Unit 8:
Internal dynamics of the Earth

1. The internal heat of the earth

2. Plate tectonics theory

3. Internal geological processes

3.1. Volcanoes

3.2. Earthquakes

3.3. Rock deformation

3.4. Mountain ranges formation

Think and answer

a. What type of geological process can you see in the photograph?

b. Why do earthquakes occur?

c. How do mountains form?

d. What is the origin of the energy that drives these phenomena?

UNIT OBJECTIVES

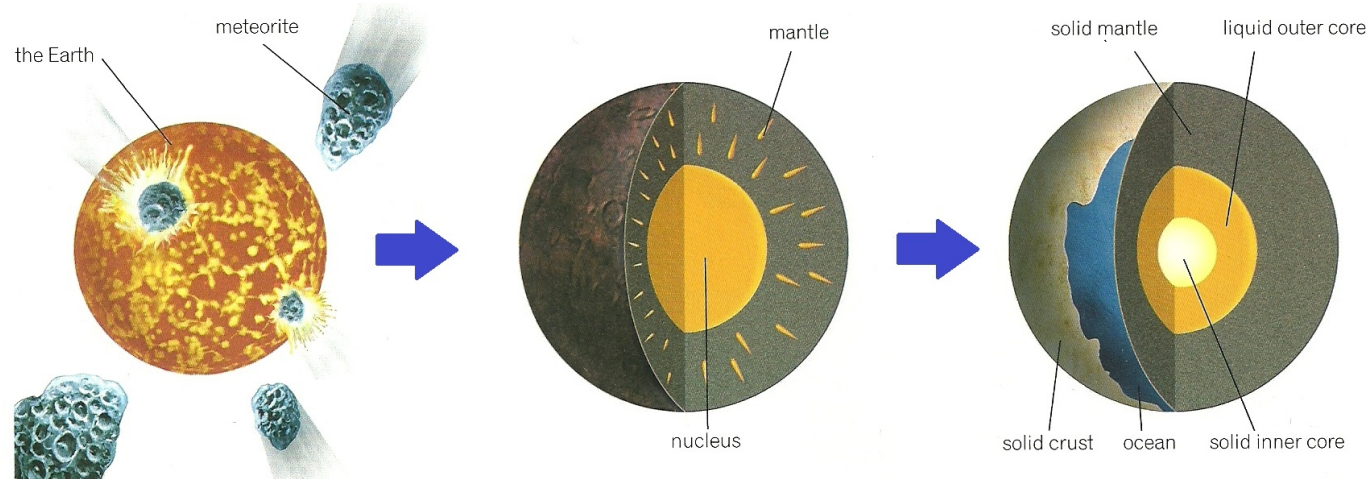
In this unit you will learn:

- To learn about internal energy of the Earth and the geological phenomena it provokes.
- To know the basis of the Tectonic plates theory.
- To relate Tectonic Plates theory and volcanism, seismicity, rocks deformation and mountain building.
- To understand the importance of prediction and prevention of natural disasters such as earthquakes and volcanic eruptions.

1. The internal heat of the Earth.

The interior of the Earth is hotter than the exterior, because of the heat generated when the Earth was formed and that remains inside it.

The temperature in the inner core is higher that the sun surface, above 6,000°C. Measured from the Earth's surface the temperature increases by about 30°C/km in depth.



4,600 million years ago.
Earth started to form by addition of fragments of rocks that collided. Slowly the young planet grew. The heat generated with constant collisions kept the Earth molten.

4,000 million years ago.
Collisions decreased and the heavy materials sunk to the center of the planet, forming the core, while, the surface light materials started to solidify forming the crust.

The Earth today.
The Earth has a core divided into:
- Inner core, solid due to the tremendously high pressure in the center at the Earth
- Outer core, molten.

The Earth's internal heat, called **geothermal energy**, is responsible for the internal dynamics of the geosphere. This energy is slowly released from the inner layers to the surface.

The intense heat of the deep mantle, heated by the core, provokes the rocks melt. As they melt they become less dense, and rise towards the surface. At the same time, rocks of the upper mantle, colder and denser sink to the deeper zones, where they heat up and consequently rise up again. This circulation of materials is known as **convection currents**.

