### MODULE 3: EARTHQUAKES & TSUNAMIS

<table>
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<th>Activity no.</th>
<th>Title</th>
<th>Type</th>
<th>Location</th>
<th>Extra materials?</th>
<th>Time</th>
<th>Skills developed</th>
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<td>1</td>
<td>Stressed Out!</td>
<td>Paper exercise</td>
<td>Classroom</td>
<td>No</td>
<td>15 mins</td>
<td>Investigative, interpretation of text</td>
</tr>
<tr>
<td>2</td>
<td>Let's Make Earthquakes</td>
<td>Practical Exercise</td>
<td>Classroom</td>
<td>Yes</td>
<td>60 mins</td>
<td>Practical experiment; Team work</td>
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<td>3</td>
<td>Where Does the Earth Quake?</td>
<td>Paper exercise</td>
<td>Classroom</td>
<td>No</td>
<td>30 mins</td>
<td>Investigative, interpretation of text; Map and Photo interpretation</td>
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<td>4</td>
<td>Tsunami Alert</td>
<td>Paper exercise</td>
<td>Classroom</td>
<td>No</td>
<td>15 mins</td>
<td>Investigative, interpretation of imagery &amp; text; Map interpretation; Scenario task</td>
</tr>
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Total time: 2 hrs

All activities are developed in accordance with the national core curriculum. Activities are listed in order of execution.

This educational module is one of a series of five modules developed for primary schools in the Burren region of Ireland as part of the Northern Environmental Education Development (NEED) Project (2008-2010). Modules are also available for secondary schools, visitor centres, and adult learners. This transnational education project aims to raise awareness of geological heritage and related environmental issues, and to use this enhanced awareness to promote sustainable “eco-“ tourism in key natural regions in Europe. For more information see [www.GeoNeed.org](http://www.GeoNeed.org) or [www.burrenconnect.ie/geopark/need](http://www.burrenconnect.ie/geopark/need).
ACTIVITY 1: STRESSED OUT!

Teachers Notes:
Student Worksheets:

ACTIVITY 2: LET'S MAKE EARTHQUAKES...!

Teachers Notes:
Student Worksheets:

ACTIVITY 3: WHERE DOES THE EARTH QUAKE?

Teachers Notes:
Student Worksheets:

ACTIVITY 4: TSUNAMI ALERT!

Teachers Notes:
Student Worksheets:
Activity summary:

Students will learn how rocks can be broken and deformed (strained) by the actions of stress (physical force). Students will consider how heat and pressure can affect the properties of a solid object.

Level: 5th and 6th class

Time required: 15 mins (activity)

Curriculum links: SESE Geography:
Strand: Natural Environments
   Unit: The local natural environment
   Unit: Rocks and Soil
   Unit: Planet Earth in Space

Strand: Environmental Awareness
   Unit: Environmental Awareness

SESE Science:
Strand: Materials
   Unit: Properties and characteristics of materials
   Unit: Science and the Environment
   Unit: Energy and Forces

Objectives:

- To learn how pressure and heat can change the form of solid objects
- To understand the concept of stress – and how it affects materials
- To see how stress affects rocks by folding them and fracturing them
- To consider where rocks may become subjected to stress (folding and faulting)
Skills and concepts development:

Maps, Globes and Graphical Skills
  o Using Pictures, Maps and Models

A Sense of Place and Space
  o A Sense of Space

Geographical Investigation Skills\Working Scientifically\Designing and Making
  o Observing
  o Exploring
  o Estimating and Measuring
  o Analysing
  o Recording and communicating
  o Evaluating

Background information and context:

The rocks of the Burren have been subjected to both folding and faulting actions. These actions are caused by STRESS. The study of stress in geology forms the basis of the field of Structural Geology. By understanding how rocks respond to stress, we can try to understand a region’s geologic past and the structural evolution of an area. This can be done by observing regionally widespread patterns of rock deformation.

