STRUCTURE AND COMPOSITION OF THE EARTH

UNIT 1

1. Direct methods for studying the inner of the Earth.
   - 1.1. Geological exploration (geological maps)
   - 1.2. The mines
   - 1.3 Geological survey
2. Indirect methods: geophysical prospecting..
   - 2.1. Seismic method
   - 2.2. Gravimetric method
   - 2.3. Magnetic method
   - 2.4. Electric method
   - 2.5. Geothermal method
   - 2.6. Meteorite study
3. Models of the internal structure of the Earth.
   - 3.1. Geochemical model of the structure of the Earth. 3.2. Geodynamic model of the Earth's structure.

BIOLOGY AND GEOLOGY 4ºE.S.O.

GEODESY: part of the geology that studies the origin of the Earth, its layered structure and the materials from which it is formed.

- Antiquity: the interior is equal to the surface.
- 18th century: for the count of BUFFON the interior is homogeneous and glassy.
- 19th century debate between: "solidists" for whom the interior is solid and cold and "fluidists" who considered the interior to be hot and liquid.

1. DIRECT METHODS FOR STUDYING THE INNER OF THE EARTH

The structure and composition of the Earth can be studied through study methods that can be direct and indirect.

✔ Direct methods are based on the direct collection of materials for further study. They can be by:

- collection of samples in geological exploration,
- the mines
- Drillings holes

With them we can only explore the superficial part of the Earth

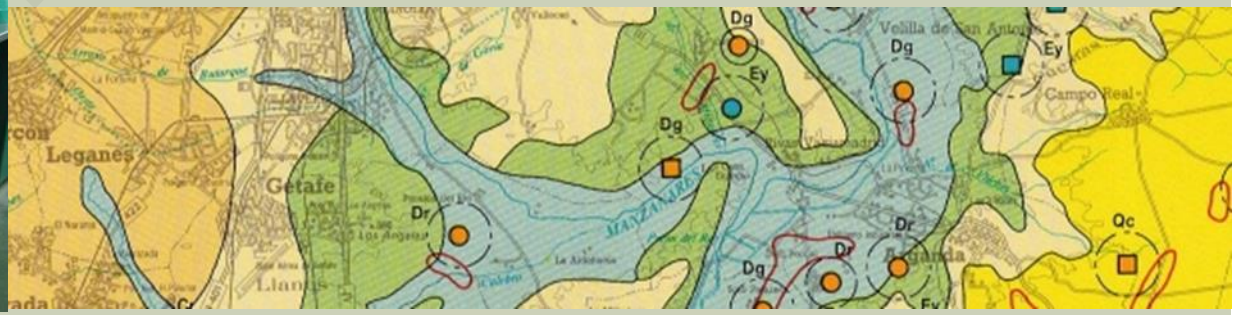
1.1. GEOLOGICAL EXPLORATION

Samples are taken on the surface and outcrops (slopes, volcanoes) of rocks and minerals and analyzed in the laboratory.

From this we obtain information from:

- type of material,
- provision,
- structure,
- age...

Then geological maps are produced where this information is reflected.



1.2. THE MINES

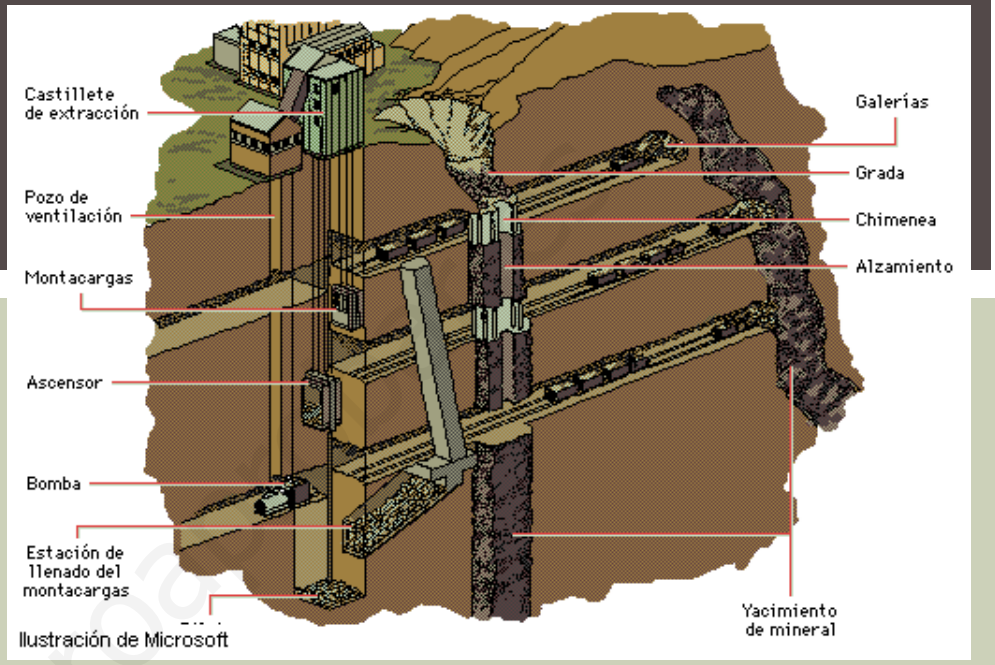


Ilustración de Microsoft

- They are excavations in the subsoil.
- Types: underground (wells and galleries) or open- pit mining.
- We can reach up to 3 km deep.

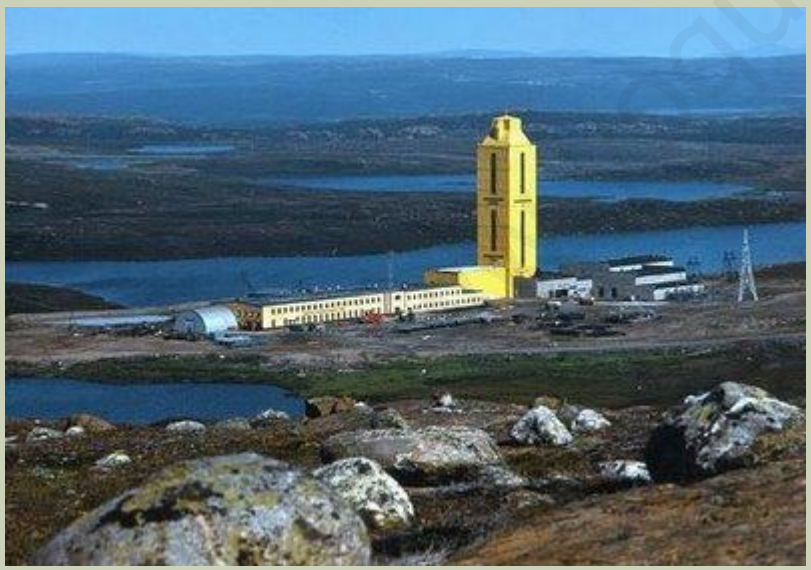
Investigate what the "Big Hole" is and where it is located https://www.youtube.com/watch?v=zz6v6OfoQvs

1.3. GEOLOGICAL SURVEY *(sondeo)*

A survey is a drilling of the ground.

- By opening very small holes (60 cm)
- Using augers or probes. (barrenas o sondas)
- A column of material is obtained (up 12'5 km) and it is called control. (testigo)

Península de Kola (1970-89-crust)



Mohole proyect (1957-moho)⇒ Perforadora JOIDES (2012-manto)

2. INDIRECT METHODS FOR THE STUDY OF THE EARTH

Direct methods do not allow us to know the interior of the Earth, for it we must use indirect methods such as:

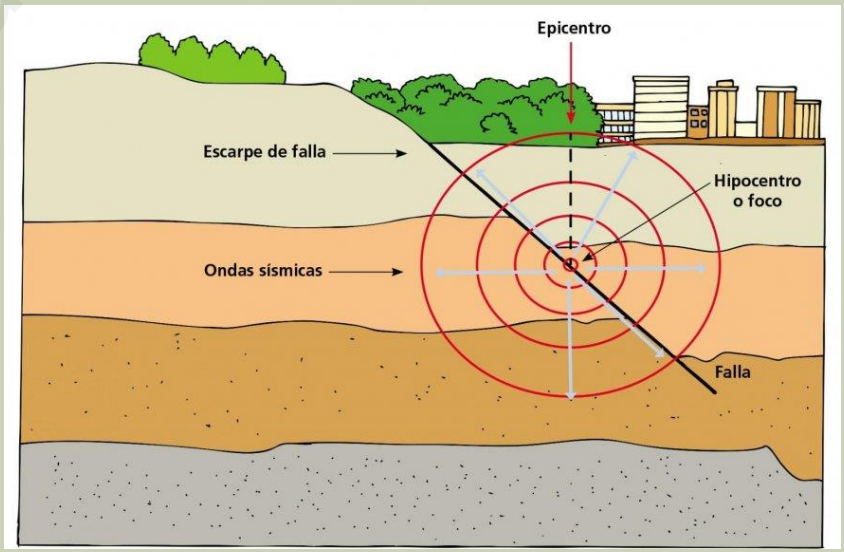
- ✔ seismic method,
- ✔ gravimetric, magnetic,electric and geothermal methods.
- ✔ meteorite study

2.1. SEISMIC METHOD

EARTHQUAKE:

Earthquakes are the vibration of the Earth by a fast release of energy.