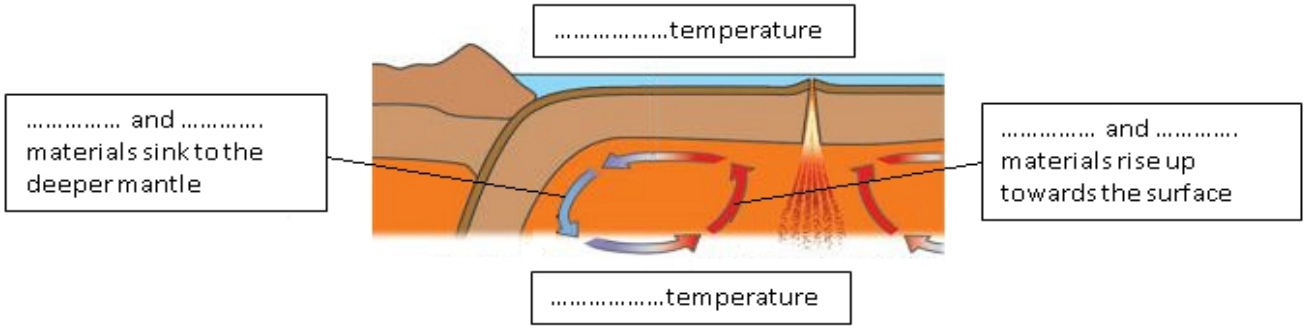
READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

1.1. Answer these questions:

a. What is the origin of the Earth's internal energy?
b. How were the layers of the Earth formed?
c. Why can we explain that the inner core is solid while the outer core, colder, is molten?

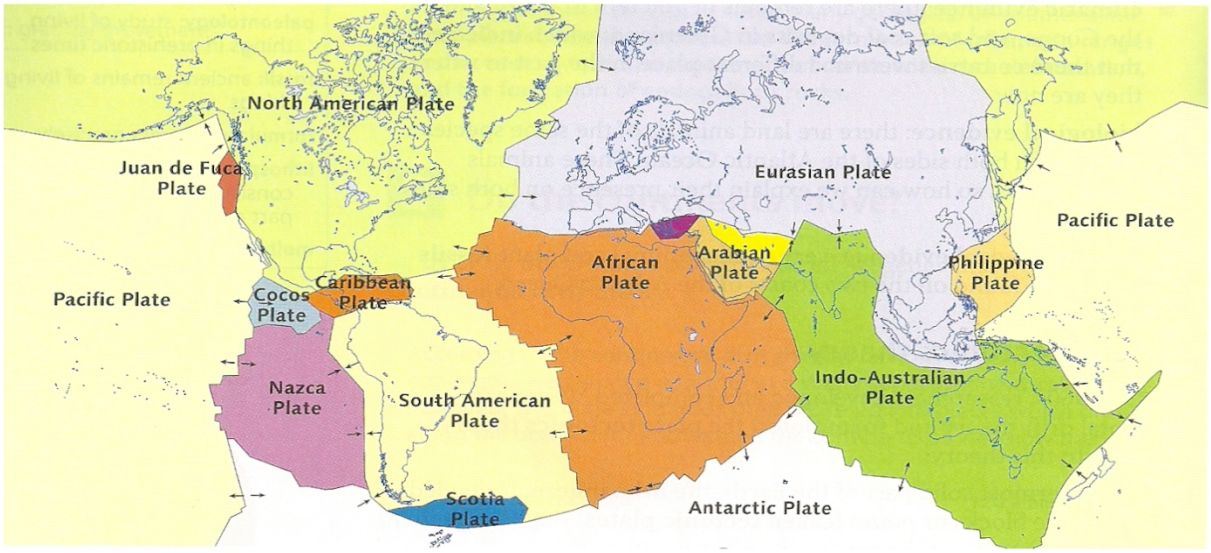
1.2. Complete the sketch with the following words: *light, high, cold, heavy, hot, low,* What does it represent?



2. Plate tectonics theory.

The **Plate tectonics theory** was formulated in the 1960's. According to this theory:

- The outermost solid part of the Earth, the **lithosphere**, is divided into large blocks called **tectonic plates** that fit together in the same way as pieces of a giant jigsaw puzzle.

