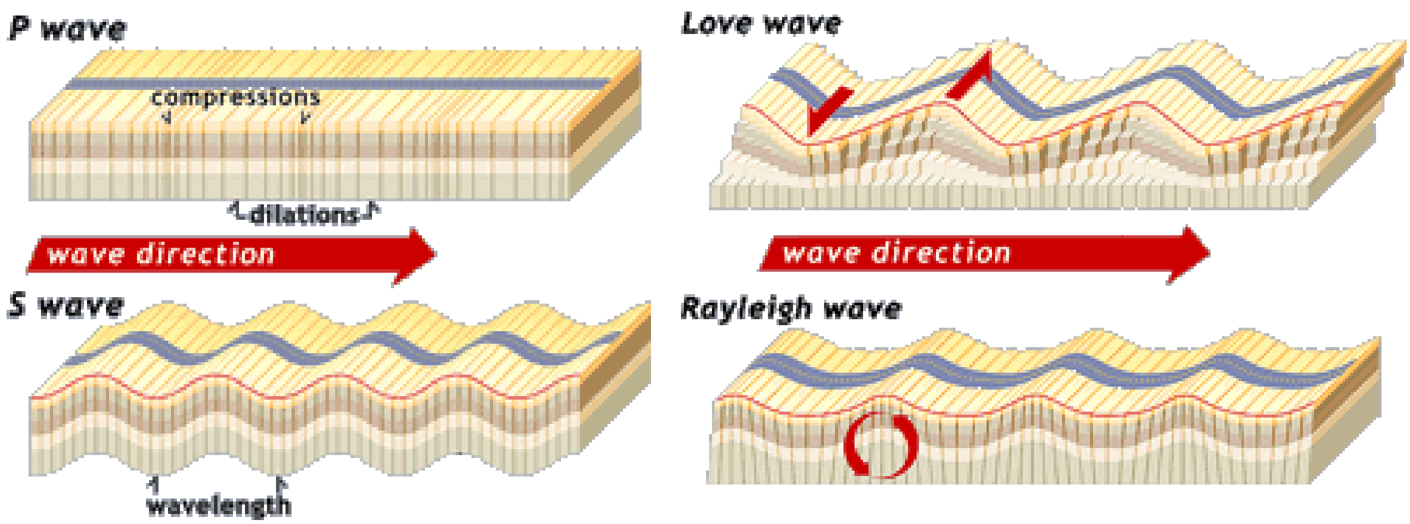


Figure 15: Diagrammatic representation of the wave from an earthquake

Wave Type	**Description of Particle Motion**
P, Compressional, Primary, Longitudinal	Alternating compressions and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the ray path); and therefore, perpendicular to the wave front.
S, Shear, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the ray path); commonly polarized such that particle motion is in vertical or horizontal planes.
L, Love, Surface, Long	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface.
R, Rayleigh, Surface, Long, Ground roll	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde.

ACTIVITY 9 - Wave Generation using the Slinky Model

OBJECTIVES

1. Explaining travel paths of different waves during an earthquake.

MATERIALS

- Slinky Model (refer to figure 16)

PROCEDURE

You can use the provided slinky model to show how an earthquake generates P-waves and S-waves:
1. Five students - the ‘observers’ - each hold on to the unattached end of a ‘slinky’, so it is stretched out loosely across the room (not touching the bench top).
2. Another person – ‘the earthquake’ - should stand at X and give the box a quick push.
3. What kind of wave does each of the observers detect, an S-wave (transverse) or a P-wave (longitudinal)?
4. What happens if the earthquake push is at Y instead?
5. Now repeat the single push at X, with the three observers on the opposite side of the file all at the same distance. (Pull the ‘slinkies’ to the same length and coil spacing).
6. What do you notice about the arrival time of the pulse at each of these observers?
7. Now have the three ‘observers’ standing at different distances, but keeping the coils with the same spacing, as shown on the right.
8. What happens if you send the pulse now?

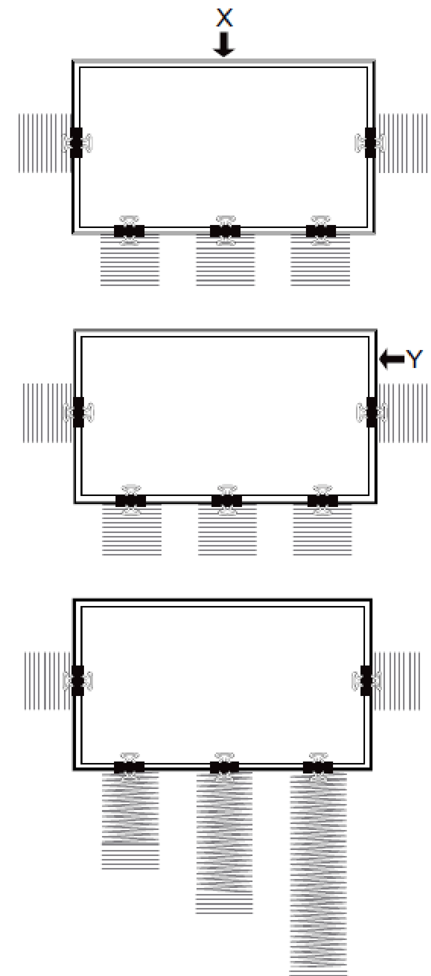


Figure 16: Slinky Model

DISCUSSION

If the three students immediately in front of you keep their coils to the same length and tension, then a single pulse will arrive at the same time for all three students; if the three students stand at different travel distances (but still keeping the tension the same), then there should be a difference in arrival times of the wave pulses. This simulates the difference in arrival times for the same kind of wave at different distances from the earthquake. It is important to keep the coil spacing the same because differences in the coil spacing would be the equivalent to waves travelling through rocks of differing densities.

Striking the box as shown results in the three students immediately in front of you receiving P-waves, while the students at each side receive S-waves.

Pushing the box at the point marked Y will mean that one student detects a compression wave first, while the other detects an expansion wave.

Figure 17: Illustration of how to use the Slinky Model

ACTIVITY 10 - Understanding a Seismogram

OVERVIEW

Earthquakes are commonly known as the sudden shaking of the earth's surface. During a large earthquake, you can also see the shaking by looking at buildings, lights poles or the ground. This is difficult to measure by observation, so earthquakes are translated to a visual representation using seismometers. These diagrams are called seismograms which seismologists use to analyse an earthquake.

OBJECTIVES

1. Learning about the seismogram and what information they show about an earthquake.

MATERIALS

- jAmaSeis software [8]
- Sample data provided

PROCEDURE

A seismogram is the wiggly trace that records the vibrations caused by an earthquake at a particular recording station. Once you know what some parts of a seismogram show, you can start to understand how seismologists can use seismograms to learn more about earthquakes.

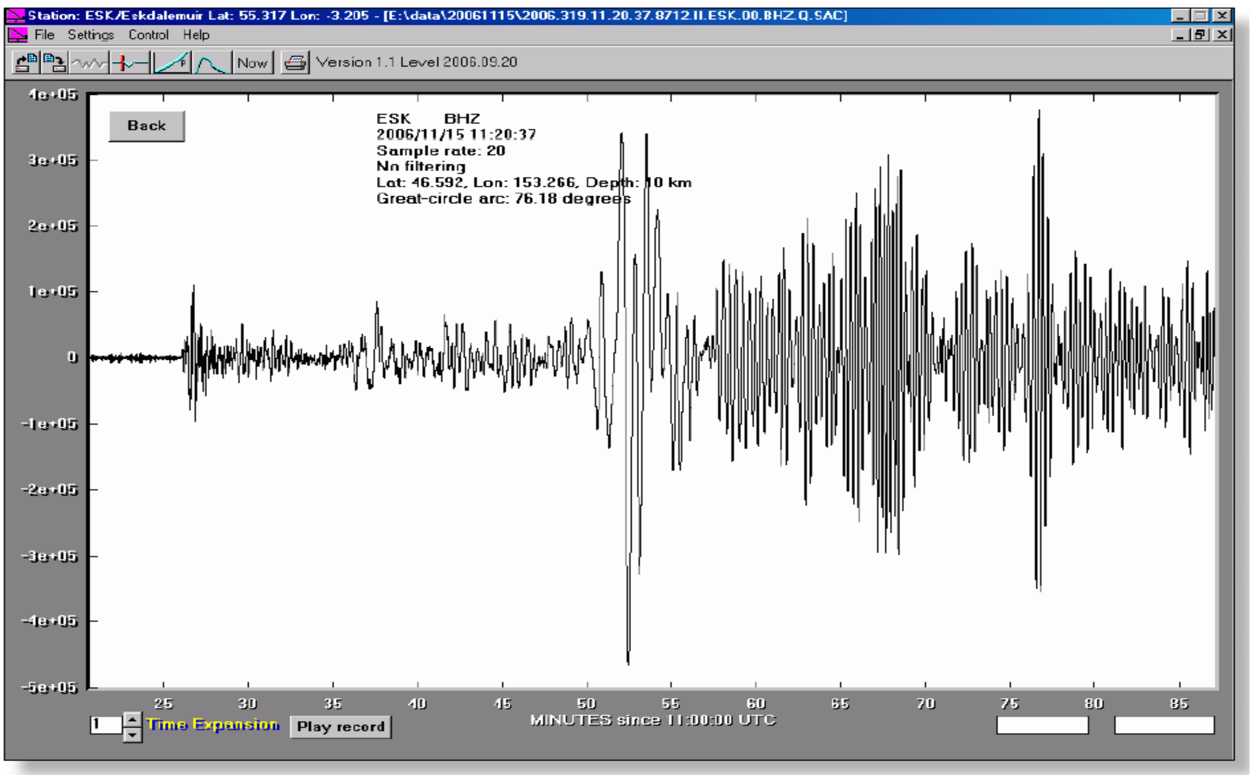


Figure 18: A seismogram of a real earthquake event (a Magnitude 8.3 event in the Kuril Islands)[9]

1. The seismogram is based on data from Eskdalemuir seismic recording station. What is the location of Eskdalemuir (Latitude and Longitude values) shown?
2. This seismogram shows information for a particular earthquake, at Latitude 46.592°, Longitude 153.266°, and Depth 10km. Find this information on the diagram, then write down the information given in the line below it: it tells you the distance from the earthquake to the recording station in degrees (a degree is equivalent to about 111km on the Earth's surface).

[8]jAmaSeis Download: http://www.iris.edu/hq/jamaseis/

[9] A larger diagram is provided in Additional Resources on page 51. An example of seismic waves from (1) earthquake received at (3) stations can be seen on page 52.

3. The horizontal axis shows time in minutes since an identified time (11.00.00 UTC in this example). For the chosen earthquake event, the predicted arrival times for the first P-waves and S-waves at this location are as follows: P-waves 11:26:13; S-waves 11:35:57. Mark the corresponding 'wiggles' on the screenshot.
4. As well as P-waves and S-waves ('body' waves), there are also surface waves, which are much slower. Mark the zone on your seismogram corresponding to the first group of surface waves, and label these 'Love waves'. Mark the zone corresponding to the second group of surface waves, labelling this 'Rayleigh waves'.
5. The average frequency content of the different wave types in this plot is 0.2 Hz for P-waves, 0.05 Hz for S-waves and 0.01 Hz for Surface waves. In the crust, P-waves have an average velocity of 6.5 km/sec, S-waves 3.7 km/sec and surface waves 3.5 km/sec. What is the wavelength of these different wave types in the crust?

ACTIVITY 11 - Exploring jAmaSeis

OBJECTIVES

1. Using jAmaSeis to analyse seismic data.

MATERIALS

- Computer with jAmaSeis Software installed[10].
- Internet

PROCEDURE

Downloading Data

To download the sample data for this activity, log on to: http://geoserver.iris.edu/node/202382 . Download the three (3) **.sac** files from the stations that recorded the event at the Northern Mid-Atlantic Ridge. The file will automatically be downloaded to your computer. Be sure to save this file in a location that is easy to access. This will be helpful when you need to access this data later on.

Using jAmaSeis

Run the program and locate the 'Go To Event View' tab on the top right corner.