- THEY ARE PRODUCED: generally due to breakage of the rocks causing failures or displacements of the rocks on a plane of pre-existing failure.
- ELEMENTS:
  - Hypocenter or focus.
  - Epicenter: surface point on the hypocenter
  - Seismic waves: they are originated in the hypocenter and are transmitted to all directions.



ORIGIN AND PROPAGATION OF AN EARTHQUAKE:

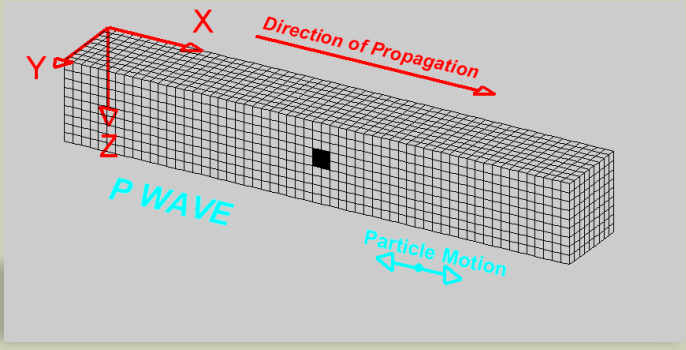
- They are originated as a result of forces acting on the rocks,
- These forces can be so powerful that they deform the rocks,
- If they persist they can cause them to break into blocks that move between them.
- The break releases accumulated energy and causes a vibration movement that ends when the deformed rocks return to their starting position, the "elastic rebound" according to Reid. These vibrations are the earthquake and energy is propagated by seismic waves.

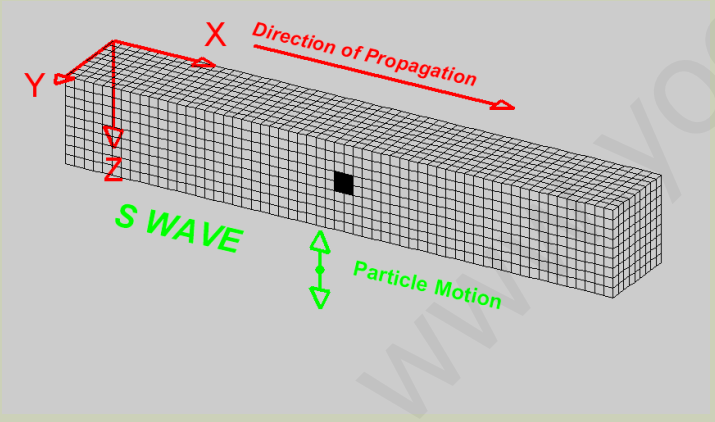
The break begins at one point, the focus or hypocenter, and extends throughout a plane of failure. From there, seismic waves move in all directions.

Before the main earthquake there are usually small shocks, *precursor earthquakes.* The adjustments that follow the main earthquake often generate shorter earthquakes called *replica earthquakes*. In both cases their hypocenters are also located in the same fault plane.

SEISMIC WAVES:

- The energy released in an earthquake is transmitted through of seismic waves.
- They are transmitted in all directions.
- When the are moving from one state to another with different rigidity: they differ, refract, change speed or diffract. *This allows us to study the interior structure of the Earth.*



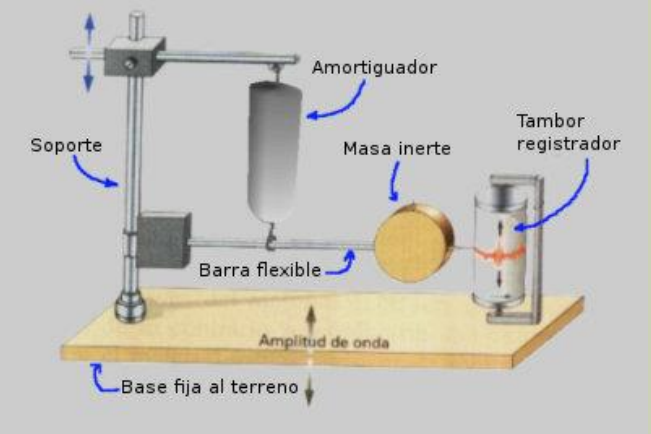


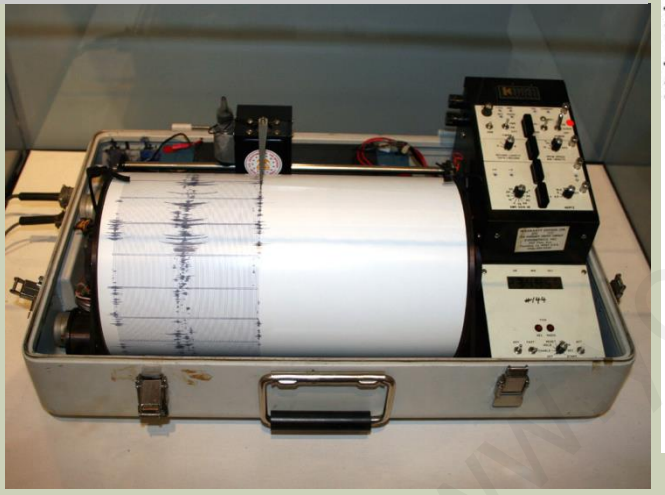
There are three types of waves:

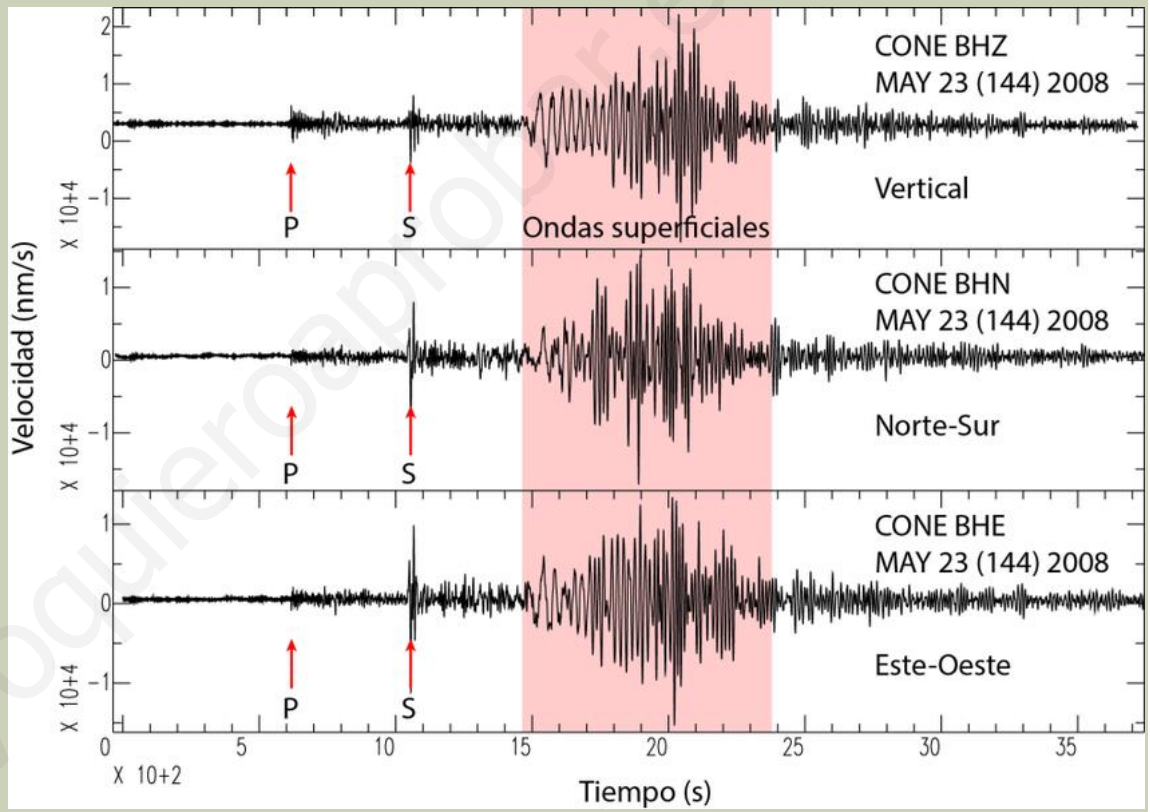
- **PRIMARY OR P WAVES**:
  - They are the first to be detected.
  - The vibration occurs in the same direction of propagation.
  - They are compression and decompression waves.
- **SECONDARY OR S WAVES:**
  - They are the second to be detected.
  - The vibration occurs perpendicular to the direction of propagation.
  - Its speed is less than that of the P waves.
  - They are not transmitted in liquids.
- **SUPERFICIALS:**
  - They are generated when the s waves reach the surface. They form and propagate from the epicenter.
  - They are only transmitted by the earth's surface. They have no interest for the study of the interior of the Earth.
  - They are the cause of seismic disasters.