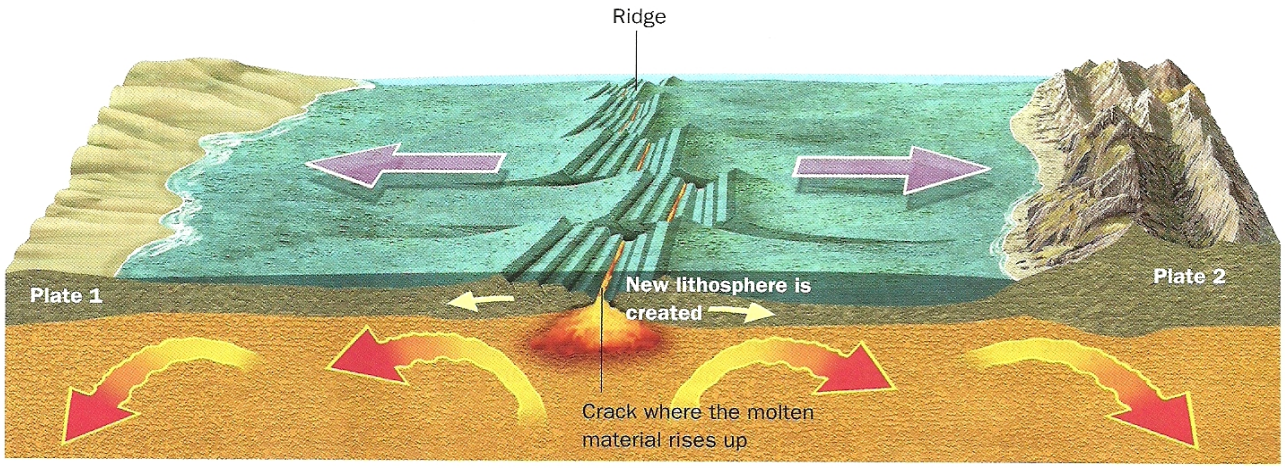


- The plates float on top of the **asthenosphere**, the layer just below the lithosphere. The asthenosphere is denser than the lithosphere and is partially formed by molten materials that circulate in convection currents.
- The **convection currents** of the asthenosphere are the engine that moves the tectonic plates.

The points where two tectonic plates meet are called **boundaries**. Earthquakes, volcanic eruptions, formation of mountain ranges and rock deformation are most likely here. The plates can move one with respect to another in different ways: they can collide, separate or slide past each other.

a) Divergent boundaries

When plates separate they form a **divergent boundary**. Materials from the inside of the Earth rise up between the plates forming new lithosphere and provoking their separation. The limit between the plates is a **ridge**. For example in the middle of the *Atlantic Ocean*, the *Atlantic Ridge* separates the *African* and the *South American Plates*.

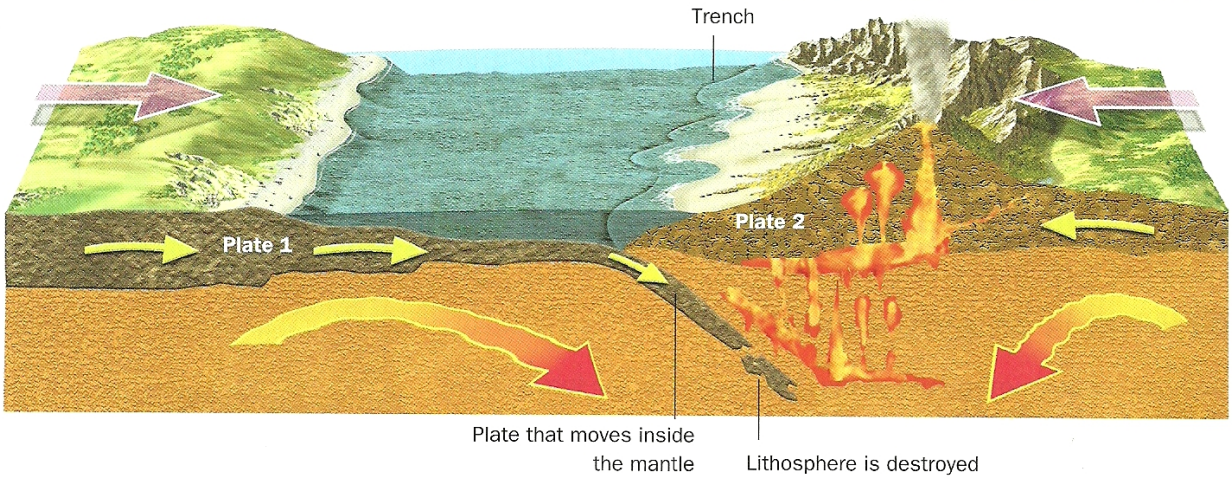


b) Convergent boundaries

When plates collide they form a **convergent boundary**. These limits can be of two types:

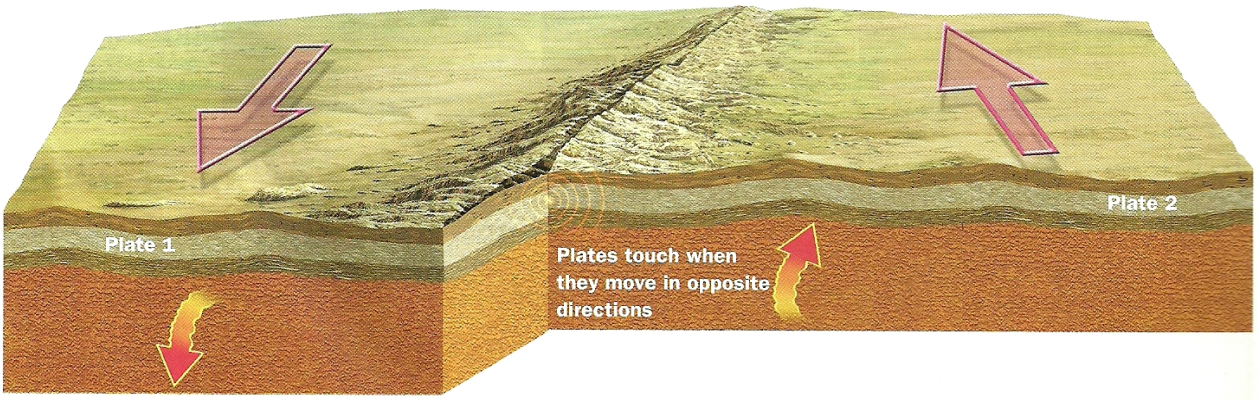
- When one plate collides by its continental side with other by its oceanic side, the oceanic plate sinks underneath the other one (**subduction)**. The subducting plate is destroyed, molted into the asthenosphere. When plates converge they cause earthquake and form **volcanic mountain ranges** in the continent and a **trench** in the ocean. For example *Nazca Plate* is subducting underneath *South America Plate*, forming the *Andes Mountain Range*.

- When two plates collide by their continental side neither one nor another subduct. In this case, a huge mountain range is formed and plates fuse (**obduction**). For example *African plate* is colliding with *Eurasian plate* forming the *Pirineos* and the *Alpes*.



c) Transform boundaries

When plates slide past each other, moving in opposite directions, they form a **transform boundary**. The friction between the plates provokes intense earthquakes, but lithosphere is neither created nor destroyed. This limit is called **transform fault**. An example is the *San Andrés fault* between the *North American* and *Pacific Plates*.



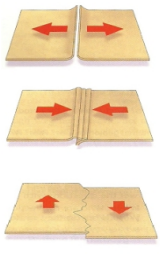
READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

2.1. Define these terms:

a. Tectonic Plate b. Convection current c. Asthenosphere

2.2. Complete the following chart:



Relative movement of the plates	Type of boundary	Geological limit

3. Internal geological processes.

The internal dynamics of the Earth has as a result different geological phenomena known as internal geological processes. The main ones are: volcanism, seismicity, mountain formation and rocks deformation.