The Event View Window

[10] If there are any issues in using the software, please refer to the Troubleshooting Manual for the SEP Seismometer or the Starter Guide, previously handed out to the lead teacher(s) for your school.

This window allows users to analyse earthquake data that would have been extracted from the Stream View Window or downloaded previously. To add the data you previously downloaded select “**Add Station**”. This will give you the option to browse to the location where you stored your downloaded data.

Alternatively, after selecting data from the Stream View Window, clicking “**Extract Selection**” will take you to the “**Selection View**” window where data can be edited before clicking “**OK**” to move to the **Event View** window.

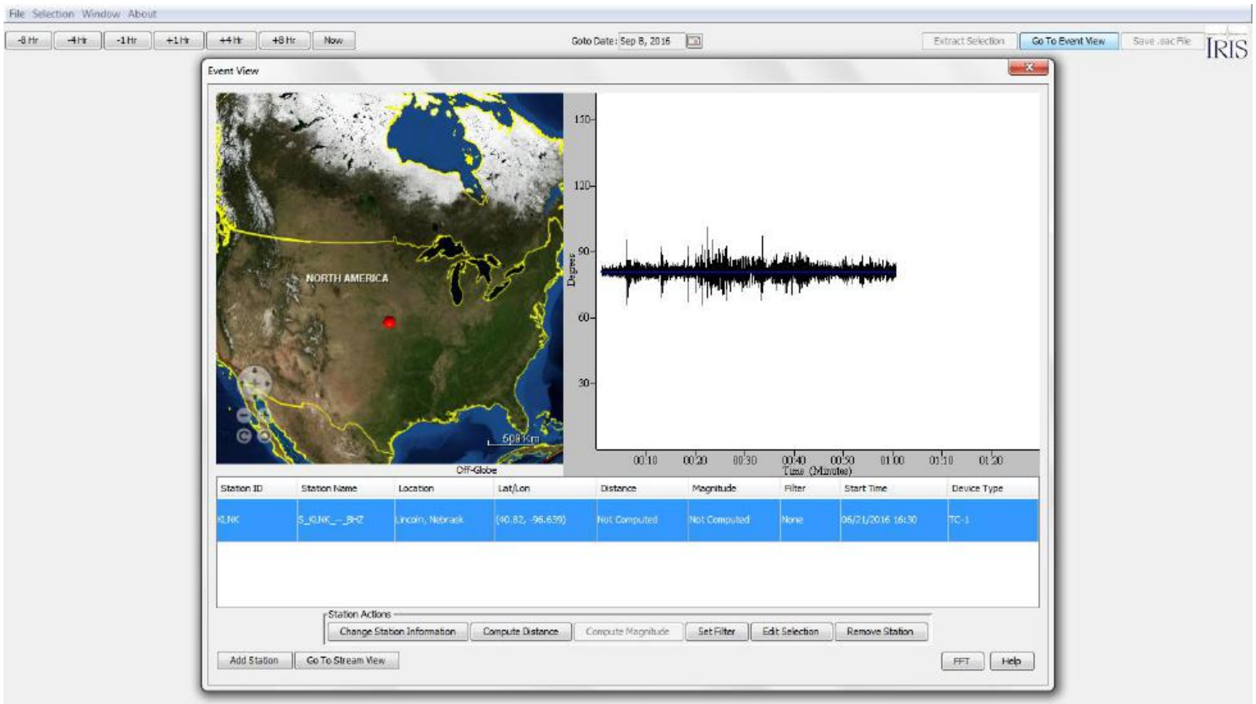


Figure 19: Sample image of Event View

1. From your observations, what seismic data is shown in the table?
2. Can you identify the data that needs to be calculated?
3. Click on the ‘Edit Selection’ tab and explore the seismograph. What observations do you make when using the features? Can you add or remove data from the seismograph?
4. Try uploading the additional two stations’ data that you previously downloaded.
5. Can you identify which two countries the stations are located in?

Finding the Distance

To calculate the distance of an earthquake from a single station, select the current station in the **Event View** window. It will be highlighted in blue. Click “**Compute Distance**”. This will open the “**Travel Time Computation Window**”.

The earthquake waveform recorded at that station will be displayed. To the left of the window check “**Display Curves**” then un-check “**Surface Waves**”. This will display in **BLACK** two curves showing the relationship between primary and secondary wave arrival times.

You will need to pick the arrival of Primary (P-waves) and Secondary (S-waves). To pick the arrival of the P and S waves double click on the waveform. The pick lines for the selected P and S waves, appear in **RED**. Primary waves are generally of high frequency and Secondary waves a lower frequency. Pick lines can be adjusted by dragging them along the wave form and removed by double clicking directly on them.

To compute the distance of the earthquake from the station, adjust the position of the waveform so that the Primary wave pick line intersects the "P" curve as the Secondary wave pick line intersects the "S" curve. On the map a circle will describe the distance of the event away from the station.

Have fun exploring and see if you can compute the earthquake distance for the event. Note that this takes some practice.

ACTIVITY 12 - Earthquake-Proof Structures

OBJECTIVES

1) Observing how different structures are affected by differing magnitudes of earthquakes.

MATERIALS

For the entire class:

- 10-20 sandbags consisting of 250 grams of sand in a sandwich sized zip lock bag. The bag should be taped into a sausage shaped cylinder for rigidity and ease of mounting onto the towers.
- 1 earthquake tower testing platform with a movable platform / shake table connected to a rigid frame by rubber bands, springs, or a motor. One design may be found in the Additional Resources.[11]
- 4 large binder clips to secure the cardboard bases to the shake table platform.

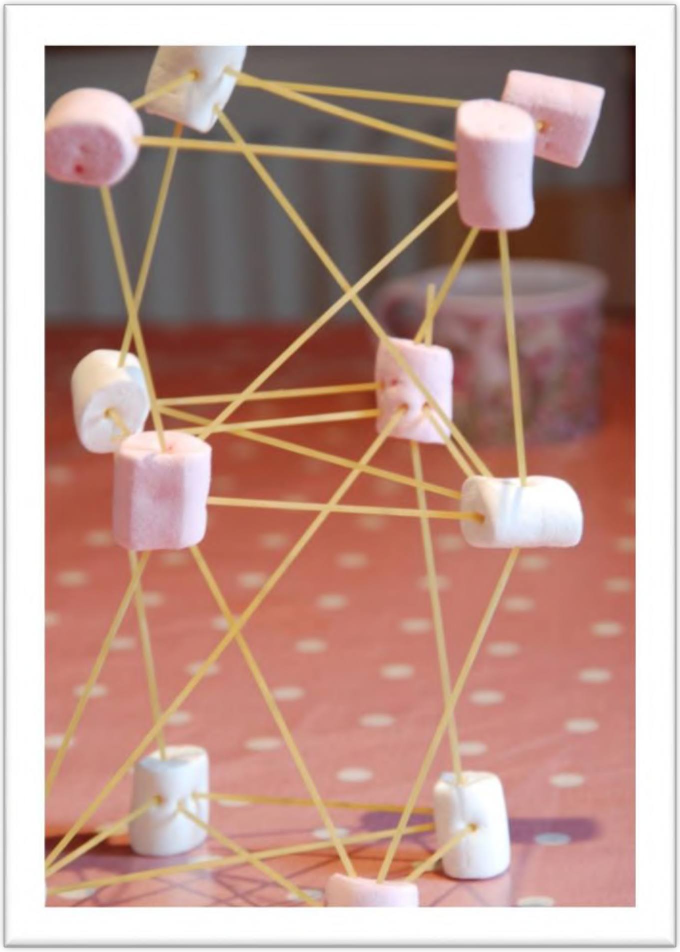
For each group:

- 1 cardboard base (approximately 25cm by 25cm)
- 30 straws
- 100 paper clips (one box)
- 20 straight pins
- 2 meters of string

[11] Instructions for constructing a shake table can be found on page 53.

CHALLENGE

Students should construct towers out of drinking straws that must withstand simulated earthquake vibrations and incrementally increasing loads of 250 gram sandbags. After each test, students have 2 minutes to repair any damage before the next begins. Students learn basic principles of earthquake engineering and design, as well as team skills essential to all fields of science and engineering.



A. Pre Activity – Simple Earthquake Proof Structure

A simple exercise can be conducted using spaghetti sticks and marshmallows. Each student is given 20 spaghetti sticks and 10 large marshmallows. They must briefly discuss and design a simple structure that can withstand a simulated earthquake generated from the cover of your seismology kit box storage container. Look at some of the designs they develop and briefly discuss strengths and weaknesses. Note that principles learnt during this exercise are essential for the accompanying challenge.

Figure 20: A simple marshmallow and spaghetti building replica structure

B. Preparation for Challenge

1. Build the earthquake shake table as described in Additional Resources on page 52. This is an activity that might be done as a whole class activity, (depending on age group/class size) or teachers may wish to prepare it ahead of time.

2. Do a trial run with a structure of your own design to see where students may run into trouble (two possible problem areas include securing the structure to the foundation and securing the joints).

3. Have the students help prepare 10-20 sandbags consisting of 250 grams of sand in a sandwich-sized zip lock bag. Each bag should be taped into a sausage shaped cylinder for rigidity and ease of mounting onto the towers.

PROCEDURE

1. Divide students into small working groups (2-4 students). Distribute the student handout[12] and explain the rules and requirements of this building challenge.

2. Demonstrate the testing procedures and show how the shake table works. Please refer to the Additional Resources for the teacher handout.[13]

3. Show students some of the different methods for joining straws together without folding the straws and compromising their integrity.

- Two straws may be pinned together with a straight pin.
- A paper clip may be partly opened up – the inner U pulled out from the outer U – and each U may be slipped into a different straw.
- Holes may be drilled with the pins and the string slipped through to tie straws together.

Figure 21: How to connect straws using paperclips

4. Allow students to begin designing and building.

5. Pause the class once or twice a class period for 5 minutes “Student Showcases or Student Displays” to point out various successful student designs or to address problems multiple teams may have encountered.

Tips and discussion prompts may include:

- Strategies for how to secure the structure to the foundation using paper clips, pins and/or string.
- A description of trusses and cross-bracing and discussion of their use in bridges, earthquake retrofitting, and other structural engineering.
- Would a better structure have a wide base or a narrow base?
- Would a better structure be symmetrical or asymmetrical?
- How can you secure the sand bags so that they don’t fall off?

6. Once students have built their structures, have them answer the structural analysis questions posed on the towers handout:

- During construction, how did you test the strength and stability of your structure?

[12]Student Handout can be found in the Additional Resources on pages 54-55.
[13]Teacher Handout found in the Additional Resources on pages 56-57.

- During construction, what strategies did you use to strengthen the weaker areas? Why?
- What are the strongest parts of your building? Why?
- What are the weakest parts of your building? Why?
- Where did you use string in your structure? Why?
- Where did you use pins in your structure? Why?
- If you had 5 more straws, where would you add them? Why?

7. Test the structures. To save time, you may have the groups test their structures as they finish, which also allows work to proceed at a varying pace. Or, all teams can finish building on the same day, with testing taking place on the next day. In this way, the students can watch others and make observations, noting what worked and what didn't.

Figure 22: The testing of a straw structure

ACTIVITY 13 - Disaster Supplies Kit Concentration Game

OVERVIEW

This activity is designed to increase student knowledge about earthquake science and preparedness.

OBJECTIVE

1. Understanding the effects of a natural hazard such as an earthquake.
2. Understanding how to be prepared and be proactive for any disaster.

3. Identifying useful disaster supplies kit items by playing a classroom matching game

MATERIALS

- 13 pairs of cards with items from a disaster supplies kit printed on them
- Tape

PREPARATION

Print out the cards in the Additional Resources[14] which consist of 13 pairs of cards with important disaster supplies on them (two to a page). Print out one full set onto thick paper. Cut out each page in half to create the card pairs. If possible, laminate the cards to increase their durability. Use a chalkboard, whiteboard, or wall with enough space to place the cards in rows of 5 to 7 each to form a grid. Turn the cards around and tape them upside-down along their top edge so that they can be flipped open.

