I INVITE YOU TO KNOW THE EARTH II

5th to 8th GRADE OF PREPARATORY SCHOOL

TEXTBOOK

SERVICIO HIDROGRAFICO Y OCEANOGRAFICO DE LA ARMADA DE CHILE
INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
INTERNATIONAL TSUNAMI INFORMATION CENTER

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5th to 8th Grade of Preparatory School

ABOUT THE TEXTBOOK

This book is the result of both the implementation of Recommendation ITSU-XI11.3 of the Thirteenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, and the work of several education experts. An ad-hoc Working Group headed by H. Gorziglia (Chile), revised the work done by the experts who were partially funded by the Intergovernmental Oceanographic Commission.

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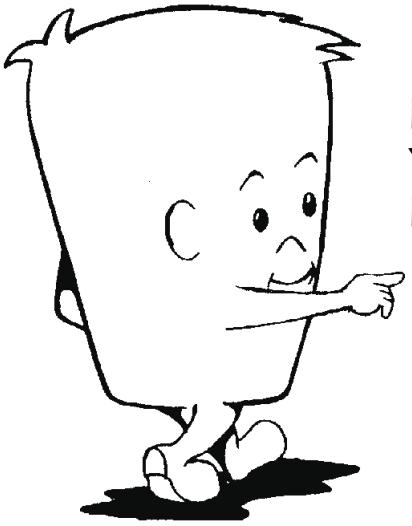
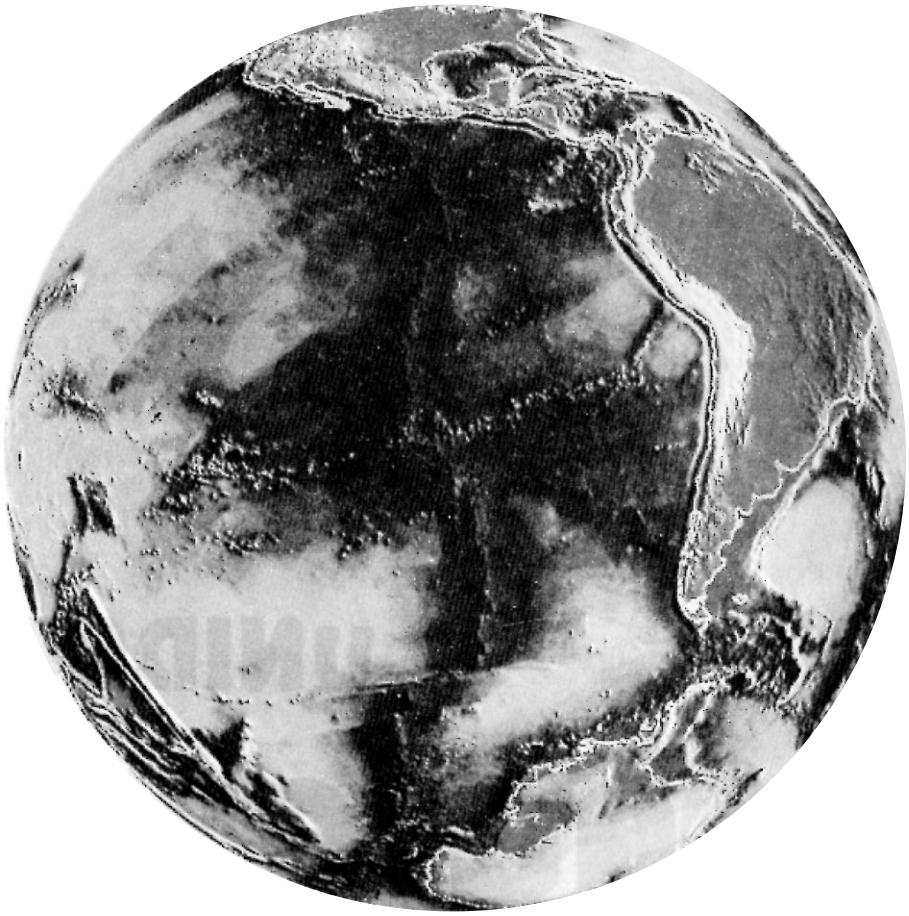
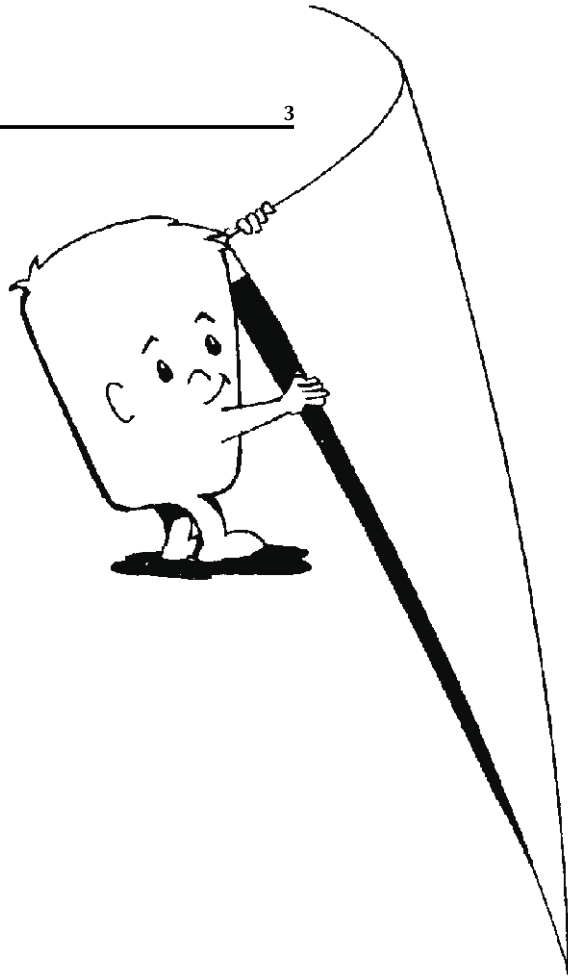