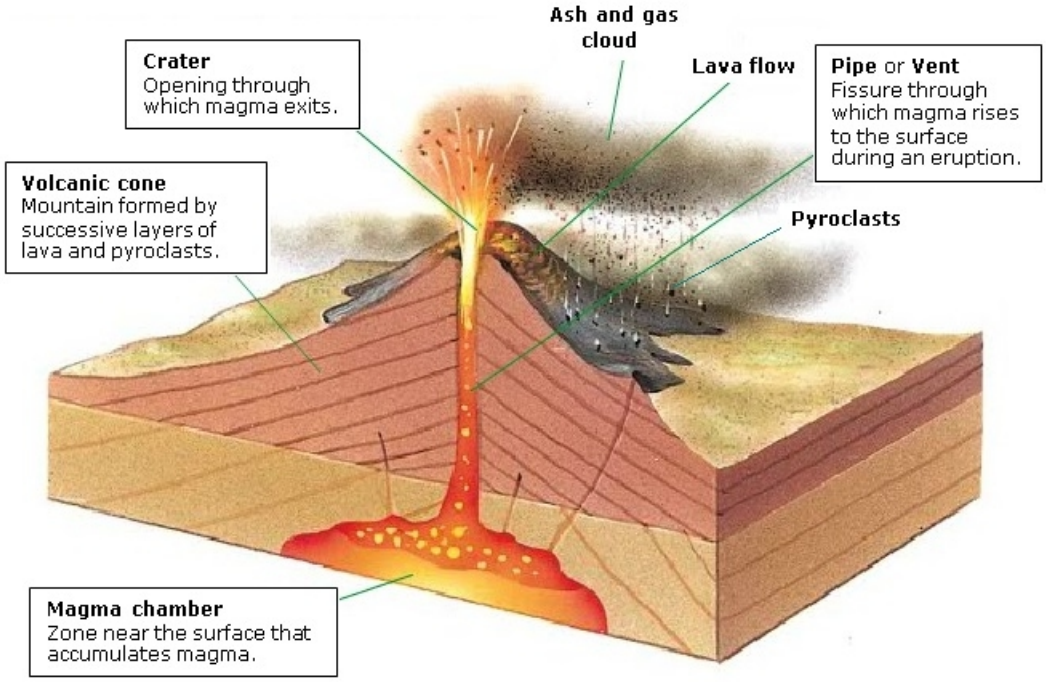
3.1. Volcanoes

Volcanoes are openings in the Earth's crust through which magma flows from inside the planet to the surface. **Magma** is an extremely hot mixture of molten minerals which contains different amounts of water, gases and small pieces of solid rock.

Although in the mantle the temperature is extremely hot, the high pressure keeps rocks in solid state. However in some places the temperature is slightly higher or the crust is thinner and exerts less pressure. In these conditions, rocks start to melt and magma forms.

Melted rocks are lighter that solid rocks and they tend to rise up. If this magma finds an exit to the surface, a volcanic eruption occurs.

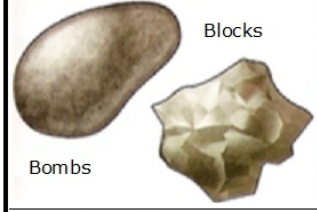
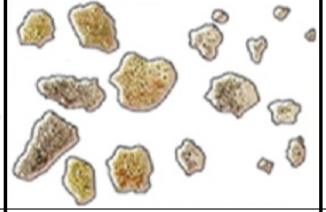
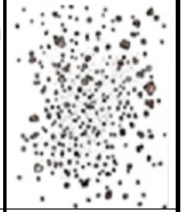
a) Parts of a volcano



b) Volcanic materials

When a volcano erupts, it expels different kind of materials:

- Gaseous materials. Gases are released from magma when it reaches the surface.
  The main **volcanic gases** are water vapour, carbon dioxide and sulphides of hydrogen and nitrogen.
- Liquid materials. The magma without gases is called **lava**.
- Solid materials. They are known as **pyroclasts**. They are solid fragments wrenched from the volcanic cone during the eruption. They can be very large (volcanic bombs and blocks), gravel sized (lapilli) and dust sized (ashes)

Volcanic bombs and blocks	Lapilli	Ashes
		
Several diametres	64 mm	2 mm

c) Types of volcanic eruptions

Magma is classified according to the amount of gases and the type of minerals it contains. The type of magma determines the type of eruption and the type of volcanic cone that is formed as a result.

- Effusive eruptions

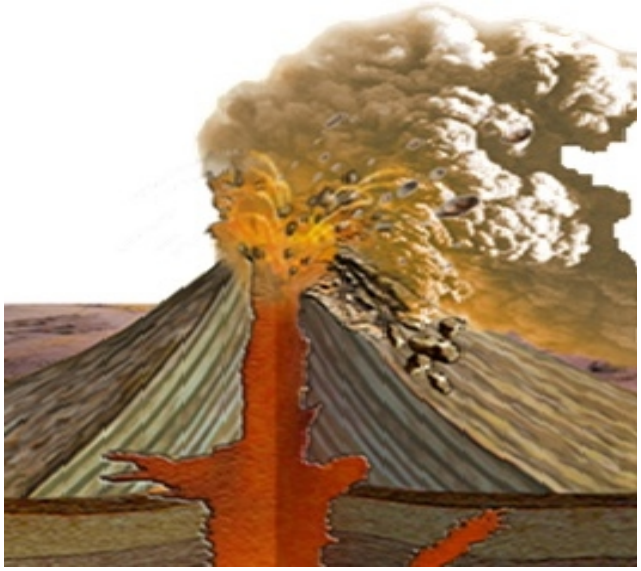
In this kind of eruptions, the magma is very fluid and forms extensive *lava flows*.
The accumulated *gases* easily escape from it and eruptions are very mild.
They do not produce *pyroclasts*.

The crater of these volcanoes can be:
- a typical opening. They are known as **hawaiian volcanoes**.
  (E.g. Kilauea, Hawaii Islands)
- a large longitudinal fissure, as in the case of oceanic ridges. They are known as **icelandic volcanoes** (E.g. Laki, Iceland).

- Explosive eruptions

In this case, the magma is viscous. Gases cannot escape easily from it and eruptions are violent, with explosions that produce a large amount of *pyroclasts*, *gases clouds* and *lava flows*.
In the most extreme eruptions, very destructive clouds, known as *pyroclastic flows*, may form close
to the ground and move at high speeds.

