CHAPTER 1

OUTSIDE AND INSIDE THE EARTH

The picture shows our earth as it looked by the astronauts who were in space. They noticed how friendly, yet isolated, the earth seemed. This view, plus measurements taken on earth have- improved our understanding of our planet.

This chapter has many "vital statistics" about the earth. The first section discusses the shape of the earth and the distribution of land and water masses. The chapter ends describing the internal structure of the earth and the formation and propagation of different seismic waves.

CHAPTER OBJECTIVES

1. Describe and identify the shape and dimensions of the earth.
2. Describe and locate the continents and the oceans.
3. List, compare and describe the layers of the earth.
4. Describe the generation and propagation of seismic waves, and their classification.

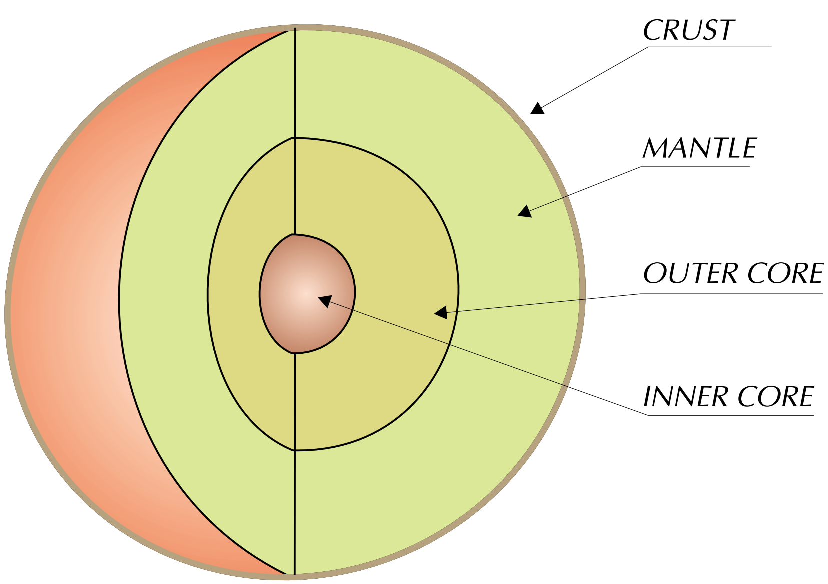
1.1 CHARACTERISTICS OF THE EARTH

• SHAPE AND DIMENSIONS

For a better understanding of natural hazards it is necessary to know some general concepts about the shape, size and internal structure of the planet where we live: the Earth.

As we know, the earth is just one of the millions of bodies in the Universe. However, the earth is not just a planet, but one of the few, or maybe the only one having natural conditions allowing the existence of plant and animal life, and therefore of Man. This is mainly due to the fact that the temperatures on the surface of the earth keeps the water in its liquid phase, which is essential for life. Other planets have very high or very low temperatures, with no liquid water and therefore no possibility to develop any form of life.

The earth's shape is an oblate spheroid, flattened at the poles. To a first approximation the earth is an ellipsoid of revolution (spheroid). Its dimensions are: equatorial radius= 6,378 kilometers; polar radius= 6,356 kilometers; circumference= 40,000 kilometers.

