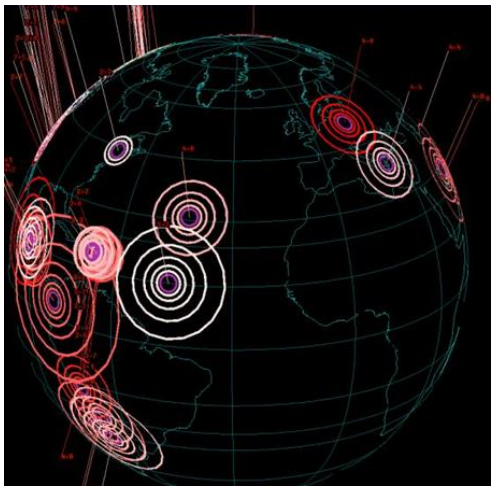
Earthquakes and tectonic plates

A lesson plan for junior high-school students (ages 12-14) in accordance with the Greek Science Curriculum

Introduction and orientation

(Provoke curiosity)

Observe carefully the following images:



Have you ever wondered what an earthquake is?

Have you ever experienced an earthquake?

Watch the following video of earthquakes happening all over the world:

http://video.nationalgeographic.com/video/earthquake-montage

Watch the following video on the Earthquake of San-Francisco in 1989:

http://www.history.com/topics/san-francisco/videos/mega-disasters-san-francisco-earthquake

Discuss your ideas concerning earthquakes.

How do you believe they are generated?

Define goals and/or questions from current knowledge

Definition:

An Earthquake is the shaking and vibration at the surface of the earth resulting from underground movement along a fault plane or from volcanic activity.

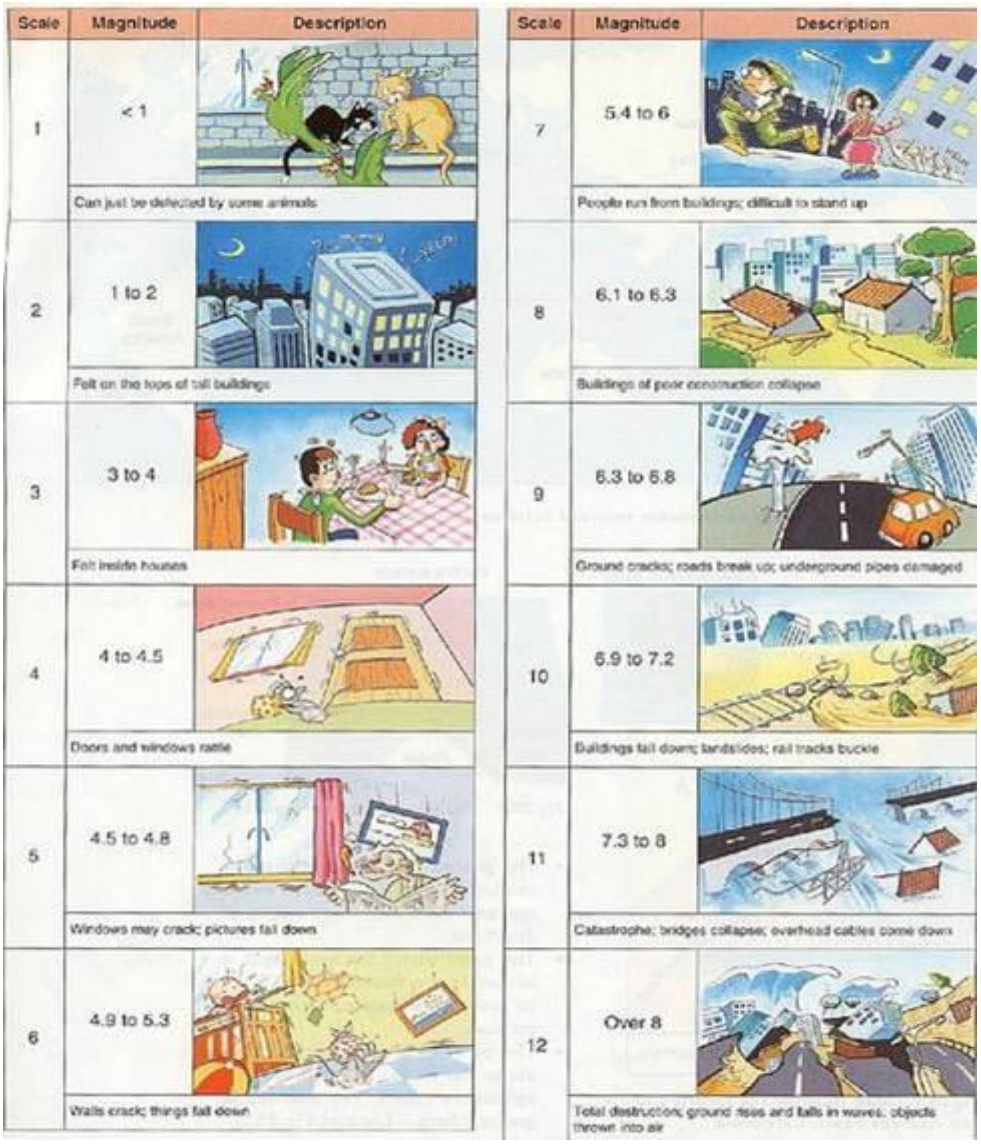
Earthquake Scales:

As we have seen, earthquakes can cause major destructions. In order to describe the severity of these destructions, scientists have invented the Richter and Mercalli scales.

The **Richter magnitude scale** is a measure of the energy released by an earthquake. The earthquake magnitude M ranges from 1 to 10, with 1 being equal to the vibration of the earth when a train passes by. When earthquake A has one unit more magnitude than earthquake B, this means that A is 10 times stronger than B, or:
A releases 31.6 times more energy than B!!

The **Mercalli intensity scale** is a measure of the observed effects of an earthquake to both natural and human environment.
The value of the Mercalli scale depends on the distance from the epicentre of the earthquake (a.k.a its source) and on the structure of the ground.

Look at the picture below and discuss the relations between the Mercalli and the Richter scales. In the picture, the term: Scale refers to Mercalli and Magnitude to the Richter scale.



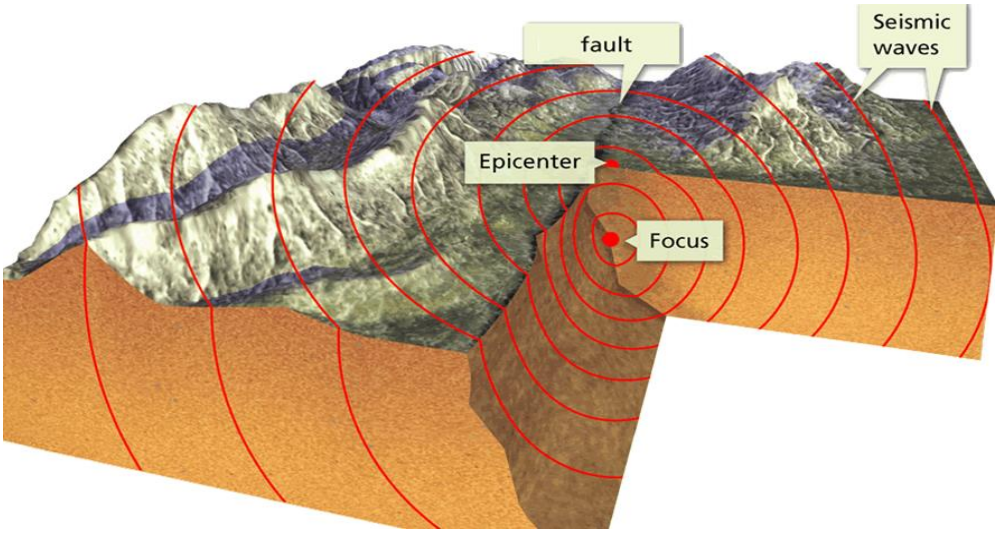
Scale	Magnitude	Description
1	< 1	Can just be detected by some animals
2	1 to 2	Felt on the tops of tall buildings
3	3 to 4	Felt inside houses
4	4 to 4.5	Doors and windows rattle
5	4.5 to 4.8	Windows may crack; pictures fall down
6	4.9 to 5.3	Walls crack; things fall down
7	5.4 to 6	People run from buildings; difficult to stand up
8	6.1 to 6.3	Buildings of poor construction collapse
9	6.3 to 6.8	Ground cracks; roads break up; underground pipes damaged
10	6.9 to 7.2	Buildings fall down; landslides; rail tracks buckle
11	7.3 to 8	Catastrophe; bridges collapse; overhead cables come down
12	Over 8	Total destruction; ground rises and falls in waves; objects thrown into air

<u>Activity!</u>

If you have experienced an earthquake try to find out what effects you observed on the Mercalli scale.
Then go to the previous picture and make an estimate of the Earthquake's magnitude in the Richter scale.
Compare your finding with the original reports from the news on the magnitude of the earthquake.
Was this method successful?

Fundamental Characteristics of Earthquakes

Observe the following picture: You can observe the seismic waves expanding from a source inside the earth.



This "source" of the seismic waves is the **Focus** (or hypocentre).