DETECTION OF A SEISM;

Seismic waves are detected with **seismographs** in seismological observatories and recorded in graphs called **seismograms.**







The IMPORTANCE of an earthquake depends on:

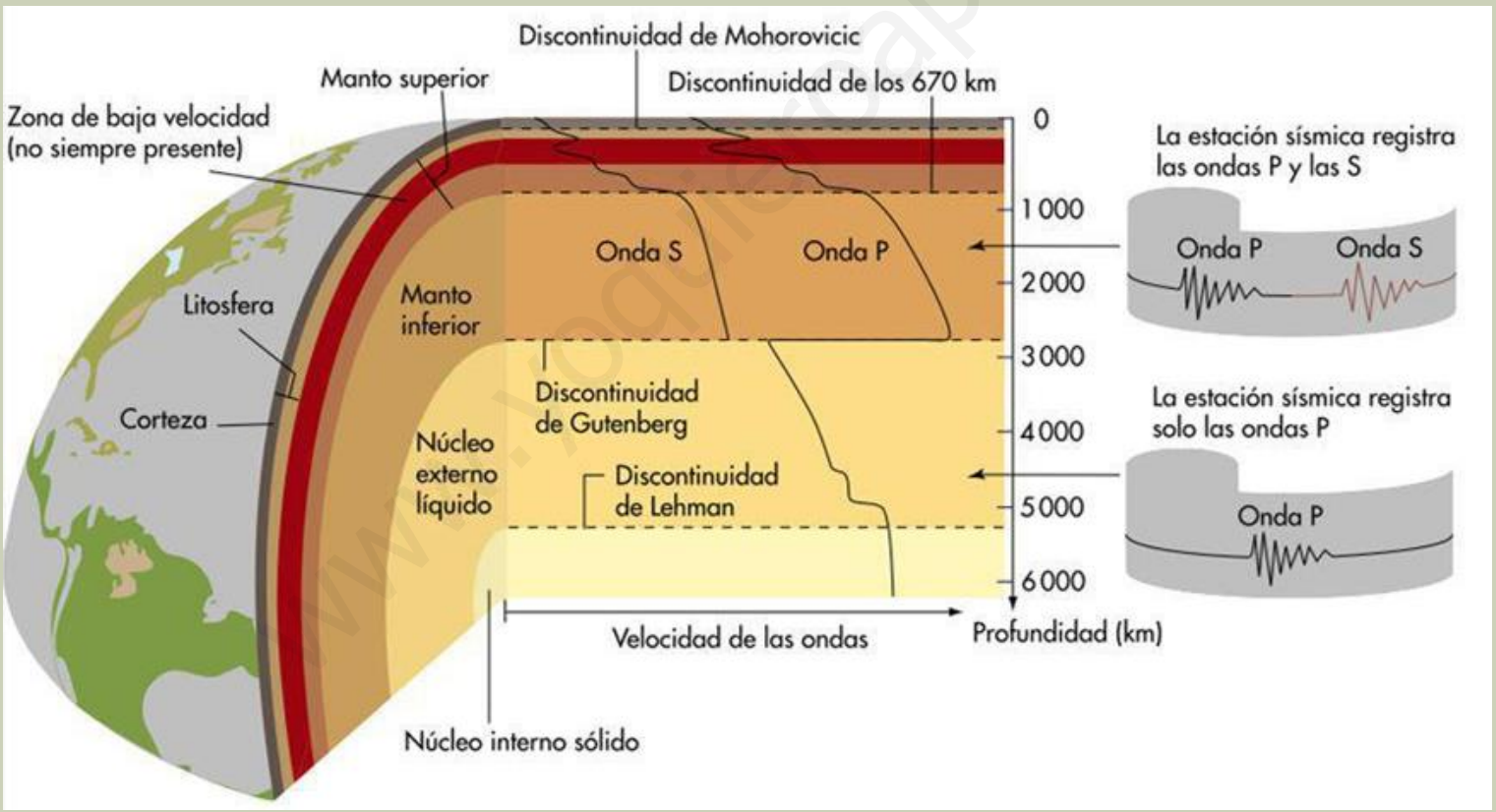
- **MAGNITUDE:** It is the amount of energy released and is measured with the "Richter Scale".
- **INTENSITY**: it indicates the superficial effects, so the devastation and damages produced. The most used is the "Modified Mercalli Scale".

GRAPHICS OF THE SEISMIC WAVES:

- DATA TO TAKE INTO ACCOUNT:
  - Speed increases when idensity / stiffness increases
  - S waves do not travel by liquid medium..

  GRAPHICS
  - They represent speed / depth.
  - Sudden changes produce jumps in the graph that are called *discontinuities*.
  - Discontinuities indicate changes in the composition of the Earth.

- DATA:
  - 30-70 km Mohorovicic discontinuity ⇒ Crust - Mantle.
  - 670-1,000 km separation upper and lower mantle
  - 2,900 km Gutenberg discontinuity ⇒ Mantle-External core.
  - 5,000 km According to Jeffrys .... Wiechert-Lehman discontinuity ⇒ External-internal core



SEISMIC METHOD WITH CONTROLLED EXPLOSIONS:

UTILITY: Search for minerals, oil ...

METHOD:

- Small controlled explosions are caused at shallow depth.
- The waves are reflected and refracted as they pass through the different subsoil materials.
- They are detected in **geophones** located in nearby areas.

The arrival times of the different waves give us an idea of the structure and density of the materials they pass through.

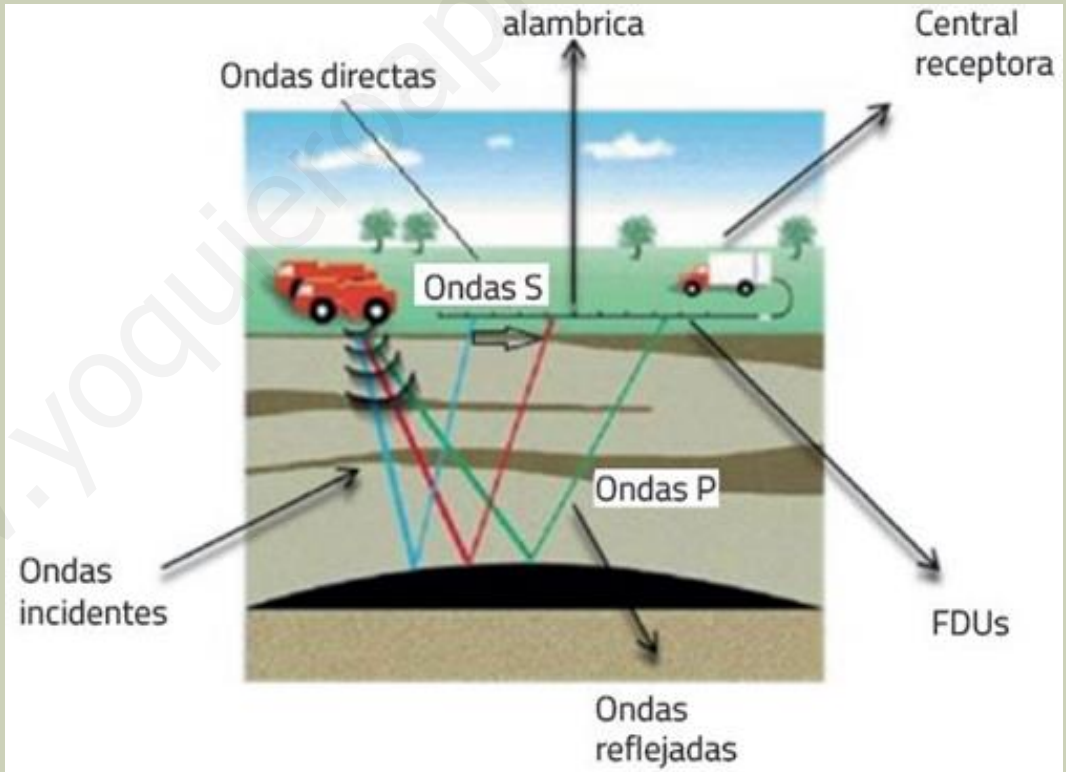


Figura 1. Prospección sísmica por reflexión.

