

## The study of earthquakes

- An earthquake is a very frequent phenomenon in time, but localised in space. *Seismic* events are concentrated inside **seismic belts** that define the limits of **aseismic areas**.
- An earthquake is manifested as a more or less strong movement of a sector of the Earth's surface as a result of the sudden release of energy from a point within the Earth, called the **focus** or **hypocentre**.
- Ongoing forces within the Earth cause the elastic deformation of rock bodies. If these forces exceed breaking point, the rocks are fractured and a **fault** is

created (or reactivated). An earthquake occurs along the surface of a fault when deformed rocks abruptly return to equilibrium through the mechanism of **elastic rebound**, characterised by violent oscillations. This perturbation propagates in the surrounding areas.

- The process of elastic deformation of the rocks, up to the breaking point, and the successive elastic rebound, collectively constitute the **seismic cycle**, which can be repeated systematically in a region.

## Propagation and recording of seismic waves

- Throughout the manifestation of elastic rebound the perturbation propagates from the hypocentre in every direction by means of elastic waves. The area on the surface located vertically above the hypocentre is called the **epicentre** of the earthquake.
- An earthquake generates elastic waves of three types:
  - **longitudinal waves** (or **compressional waves**) – as they pass, a rock undergoes contractions and expansions in the same direction as the wave propagation. They are the fastest waves and are therefore also known as **P-waves** (from the Latin *Prima*, meaning *first*).
  - **transverse waves** (or **shear waves**) – as they pass, a rock oscillates transversely to the direction of wave

propagation. They are slower and are therefore also known as **S-waves** (from the Latin *Secundae*, meaning *second*). S-waves do not propagate in fluids.

- **surface waves** are generated when the inner waves (P and S) reach the surface of the Earth. They travel on the surface but rapidly diminish in depth. There are two types of surface waves: **Rayleigh waves** (or **R-waves**) and **Love waves** (or **L-waves**).

- Movements of the ground during an earthquake are collected by **seismographs** and recorded in charts called **seismograms**. From the collected data information can be extracted, such as the duration and the “strength” of an earthquake, the location of the epicentre and hypocentre etc.

## The “strength of an earthquake”

- The “strength” of an earthquake is evaluated in terms of intensity and magnitude.
- **Intensity** is the evaluation of the effects produced by a seismic event on people, objects and territory. The scale used in Europe and America to evaluate the intensity of seismic events is the **MCS scale** (Mercalli- Cancani-Sieberg), divided into 12 degrees.
- The values of intensity are also used for cartographic representations of the effects of an earthquake. **Isoseismal lines** are the lines that identify the boundaries of the bands in which earthquakes occur with equal intensity.
- **Magnitude** measures the strength of an earthquake compared to a standard earthquake taken as a reference. It is calculated from the seismograms by measuring the maximum amplitude of the waves recorded by a seismogram, relative to the maximum amplitude of the waves recorded for a reference earthquake. The reference

earthquake is one that produces, on a standard seismograph located 100 km from the epicenter, a seismogram with maximum amplitude equal to 0.001 mm. The scale of magnitude (**Richter scale**) is logarithmic: an increase of one unit of magnitude corresponds to an increase in size of ground motion by a factor of 10.

- At present, different scales for the measurement of magnitude are in use: **mb** for body waves; **MS** for surface waves; and **MW** for moment magnitude.
- **Strong motion and acceleration.** Earthquakes cause destruction in several ways. The primary hazards are the breaks in the ground surface that occur when faults rupture and the ground shaking, caused by seismic waves, radiated during the rupture. The **ground accelerations** near the epicenter of a large earthquakes can approach and even exceed the acceleration of gravity, so an object lying on the surface can literally be thrown into the air.

## Effects of an earthquake

- The arrival of seismic waves on the surface causes a complex oscillation of the ground, which is transmitted to overlying objects.
- The main damage to buildings is caused primarily by horizontal movements of the ground and depends on several factors:
  - ground accelerations,
  - duration of the ground motion,
  - type of construction,
  - geological nature of the land on which they rest.

- If an earthquake occurs beneath the seafloor, in coastal areas the effects of a **tsunami** may be felt. When the movement of the fault causing the earthquake abruptly raises or lowers the seafloor, the resulting oscillation of the mass of overlying water results in very long waves propagated at very high speeds. When the waves approach the coast they can reach 30 m in height.

## Earthquakes and the Earth's interior

- The study of the propagation of seismic waves enables information about the internal structure of the Earth to be obtained. The planet is made up of concentric layers separated by **seismic discontinuities**, through which the waves abruptly change speed.
- Three principal layers are identified:
  - the **crust**, which extends from the surface to a depth of 10–35 km. It appears solid and is separated from its underlying layer by the Mohorovičić (or Moho) discontinuity;
  - the **mantle**, extending from the Moho up to about 2,900 km in depth. It is solid, although there is a low-velocity layer (between 70–250 km in depth), called the **asthenosphere**, which displays a more plastic behaviour. At the base of the mantle there is the **Gutenberg discontinuity**, which separates the mantle from the successive layer;
    - the **core**, which is divided into the **outer core**, liquid (from 2,900–5,170 km in depth) and the **inner core**, solid (from a depth of 5,170 km to the centre of the Earth).
- The crust and the outermost zone of the mantle down to the asthenosphere form the rigid **lithosphere**.

## Geographical distribution of Earthquakes

- The geographical distribution of the epicentres of earthquakes are aligned according to defined bands.
- **Seismic zones** correspond to specific structures of the Earth's surface:
  - **Ocean ridges**, characterised by earthquakes with surface hypocentres;
  - **Ocean trenches**, with hypocentres aligned along the **Benioff-Wadati zones**, from the Earth surface to a maximum depth of about 700km;
  - **Mountain ranges** of recent formation, with hypocentres from the surface to intermediate-depth (70–300km).
- In addition, there is a volcanism -related seismicity. Volcanic earthquakes (**tremors**) are ground vibrations produced by the movement of rising magma within the crust and the volcanic vent.
- Coupling *World seismicity map* and seismic data (intensity, frequency and so) from historical earthquakes resulted in a *World seismic hazard map*, which describes the intensity of seismic shaking and ground disruption that can be expected over long term at some specified location (in PGA, *Peak of Ground Acceleration*).

## Defense against earthquakes

- Knowledge of seismic events is a prerequisite for defense against **seismic hazard**.
- The most common approaches for the prediction of earthquakes include:
  - **deterministic prediction**, which analyses the **precursory phenomena**, that is the events that are expected to precede an earthquake;
  - **statistical prediction**, based on the study and identification of seismic zones and the frequency with which earthquakes occur in these areas. Basic tools for statistical prediction are the **seismic catalogues**, which contain the characteristic data of all the earthquakes that have been reported or for which an instrument record is available.
- In all areas at risk, **prevention** of seismic hazard is essential. This can be achieved by various measures including the construction of earthquake-resistant buildings, education of the population, etc.