Now, let's draw a vertical line that starts from the focus and ends at the surface of the earth. The length of the line is called the "**depth**" of the earthquake. The point on the surface of the earth exactly above the focus is called the "**epicentre".**

Earthquake waves travel through and on top of the surface of Earth carrying huge amounts of energy and causing the shaking and vibrations on the ground.
Earthquake waves can travel hundreds of kilometres causing earthquakes to be felt a long way away from the origin.

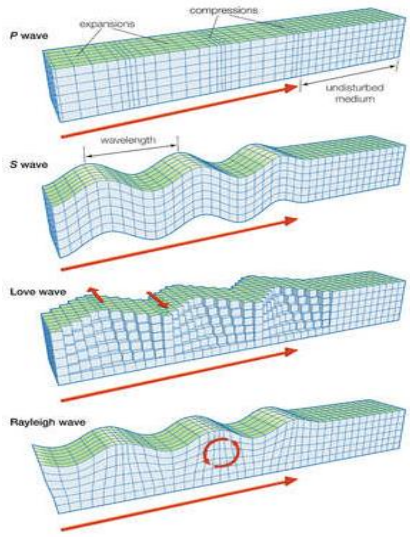
Types of Seismic Waves

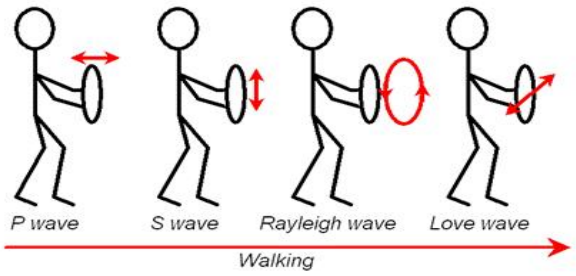
There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are **body waves** and **surface waves**. Earthquakes radiate seismic energy as both body and surface waves.

Body waves have high frequency and can travel through the earth's inner layers. They are divided in two categories: The P- Waves (P: Primary), which arrive first, and the S-Waves (S: Secondary) which arrive after the P- Waves. This time difference between P- and S- waves is one of the most prominent characteristics which is taken into account when we detect earthquakes.

Surface Waves have lower frequency than the body waves and arrive after them during the earthquake. They can only move along the surface of the planet like ripples on water. Surface waves divide in Love waves and Rayleigh waves and are responsible for the majority of destruction taking place during an earthquake.

Look at the pictures below:





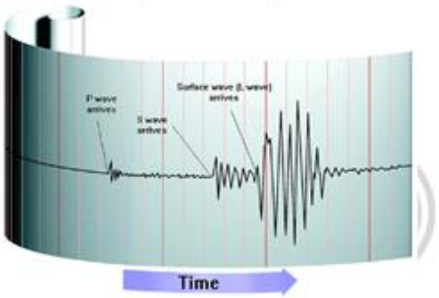
Can you describe the different kinds of motion that earth is being put into due to the different kinds of seismic waves? Can you replicate the waves using your body?

Detecting Earthquakes

In order to detect earthquakes, scientists use seismographs:

From the seismographs one gets the **seismogram**:

Sample Seismogram



Using the seismogram we can find the distance of the epicenter from our location. Combining seismograms placed at different locations we can identify the location of the epicenter.

Let's see how this is done:

This is how a seismogram is produced:
http://www.estium-concept.com/en/computer_graphics-geology_seismometerElect.htm

The seismogram can be used to find the epicentre distance from our station.

This is how we can locate the epicenter combining data from many stations:
http://www.estium-concept.com/en/computer_graphics-geology_epicenter.htm

General Remark: So far we have discussed the how's of the earthquake, but not the Why's. The basic definitions have been provided and a short overview of detection principles has been presented.
We have not given any leads as to why the earthquakes happen, as this is the body of the activity that will follow.

For more resources concerning the science behind earthquakes, you can visit the following link:
http://www.geo.mtu.edu/UPSeis/waves.html
http://authors.library.caltech.edu/51563/1/HKpt01.pdf

A more advanced activity for older students focusing on earthquake epicentre detection can be found here:
http://tools.inspiringscience.eu/delivery/view/index.html?id=0ab2173a003f40b48d1caf1639399aac&t=p

For further information concerning the earthquake epicenter detection, visit the following link:
https://www.youtube.com/watch?v=694yaY2ylTg

Generation of hypotheses or preliminary explanations

So far we have discussed the fundamental characteristics of earthquakes, but do we really know why earthquakes happen?

Suppose that you live in the middle of Siberia while a friend of yours lives in Italy or in Greece. Which of the two is more likely to experience an earthquake?