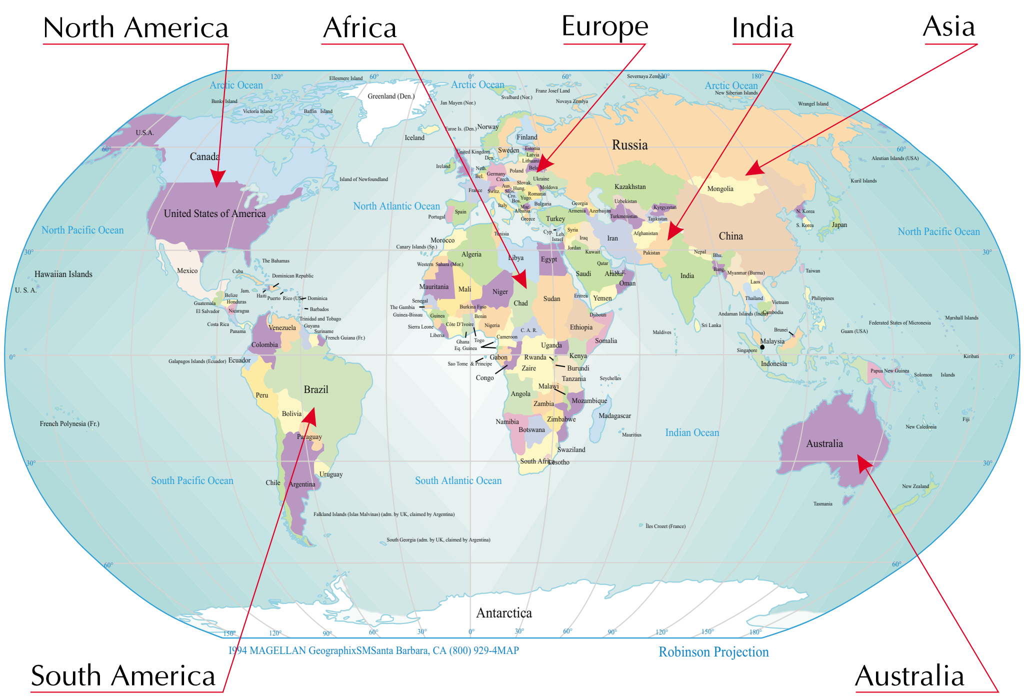


Internal structure of the earth.

The ellipticity of the earth's shape is due to the centrifugal forces produced by its rotation. The resultant forces from rotation have other effects, including the global wind patterns in the atmosphere, the currents in the oceans, and the flow of hot viscous material in its interior.

• DISTRIBUTION OF OCEANS AND CONTINENTS

One of the most relevant aspects of its surface is the vast expanse of the oceans. More than 70 % of the surface of our planet is covered by oceans and in the Southern Hemisphere the oceans represent almost 85 % of the total surface as seen in the figure below.



Distribution of oceans and continents.

The Pacific Ocean is the largest ocean on the earth, encompassing more than one third of the total surface of the planet, and its huge marine currents regulate an important part of the world climate. It is also the deepest ocean. Its mean depth is 200 meters greater than the oceanic average of 3,700 meters. It is in the Pacific Ocean, because of its size and the geological structure of the ocean floor, where most of the earthquakes and tsunamis of the world occur.

DO YOU KNOW HOW WATER DEPTH IS MEASURED?

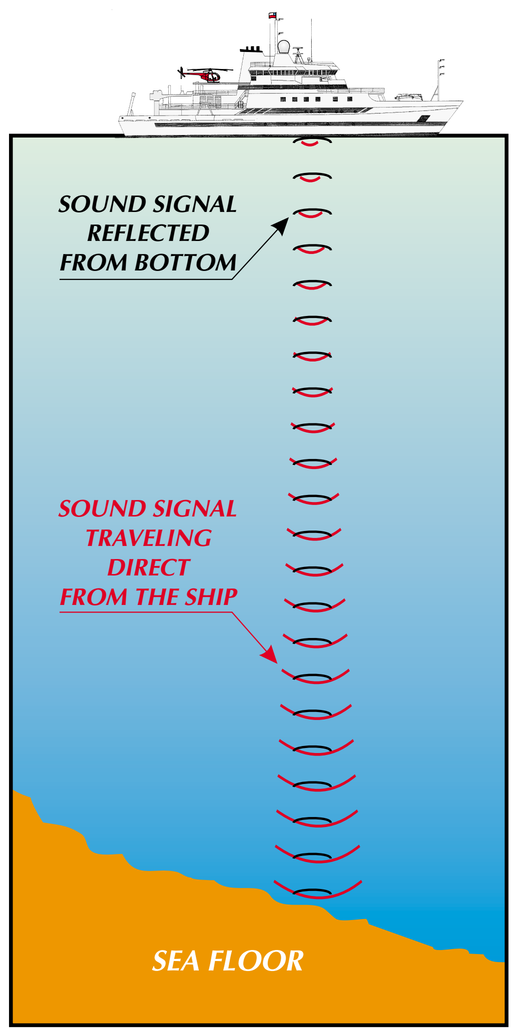
Soundings are measurements of water DEPTH. In the past, sailors took soundings by lowering ropes with weights. When the weight touched the bottom, the length of wet rope showed the depth of the water. In deep water, a sounding was inaccurate because of the water's movement.