By understanding STRESS – we can explain how Earthquakes happen and how great mountain ranges are built. We can also understand some of the features we see in the Burren – particularly:

  o why the rock layers of the Burren slope gently to the south (2° - 5° south)
  o why the strata around Mullaghmore are folded
  o why the Burren is criss-crossed by fractures

What is Stress?

Stress is the application of force on an area or object. If you lean against a table, you are putting some stress on it. A strain is when the table moves, so strain is the change in shape or volume.
Plastic strain occurs when stress is applied to an object, and it becomes deformed - and then stays in that same (new) shape - it doesn't resume its original shape.

Folded rocks have been subjected to a plastic strain.

Elastic strain happens when an object is deformed, and then when the stress is removed, it returns to its original shape. But - if you exceed an objects elastic limit, then the object will break and shatter. (Just like with a plastic ruler, or a length of uncooked spaghetti.)

Faulting (or fracturing) occurs when the strain exceeds the elastic limit of a material, and the rock breaks or fractures.

Prior Knowledge:

Students should be familiar with the following:

- Rocks can be folded
- Rocks can be fractured/faulted
- The Earth’s temperature increases with dept (about 20-30°C per km depth)
- The Burren was once buried ~2.5km below the surface (300 million years ago)

Apparatus and materials:

- Student worksheets

Organisation of Students:

- Students can work individually

Activity:

(1) Each student is given a worksheet

(2) Students look at the photographs on the worksheet and try to answer the accompanying questions
Student questions and answers:

Q. Someone was sitting on one of these Mars bars for a while! Which one?
A. Mars Bar B

Q. How do you know?
A. Because it looks like it is soft, gooey and melted

Q. What do you think made the Mars bar go soft?
A. The pressure/weight of someone sitting on it – and the heat of their bum!

Q. The other Mars Bar was in the fridge for a while - what do you notice about how the cold Mars bar breaks in two?
A. It breaks/cracks cleanly.

Q. Which rocks were stressed when they were warm?
A. A and D

Q. Which rocks were stressed when they were cold?
A. B and C

Q. When two sides of a rock move along a crack, we call it a “fault”. Can you see any faults in these rocks? Draw along the faults with a marker or colouring pencil.
A. (Illustrative answer)

Q. Where do you think the rocks were when they were stressed? Mark one letter in each box on this diagram.
A. B and C near the surface. A and D deep underground

Q. Photo on left = Joints (Fractures) in limestone pavement:

- Cold
- Near the surface
- Happened later

Photo on right = Folded strata on Mullaghmore:

- Warm
- Deep
- Happened first
STRESSED OUT!

People say they’re stressed when they are under pressure. But other things get stressed too... Look at what happened when we tried to break these Mars bars.

![Mars bars](image)

Q1. Someone was sitting on one of these Mars bars for a while! Which one? ______
How do you know? __________________________

Q2. What do you think made the Mars bar go soft? __________________________

Q3. The other Mars Bar was in the fridge for a while - what do you notice about how the cold Mars bar breaks in two? __________________________

Rocks can be stressed in the same way as a Mars bar. Look at these four pictures.

![Rocks](image)

Q5. Which rocks were stressed when they were warm? __________________________

Q6. Which rocks were stressed when they were cold? __________________________

Q7. When two sides of a rock move along a crack, we call it a “fault”. Can you see any faults in these rocks? Draw along the faults with a marker or colouring pencil.
STRESSED OUT!

Where do you think the rocks were when they were stressed? Mark one letter in each box on this diagram.

The rocks of the Burren have also been stressed. Match up the words with the pictures.
ACTIVITY 2: LET'S MAKE EARTHQUAKES...!

TEACHER’S NOTES

Activity summary:

Students will conduct a practical experiment to observe how stress can build up between two solid bodies (bricks) – and is then suddenly released. Students will see that the build up and release is not always the same – and hence that earthquakes are difficult to predict.