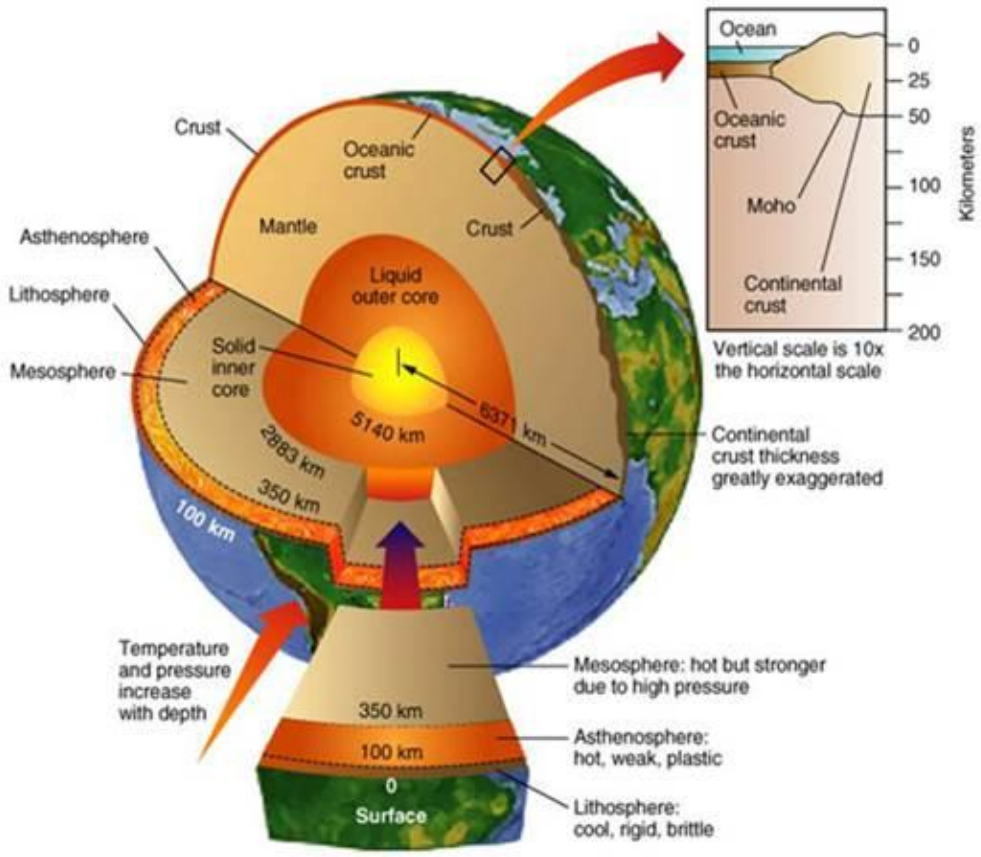
Back till the 60's, people knew that earthquakes and volcanoes tended to appear in certain parts of the world.
They knew for example the so called "ring of fire": a belt of going around the edge of the Pacific Ocean in which exist active volcanoes and there is strong seismic activity. The belt goes through New Zealand, Indonesia, Japan, Alaska and the North America.

On the contrary, places like Britain have neither active volcanoes nor strong seismic activity.

People assumed that the Earth's crust was ripped open along these "lines of weakness" for some reason allowing the molten rock from under the surface to pour out in volcanoes. The reasons for these cracks of the Earth were unknown. Maybe it was just chance. With this course of thought, a crack might appear anywhere in the world at any time creating volcanoes and producing seismic activity!

Discuss: What would you do in order to investigate the seismic activity with respect to geographic region?

Let's dive in the interior of the earth:



Discuss: Can you describe the interior of the earth? Observe the picture and think: Is the earth's interior uniform or does it have separate components? If so, can you name the components?

Of particular interest to us is the **Earth's Lithosphere**:
The lithosphere is the bedrock on which lay the earth's ocean (oceanic crust) and its continents (continental crust).
It is 50-100 km thick and manifests itself as the common ground between the upper mantle and the crust of the planet.

Without doubt, the earthquakes and the volcanic activity must be connected somehow with the structure of

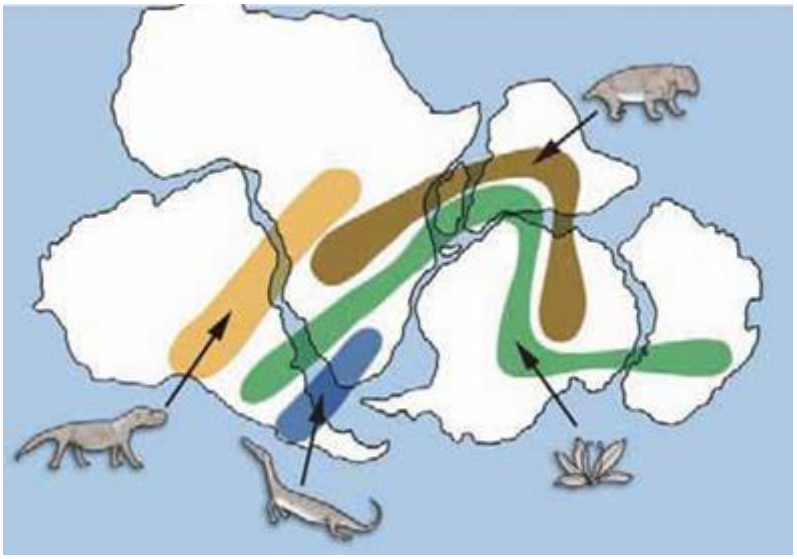
the lithosphere!!!