PROCEDURE

1. Briefly discuss and engage in a discussion with regards to an earthquake being a natural hazard or disaster. Encourage students to identify some of the effects of an earthquake and how they affect humans.
2. Start another discussion by prompting students to answer the following: If you had to leave your house in a hurry because of an emergency, what are some important items you should take with you? (Water, food, medicine, contact information, etc.)
3. Inform students that they will be learning about essential items needed in a disaster supplies kit: “Today we will learn about very important items needed for a disaster supplies kit by playing a game called Disaster Supplies Kit Concentration”.
   a. Describe the rules: “The game is played by having one student come up to the board and flip over one card. The student then tries to find its pair by flipping another card”.
   b. Then say: “If the person finds a pair, they can hold on to them and take it back to their seat. The next student then tries to find the next pair. Try to remember the location of the cards for when it is your turn! We will do this until all the cards have been matched”.
4. Once all of the items have been paired, have the students show the class what items they have: “Everyone that found a pair please come up to the front of the class and show everyone what you have. What do you have, student name? (Student answers)
   The ___ (item) ____ is important because…” Write down the name of the item on the board and repeat until each one has been discussed.
5. Instruct students to copy down the list and emphasise the importance of having these items in case of a disaster: “Please copy this list because these items are very important. You can

[14] Refer Additional Resources on pages 59-62.

go home and create your own disaster supplies kit. It can be used for any disaster, not just earthquakes. Store it in a safe place where you can easily access it, such as in a room where you spend most of your time or in the family car".

DISCUSSION

1. **Bottled Water:** Tap water may stop flowing if strong ground shaking breaks old, brittle water pipes and connectors. It is important to have enough water to provide for one gallon per person, per day after a major earthquake to last at least 3 days and ideally for 2 weeks. Water should be replaced every year.
2. **Canned Goods:** In addition to providing sustenance, canned fruits and vegetables retain water that can supplement the bottled supply.
3. **Can Opener:** While some cans have a metal tab available for opening, most do not, and require the use of a can opener.
4. **Contact List:** A list of emergency contacts including an out-of-town contact that can be reached in case local phone lines are busy. The numbers should be kept in a waterproof container.
5. **Copies of Important Documents:** Copies of important documents such as identification, insurance policies, and financial records should be kept in a secure, waterproof container in case anything happens to the originals or they become unreachable.
6. **Dried Snack Foods:** Food items such as energy bars and dried fruit are less perishable than other foods, and unlike the water in the kit, do not need to be replaced yearly.
7. **Emergency Cash:** Power may be disrupted in large regions, making people unable to withdraw cash or use credit cards to purchase needed goods.
8. **First Aid Kit:** Small tools, alcohol swabs, and medicines will allow you to handle minor injuries immediately in the likely case that outside help takes time to arrive.
9. **Flashlight:** Crank-powered or shake-powered flashlights are ideal to set aside for use during emergencies when the power is out and batteries are unavailable or drained.
10. **Medicines:** Medicines vital to any member of the household – including babies, the elderly, or pets – should have an extra supply of unexpired medications stored together with the rest of the emergency kit for emergency use.
11. **Radio:** Radios are important for receiving information and announcements about the development of post-disaster directions, activities, and warnings, particularly when all other forms of communication are either down due to loss of power (internet, television) or busy from a system overload (phone). Crank-powered radios are also preferable to battery-operated radios because they can function continuously without extra supplies.
12. **Toiletries:** Items that aid in maintaining hygiene are important to have after any devastating disaster not only for personal reasons, but also for people to avoid falling ill due to unsanitary practices at a time when little medical treatment will be available.
13. **Whistle:** Emergency rescuers are trained to be alert to whistles and knocking coming from people who are trapped in rubble. Using a whistle instead of yelling also helps conserve energy in case it takes a while for the rubble to be cleared.

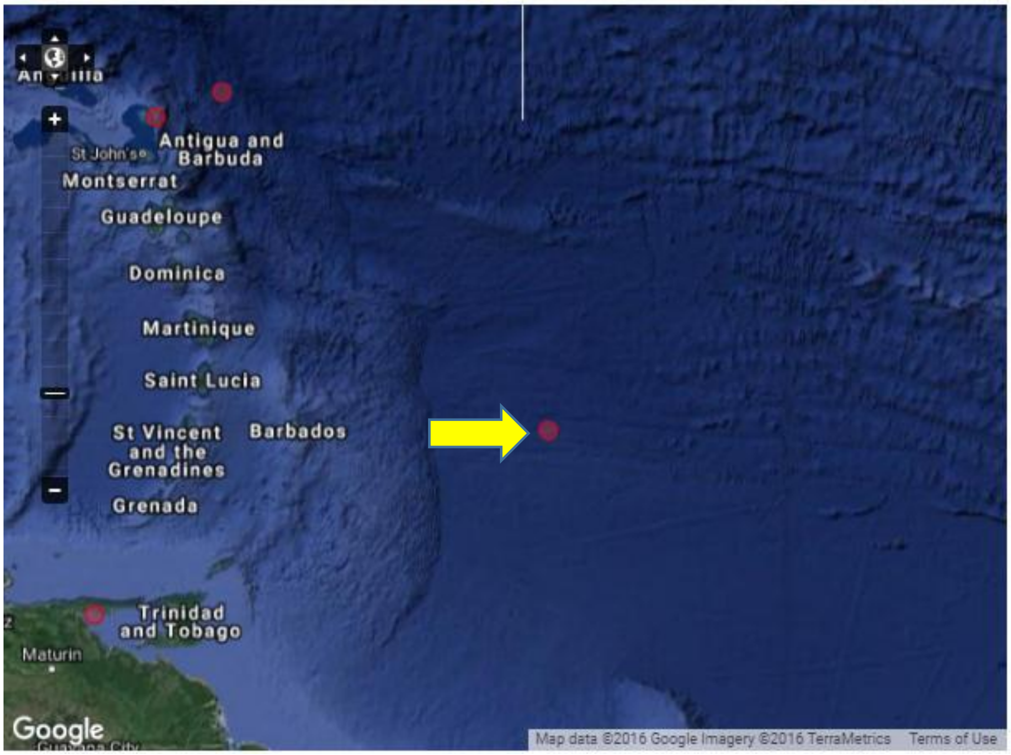
Table of Activities

Seismology Word Search

E	S	U	B	D	U	C	T	I	O	N	H	E	C	N
L	T	N	V	E	L	O	C	I	T	Y	T	K	L	O
O	Y	G	O	L	O	M	S	I	E	S	G	A	K	E
C	S	F	T	R	U	P	T	U	R	E	N	U	C	L
N	E	L	O	T	C	R	A	H	O	I	E	Q	O	M
N	N	M	M	C	R	E	M	T	D	S	L	H	H	P
M	O	O	S	S	U	S	O	U	O	M	E	T	S	T
A	N	M	M	S	U	S	T	U	E	O	V	R	R	T
E	O	E	D	U	T	I	N	G	A	M	A	A	E	F
E	N	N	L	C	G	O	T	A	B	E	W	E	T	T
T	I	T	Q	N	V	N	T	U	O	T	O	M	F	S
C	E	N	O	I	T	A	R	E	L	E	C	C	A	R
D	C	L	E	C	S	L	E	U	I	R	F	F	T	U
S	D	E	F	A	S	V	A	R	M	T	G	E	N	R
Q	Y	D	S	E	C	F	S	A	K	A	V	O	R	A

acceleration	aftershock	compressional
earthquake	fault	focus
longitudinal	magnitude	moment
rupture	seismology	seismometer
subduction	velocity	wavelength

Activity 1: Solutions Earthquake A



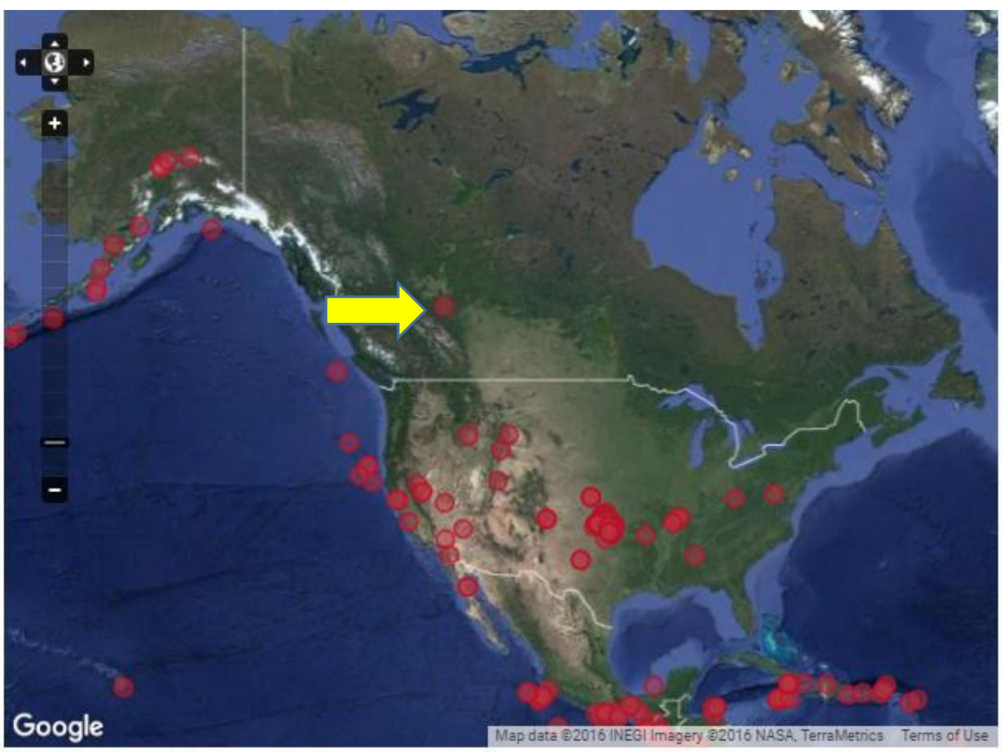
NORTH ATLANTIC OCEAN

Date and Time:
2016-04-20 10:51:39
Magnitude:
5.6
Latitude / Longitude:
13.20 / -55.89
Depth (km):
10

Register Your Station

Login

Earthquake B



ALBERTA, CANADA

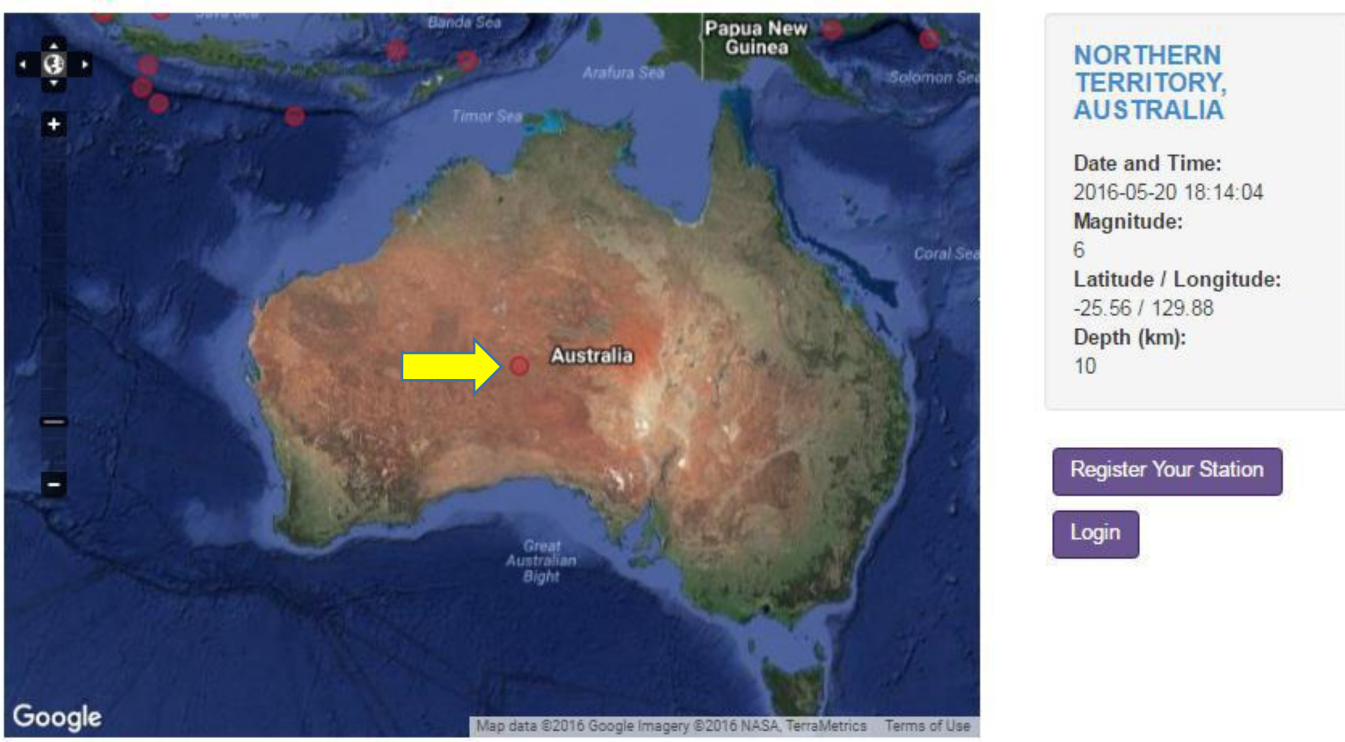
Date and Time:
2016-01-12 18:27:22
Magnitude:
4.2
Latitude / Longitude:
54.45 / -117.03
Depth (km):
5