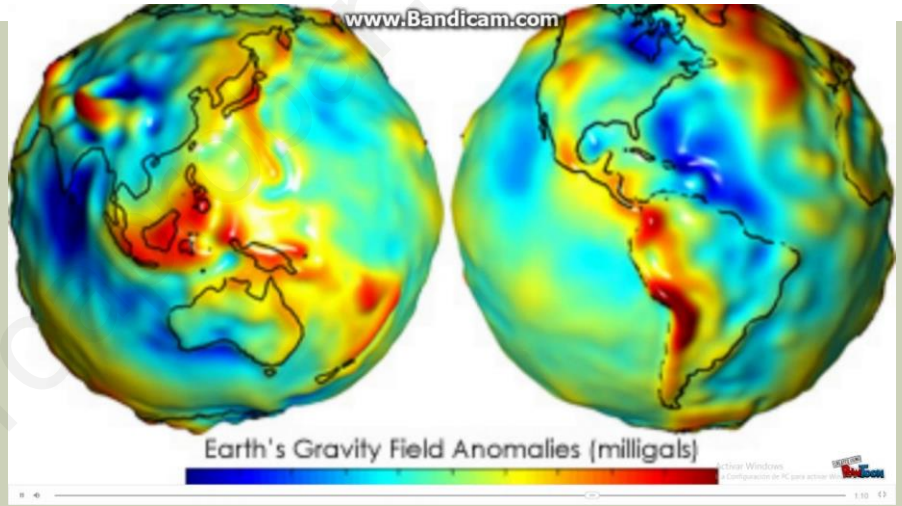
2.2. GRAVIMETRIC METHOD

- **VARIATION OF gravity:** As the Earth is not a sphere and its composition isn´t homogeneous, the value of gravity varies according to:
  - **Latitude**:> Latitude <radius> g
  - **Altitude**: more altitude, more radius LESS gravity
  - Due to the different **density** of subsoil materials.

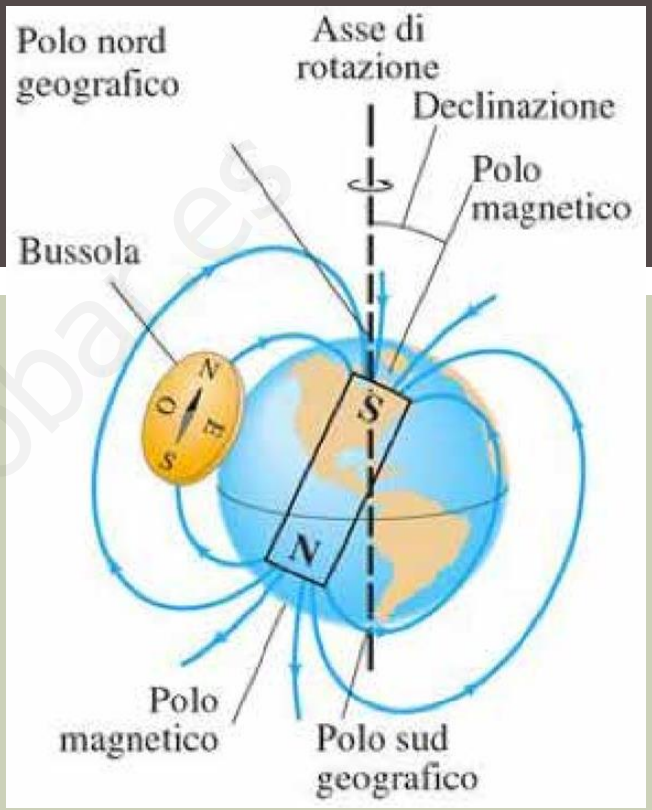
- **MEASUREMENT OF gravity:** gravimeters are used.

- **GRAVIMETRIC ANOMALIES:** Normally the difference between the measured value and the theoretical value is very small. But if it is appreciable it is said that there is a gravimetric anomaly at that point:
  - If the measured value> theoretical value .... positive anomaly.
  - If the measured value <theoretical value .. negative anomaly.

UTILITY: the positive anomalies indicate that there are denser materials (metals) in the subsoil, the negative ones would indicate areas with less dense materials (saline domes or warmer areas of the mantle).



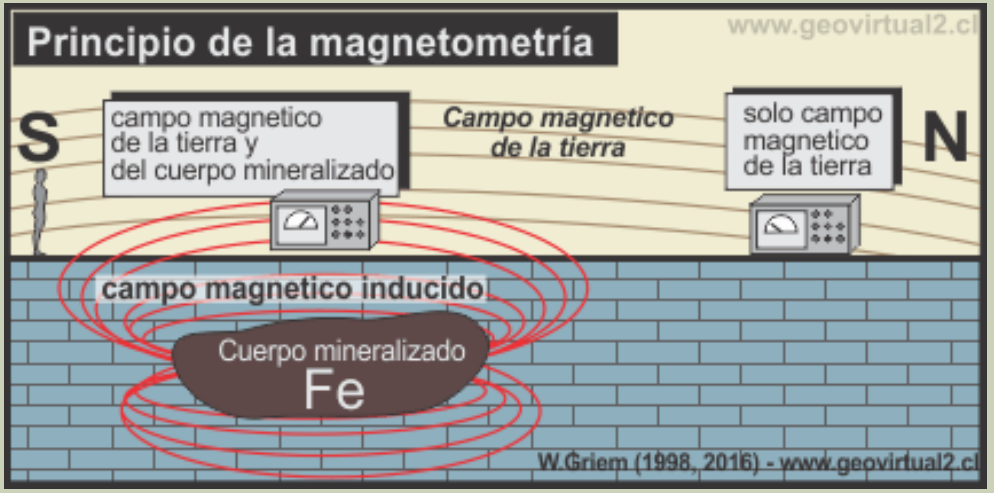
2.3. MAGNETIC METHOD



- IT IS BASED: in the variations of the Earth's magnetic field.
- TERRESTRIAL MAGNETIC FIELD: the rotation of the Earth's core makes it behave like a dynamo and generates a magnetic field.

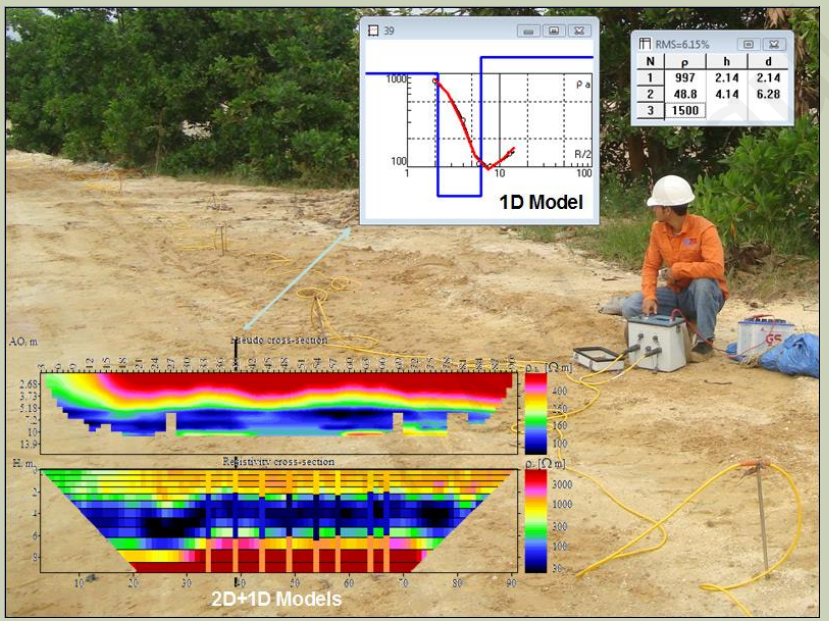
The magnetic poles: They do not coincide with the geographical ones. The angle formed is called magnetic declination, δ (about 11º). It has varied throughout Earth's history

- MEASUREMENT INSTRUMENT: the device used is the **magnetometer.**
- MAGNETIC ANOMALIES: The rocks that contain iron can be magnetized and form a weak magnetic field but that alters the intensity and orientation of the current field in that area, a magnetic anomaly has formed.