Let's check some clues coming from palaeontology:

Long research in this field has led the scientists with some striking conclusions. Let's summarize some of them:

- The shores of West Africa are very similar to the shores of South America
- Traces of Ancient vegetation existing in Africa were found in Europe
- Although there is no Volcanic action in Britain, volcanic rocks could be found in many regions, including North Wales and Scotland

Many observations like the one stated above, led the scientists to propose the theory of "Tectonic Plates".

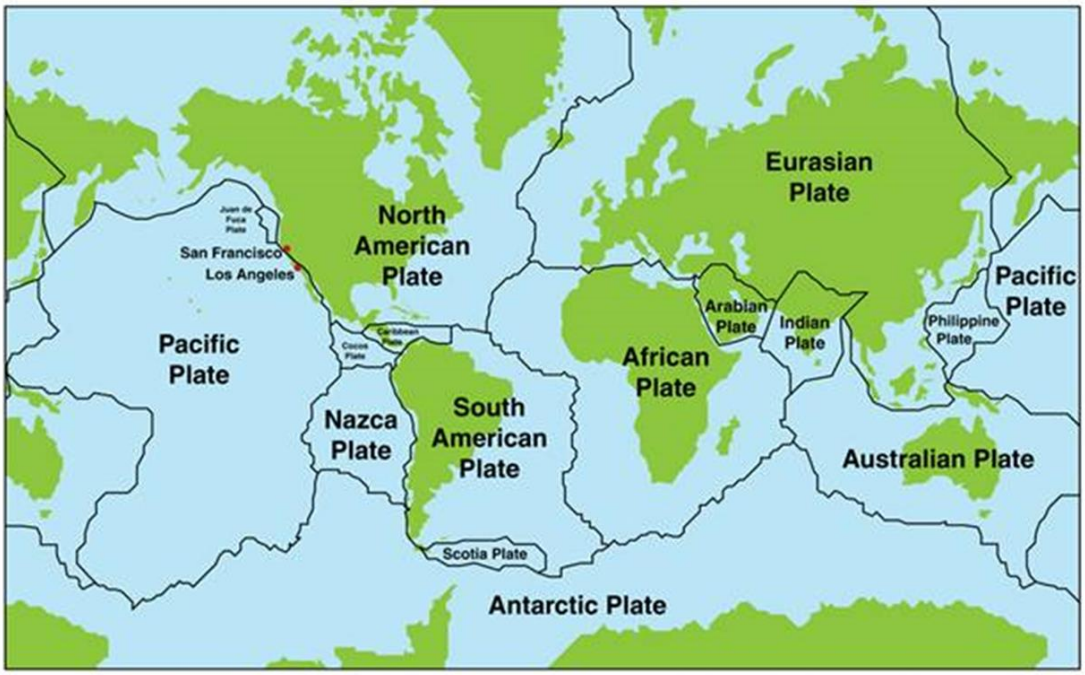


There is too much material concerning the field of plate tectonics online, a great collection of which can be found here;
http://pubs.usgs.gov/gip/dynamic/dynamic.html

However, this educational activity mainly focuses on the key points of plate tectonics and the correlations with earthquakes so we will constrain ourselves and mainly outline the definitions.

Design/Model

According to the theory of tectonic plates, first developed by Wegener, the earth's lithosphere is not uniform. On the contrary, it is broken in many parts, the "plates" which slide on the top of the upper mantle.



The plates are constantly moving with respect to each other and colliding.
This theory explains among others the multitude of geographical and palaeontological results in terms of continental drift, according to which the earth's surface has been subject to constant change due to plate collisions and drift.

What about the earthquakes though?