Level: 5th and 6th class

Time required: 60 mins (activity)

Curriculum links: 

SESE Geography:

Strand: Natural Environments
Unit: The local natural environment
Unit: Rocks and Soil
Unit: Land, rivers and seas of Ireland

Strand: Environmental Awareness
Unit: Environmental Awareness

SESE Science:

Strand: Materials
Unit: Properties and characteristics of materials
Unit: Science and the Environment
Unit: Energy and Forces
Objectives:

- To carry out a scientific experiment
- To work in a team with different roles
- To learn that earthquakes are unpredictable
- To appreciate that steadily increasing stress leads to brittle failure
- To consider how these forces and processes are fundamental to earthquakes
- To appreciate how earthquakes (natural processes) are difficult to predict

Skills and concepts development:

Maps, Globes and Graphical Skills

- Using Pictures, Maps and Models

A Sense of Place and Space

- A Sense of Space

Geographical Investigation Skills\Working Scientifically\Designing and Making

- Observing
- Predicting
- Investigating and Experimenting
- Estimating and Measuring
- Analysing
- Recording and communicating
- Evaluating

Background information and context:

**Stress** can build up in rocks when a **force** is applied to the rocks. The movement of the Earth’s **crust plates** can cause stress to **build up** in rocks. When the stress is **suddenly released** due to rock **failure** – an **earthquake** can occur. The moment when the release of the stress is often **unpredictable**. This is why earthquakes are some **difficult to predict** and why rescue/response authorities are faced with difficulties.
Prior Knowledge:

Students should be familiar with the following:

- The surface of Planet Earth is made up of several crustal plates that move very slowly
- Most earthquakes occur at plate boundaries – mostly where plates collide (collision zones) or slide past each other (transform zones), but also at boundaries such as oceanic ridges (spreading zones)
- Earthquakes can occur when stress that builds up in rocks is released due to rock failure

Apparatus and materials:

- Four bricks (e.g. red bricks for building)
- Bungee cord
- Cord to tie around brick to be pulled
- Metre stick/Measuring Tape
- Sand
- Student worksheets

Organisation of Students:

- Students work in groups of four or five
Activity:

Each student is given a worksheet to record their groups observations

Set Up:

1. Align **3 bricks** in the centre of a table (to minimize chance bricks falling off table). These bricks are to remain **stationary**. One student holds these 3 bricks in place. *(Pupils should be warned to be careful of bricks that may fall off the table)*
2. A **cord** is tied around a fourth brick and the brick is place **on top** of the stationary bricks.
3. Attach the **bungee cord** to this cord/brick.
4. **Pull steadily** on the bungee cord until the top brick suddenly begins to slide over the lower ones. This represents the point at which rocks below the ground fail, resulting in an earthquake at the surface.
5. **Repeat** the activity five times
6. **Record the distance** moved by the top brick for every pull.
7. Sprinkle some **sand** on the stationary bricks and **repeat the activity** five times.
8. **Record the distance** moved by the top brick for every pull.
9. **Answer the question** on the worksheet.

![Diagram of brick setup](image)

**Answers to questions**

A. Sand limits the stress that builds up between the bricks as the individual particles begin to move as stress increases.
LET’S MAKE EARTHQUAKES!

Name: __________________

Stress can build up in rocks. When this stress is released suddenly, we call it an earthquake. You are going to do an experiment to see how this happens.

In the table below, write the distance the brick moved after each “pull” and then answer the questions.

<table>
<thead>
<tr>
<th>Pull no.</th>
<th>Bricks on their own</th>
<th>Bricks with sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q1. Were the results the same for every pull:
   (a) without sand ____________________ (b) with sand ____________________

Q2. Why do you think this is? __________________________________________________________
                                                                                       __________________________________________________________

Q3. In general, did using sand make a difference? What kind of difference? __________
                                                                                       __________________________________________________________

Q4. Why do you think this is? __________________________________________________________

Q5. You have seen how stress builds up in bricks, just as it does in rocks. Do you think
    that it is easy to predict when earthquakes will happen? ________________________________
ACTIVITY 3: Where Does the Earth Quake?