2.4. ELECTRIC METHOD

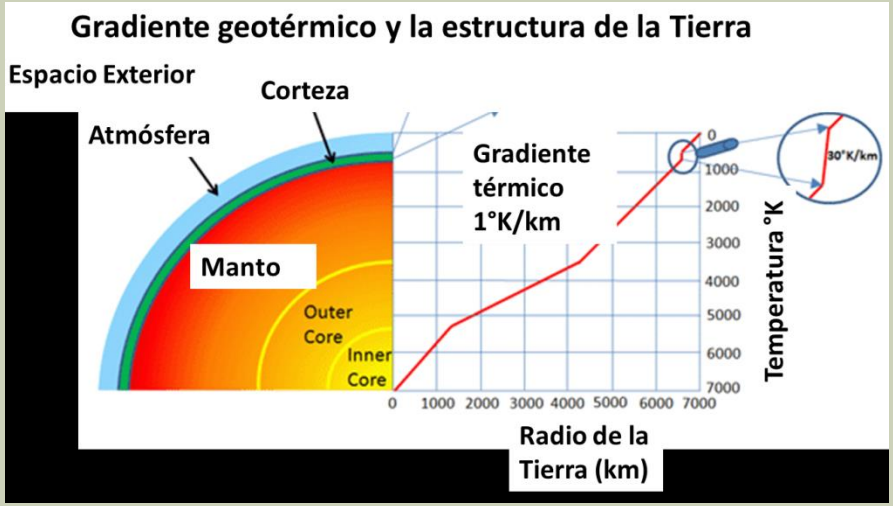
- IT IS BASED: in the study of the changes in the electrical conductivity of the different materials. As it is very low we talk about electrical resistivity.



2.5. GEOTHERMAL METHOD

- IT IS BASED: in the study of terrestrial geothermal energy

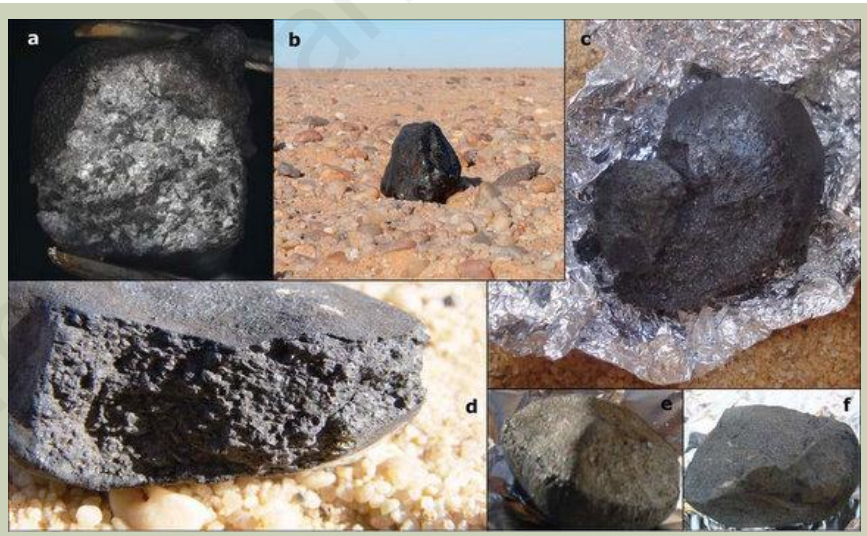
- TEMPERATURE VARIATION:
  - From the land surface to the interior: every 33 m increases 1º C.
  - This variation is called a geothermal gradient.
  - This variation becomes smaller as we approach the core.

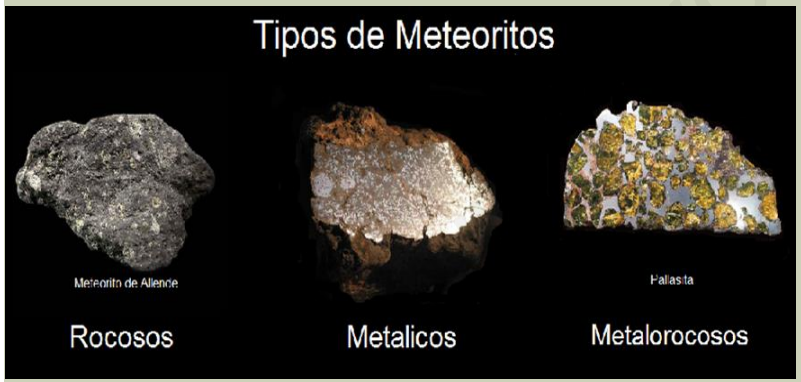


2.6. METEORITE STUDY

- The age of the meteorites is 4,500 Ma = to Earth.
- Its composition can be comparable to that of the inner layers of the Earth.

They are of different types: rocky, metallic and mixed.



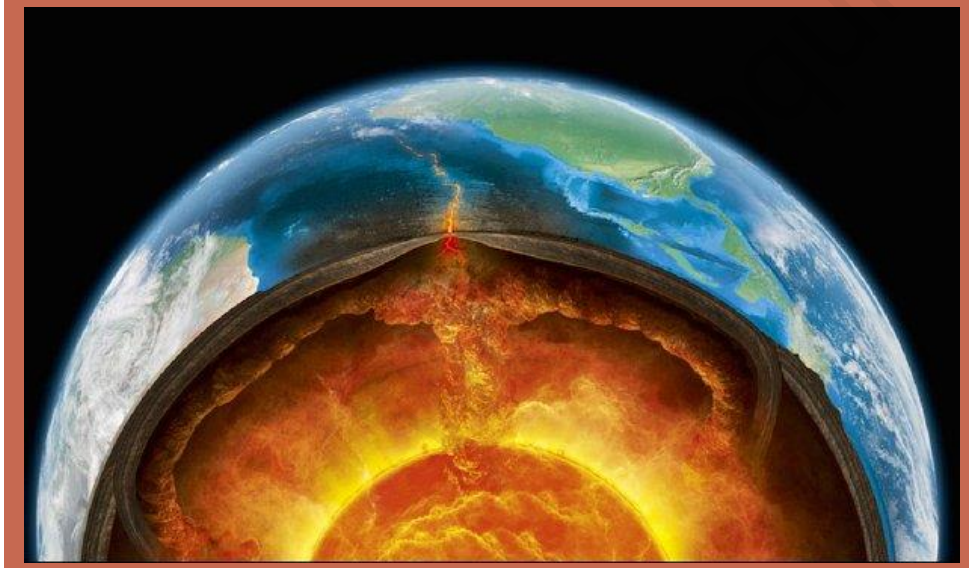


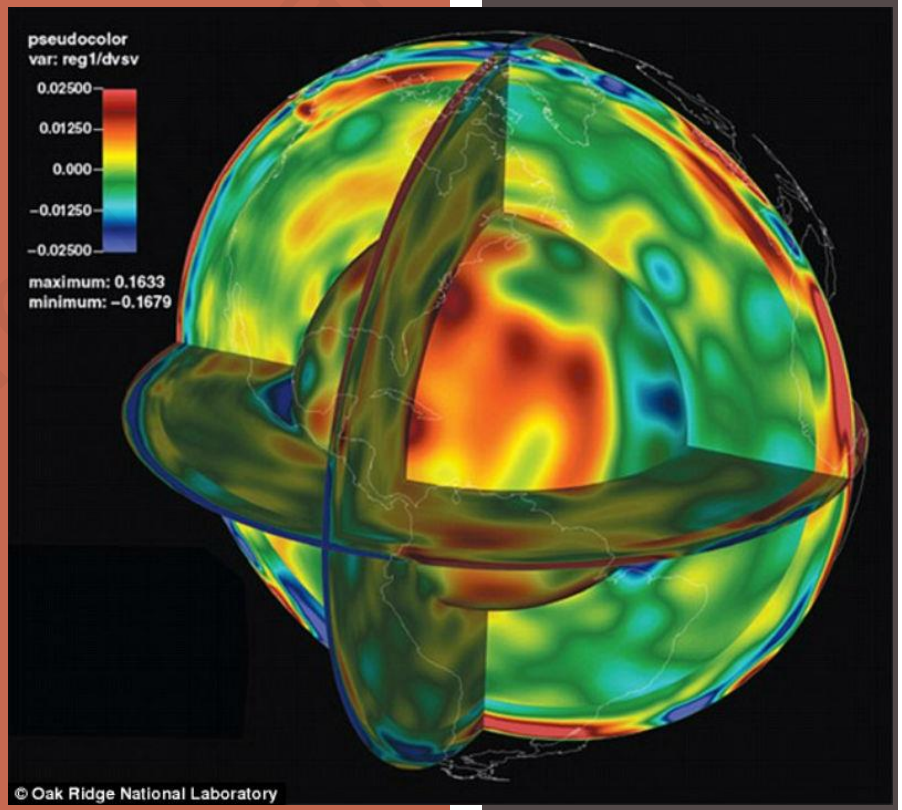
- In its composition we find:
  - silicates of iron, calcium and magnesium ≈ to the earth's oceanic crust basalts. (9% of the total)
  - magnesium silicates ≈ to the earth's mantle (86% of the total)
  - organic compounds and water
  - Fe and Ni ≈ alloys (aleación) to the Earth's core (4% of the total)

3.MODELS OF THE INTERNAL STRUCTURE OF THE EARTH

Taking into account the data obtained with the previous methods, two complementary models are proposed:

- Geochemical model
- Geodynamic model





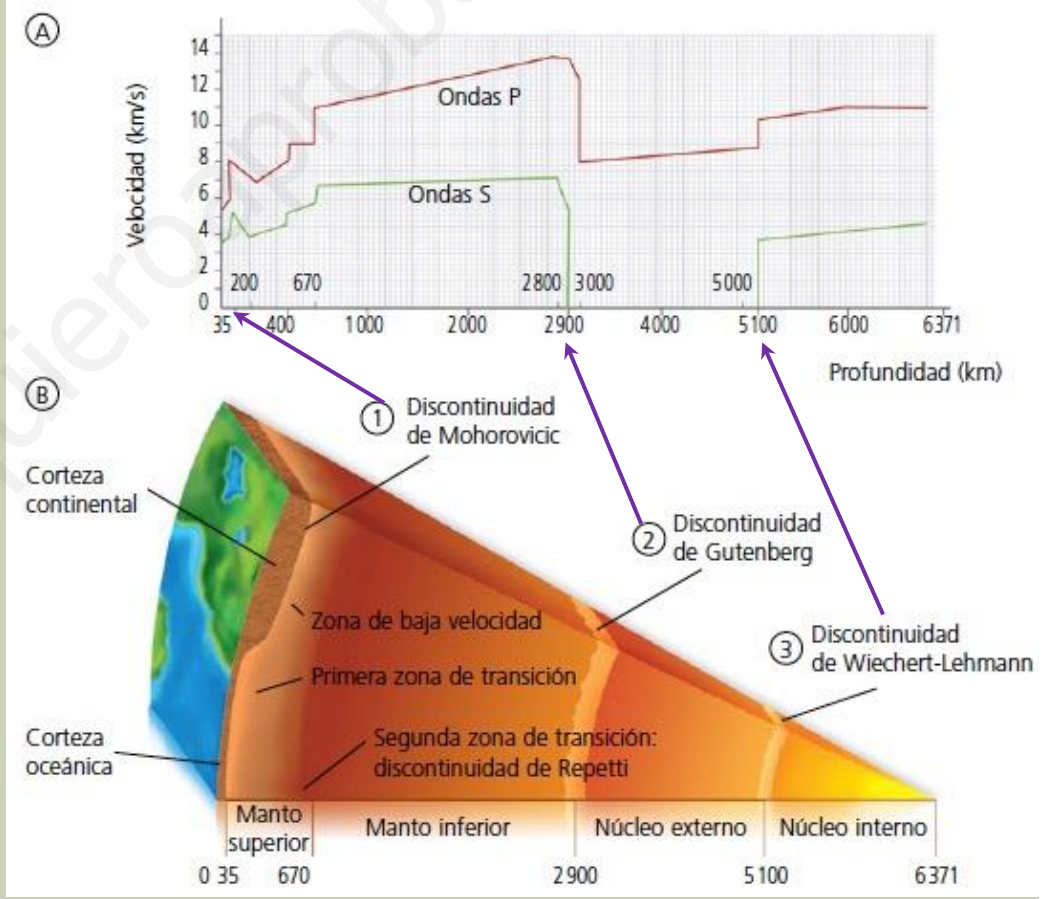
3.1. GEOCHEMICAL MODEL OF THE STRUCTURE OF THE EARTH

It is based on the chemical and mineralogical composition of the Earth.

Obtained from the discontinuities observed in the graphs of seismic studies.

The Earth is divided into three main concentric layers separated by discontinuities:

- **Oceanic and continental crust,**
  - Mohorovic discontinuity
- **Mantle that is divided into:**
  Upper mantle
  - Repetti discontinuity
  Lower mantle,
  - Gutenberg discontinuity
- **Nucleus that is divided into:**
  External nucleus
  - Wietchert-Lehmann discontinuity
  Internal core



CRUST:

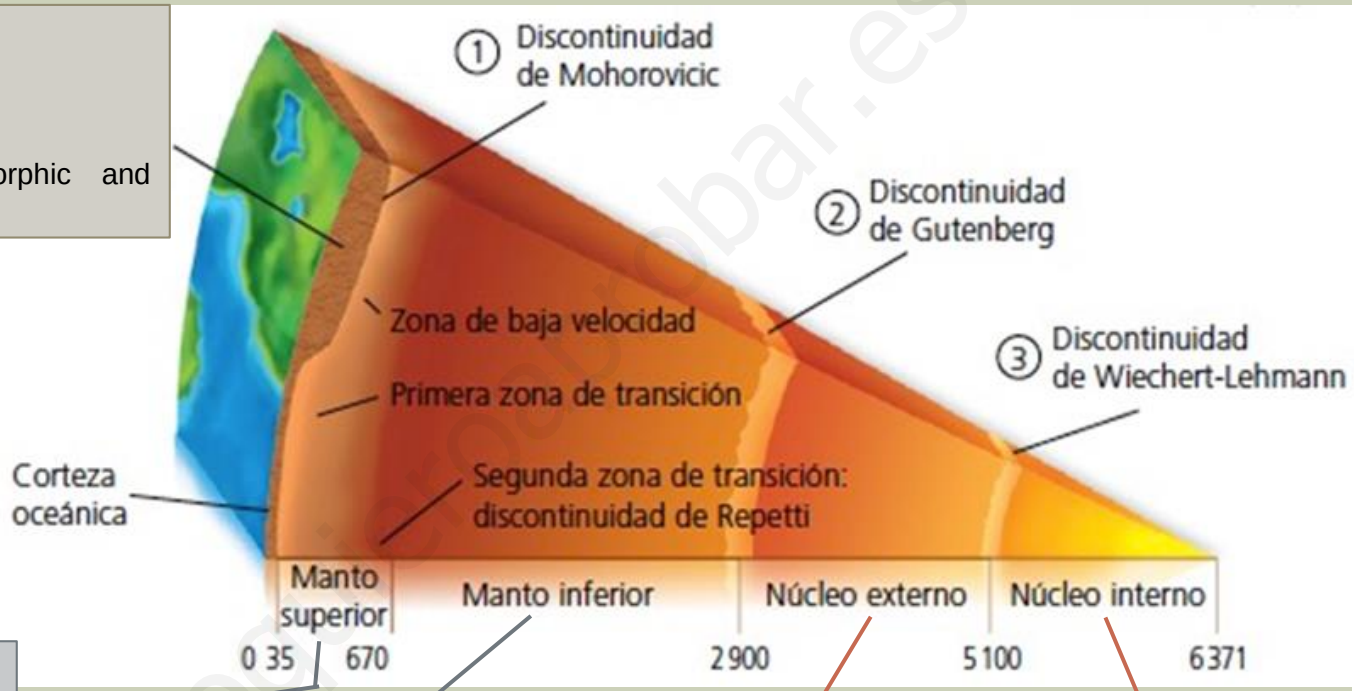
- **Up to 8 or 70 km (Mohorovicic discontinuity)**

CONTINENTAL CRUST:

- Thicker (30-70km)
- Less dense
- Very old (> 250 Ma)
- Formed by igneous, metamorphic and sedimentary folded rocks.

OCEANIC CRUST:

- Very thin (8-10 km)
- More dense
- Very young (<250 Ma)
- Formed by igneous rocks: lavas (basalt) and gabbro



UPPER MANTLE:

- From disc. Moho a 400 km
- Composition: *peridotitas* (olivine)

LOWER MANTLE:

- From 700 to 2900 km disc. Gutenberg
- Composition *peridotitas* (perovskita)

OUTER NUCLEUS:

- From 2900 to 5150 km
- Formed by Fe y Ni
- Fluid and mobile.

INNER NUCLEUS:

- From 5150to 6730 km
- Formed by Fe
- Solid with rotation

THE MANTLE :

- **Approximately 70% of earthly matter.**
- **THICKNESS: From 30 km (Moho to 2900 km (Gutenberg).**

THE NUCLEUS:

- **DENSITY: Denser layer = 11 g / cm3.**
- **TEMPERATURE: in the center it is 6700ºC.**