Today, scientist find the depth of water by using an echo sounder. This device measures depth by bouncing sound waves off the ocean floor. The echo sounder measures how long a sound wave takes to reach the ocean bottom and return to the ship. Since the speed of sound in sea water is known, the sounder can calculate the ocean's depth at that spot.

DO YOU KNOW?

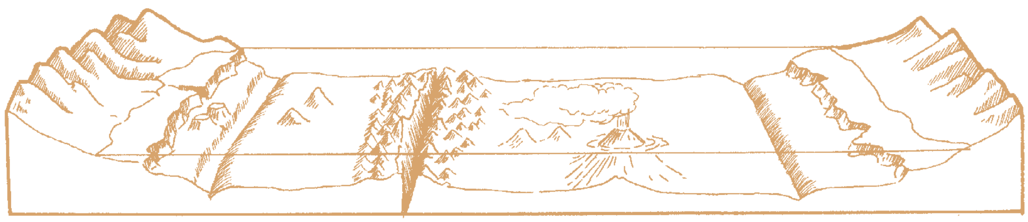
The Pacific Ocean is so large that all the continents put together could fit into it. It covers 165,200,000 square kilometers.

The Pacific Ocean is surrounded mainly by linear mountain chains, trenches, and island arc systems that in most areas effectively isolate the deep-sea basins from the influences of continental sedimentation.



Echo sounder operation.

If all the water were removed from the ocean basins, there would be revealed a pattern of topographic features dominated by a system of ridges and rises encircling the globe with intervening deep-sea basins between the ridges and the continents. The pattern shows that the deepest parts of the oceans do not occur in the middle as one might expect, but close to the continents and island arcs.



Topography of the ocean bottom.

HAVE YOU HEARD?

The deepest spot in all the oceans is Challenger Deep. It is in the Marianas Trench in the western Pacific Ocean. It is more than 11,000 meters deep! This depth is 1,600 meters greater than the height of Mount Everest, the highest mountain on land.

The middle of the ocean is shallower because of the mid-oceanic ridges. This is similar to the patterns of major mountain chains around the earth which, except for the Himalayas and a few other chains, are not located near the middle of continental masses but near the edges facing deep oceanic trenches. Thus, both continental and oceanic areas exhibit greatest vertical change in narrow zones of the earth’s crust.

1.2 INTERNAL STRUCTURE OF THE EARTH

Everybody knows what the surface of the earth looks like, since we see it frequently in maps and pictures, and in the landscapes around us, but how does the interior of the earth look like?

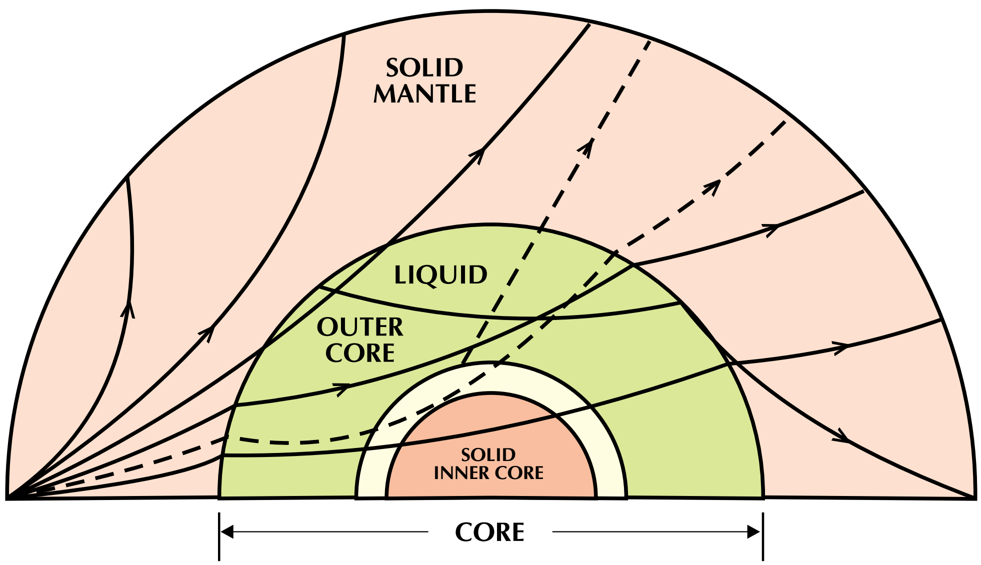
Nobody can make a trip to the center of our planet to discover its internal structure, however, today we know the internal structure thanks to instruments that record the waves produced by earthquakes.