Register Your Station

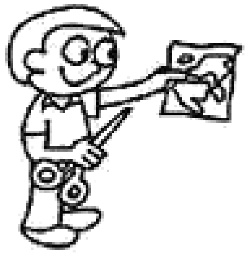
Login

Earthquake C

Earthquake D

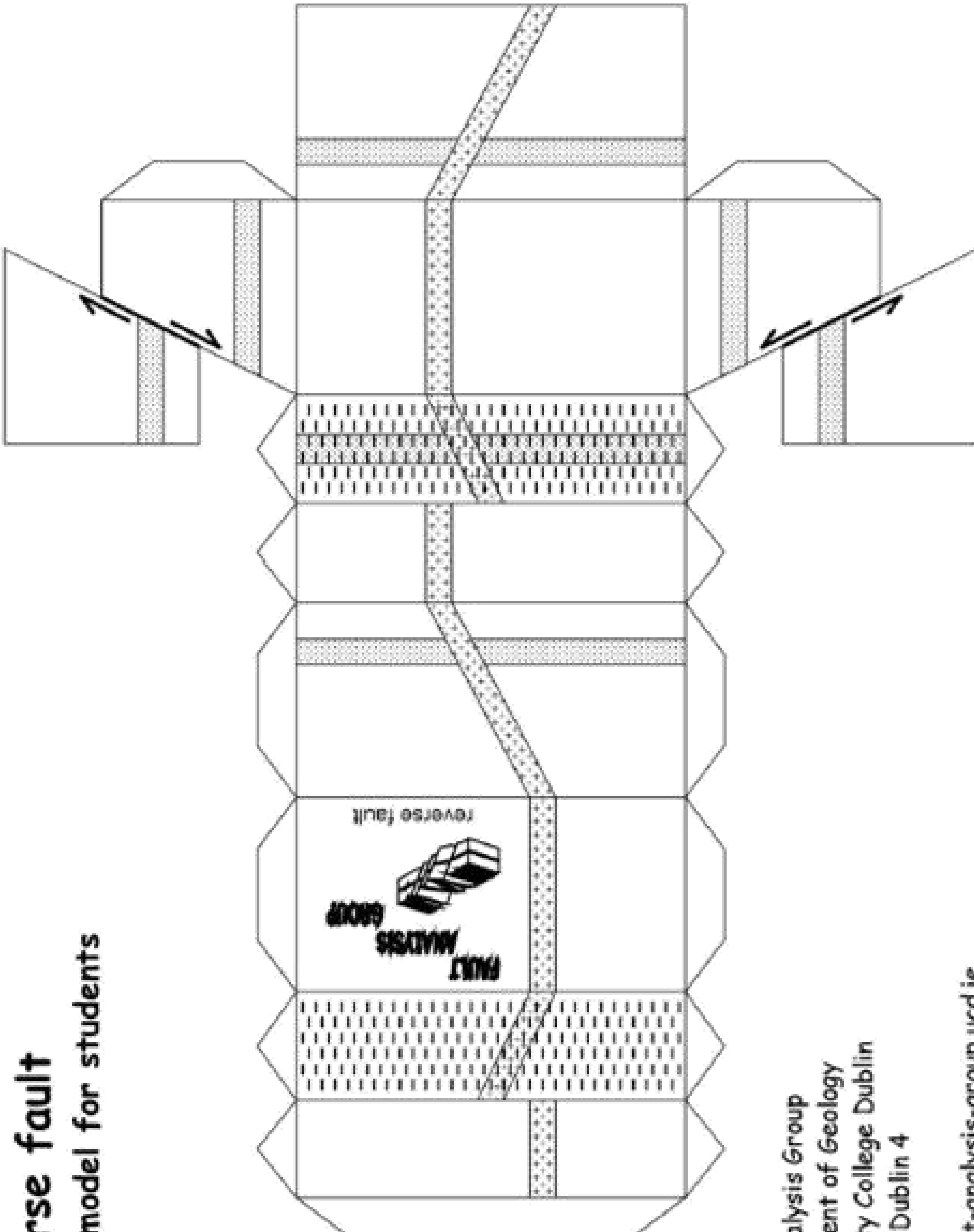


Activity 3



Pangea Cutouts

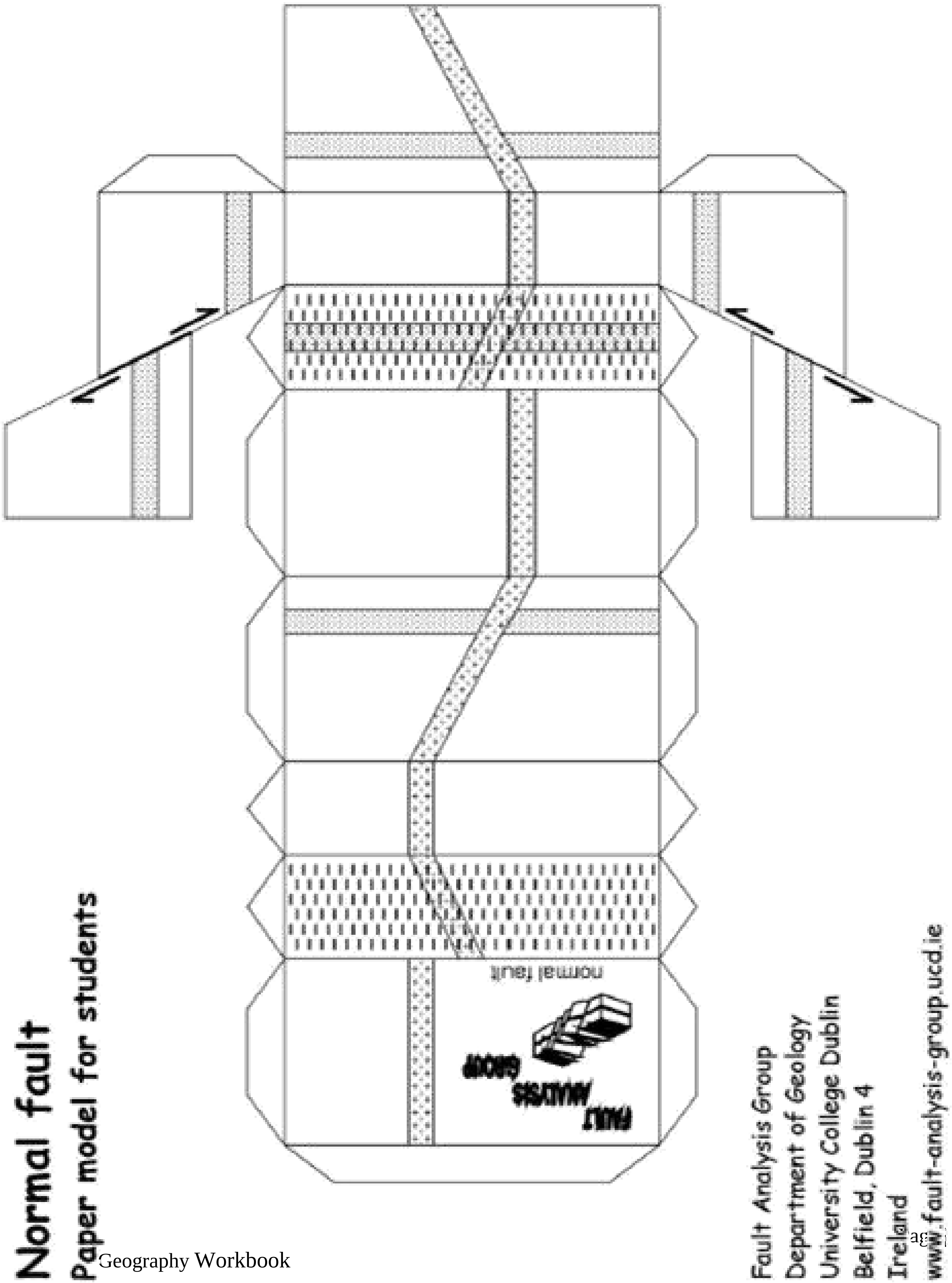
Activity 4



Reverse fault

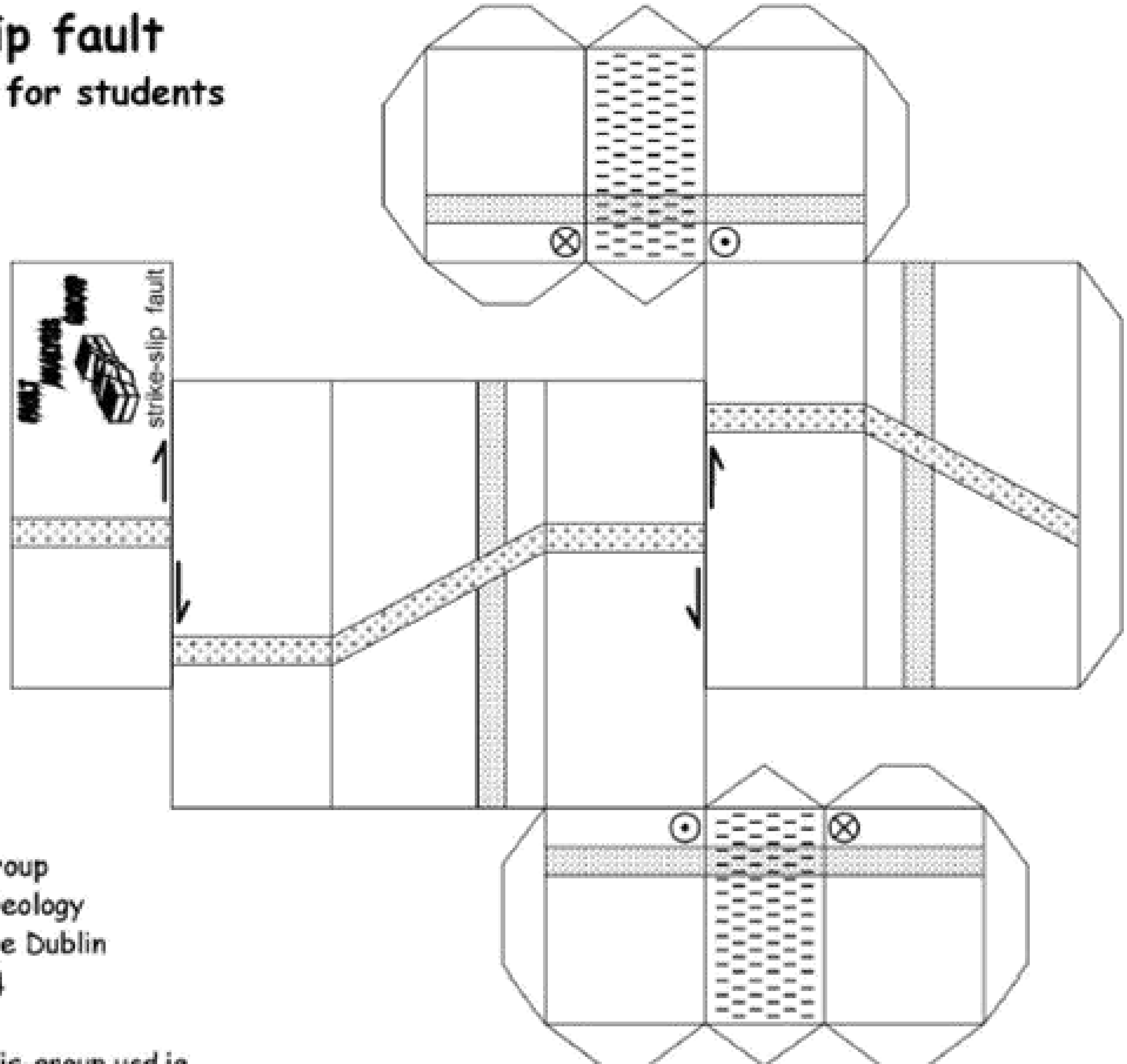
Paper model for students

Fault Analysis Group
Department of Geology
University College Dublin
Belfield, Dublin 4
Ireland
www.fault-analysis-group.ucd.ie


