

## What is an earthquake?

The origin of seisms is almost every time the same: a sudden break of rocks at a point named focus (or hypocentre) which, very often, is located in the first hundred kilometres of the external layer of the Earth. (The place directly above the focus on the surface of the Earth is called epicentre.) This break happens where there is a fault in an area where the Earth's crust undergoes tectonic constraints (slow movement of one hard block regarding to another). Slowly, the rocks bend as a plastic ruler does in your hands. When the ruler breaks, energy is suddenly released: the sides of the faults are rubbing against each other so that energy dissipates first as heat, then as vibrations, seismic waves, that propagate in all directions from the focus.

## Earthquake and Tsunami near Sendai, Japan

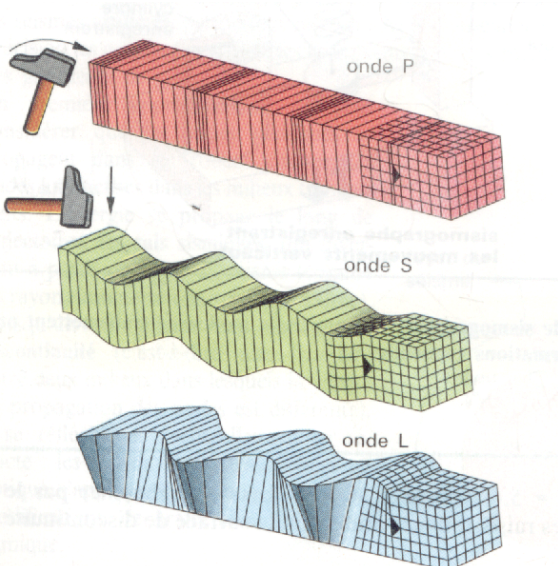
A strong earthquake took place on Friday, March 11<sup>th</sup>, 2011 off the coast of Sendai (north-east of the island of Honshu, Japan) at 14:26 local time (6:46 French time). The epicentre was 130 kilometres (80 miles) east of Sendai, and 373 kilometres (231 miles) northeast of Tokyo. According to the U.S. Geological Survey (USGS), the earthquake occurred at a depth of 24.4 kilometres (15.2 miles) beneath the seafloor. The powerful earthquake with a magnitude of 9.0, caused extensive direct but also indirect damage because of the ensuing tsunami. There were at least 15,000 victims. Incidents on several nuclear reactors affected by the earthquake and tsunami have created an additional risk. The situation remains tense around the Fukushima nuclear power plant where high levels of radiation have been recorded. The 9.0 value of the magnitude indicates that this was an extreme event, even stronger than the earthquake of Conception, Chile in February, 2010 (magnitude 8.8). Combining the location of the seismic focus and the knowledge of the geodynamic context (Pacific plate subducting under Japan), scientists have deduced that the displacement corresponds to an overlap.

from <http://earthobservatory.nasa.gov>



## Seismic waves

Earthquakes, complex phenomena, can be explained by the propagation of waves which can be described as follow:



D'après C. Allègre « Les fureurs de la Terre ».

- **The primary waves or P waves** (pressure waves)

They correspond to a succession of compression and expansion of matter. They are the fastest.

They can move through both solids and fluids (in the atmosphere as well). They are at the origin of the muffled growling that can be heard at the beginning of the seism.

- **The secondary waves or S waves** (shear waves)

They can travel through the solid of the mantle but not through the liquid of the outer core because the liquids can't be subjected to shearing.

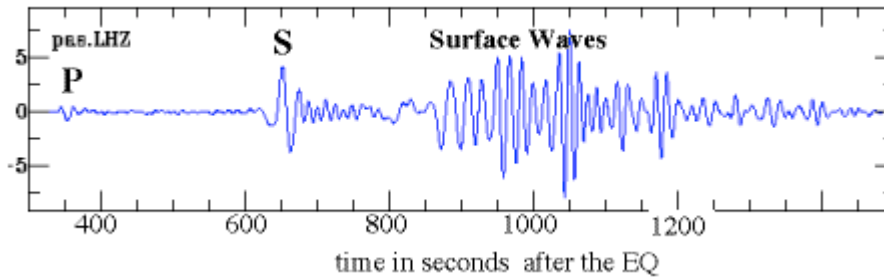
*P and S waves propagate inside the globe.*

- **The Love waves or L waves** (surface waves)

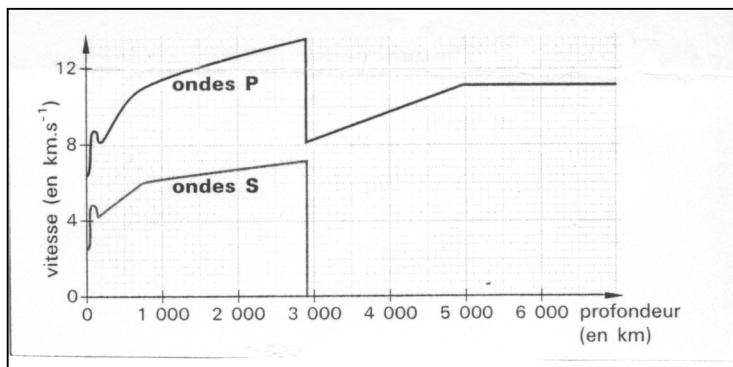
They correspond to very complex distortions of the ground. Contrary to the two former ones, these L waves are guided by the upper layers of the globe. They will arrive last but do the most damage because of their wide amplitude.

*S and L waves are the most destructive.*

After an earthquake, the shaking of the Earth's crust recorded by a seismograph shows a complex graph: the latter corresponds to the successive inscriptions of influxes of waves which have travelled, along the globe, following varied routes, and which have crossed, more or less quickly, areas with different features. Analysing these graphs enable to define the three major types of waves.



The speed of the S and P waves inside the globe is given in this graph as a function of the depth:



## QUESTIONS

### I. Earthquake description (justify your answers using the documents)

- 1- What is the geological origin of earthquakes?
- 2- What are the effects of an earthquake? In which order are they perceived?
- 3- What can be said about these effects when we move away from the focus of the seism?
- 4- The seismogram enables to determine the evolution in time of a feature. What is this feature? (Choose between the following proposals: energy, period, power, displacement, frequency, speed) Why does it vary?
- 5- All the earthquakes don't have the same impact in a given place. Find the initial conditions this impact depends on.

### II. Building models using mechanical waves

- 1- Using a rope, which type of seismic waves can you easily build a model of?
- 2- Using a spring, which other type of seismic waves can you easily build a model of?
- 3- Describe the motion of one point of the rope or the spring located on the route of each wave (you can draw a diagram if you need).
- 4- Is there any matter carried between the focus and the impact area? Why do we speak about the propagation of a disturbance?
- 5- Compare the orientation of the propagation with the one of the distortion for the two types of wave you have built a model of.
- 6- Associate to each of these types of wave its model (rope or spring) and the correct qualifier (longitudinal or transverse).
- 7- For a same type of wave, on which parameter(s) does its speed depend on?

#### Longitudinal vs transverse

In a longitudinal wave, the distortion displacement is parallel to the orientation of the wave propagation.

In a transverse wave the distortion displacement is perpendicular to the orientation of the wave propagation.