There are different types of explosive volcanoes depending on the *viscosity* of the magma and their *explosiveness*. In order of increasing level they are: **strombolian** (E.g. Stromboli, Italy), **vulcanian** (E.g. Mont Vulcano, Italy), and **plinian** (E.g. Vesuvius, Italy) and **pelean** (Mont Peleé, Martinique Island).



d) Low-intensity volcanism

In areas of volcanic activity near active volcanoes, it is possible these phenomena occur:

Smoking volcanoes (fumarolas).
They are cracks that emit gases at high temperature.

Geysers.
They are cracks that emit from time to time eruptions of hot mineralized water.

Hot springs.
They are springs that emit hot water which is rich in minerals salts.

e) Dangers of volcanoes

Volcanic activity can cause very serious **catastrophes**: lava flows, clouds of burning rocks and gases can destroy everything in their path, gas emission can be toxic, piroclasts and ash emission can destroy vegetation, intense heat can melt frozen areas around them causing floods and rivers of mud.

Although it is impossible predict accurately when a volcanic eruption is going to be, there are some signs that indicate it is near to occur. For example, cracks appearing through which gases escape, Increase of the soil temperature, tremors, etc.

To prevent disasters, it is important to take the correct **prevention measures**:
- Inform to people about the volcanic risks and what to do in case of eruption.
- Establish civil protection programmes.
- Build dykes to change the course of rivers of lava or mud.

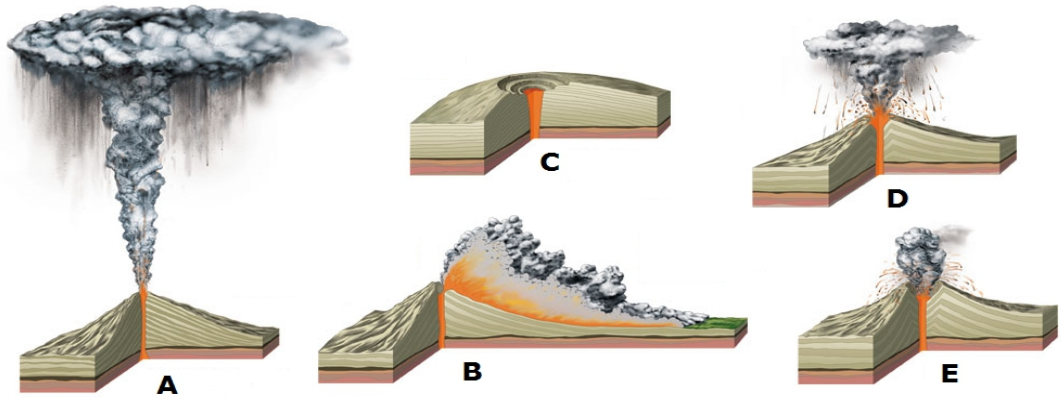
READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.1. Answer these questions:

a. What are the factors that determine the explosiveness of a volcanic eruption?
b. What is the difference between a fumarole and a geyser?
c. What criterion is used to classify the pyroclastic materials?
d. Is it the same magma than lava?

3.2. Identify and order the following pictures from lower violent eruption to higher one.



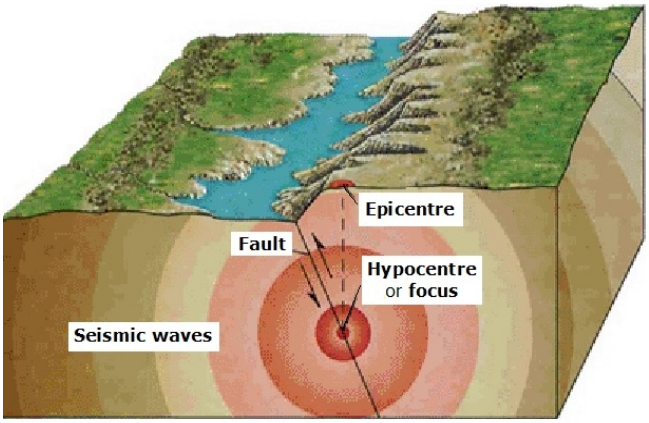
3.2. Earthquakes

Earthquakes are sudden movements of the surface layers of the Earth. They occur when large rocky masses inside the Earth's crust move past each other.