Normal fault
Paper model for students
normal fault
FAULT ANALYSIS GROUP
Fault Analysis Group
Department of Geology
University College Dublin
Belfield, Dublin 4
Ireland
www.fault-analysis-group.ucd.ie

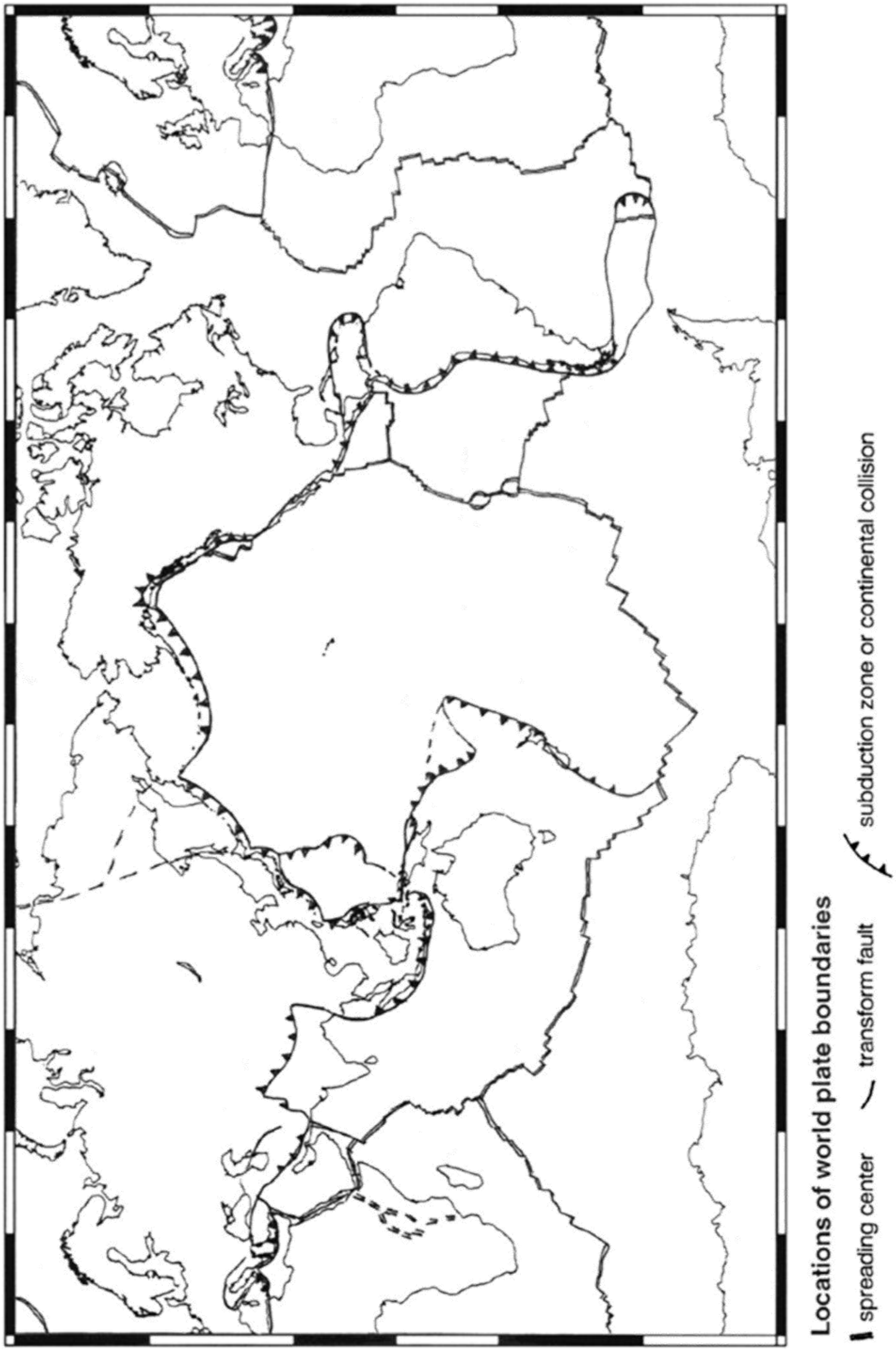
Strike-slip fault

Paper model for students



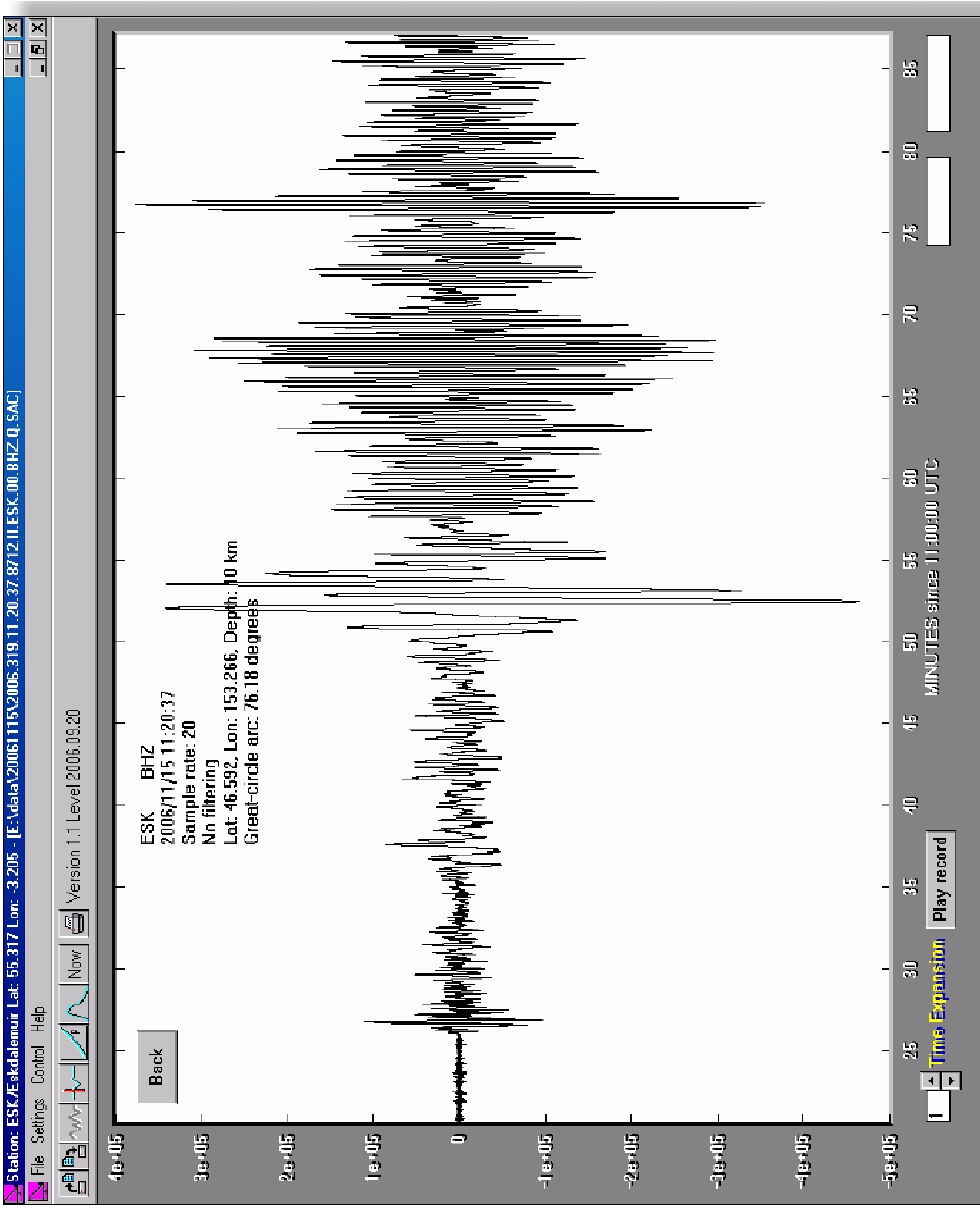
Fault Analysis Group
Department of Geology
University College Dublin
Belfield, Dublin 4
Ireland
www.fault-analysis-group.ucd.ie

Activity 5



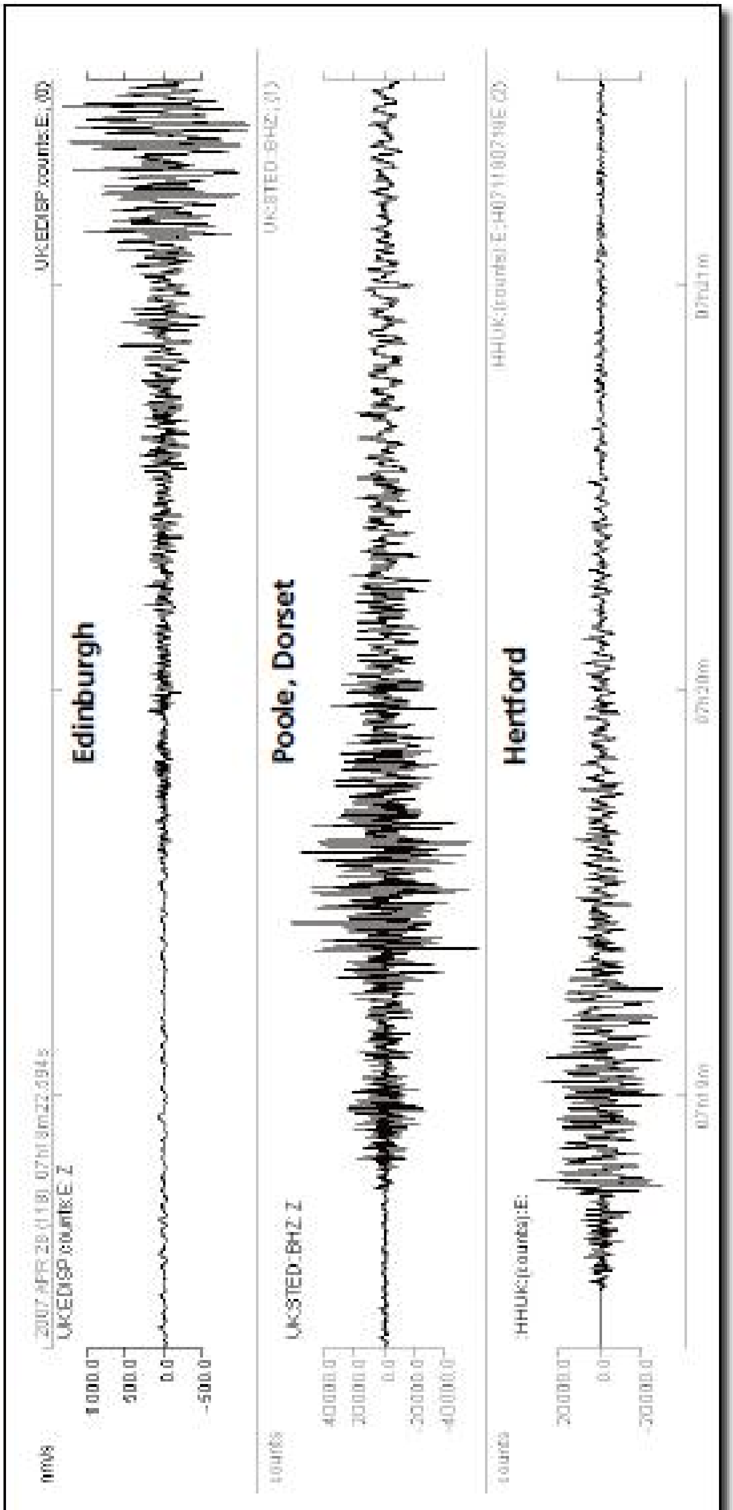
http://www.chaucer.ac.uk/ctsshared/Geography/GCSE%20Geography/AQA_1%20Restless%20Earth/restless%20earth%20challenge%20tasks/MAP%20blank%20plate%20margin%20Auz-Centre.jpg

Activity 10: Seismograph



Activity 10: An example of seismic waves received at (3) stations for an earthquake event.