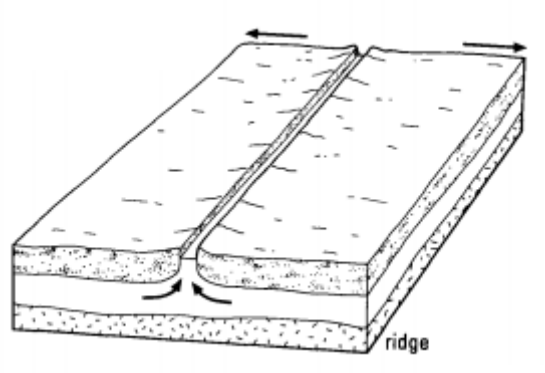
The Tectonic plate theory assumes that: very high tensions develop around the borders between plates and this is why Earthquakes happen!

Is this theory correct?
This is what we are about to find out in our activity!

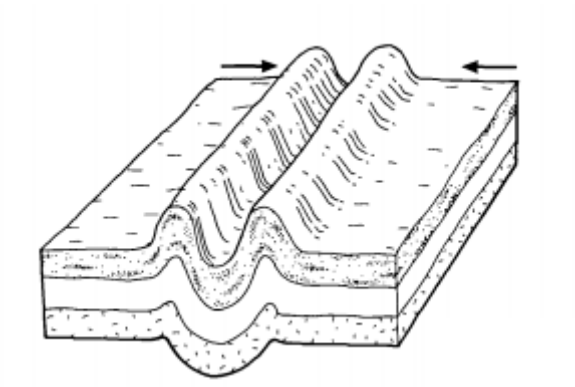
You could use this material to stimulate further discussion with your students:

<u>How do the tectonic plates collide?</u>

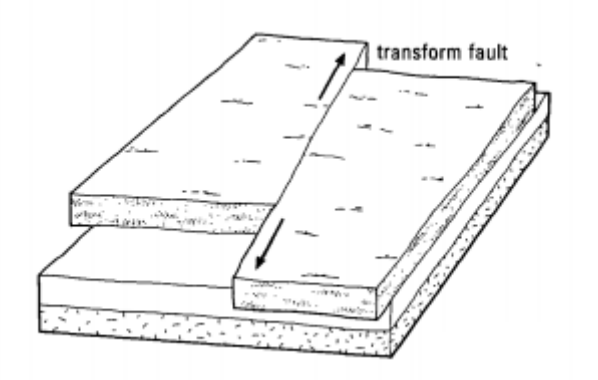
Where the plates drift apart from each other, a crack opens up allowing molten rock to flow out of volcanoes and fill the gap.



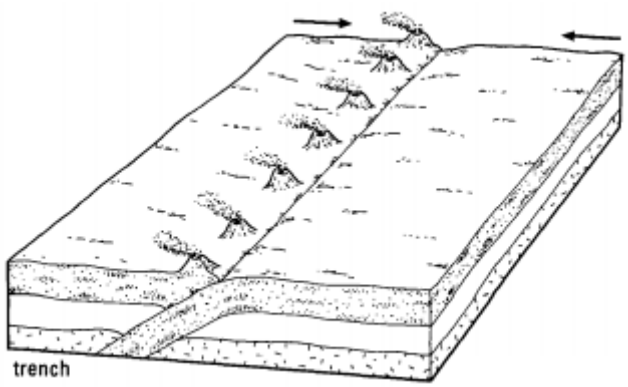
Sometimes the plates push up against each other, causing the rocks to buckle and fold up producing series of mountains. This is how the Alps and Himalaya were created!



In cases such as the San Andreas Fault in California, the tectonic theory supports that the plates push past each other as we can see below:

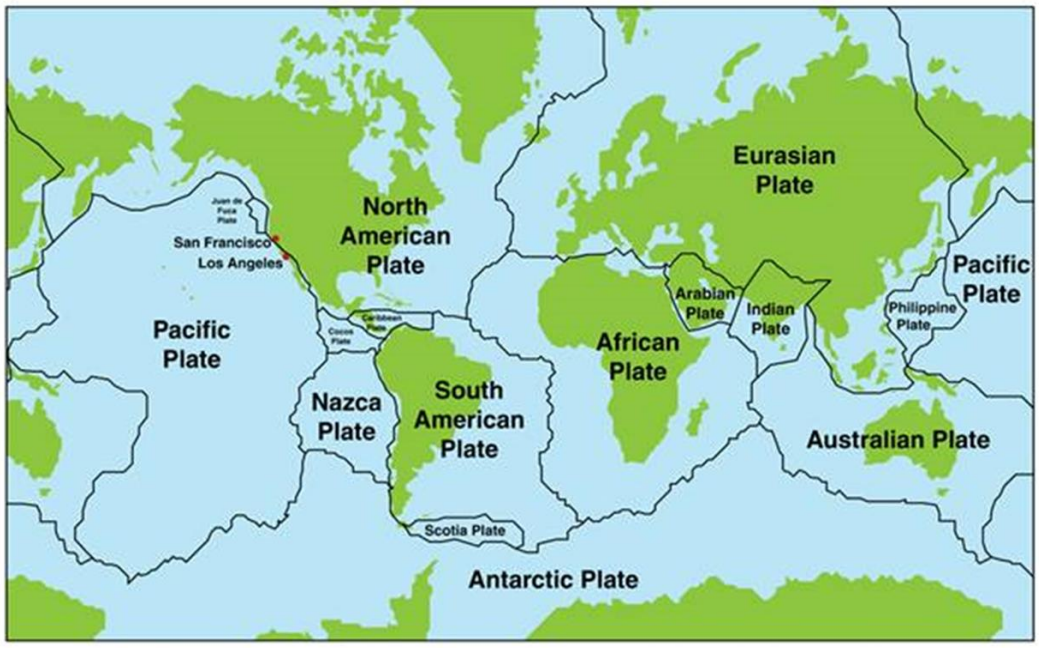


There are also cases such as the one illustrated below, that a plate is pushed below the surrounding plates and melts when it goes deep inside. This leads to extreme volcanic and earthquake activity and the creation of mountains as happens in Japan for example.



Plan investigation

In this part of your investigation, you will check the hypothesis of earthquake generation at the intersection lines of the lithospheric plates.
Look at the Map: You can see the lithospheric plates of the earth.
Try to find the countries where the lithospheric plates meet.

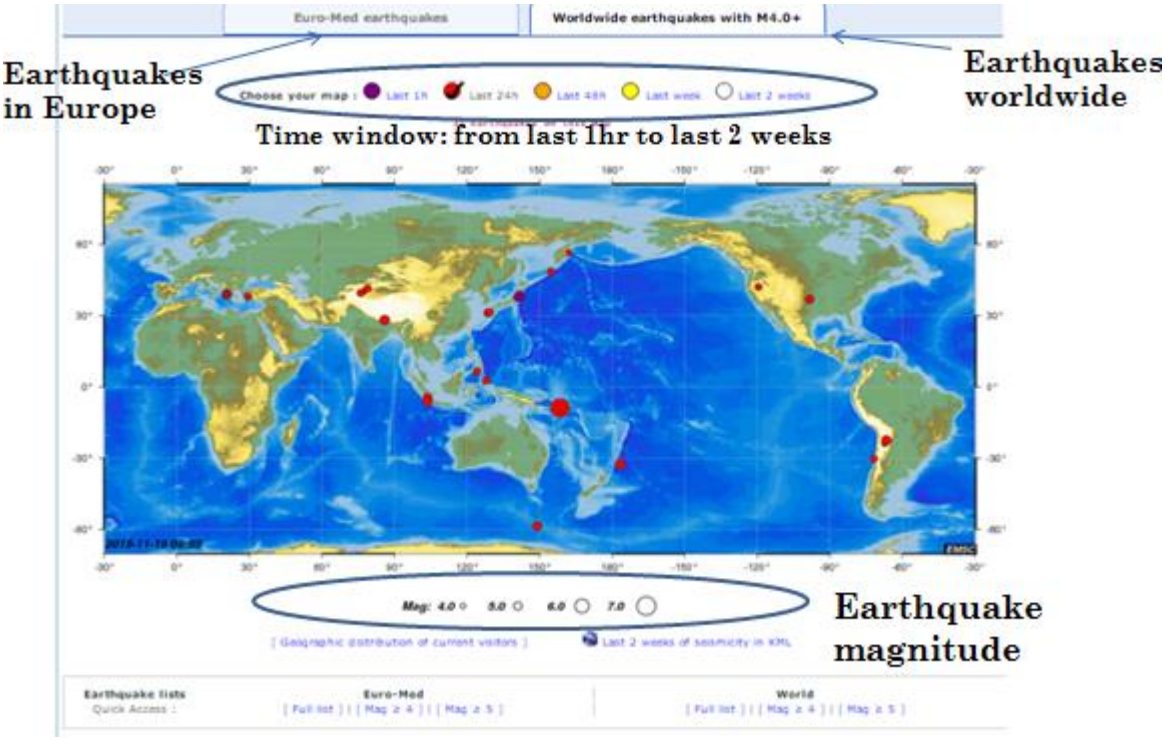


Name the countries that, according to the map on the previous slide, are expected to be more frequently subject to earthquakes.
What do you think about Australia, Russia, Philippines, Nepal, and Turkey?
Discuss with your classmates.

Perform investigation

Now, let's visit this link:
http://www.emsc-csem.org/#1w

Here we can see a list of earthquakes on an interactive map. The list is updated every hour. Each circle represents an earthquake.