I AM TOMMY TSUMI
YOUR GUIDE AND FRIEND
IN THIS EXPLORATION.

WELCOME TO THIS ADVENTURE

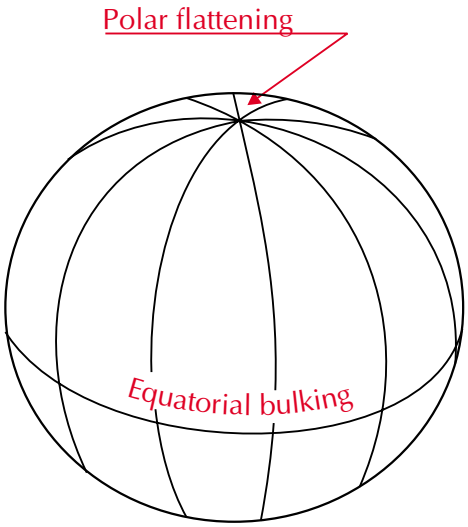


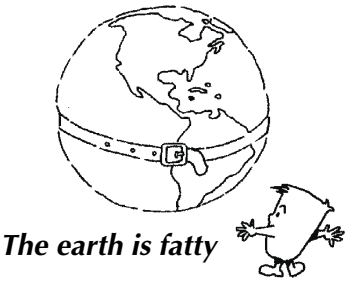
UNIT I



THE SURFACE OF THE EARTH

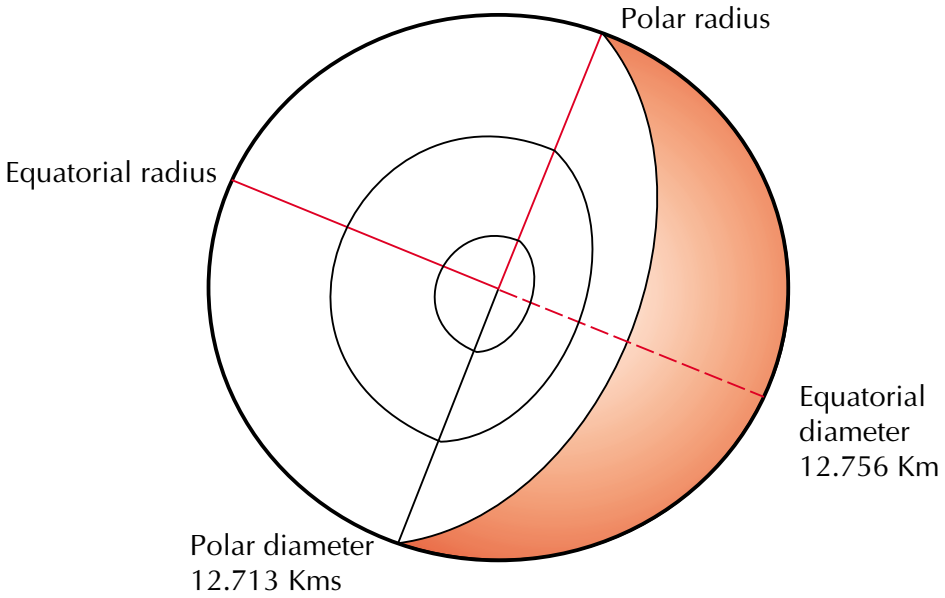
DRAWING 1





MEASURES OF THE EARTH		
	DIAMETER	RADIUS
EQUATOR		
POLES		

DRAWING 2



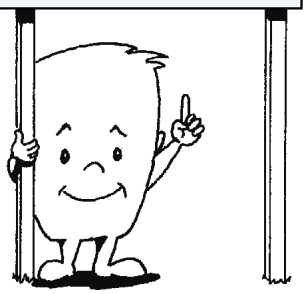
WHAT IS THE SHAPE OF THE EARTH?

ACTIVITY:

Locate in the drawing of the earth the measurements corresponding to the polar and equatorial radii.

Compare them.

Which is larger?

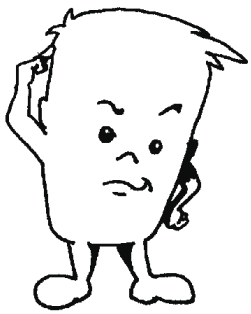


As we know, the earth is just one of the millions of bodies in the Universe. However, the earth is not just a planet, but one of the few, or maybe the only one having the natural conditions allowing the existence ot plant and animal life, and therefore of Man. The earth has the shape of a sphere slightly flattened at the poles. Do you know how this can be shown? Let's start by comparing the different dimensions of the earth.