At 7.18am on n April 28th, 2007 a magnitude 4.3 earthquake occurred in the English Channel, near Folkestone. The seismograms below were recorded at three UK stations:



Seismograms provided by BGS: www.bgs.ac.uk/schoolseismology.

Station	Location	Latitude	Longitude	Sensor	Orientation	Bandwidth
EDISP	BGS offices Edinburgh	55.924	-3.179	SEP	East	15 sec-5 Hz
HHUK	Hailey Hall School, Hertford	51.778	0.015	SEP	East	15 sec-5 Hz
STED	St. Edward's School, Poole	50.74	-1.96	Guralp EDU	Vertical	30 sec-10 Hz

Event date	Time	Magnitude	Latitude	Longitude	Depth/ km
28/04/07	07:18.08	4.3	51.1	0.9	2

Activity 12: Instructions for Constructing Shake Table

To create your own very simple earthquake table that is more like a trampoline than a standard, motor controlled earthquake table:

1. Cut a piece of board or plywood into a 12” square. If you wish, create a raised edge for your platform by nailing lengths of 1/2” square dowel on top of each of the sides.
2. Mount wood screws on the underside of the plywood at each corner and at the centre of each side. Don’t screw the screws in all the way, make sure at least 1/4” sticks up so you can loop a rubber band around it.
3. Construct a frame out of 2” x 4”s that fits around the wood square with around 1/2” clearance between the outer edge of the square and the inside edge of the frame. Make sure the 2” x 4”s are oriented so that the frame is 4” high.
4. Mount wood screws on the top edge of the frame at each corner and at the centre of each side. Again, don’t screw in the screws all the way.
5. Loop a rubber band around each pair of screws so that the plywood square is suspended like a trampoline within the frame.

Activity 12: Student Handout

Earthquake Tower Challenge

100 points

You and your partner have been hired as the structural engineers in charge of designing a new 2-story art building. There are many building codes you must follow. Each floor of the building must support ***at least*** 250 grams of weight. Also, the building will be located near an earthquake fault; therefore your building must be able to withstand ***both*** small and large earthquakes. Since the building will be used for art classes, you may be as creative as you like with the shape and design of the building (it does not need to be box shaped).

You are limited to the following materials:

- 1 cardboard base (approximately 25cm by 25cm)
- 30 straws
- 100 paper clips (one box)
- 20 pins
- 2 meters of string

Your building must meet the following requirements:

- The building must fit on the base. Attach your building to the base using pins, paper clips, or string.
- Your building must be at least 36 cm tall.
- Your building has 2 stories that are each at least 18 cm tall (approximately the height of 1 straw).
- Each story must support the weight of at least 1 sand bag (250 grams) without collapsing.
- A construction drawing with measurements and analysis must be submitted before earthquake testing.
- To survive an earthquake test, the building must not collapse for 10 seconds after the earthquake begins. The weights must stay on the building. You have 2 minutes to repair any damage to your building before the next earthquake test.

Hints and tips:

- **PLAN CAREFULLY!** Additional supplies will not be provided.
- Remember these words of wisdom: "Measure twice. Cut once."
- Use the concepts of tension and compression. If an element is in tension and not compression, you can use string instead of straws.
- Try building without pins first, then add pins where connections need reinforcement.
- Make sure that your foundation is very strong.

- Remember to design a way to secure the weights so that they don't fall off **AND** so you can add additional weights to the top story.

<u>Grading:</u>

25 points	Building stands by itself, fits on the base, is secured to the base, is at least 36cm tall, and has 2 stories that are each at least 18cm tall.
10 points	Building supports 1 sand bag on the first story.
10 points	Building supports 1 sand bag on the top story.
10 points	A clear, detailed construction sketch was completed. Straws and string should be easily distinguished. All important design features and all critical measurements should be labelled on the sketch.
20 points	A structural analysis of your building was completed. The following questions should be answered clearly and completely: • During construction, how did you test the strength and stability of your structure? • During construction, what strategies did you use to strengthen the weaker areas? Why? • What are the strongest parts of your building? Why? • What are the weakest parts of your building? Why? • Where did you use string in your structure? Why? • Where did you use pins in your structure? Why? • If you had 5 more straws, where would you add them? Why?
5 points	Building remains standing with 1 sand bag on the top story after a mild earthquake.
5 points	Building remains standing with 1 sand bag on the top story after a major earthquake.
5 points	Building remains standing with 1 sand bag on the top story and 1 sand bag on the first story after a major earthquake.
5 points	Building remains standing with 2 sand bags on the top story and 1 sand bag on the first story after a major earthquake.
5 points	Building remains standing with 2 sand bags on the top story and 2 sand bags on the first story after a major earthquake.

<u>Bonus:</u>

The building in each class that can hold the most weight and remain standing after a major earthquake will be awarded 20 bonus points.

Activity 12: Teacher Handout

Testing and Evaluating the Structures

Grading rubric: the structures must meet the following requirements:

- The building must fit on the base.
- The building must be at least 36cm tall.
- The building must have 2 stories that are each at least 18cm tall (approximately the height of 1 straw).
- Each story must support the weight of at least 1 sand bag (250 grams) without collapsing.
- A construction drawing with measurements and analysis must be submitted before earthquake testing.
- To survive an earthquake test, the building must not collapse for 10 seconds after the earthquake begins. The weights must stay on the building.

Point values

- 25 points – Building stands by itself, fits on the base, is secured to the base, is at least 36cm tall, and has 2 stories that are each at least 18cm tall.
- 10 points – Building supports 1 sand bag on the first story.
- 10 points – Building supports 1 sand bag on the top story.
- 10 points – A clear, detailed construction sketch was completed. Straws and string should be easily distinguished. All important design features and all critical measurements should be labelled on the sketch.
- 20 points – A structural analysis of your building was completed. The following questions should be answered clearly and completely:
    - During construction, how did you test the strength and stability of your structure?
    - During construction, what strategies did you use to strengthen the weaker areas? Why?
    - What are the strongest parts of your building? Why?
    - What are the weakest parts of your building? Why?
    - Where did you use string in your structure? Why?
    - Where did you use pins in your structure? Why?
    - If you had 5 more straws, where would you add them? Why?
- 5 points – Building remains standing with 1 sand bag on the top story after a mild earthquake.
- 5 points – Building remains standing with 1 sand bag on the top story after a major earthquake.
- 5 points – Building remains standing with 1 sand bag on the top story and 1 sand bag on the first story after a major earthquake.
- 5 points – Building remains standing with 2 sand bags on the top story and 1 sand bag on the first story after a major earthquake.
- 5 points – Building remains standing with 2 sand bags on the top story and 2 sand bags on the first story after a major earthquake.

<u>Bonus:</u> The building in each class that can hold the most weight and remain standing after a major earthquake will be awarded 20 bonus points.

<u>Observing the structure</u>: If at any point the structure buckles to the point that the sandbags fall off or drop by more than halfway to the ground (a sandbag on the first story 18cm high can fall as much as 9cm and still be considered passing while a sandbag on the second story 36cm off the ground can fall 18cm), the structure should be considered to have failed that stage of testing. Students should be given 2 minutes to repair any damage to their structure between each stage of testing although no new straws or materials could be provided. The best structure in the class will likely survive until it encounters a major earthquake with 4 sandbags on the top story and 3 sandbags on the first story.

Testing levels:

Level 1. Place 1 sandbag on the first story.

Level 2. Place 1 sandbag on the second story.

Level 3. Minor earthquake with 1 sandbag on the top story. Move the platform horizontally, side to side so that it touches the frame. No vertical motion is involved.

Level 4. Major earthquake with 1 sandbag on the top story. Move one corner of the platform so that it touches the corner of the frame, as well as the table below, to start a major earthquake and lead to both horizontal and vertical motion.

Level 5. Major earthquake with 1 sandbag on the top story and 1 sandbag on the first story.

Level 6. Major earthquake with 2 sandbags on the top story and 1 sandbag on the first story.

Level 7. Major earthquake with 2 sandbags on the top story and 2 sandbags on the first story.

Level 8. Continue major earthquakes adding 1 sandbag at a time, first to the top story, then to the first story.

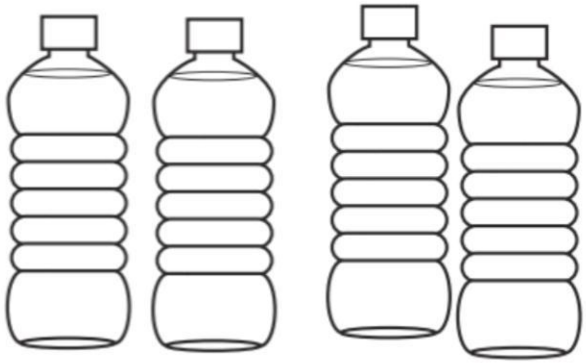
Activity 13: Disaster Supplies Kit Concentration Game

An individual emergency survival kit requires:
- Torch + spare batteries
- Radio + spare batteries
- Bottled water and disinfectant
- First aid kit
- High energy, non-perishable food
- Blanket/small sleeping bag
- Spare change of clothes
- Tarpaulin (to create shelter)
- Money, both notes and coins
- Small camping stove
- Matches
- Any special requirements i.e. glasses, hearing aid etc.
- Important documents i.e. identification, financial information etc.
- Small selection of toiletries
- Small recreational items for children
- Pet supplies
- Strong outdoor shoes

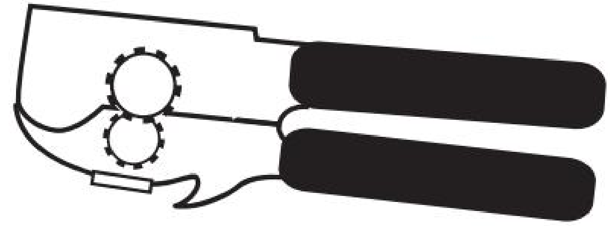
Useful to have multiple kits around the house so they are easy and quick to access when required.

Large survival kit (things for individual plus):
- Adjustable wrench (for turning off gas and water)
- Fire extinguisher
- Enough food and water for at least 3 days
- Manual Can opener
- Tent
- Large rubbish bags
- Toilet paper
- Face/dust masks
- Additional water for washing and cooking
- Work gloves, hard hat etc.
- Crowbar, hammer, shovel

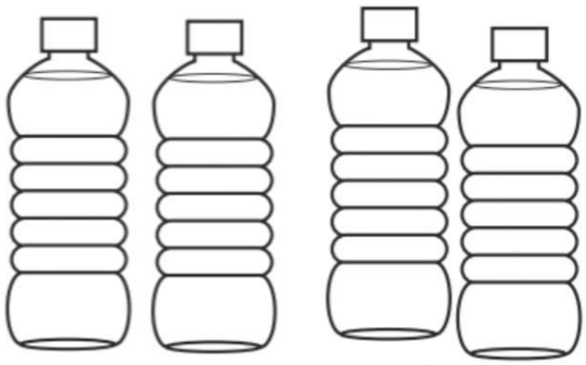
Good idea to store in a strong box or trash can stored off the ground.
Good idea to have an emergency kit in the car also.
Check and update twice a year.