The movement of these rocky masses releases a large amount of energy, and this can be sudden, violent and destructive.

a) Elements of an earthquake

An earthquake has the following elements:



- The **hypocentre** (or **focus**) is the point in the Earth's crust where the earthquake starts and produces seismic waves. At an earthquakes hypocentre the rocks break up, which causes the ground to move violently, and energy is released.

- The **epicenter** is the point on the Earth's surface that is directly above the hypocentre. The epicentre is the place where the seismic waves first reach the Earth's surface and the effects of the earthquake are felt most intensely.

- The **seismic waves** are vibrations that extend in all directions from the hypocentre. When they reach the surface, they produce catastrophes.

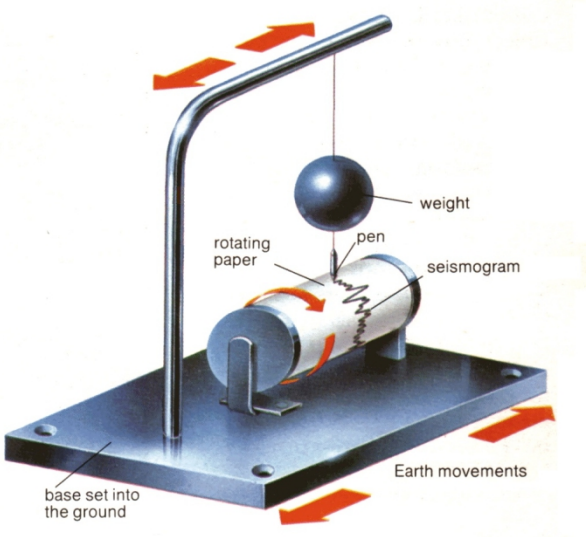
b) Measuring of an earthquake

Seismographs are the devices that geologists used to detect and record earthquakes. A seismograph consists of a hanged weight with a pen which draws on a roll of paper located below. During the shake, the base of the seismograph and the roll of paper move but not the weight, so that the pen draws squiggly lines on the paper, creating a record of the earthquake. This graph is called a **seismogram**.

We can use two different parameters to measure earthquakes:

- The **magnitude** of an earthquake tells us how much energy is released during a tremor.
  We use a 9-degrees scale (**Richter scale**) to measure the magnitude of an earthquake. On this scale, each number represents a release of energy that is 10 times more than the previous number.

- The **intensity** of an earthquake is determined by studying how much destruction it causes.
  To express intensity we compare the various levels of destruction caused by an earthquake with a 12-degree scale of descriptions (**Mercalli scale**). This scale is not very reliable because the destruction caused depends on factors like the quality of the constructions.



c) Danger of earthquakes

An earthquake is one of the natural disasters that can cause most death and destruction, mainly because they can provoke buildings collapse, landslides, floods, fires, etc. If the earthquake occurs under the sea floor, tsunamis can destroy coastal areas.

As it is extremely difficult to predict earthquakes, there are some measures to prevent earthquakes disasters. The main ones are:

- Elaborate earthquake risk maps that indicate areas of high risk.
- Build earthquake-resistant buildings.
- Develop civil protection programmes for catastrophic situations.
- Inform people about the measure they should adopt during and after an earthquake.

READING ACTIVITIES

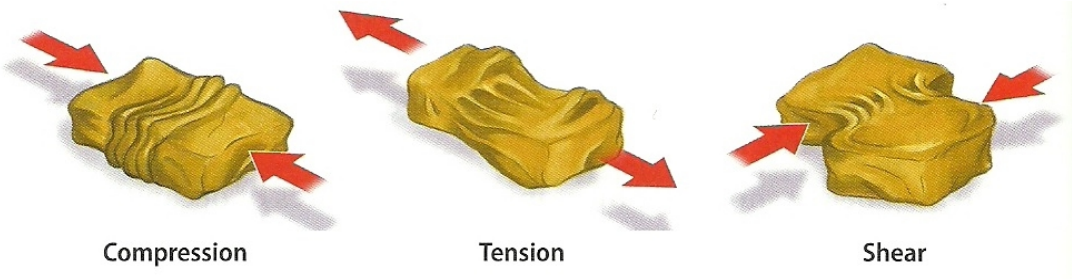
After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.3. Indicate the differences between:

a. Hypocentre - Epicentre
b. Magnitude of an earthquake - Intensity of an earthquake.