TEACHER’S NOTES

Activity summary:

Students will learn where Earthquakes occur around the Earth. Students will see the relationship between crustal plate boundaries and earthquakes. Students will become familiar with the Richter Scale and consider the effects of earthquakes with different magnitudes/strengths.

Level: 5th and 6th class

Time required: 30 mins (activity)

Curriculum links: SESE Geography:

Strand: Natural Environments
Unit: The local natural environment
Unit: Rocks and Soil
Unit: Planet Earth in Space

Strand: Environmental Awareness
Unit: Environmental Awareness

SESE Science:

Strand: Materials
Unit: Properties and characteristics of materials
Unit: Science and the Environment
Unit: Energy and Forces
Objectives:

- To investigate where earthquakes occur and why they occur in these places and not in others
- To consider Ireland’s location with regard to earthquake zones
- To identify locations on a map and interpret associated map information about earthquakes

Skills and concepts development:

Maps, Globes and Graphical Skills

- Using Pictures, Maps and Models
- Maps and Globes

A Sense of Place and Space

- A Sense of Space

Geographical Investigation Skills\Working Scientifically\Designing and Making

- Observing
- Exploring
- Estimating and Measuring
- Analysing
- Recording and communicating
- Evaluating

Background information and context:

Plate boundaries are found at the edge of the Earth’s crustal plates. There are three types, collisional (convergent), spreading ridges (divergent) and transform (conservative). The three boundaries are characterized by their distinct motions.
Most earthquakes occur near plate boundaries, where stresses between adjacent plates can build up. When suddenly released, a sudden shock occurs in the crust – what we experience as an earthquake.

At spreading ridges, earthquakes are shallow, and occur along the axis of spreading. Earthquakes at spreading ridges tend to be smaller than magnitude 8.

At transforms, earthquakes are shallow, running as deep as 25 km. Transforms tend to have earthquakes smaller than magnitude 8.5.

At collisional boundaries, earthquakes are found in several settings ranging from the very near surface to several hundred kilometers depth. The coldness of the subducting plate permits brittle failure down to as much as 700 km. Collision boundaries host Earth’s largest quakes, with some events at subduction zones in Alaska and Chile having exceeded magnitude 9.

Prior Knowledge:

Students should be familiar with the following concepts and terms:

- The surface of Planet Earth is made up of several crustal plates
- The crustal plates move – very slowly
- Earthquakes can happen when stress is released in adjacent plates
- Richter Scale
- Magnitude = Strength

Apparatus and materials:

- Student worksheets

Organisation of Students:

- Students can work individually

Activity:

1. Each student is given a worksheet.
2. Students look at the maps and photographs on the worksheet and try to answer the accompanying questions
Student questions and answers

Q. What do you notice about where Earthquakes happen?
A. They happen along plate boundaries.

Q. Why do you think this is?
A. Because plates, especially colliding plates, build up stress – and this can cause earthquakes.

Q. How far is Ireland from the nearest Earthquake zone?
A. 1000km-1500km

Q. Do you think there are more earthquakes in areas where the Earth’s plates are moving towards each other, or where the plates are moving apart? Why do you think this is?
A. Moving towards each other. Because of the build up and subsequent sudden release of stress.

Q. Arrange these places in order of how safe they are to live in (safest first): Japan, Spain, Ireland, Australia, Iceland
A. Ireland, Australia, Spain, Iceland, Japan,

Q. Philippines: 7
   Ireland: 0-3
   India: 4-5
   California: 6
WHERE DOES THE EARTH QUAKE?

Name: ______________

This map shows the plates of the Earth’s crust. The yellow dots show where earthquakes have happened over the last 40 years.