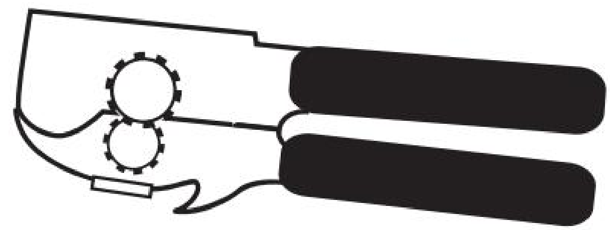
BOTTLED WATER



CAN OPENER



BOTTLED WATER



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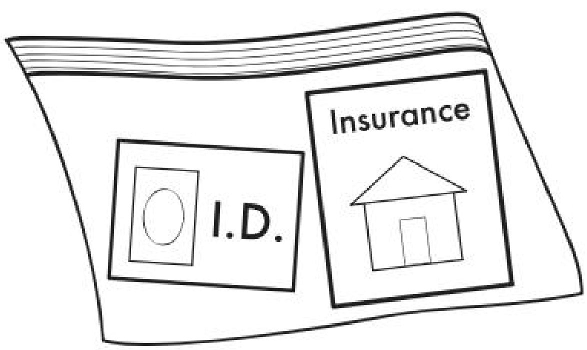
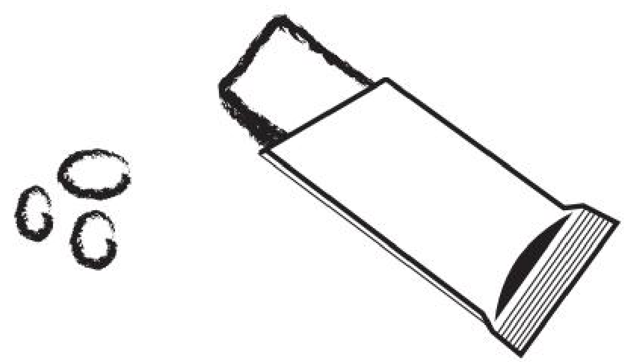
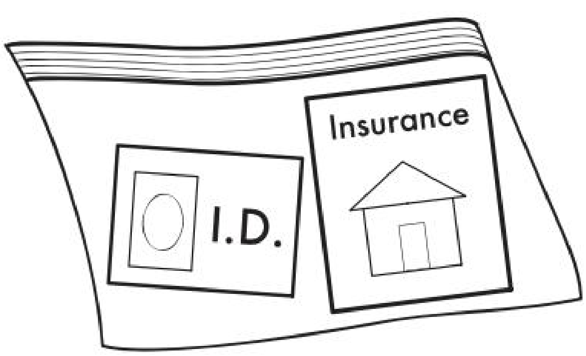


COPIES OF IMPORTANT DOCUMENTS



DRIED SNACK FOODS



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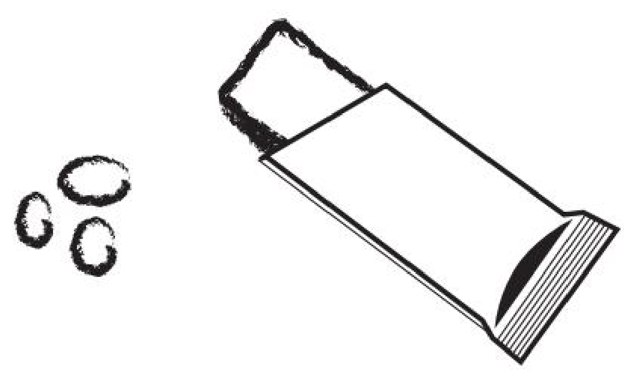

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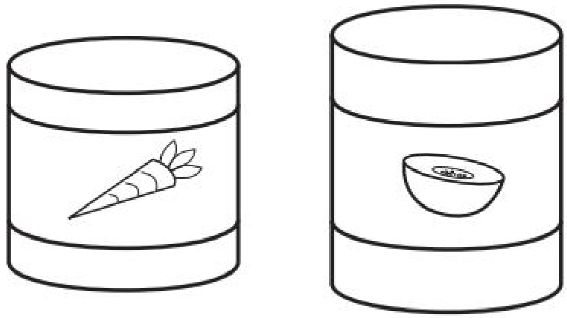
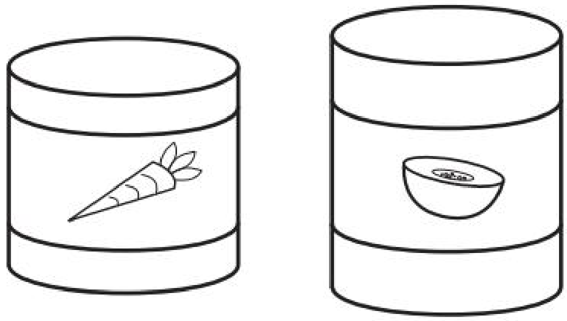