3.3. Rock deformation

Stresses inside the Earth can cause deformations in rocks. There are three types of stress: **compression, tension** and **shear.**



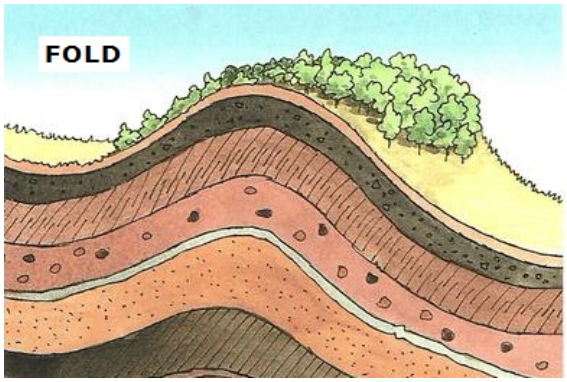
The type of deformation depends on the properties of the materials on which the stress act.

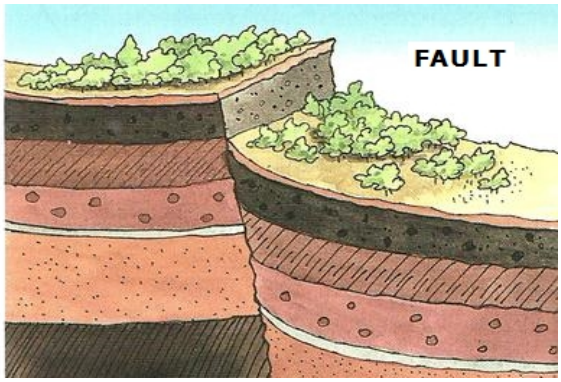
- Folds

A **fold** is a bend in the ground that is produced when plastic materials are compressed by stress in the Earth's lithosphere.

- Faults

A **fault** is a fracture in the rock caused by a displacement of the two volumes of rock either side of it. When the rocky blocks do not move, a **joint** is formed.

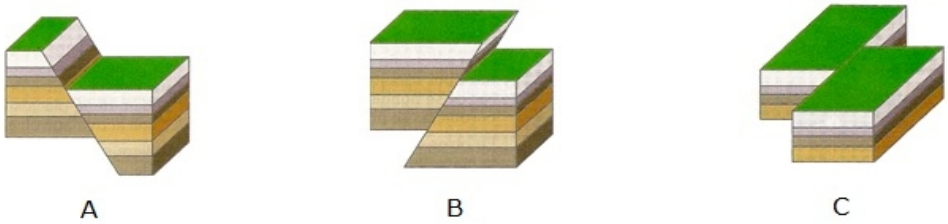




READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.4. There are several types of faults depending on what kind of stress causes them to form. Look at the pictures and indicate in each case the stress which has acted and indicate it with arrows.



3.4. Mountain ranges formation

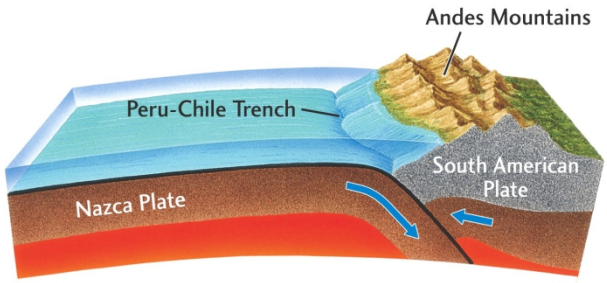
Mountain ranges or **orogens** are formed when two tectonic plates collide. The plates are subject to enormous pressure, which compresses the sediments deposited on the ocean floor between them and deforms the rocks provoking their rising up.

Earthquakes and volcanic activity are frequent in mountainous regions because mountains are formed where two tectonic plates meet.

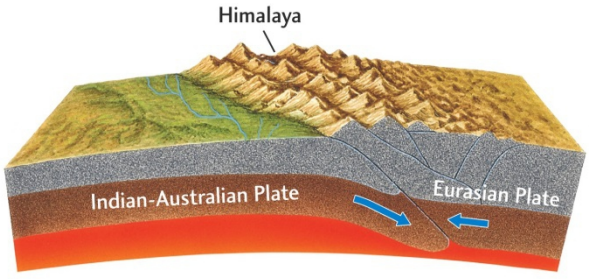
There are two types of mountain ranges:

- **Thermal orogens** are located in the margin of some continents, where a plate collides and sink below another (subduction zones). The marine sediments located on the subducting plate are folded and pushed up against the other plate. And this plate is also deformed and pushed up. This type of mountain range has an intense volcanic activity. (E.g. Andes)

- **Collision orogens** are located in the middle of a continent, where two plates collided and fused (obduction zone). This type of mountain range is much bigger than the thermal orogens and they do not have volcanic activity. (E.g. Himalayas)



Thermal orogen



Collision orogen

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.5. Indicate the differences between thermal orogens and collision orogens.