WHAT ARE ITS DIMENSIONS?

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. Also compare the measures of radii and diameters in drawing 2. Enter the values in the table.

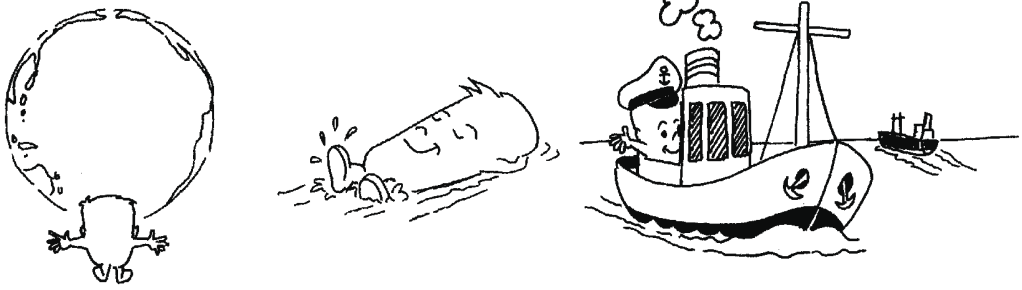
Look carefully at the drawings on each page and perform the activities proposed by Tommy Tsumi.



THE EARTH IS FLATTENED AT THE POLES AND THIS CAN BE SHOWN BECAUSE THE EQUATORIAL RADIUS AND DIAMETER ARE LARGER THAN THE POLAR RADIUS AND DIAMETER.

Oceans and continents.

DRAWING 1

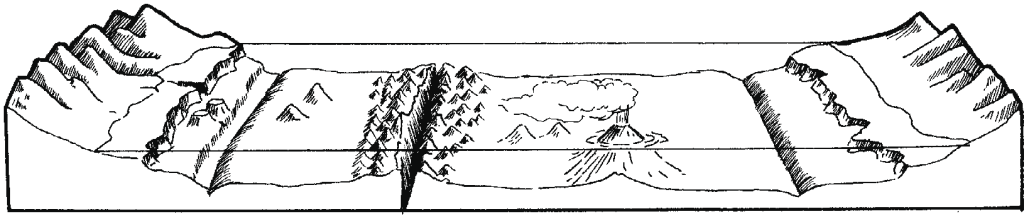


SO MUCH WATER!
The Pacific ocean
is the biggest.

The Indian
ocean is warmer!
How wonderful
is the water

Tha Atlantic ocean
is the most traveled!
Bye, bye, I'm going
to Europe.

DRAWING 2



HOW MUCH WATER IS THERE ON THE EARTH?

DO YOU KNOW?

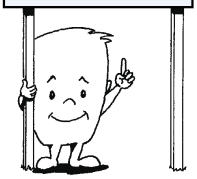
The Pacific Ocean is so large that al the continents put together could fit into it. It covers 165,200,000 square kilometers.