CANNED GOODS

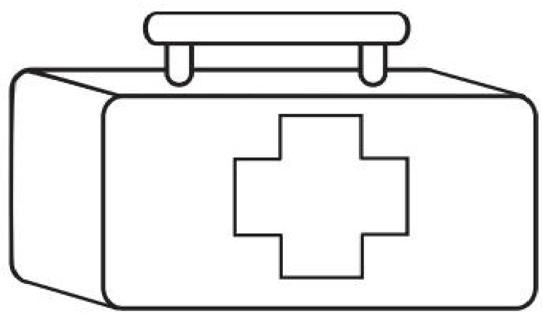
CONTACT LIST



CANNED GOODS

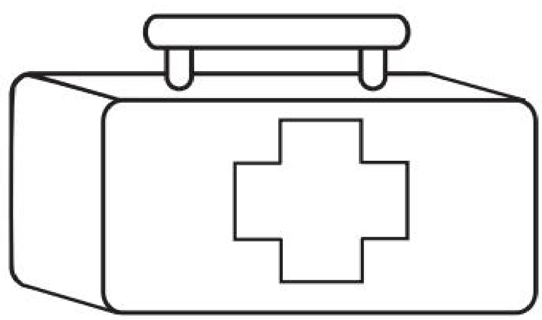
CONTACT LIST

EMERGENCY CASH

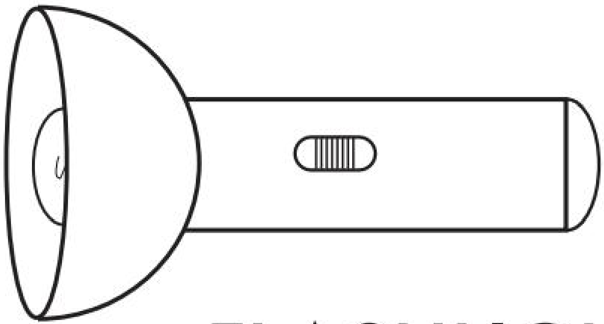


FIRST AID KIT

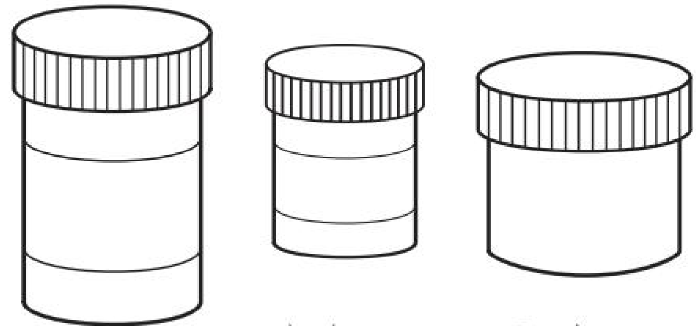
EMERGENCY CASH



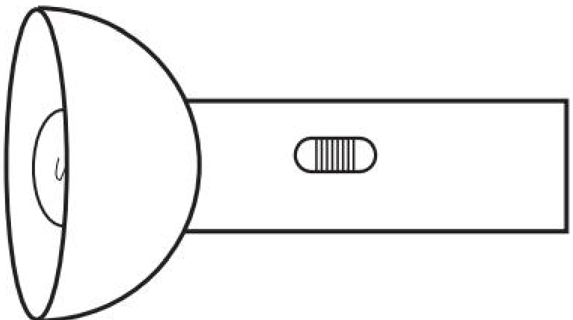
FIRST AID KIT



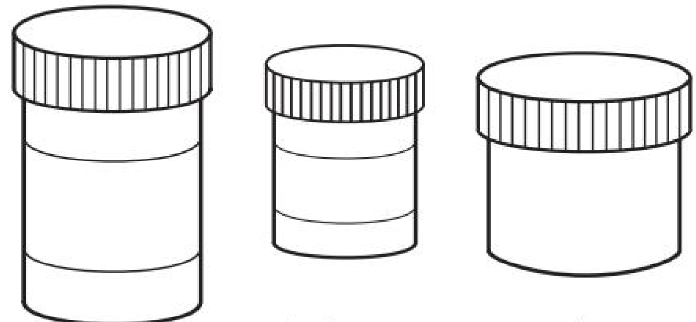
FLASHLIGHT



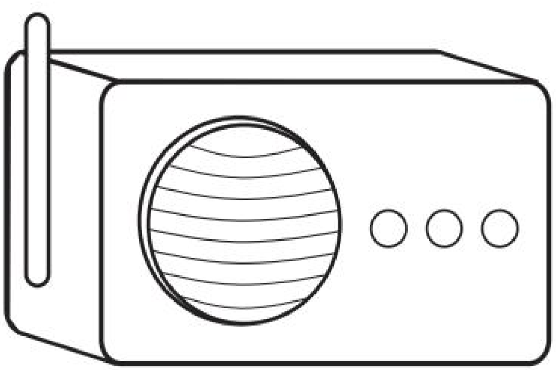
MEDICINES



FLASHLIGHT

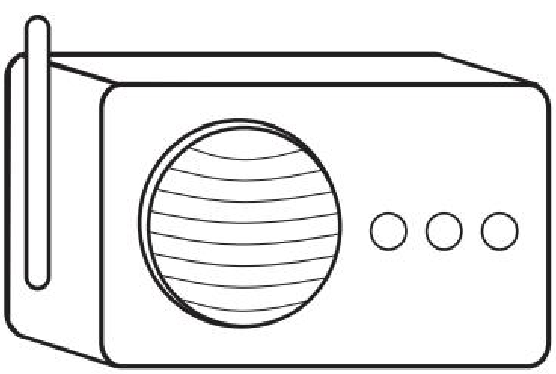


MEDICINES



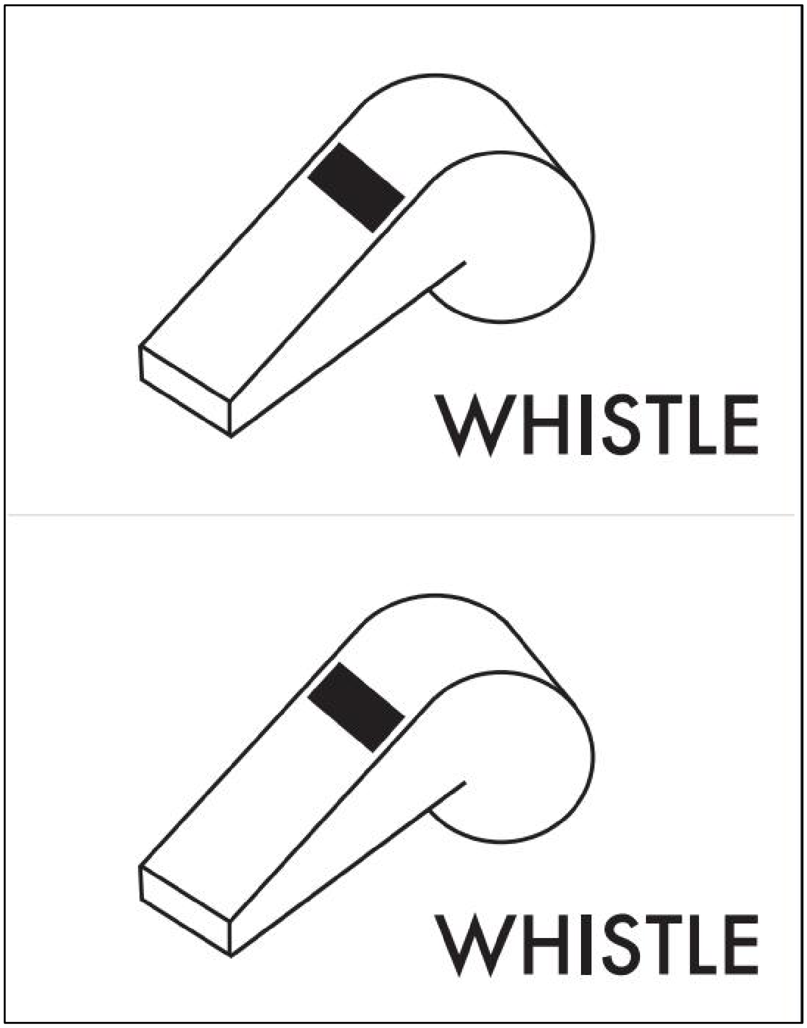
RADIO

TOILETRIES



RADIO

TOILETRIES


WHISTLE
WHISTLE

Glossary

Term	Definition
Acceptable risk	The probability of social or economic consequences due to a hazard that is a realistic basis for determining design requirements or taking certain social or economic actions.
aftershock	Smaller earthquakes following the largest or main earthquake in a series in a restricted area
alluvium	Loosely compacted sand, gravel, and silt deposited by streams in relatively recent geologic time.
amplification(seismic)	The increase in surface *ground motion* at certain frequencies in unconsolidated sediments relative to the motion in solid rock.
amplitude(wave)	Maximum deviation from normal of any wave-like disturbance.
aseismic	Almost free of earthquakes.
asthenosphere	The soft and probably partly molten layer of the earth below the *lithosphere*. Distinguished by low seismic-wave velocities and high seismic wave *attenuation*.
attenuation	The decrease in seismic signal amplitude caused by spreading of the wave and absorption and scattering of seismic energy by the materials of the earth as a wave propagates from a source.
basement	Igneous and metamorphic rocks underlying the sedimentary rocks of a region and extending to the base of the crust.
basin and range structure	The geologic structure that is characteristic of the Basin and Range province with the basins and ranges bounded on one or both sides by *normal faults*. Movement on the faults, sometimes referred to as basin and range faults, accounts for much of the topographic relief between the basins and the ranges.
bedrock	Solid rock that is exposed or under lies softer rock, sediments, or soil.
Body wave	Seismic wave propagated in the interior of the earth. *P and S waves* are examples.
Brittle behavior	Failure (sudden loss of strength) at some critical stress either by breaking along a new fracture or, most commonly, by frictional sliding on an already existing fracture.
caldera	A large, roughly circular volcanic depression whose diameter is many times greater than that of its ventor vents.
Compressional wave	See *P wave*.
core	The central part of the earth, beginning at a depth of a bout 2900km, probably consisting of iron nickel alloy; it is divisible into an outer core that may be liquid and an inner core about 1300 km in radius that may be solid.
creep(fault)	Slow movement a long a fault that does not produce earthquakes.
Critical facilities	Structures whose functioning during an emergency is essential or whose failure would endanger many lives. May include: structures such as nuclear power plants or large dams whose failure could be catastrophic; major communication, utility, and transportation systems; involuntary or high occupancy buildings such as prisons or schools; emergency facilities such as hospitals, police and fire stations, and emergency-response facilities.
crust	The outer most major layer of the earth; in Utah, ranging from 35 to 45 km thick and with a compressional seismic wave velocity(in rock)between3.0and7.5km/s.
density	The mass per unit volume of a material.
dilatancy	The increase in volume of rock due to a change in strain.
dip	The angle of a fault or other planar geologic feature relative to horizontal.

displacement	The difference between the initial position of a reference point and a later position. In geology it is the permanent off set of a reference point across a fault.
Ductile deformation	Behavior in which rocks, at a critical stress, do not rupture but instead become permanently deformed by flowing.
earthquake	The shaking or vibrating of the ground caused by the sudden release of energy stored in rock beneath the earth's surface.
Earthquake risk	The social and economic consequences of anticipated earthquakes expressed in economic loss or casualties. Risk may be expressed as the probability that these will equal or exceed specified values in an area during a specified interval of time.
Earthquake source	The origination point of earthquake energy release.
Elastic deformation	A non-permanent deformation in which a solid returns to its original size and shape after an external deforming force is removed.
Elastic rebound	The release of *strain* energy by the abrupt movement of a fault with a resultant earthquake.
epicenter	The point on the surface of the earth directly above the point where the first rupture and first earthquake motion occur.
fault	A fracture in the earth a long which the two sides have been displaced relative to each other.
fault, active	A fault along which displacement has occurred in recent geologic time or along which earthquake foci are located. Active faults areas summed to be capable of producing earthquakes.
fault, capable	An active fault or fault zone that has the potential to cause surface displacement during the lifetime of a project under consideration.
Fault, dip-slip	A fault with the major component of relative displacement along the direction of dip of the fault.
fault, normal	A sloping faulting on which the block above the fault has moved downward relative to the block below.
fault, oblique-slip	A fault with both strike-slip and dip-slip movement.
Fault segment	A discrete section of a fault, separated by recognizable boundaries that tends to rupture in dependently.
fault, strike-slip	A fault on which the movement is parallel to the fault's strike.
fault, thrust or over thrust	A dip-slip fault in which the upper block moves over the lower block. The dip of some thrust faults is low and the displacement may be tens of miles.
fault, transform	A *strike-slip fault* at the end of tectonic plates.
Fault plane	A plane that approximates the rupture surface of a fault.
Fault trace	The intersection of a fault with the land surface. Commonly plotted on geologic map store present the location of the fault.
Focal depth	The depth below the surface of the *hypocenter* or *focus* of an earthquake.
focus	The point within the earth where earthquake rupture begins.
foreshocks	Smaller earthquakes preceding the main earthquake in a series.
frequency	The number of cycles occurring in a unit time.
geodesy	The study of the shape and size of the earth.
geodimeter	An instrument used to measure distance between points on the surface of the earth.
geomorphology	The study of the origin and character of landforms.
gouge	Rock crushed in a fault zone.
graben	A block of the earth's crust, usually elongated, that has subsided relative to adjacent rocks along bounding faults.
Hertz(Hz)	A unit of frequency, equal to the number of cycles per second.

horst	An elongated block of the earth's crust up lifted relative to surrounding rocks a long bounding faults.
hotspot	A volcanic center,100 to 200 km across and persistent for at least a few tens of millions of years, that is thought to be the surface expression of arising plume of hot mantle material.
hypocenter	The point within the earth where earthquake rupture begins; the focus of an earthquake.
intensity	A subjective numerical index describing the severity of ground shaking in an earthquake in terms of the effect on objects and humans.
Interpolate earthquake	An earthquake that occurs on the boundary between two tectonic plates.
Intraplate earthquake	An earthquake that occurs within the interior of a tectonic plate.
isoseismal	A contour on a map bounding areas of equal intensity for a particular earthquake.
landslide	The perceptible downward sliding or falling of masses of rock or soil; can include earth flows, debris flows, rock avalanches, and rock falls.
Lateral spreads	*Landslides* that form on gentle slopes as the result of liquefaction of a near-surface layer from ground shaking in an earthquake.
liquefaction	The process by which water-saturated unconsolidated sediments subjected to shaking in an earthquake temporarily lose strength and behave like a fluid.
lithosphere	The solid outer crust of the earth including the crust and upper mantle.
Love wave	A type of seismic surface having only horizontal motion transverse to the direction of propagation.
magnitude(earthquake)	A number that characterizes the size of an earthquake by measuring the motions recorded by a seismograph and correcting for the distance to the *epicenter* of the earthquake.
mantle	That part of the earth between the *crust* and the *core*.
Mohorovicic (moho) discontinuity	The boundary between the *crust* and upper *mantle* usually identified by an increase in the velocity of propagation of seismic waves.
moment	A measure of the energy released in an earthquake determined by strength of the fault and the area and amount of slip.
Natural frequency	The frequency at which an elastic system vibrates when set in motion by a single pulse.
outcrop	The area where a particular rock body reaches the surface.
P wave	A seismic wave that involves particle motion in the direction of propagation. It is the fastest traveling wave generated by an earthquake and therefore the first to arrive at any point.
Paleo seismology	The study of geologically recent earthquakes.
period(wave)	The time interval required for one cycle of a wave.
phase	A stage in a periodic motion measured with respect to a reference and expressed in angular measure.
plate	A large unit of the earth's *lithosphere* that moves relative to other plates and the interior of the earth.
Plate tectonics	The theory of movement and interaction of large plates of the earth's *crust* that explains earthquakes, volcanoes and other geological processes as consequences of the movement.
Rayleigh wave	A seismic surface wave involving elliptical motion in a vertical plane oriented in the direction of propagation of the wave.
Recurrence interval	The average time between specific events at a particular site.
rigidity	The angular shear strain produced from applying shear stress to a body. See *Shear modulus*
Rock avalanche	A large mass of rock, sliding or flowing very rapidly under the force of gravity.

Rock fall	Large block(s) of rock falling under the force of gravity.
Rupture velocity	The speed at which a fault ruptures propagates along a fault.
S wave	A seismic body wave involving shear motion transverse to the direction of propagation of the wave.
Seismic wave	An elastic wave generated in the earth by an earthquake or explosion.
Seismic zonation	Geographic delineation of areas having different potential for hazardous effects of earthquakes.
Seismic zone	An area within which the seismic-design requirements are constant.
seismograph	An instrument for amplifying and recording the motions of the earth caused by seismic waves.
seismology	The study of earthquakes, earthquake sources, and the propagation of seismic waves.
seismometer	The sensor that detects the seismic wave energy and transform it into an electric voltage.
Seismotectonic zone or Province	A geographic area characterized by similar geology and earthquake characteristics.
Shear modulus	The ratio of shear *stress* to shear *strain* of a material during simple shear.
Slip	The relative displacement of one of two points on opposite sides of a fault.
Slip rate	Theaveragevelocityofdisplacementofpointsonoppositesidesofafault.
stick-slip	Jerky frictional fault slip in which the opposing blocks of rock, held by friction, episodically and suddenly slide.
Strain	The percentage change in the length, shape, or volume of a body subjected to deformation.
Stress	Force per unit area acting on a surface within a body.
Stress drop	The difference between the *stress* across a fault before and after an earthquake.
Strike	The bearing relative to north of a line defined by the intersection of a planar geologic feature, such as a fault, and a horizontal surface.
Subduction	A plate tectonic process of one plate descending into the earth below another.
Surface waves	Seismic waves that propagate along the surface of the earth(*Love* and *Rayleigh waves*).
Tectonic earthquake	Earthquakes resulting from the release of *strain* by deformation of the earth.
Tectonic province	A region characterized by uniform geologic structures.
Tsunami	A large ocean wave usually cause by movement in the sea floor related to an earthquake or volcanic eruption.
velocity(seismic)	The time rate of displacement of a reference point in an earthquake or the speed with which a particular seismic wave propagates in a rock.
Viscoelastic	A type of deformation in which a material behaves like an elastic solid when it is rapidly strained on time scales of seconds to hours, but deforms viscously by plastic flow over long periods of geologic time.
Water table	The upper surface of an unconfined body of groundwater.
waveform	A plot of the displacement produced by a seismic wave as a function of time.
wavelength	The distance between two adjacent crest sort roughs of a wave.
wavelet	A seismic pulse usually consisting of 1½ or 2 cycles.

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