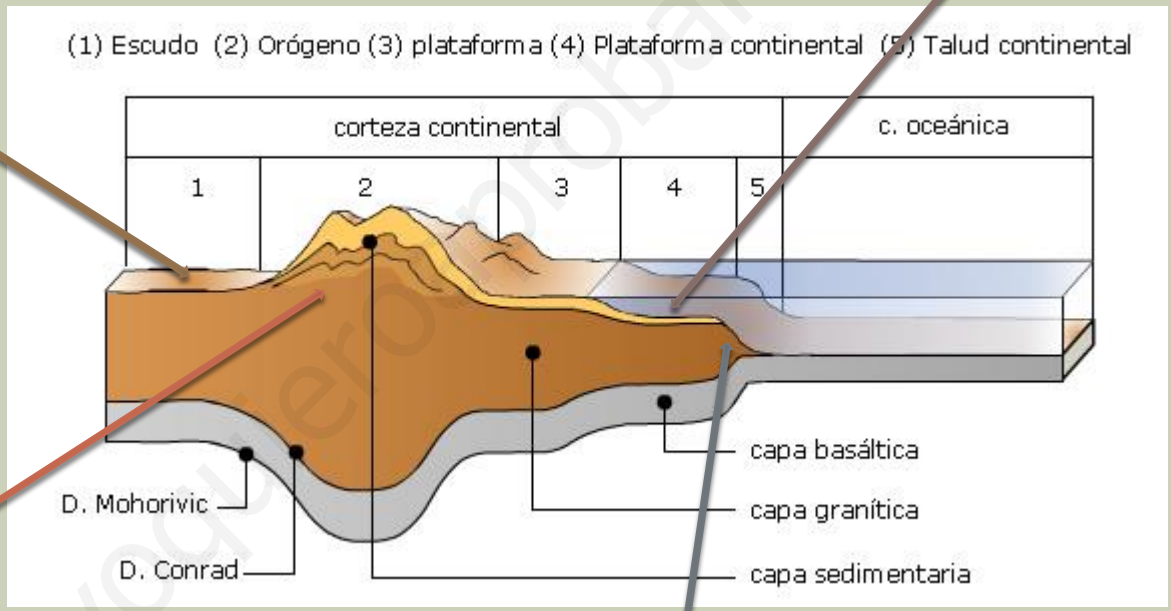
STRUCTURE OF CONTINENTAL CRUST

- It is discontinuous, thicker, younger and less dense:
  - Formed by:

1. CRATONES OR SHIELDS:

- 30 km thick
- Very stable areas, with little seismic activity.
- Very old igneous and metamorphic rocks> 250 Ma
- They appear covered by modern and horizontal sediments.
- Little relief due to prolonged erosion.

Examples: The Baltic, Siberia, the Congo, Canada, Galicia and the plateaus.



4. CONTINENTAL PLATFORM:

- 7-15 km Thick
- Submerged in the ocean (within 100 m) covered with sediments

2. OROGENIC:

- 70 km thick
- Areas with relief, are the mountain ranges, more modern areas
  The oldest> 250 Ma ⇒ Paleozoic (Urals, Appalachians and Galicia)
- The most modern> 65 Ma ⇒ Tertiary (Alps, Andes, Himalayas, Pyrenees, Penibetic System).
- They are more unstable.
- Formed by igneous, metamorphic and sedimentary folded rocks.

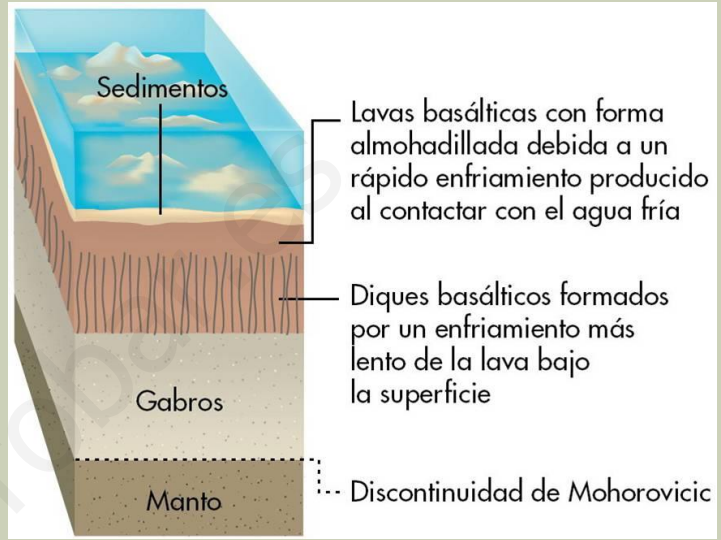
5. CONTINENTAL TALUD:

- Large escarpment that connects the continental crust with the oceanic crust

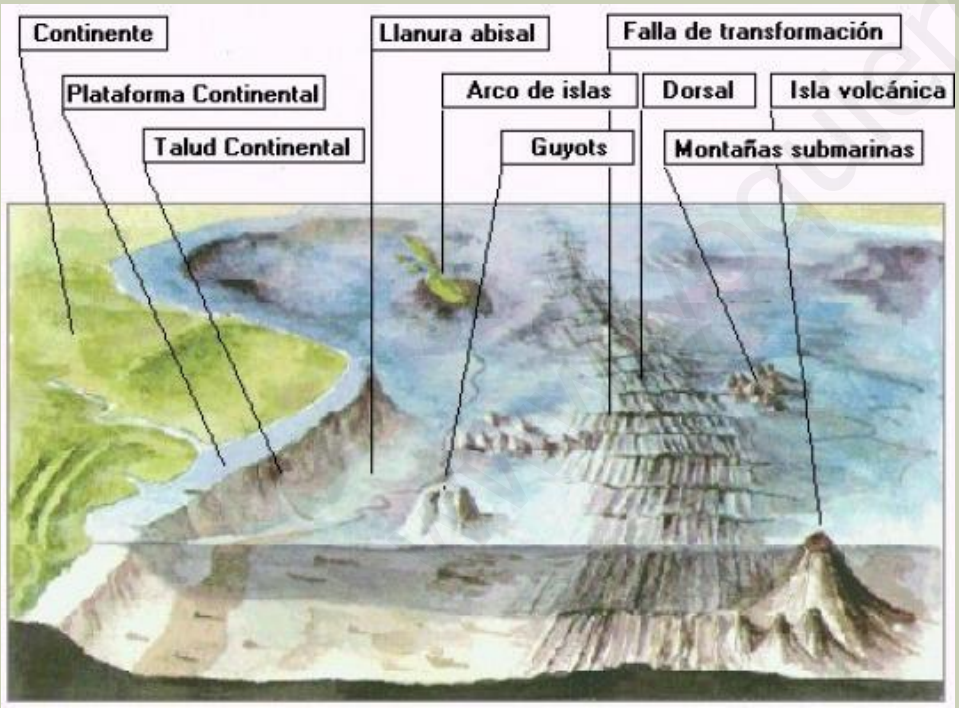
OCEANIC CRUST STRUCTURE :

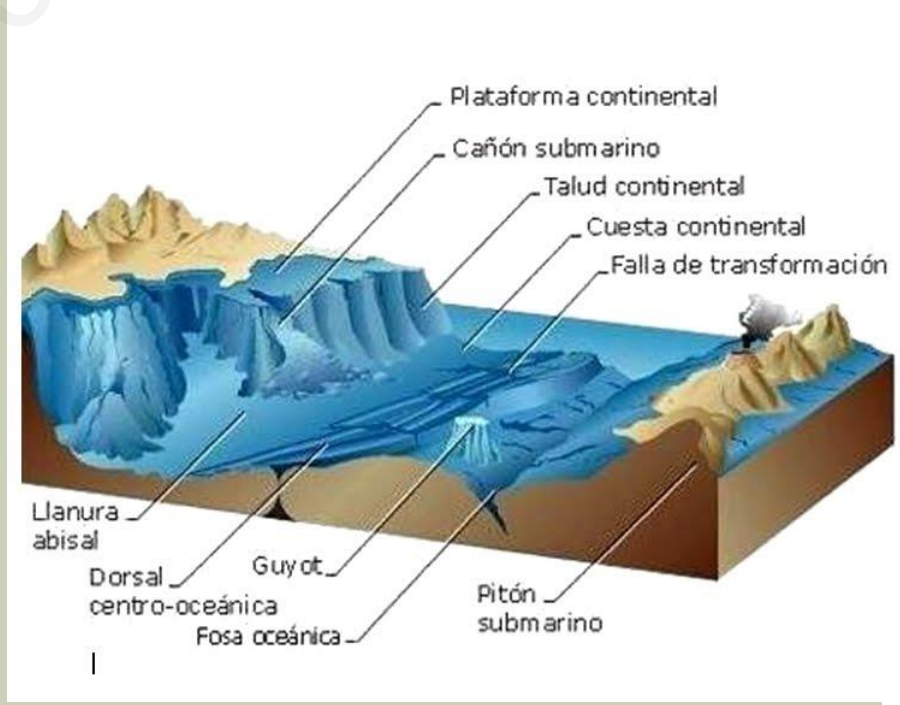
- It is very fine (8-10 km) ocean floor from the continental slope.
- Very young and thin

- Vertically three layers are distinguished:
  - Sediments of> thickness farther from the dorsals and closer to the coast.
  - Oceanic plinth: 2000 m thick. Formed by a layer of basaltic padded lavas, crossed by vertical dikes. Very fractured
  - Oceanic layer 5000 m deep, formed by gabbro



- En su estructura horizontal reconocemos: *talud continental, la llanura abisal, las fosas oceánicas y las dorsales submarinas*