- Start from the European map and observe the listed earthquakes. Choose your maps starting from the map which shows the earthquakes 1hr ago up to two weeks ago.
- You can click on each "circle" to see the exact magnitude, location, date and depth of the earthquake.
- Find the most seismic (with the highest rate of earthquakes) location in Europe. Find the magnitude of the strongest earthquake so far.
- Repeat the same steps for the world map.
- Now, shift the world map to the 2 weeks option.
- Observe the distribution of earthquakes.

- Compare your results with map 1 which presents the tectonic plates.

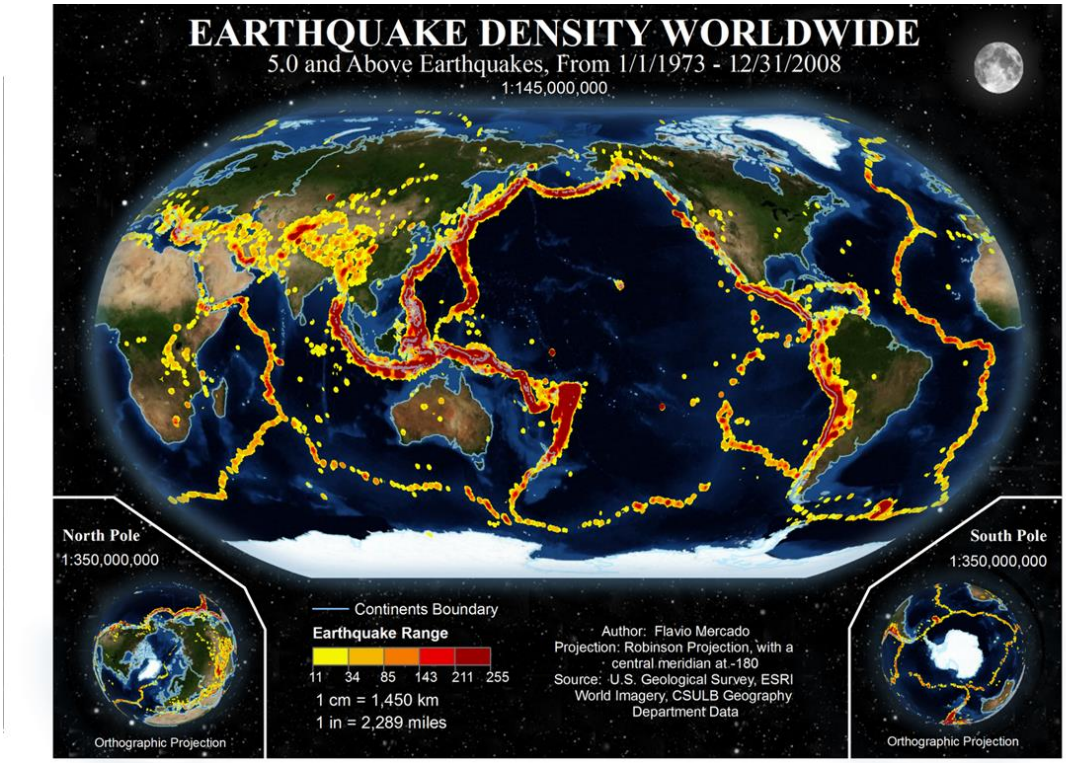
  Do you observe any correlation between the two maps?
  Discuss with your classmates.

Now, what do you think about Australia and Russia as compared to Philippines and Greece?

Can you explain the differences in seismicity between these countries?

Analysis and Interpretation: Gather result from data

Observe the Earthquake World Map from 1973-2008. Compare the map with the tectonic plate map in the previous section and with your findings from your investigation. Is the theory of Earthquake generation due to plate collision at the boundaries between plates correct?



Conclude and communicate result/explanation

Have you been convinced about the validity of the tectonic plate theory?

As a project you can search online for evidence concerning the validity of the theory and its implications for other branches of science such as palaeontology.

Watch the following video to summarize what we have learnt so far:
https://www.youtube.com/watch?v=PwtFuG_M4EE

Evaluation/reflection

Discuss your findings and make a short presentation concerning the generation and distribution of earthquakes.

Which places on earth are in greater danger due to earthquakes?

Precaution and Safety During an Earthquake

Earthquakes are destructive, and most of the times unpredictable. In order to protect ourselves from them, there are specific measures that we must take, both as countries and as individuals:

Check the following video to see a test concerning an anti-seismic building:
https://youtu.be/-N_Q6Q-3o7M

Once we know how catastrophic an earthquake can be for the environment, let's see what we should do in case an earthquake happens:
http://www.earthquakecountry.info/dropcoverholdon/

Check this video out and see how one should deal with earthquakes while at school:
https://www.youtube.com/watch?v=bAHNhtRT50A

This part of the activity can be easily connected with precaution tests for earthquakes at your school.