Every year ten or more destructive earthquakes shake our planet. The smallest of this earthquakes release energy almost one thousand times greater than from an atomic bomb. The waves produced by the shocks travel through the interior of the earth and their paths are curved and modified by the different layers of the internal structure of the earth. Thus, the seismic waves show the nature of the areas they pass through, and after being recorded on seismographs we can study them and deduce a picture of the interior. In fact, the seismologists X-ray the earth although some times they see it as through a smoked glass.

Until the beginning of seismology our knowledge about the interior of the earth was based on hypothesis and speculation. Today, thanks to this science we know the structure of the earth scientifically. Combined with the geologic information provided by surface rocks, laboratory experiments with rocks at high pressures, and certain astronomic observations, we have a very good idea of the existing conditions in its interior, its layered structure, the materials, their physical conditions, the pressure, etc.

• SEISMIC WAVES

When you throw a stone into water (e.g. a water well), you see waves spreading from the point where the stone strikes the water; but these waves are also transmitted at depth, diverging from the same point. Something similar to this happens when an earthquake occurs. From the focus or place of the rupture of the crust elastic equilibrium waves are transmitted in all directions in the interior and the surface of the earth.



Propagation of seismic waves within the earth.

DO YOU KNOW?

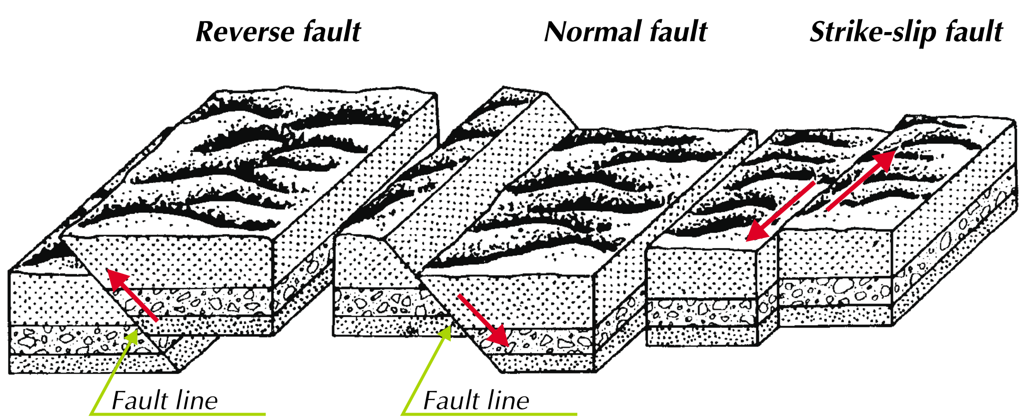
The record of drilling in the exploration of the earth's crust is held by the former Soviet Union with a well 12 kilometers deep drilled in MURSMANK.

HAVE YOU ALSO HEARD?

At a depth of forty kilometers the rocks are under a pressure of 4,000 atmospheres and a temperature of 300 degrees Celsius.

For most of the shallow earthquakes (depth of focus = 0 - 70 kilometers), the mechanism for the generation of elastic waves is a fracture or break of the Earth’s crust in the region. In other words, the stress surpasses the rupture limit of the material in that region, therefore it fractures developing what is commonly known as a "fault” and this “fault” is what generates the seismic waves.

A "fault” can be defined as the relative movement between blocks of the crust, as seen in the picture below.