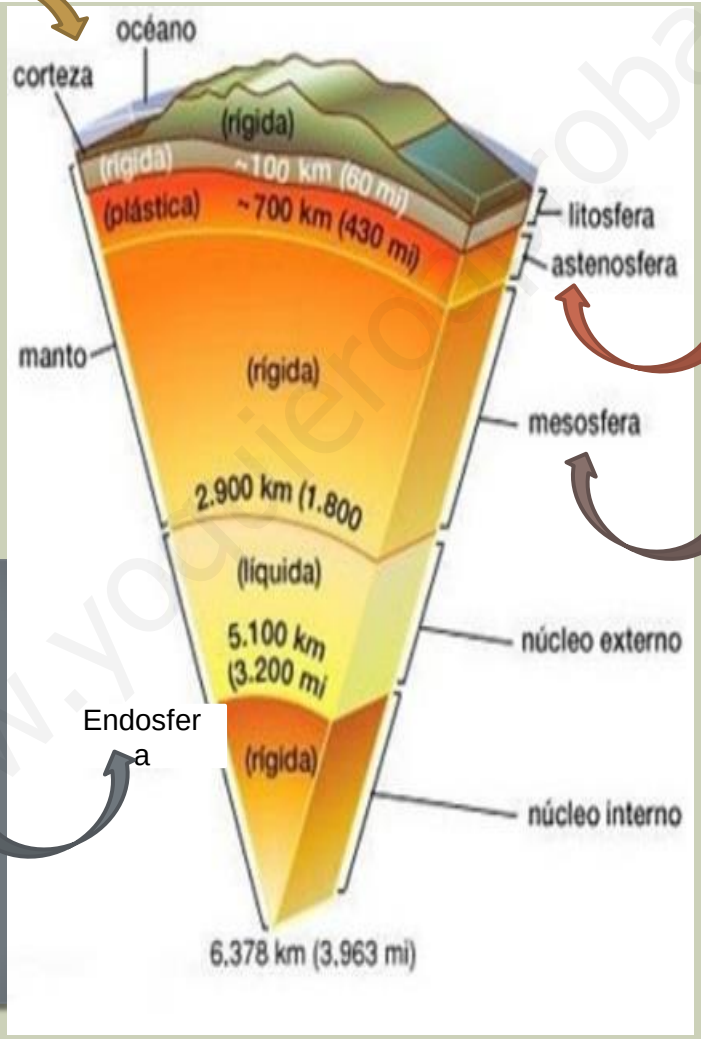




3.2. GEODYNAMIC MODEL OF THE STRUCTURE OF THE EARTH

LITHOSPHERE

- The most superficial and rigid part.
- Broken into plates
- THICKNESS: 50 to 100/300 km
- CONSTITUTED : Crust + upper mantle
- TYPES:
  - Continental lithosphere
  - Oceanic lithosphere



ASTENOSPHERE

- **DEPTH: <400 km but it is not a continuous layer. "Low speed channel"**
- **About 150 km thick.**
- **It is characterized because seismic waves greatly reduce their speed ⇒> plasticity.**

MESOSPHERE

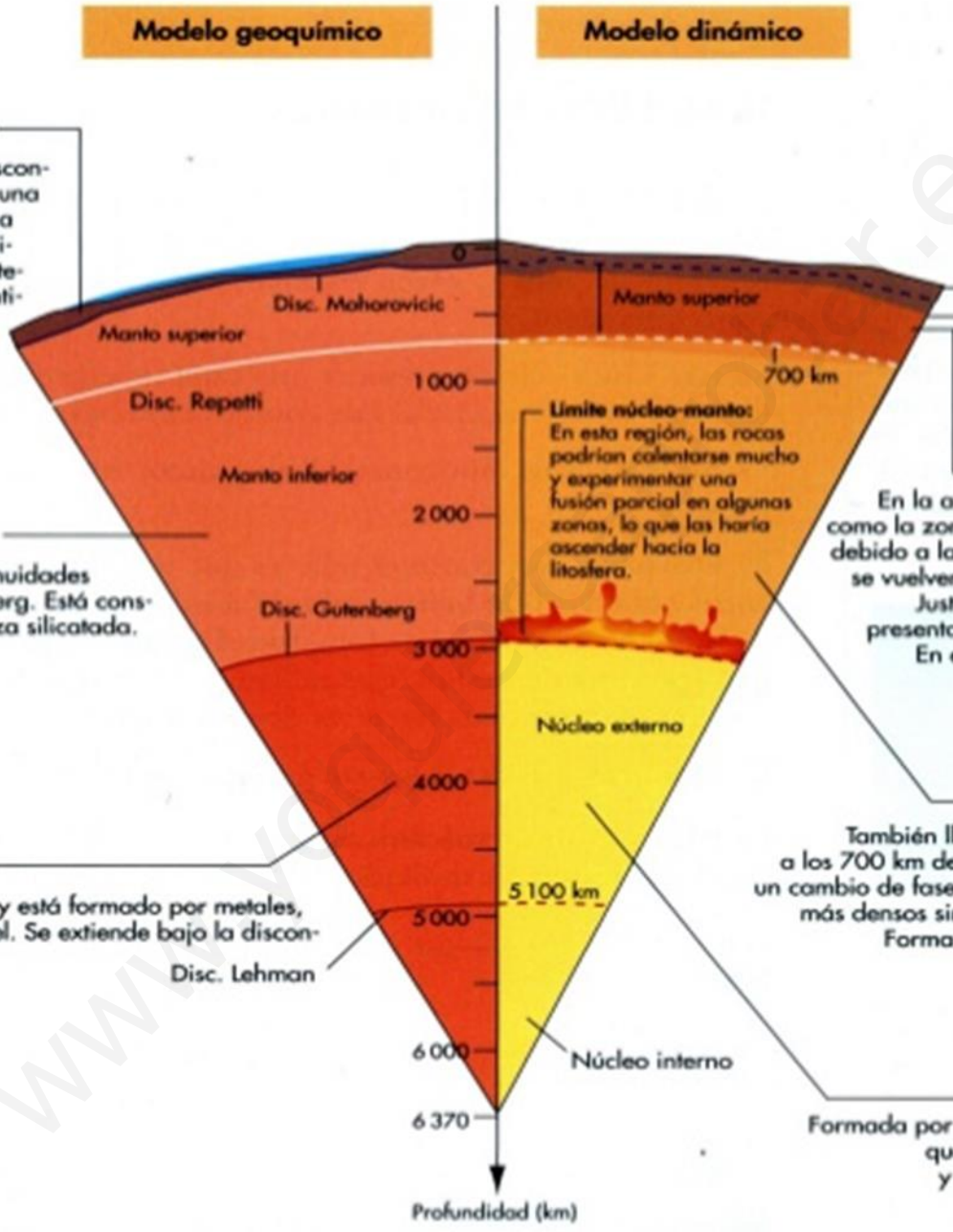
- DEPTH: 400-2900 km
- Rigid but convection currents occur there.
- In Layer D ", the last 200 km.
  - It decreases the speed of the waves and is supposed to be partially melted because it is at high Tª. Therefore, the material rises slowly like feathers to the surface (it is related to cortical volcanic activity).

THE ENDOSPHERE

- **DENSITY: Denser layer**
- **TEMPERATURE: in the center it is 6700ºC.**
- **LAYERS:**
  - **External core ⇒ Fluid and mobile.**
  - **Internal core ⇒ Solid and with rotation.**

The earth's magnetic field originates.

Endosfera



CORTEZA

Se sitúa por encima de la discontinuidad de Mohorovicic. Es una capa sólida que está formada por rocas de composición silicatada. Recuerda que la corteza puede ser oceánica o continental.

MANTO

Se localiza entre las discontinuidades de Mohorovicic y de Gutenberg. Está constituido por rocas de naturaleza silicatada.

NÚCLEO

Ocupa el centro de la Tierra y está formado por metales, principalmente hierro y níquel. Se extiende bajo la discontinuidad de Gutenberg.

LITOSFERA

Tiene unos 100 km de espesor medio, aunque puede superar los 150 km bajo las zonas montañosas. Formada por rocas rígidas y frágiles; coincide con la corteza y con la parte rígida del manto superior.

ASTENOSFERA

En la actualidad, esta capa se entiende como la zona en la que las rocas del manto, debido a las altas presiones y temperaturas, se vuelven plásticas y son capaces de fluir. Justo bajo la litosfera, la astenosfera presenta una fusión parcial de sus rocas. En esta envuelta, las ondas sísmicas disminuyen su velocidad.

MESOSFERA

También llamada manto inferior, comienza a los 700 km de profundidad, donde se produce un cambio de fase en los minerales, que se vuelven más densos sin variar su composición química. Formada por rocas calientes y sólidas, pero con cierta plasticidad.

ENDOSFERA

Formada por una capa externa fundida, en la que se producen corrientes o flujos, y otra interna sólida y muy densa.