Q1. What do you notice about where earthquakes happen? ____________________________________________________________________________

Q2. Why do you think this is? ____________________________________________________________________________

Q3. How far is Ireland from the nearest earthquake zone? __________________________________________________________________________

Q4. Do you think there are more earthquakes in areas where the Earth’s plates are moving towards each other, or where the plates are moving apart? Why do you think this is? ____________________________________________________________________________

Q6. Arrange these places in order of how safe they are to live in (safest first): Japan, Spain, Ireland, Australia, Iceland. ____________________________________________________________________________
The strength (also called the magnitude) of an earthquake is measured on the Richter scale. These pictures show the effects of earthquakes using this scale.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Magnitude</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 3</td>
<td>not felt by people, but recorded by instruments</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>windows rattle, dishes break, doors swing open</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>cracks form in plaster, bricks fall</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>chimneys fall, houses shake and move on their foundations</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>bridges twist and break, some buildings collapse</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>total destruction; all buildings collapse, objects thrown into the air</td>
</tr>
</tbody>
</table>

Four earthquakes are marked on this map of the Earth. Read the comments left by eyewitnesses. In the boxes, write what you think the earthquakes measured on the Richter Scale.

Philippines: “It was impossible to stand up. Cars were lifted up into the air, roads cracked open, and the houses just fell apart.”

Ireland: “What earthquake? I didn’t notice anything.”

India: “There is not too much damage. In our house, there are some small cracks in the walls, and some plates fell out of the cupboard and broke on the floor, but that’s all.”

California: “It was pretty scary. Everything was shaking. The wall of our garden fell over, and the chimney of our neighbour’s house fell into the street.”
ACTIVITY 4: TSUNAMI ALERT

TEACHER’S NOTES

Activity summary:

Students will learn how an undersea earthquake can create a tsunami wave. Students will learn that Ireland was hit by a tsunami in 1755, after a great earthquake struck off Lisbon. Students will consider factors that may be involved in an emergency response to a tsunami alert.

Level: 5th and 6th class

Time required: 20 mins (activity)

Curriculum links: SESE Geography:

Strand: Natural Environments
   Unit: The local natural environment
   Unit: Rocks and Soil
   Unit: Land, rivers and seas of Ireland
   Unit: Weather, climate and atmosphere

Strand: Environmental Awareness
   Unit: Environmental Awareness

Strand: Human Environments
   Unit: People living and working in the local area and a contrasting part of Ireland

SESE Science:

Strand: Materials
   Unit: Properties and characteristics of materials
   Unit: Science and the Environment
   Unit: Energy and Forces
Objectives:

- To understand how tsunamis are created by earthquakes
- To realise that Ireland was once hit by a tsunami
- To appreciate how quickly a tsunami can travel and how this can impact emergency response
- To consider how the coast of Clare could be affected by a tsunami

Skills and concepts development:

Maps, Globes and Graphical Skills

- Using Pictures, Maps and Models
- Maps and Globes

A Sense of Place and Space

- A Sense of Space
- A Sense of Place

Geographical Investigation Skills/Working Scientifically/Designing and Making

- Observing
- Exploring
- Investigating and Experimenting
- Estimating and Measuring
- Analysing
- Recording and communicating
- Planning
- Evaluating

Background information/context:

Indian Ocean Tsunami 2004

On St. Stephens Day in December 2004, an earthquake in the Indian Ocean caused a tsunami that led to the death of over 230,000 people in 11 different countries.

- It was the second largest earthquake ever recorded on a seismograph (With a magnitude of between 9.1 and 9.3).
- The earthquake had the longest duration of faulting ever observed, between 8.3 and 10 minutes.
It caused the entire planet to vibrate as much as 1 cm and triggered other earthquakes as far away as Alaska.

It is estimated that a fault-line of over 1600 km slipped ~ 15 m, where the Indian Plate subducts beneath the Burma Plate.

Tsunamis can be caused by underwater disturbances such as earthquakes, underwater landslides, underwater volcanoes and underwater explosions.