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 drawing 1.

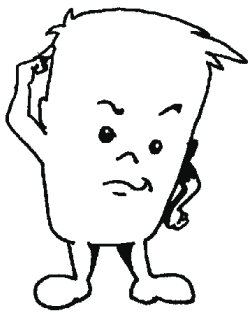
The Pacific Ocean is the largest ocean on the earth, encompassing more than one third of the total surface of the planet. It is also the deepest ocean. Its mean depth is 200 meters greater than the oceanic average of 3,700 meters. It is in the Pacific Ocean, because of its size and the geological structure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

ACTIVITY:

Write the name of every ocean you know in drawing 1.

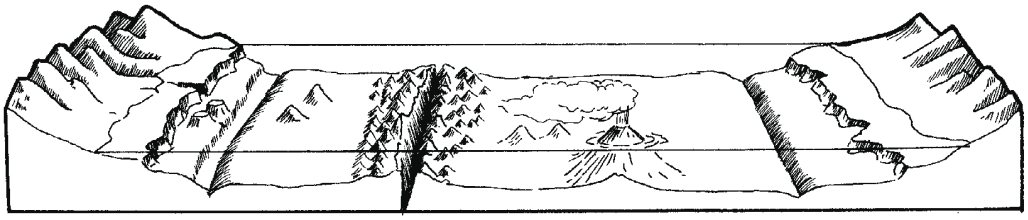


The Pacific Ocean is surrounded mainly by linear mountain chains, trenches, and island arc systems. Locate them in drawing 2 ... as ou can see the ocean bottom is not flat. Its landscape is as interesting and varied as the one you see on the surface of the earth.



OCEAN COVER ¾ OF THE EARTH'S SURFACE, THE PACIFIC OCEAN BEING THE LARGEST AND DEEPEST OF ALL.

DRAWING1

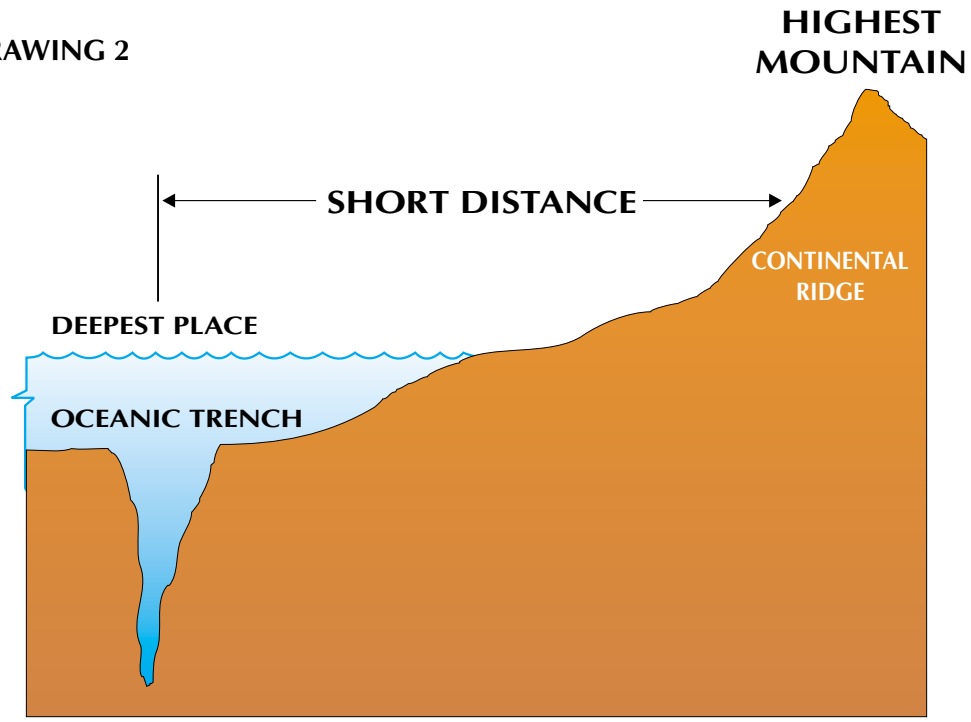


Bottom of the Pacific Ocean.

LIST OF TRENCH AND RIDGES:

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.