Once the rupture point of the material of a region has been surpassed (that is, a fault has developed), three fundamental types of seismic waves are generated:

1) ***The compressional-rarefactional wave, P***. This is analogous to a sound wave and is sometimes called a longitudinal wave. When the compressive phase of such a wave passes a seismograph station, the ground in the immediate area is compressed and the seismograph pier moves slightly in the direction in which the wave is traveling, or away from the epicenter. Conversely, when the rarefactional part of such a wave passes a station, the ground is dilated and the pier moves toward the epicenter. These directions are registered on seismographs. This wave is the fastest of the seismic waves and is therefore designated the first primary tremor, P. This wave, as with sound waves, can be transmitted through rocks and liquids.

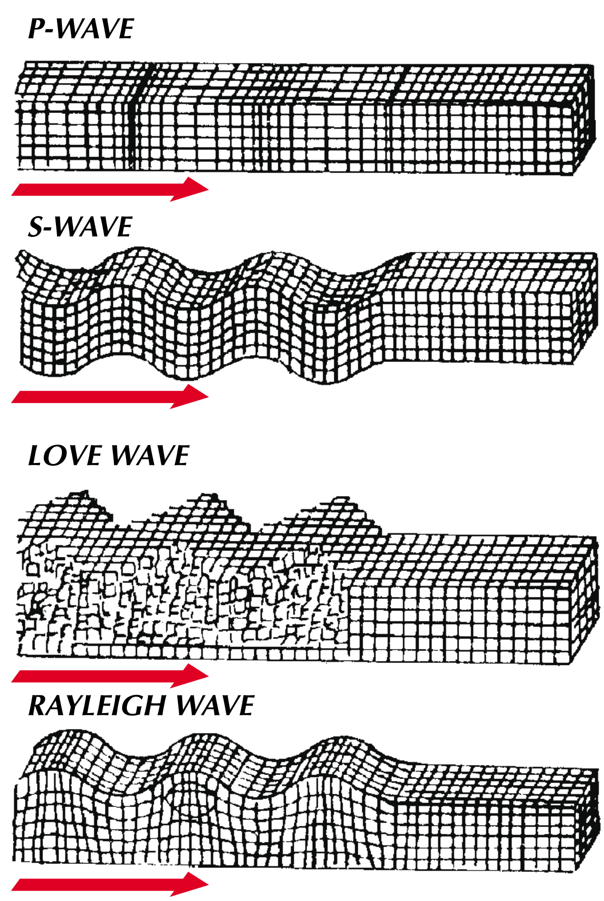
2) ***The transverse, distortional, or shear wave, S***. This is analogous to a light wave or the transverse vibration of a string. A particle is always displaced in a direction normal or transverse to the direction in which the wave is traveling. Interior transverse waves travel at about 0.6 the speed of compressive P waves and appear as the second most conspicuous

wave group. They have therefore been designated the secondary tremor, S. These waves can not propagate through fluids like liquids and gases.

Speed of the P and S waves depends on the density and elastic properties of the rocks they pass through. Typical P wave velocities in granite rock and in water are respectively, 5.5 and 1.5 kilometers per second (Km/sec), whereas the S wave speed in the same materials is about 3.0 and 0 Km/sec; this last value is due to the fact that liquids have a rigidity modulus equal to 0.

3) ***Surface waves, L***. These represent by far the greatest amount of wave energy, and they are called surface waves because they propagate close to the surface of the earth.

   There are two types of surface waves. The faster of the two is a shear wave designated as either a Love Wave, Lq, after the pbysicist who developed the theoretical concept, or a G wave, after Gutenberg, the seismologist who discovered and discussed its presence on seismographic records. The motion of a particle is transverse to the direction of propagation and takes place in the horizontal plane only, as seen in the figure below. It has no vertical component. The second type of surface wave is the Rayleigh wave, Lr, also named after the physicist who developed the theoretical concept. It arrives a short time after the surface shear wave since its speed is about 0.92 that of the shear wave. In a Rayleigh wave the earth particle follows a retrograde elliptical orbit in a vertical plane along the direction of propagation, as seen below.



Seismic wave propagation.