- Tsunamis have a small amplitude (wave height) offshore, and a very long wavelength (often hundreds of kilometres long), which is why they generally pass unnoticed at sea, forming only a slight swell usually about 3 m above the normal sea surface. They grow in height when they reach shallower water.
1755 Tsunami in Ireland

On November 1st 1755, a great earthquake struck off the coast of Portugal. The quake caused a tsunami, that reached the south and west coasts of Ireland in a matter of hours. Reports state that the wave caused damage along the coast from Kinsale to Galway City.

It is suggested that Aughinish Island, near New Quay was severed from the mainland by the force of this wave. Today, Aughinish Island is in County Clare, but can only be accessed by land via County Galway. Coastal buildings are reported to have been damaged, as was a castle at Coranroo, on the Galway-Clare border near Kinvara.

Prior Knowledge:

Students should be familiar with the following concepts and terms:

- Earthquakes and volcanoes can happen under the sea.
- Built up stress between adjacent crustal plates can be released as a sudden earthquake
- Earthquakes can happen at plate boundaries and undersea

Apparatus and materials:

- Student worksheets

Organisation of Students:

- Students can work individually

Activity:

(1) Each student is given a worksheet

(2) Students use the diagrams and maps on the worksheet to answer the accompanying questions
Student questions and answers:

Q. These diagrams show how tsunamis form. Can you describe what happens?
A. Stress builds up along a plate boundary due to two plates pushing towards each other. Eventually the stress give way – and there is a sudden shock – an earthquake. The movement in the crust upsets the overlying water column in the ocean and creates a wave.

Q. In what direction(s) do you think the wave will travel?
A. To the LEFT

Q. We’ve already seen that Ireland is 1300 km from the nearest earthquake zone. Is this zone on land or underwater?
A. Underwater

Q. How likely is it that Ireland could be hit by a tsunami? Why?
A. It is possible. An earthquake in the Atlantic could trigger a tsunami wave.

Q. True or false:
  Tsunami waves are the same length as normal waves - False
  Tsunami waves are many times higher than normal waves - False
  A tsunami is made of only one wave - False

Q. Where did the earthquake happen?
A. Atlantic Ocean off Portugal

Q. How many hours did it take for the tsunami to reach:
  Co. Clare 3-4 hours
  New York 7-8 hours
  Lisbon < 1 hour
  Brazil 7 hours

Q. If this tsunami happened today, how would you find out about it before it reached Ireland?
A. (Subjective answer/discussion)
TSUNAMI ALERT!
So far we’ve looked at earthquakes on land. But what if an earthquake happens at sea? A TSUNAMI!

Q1. These diagrams show how tsunamis form. Can you describe what happens?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Q2. In what direction(s) do you think the wave will travel?
______________________________________________________________________________

Q3. We’ve already seen that Ireland is 1300 km from the nearest earthquake zone. Is this zone on land or underwater? __________________________ How likely is it that Ireland could be hit by a tsunami? Why? ____________________________________________
______________________________________________________________________________

Q4. The picture below shows what tsunami waves look like out at sea, compared to normal waves.

normal waves

[Image of normal waves]

Tsunami waves

[Image of tsunami waves]

True or false: Tsunami waves are the same length as normal waves ____________________
Tsunami waves are many times higher than normal waves __________________
A tsunami is made of only one wave ____________________
Lisbon Earthquake - 1755

Believe it or not, Ireland was hit by a tsunami, in 1755. This map shows the time it took for the tsunami to travel through the ocean.

Q1. The earthquake epicenter was off the coast of what European country?

Q2. How many hours did it take for the tsunami to reach:

Exercise

Imagine you are working for the Irish coastguard. You have just found out that a large earthquake has happened in the middle of the Atlantic. The tsunami waves are still out at sea and are 1 m high, but they will probably get higher when they reach the shore - maybe up to 10 m.

Look at the:
   (1) Land heights map of the Burren and north Clare

Q1. What town would you evacuate first in Co. Clare? _______________________

Q2. What kind of damage do you think the tsunami would do?
   ________________________________
   ________________________________