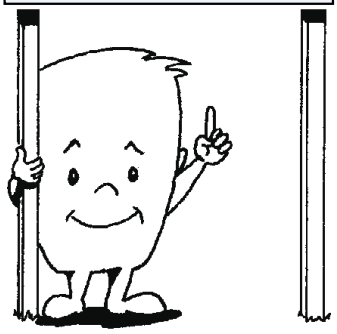
DRAWING 2



WHAT DOES THE BOTTOM OF THE OCEAN LOOK LIKE?

ACTIVITY:

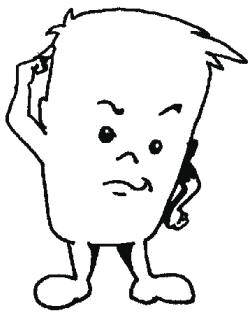
Mark on drawing 1, the trench and the ridge.



If all the water was removed from the ocean basins, there would be revealed a system of ridges and rises encircling the globe with intervening deep-sea basins between the ridges and the continents. As you can see in drawing 1, the deepest parts of the oceans are close to the continental boundaries, they are called MARINE TRENCHES.

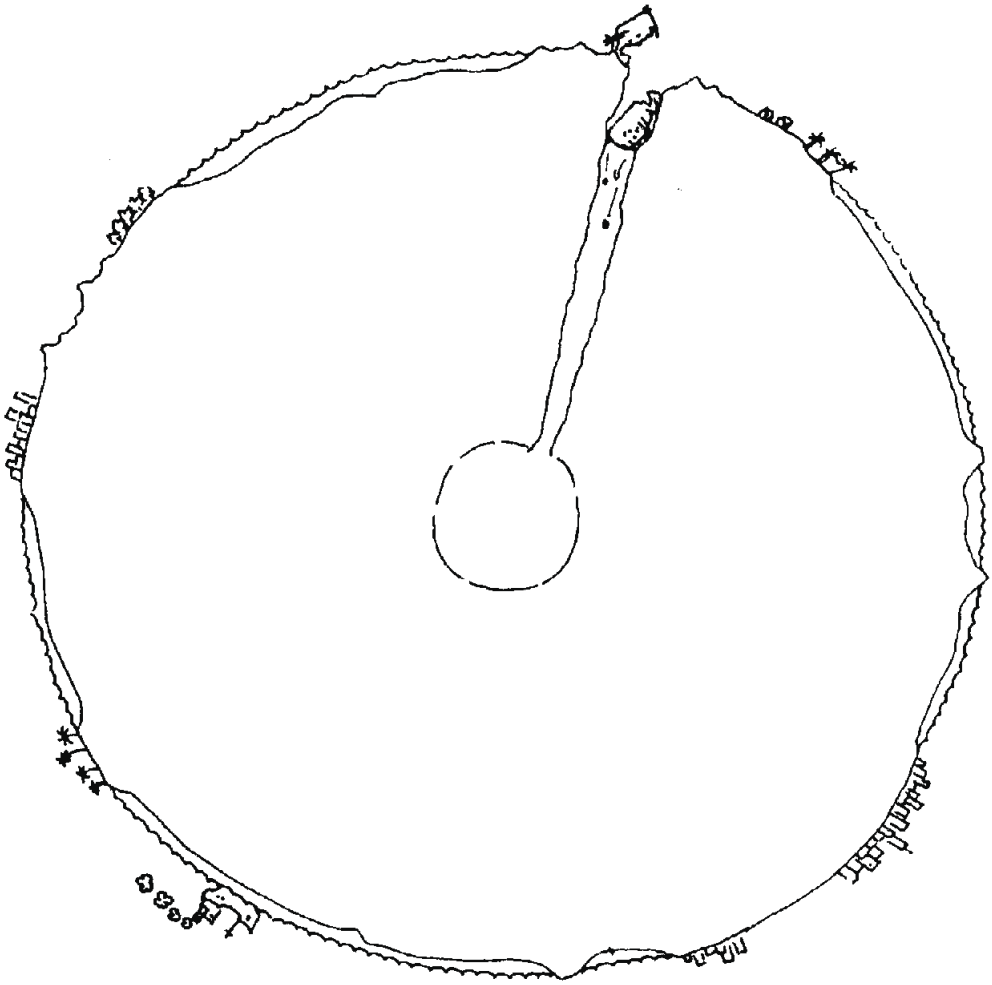
The oceans are not as deep near their centers due to the presence of MID-OCEANIC RIDGES ("mid" means it is in the middle).

Almost ever continental ridge is near a continental boundary and in front of a deep ocean trench. Thus, continents and oceans show the greatest difference in elevation over very short distances, as can be seen in drawings 1 and 2.

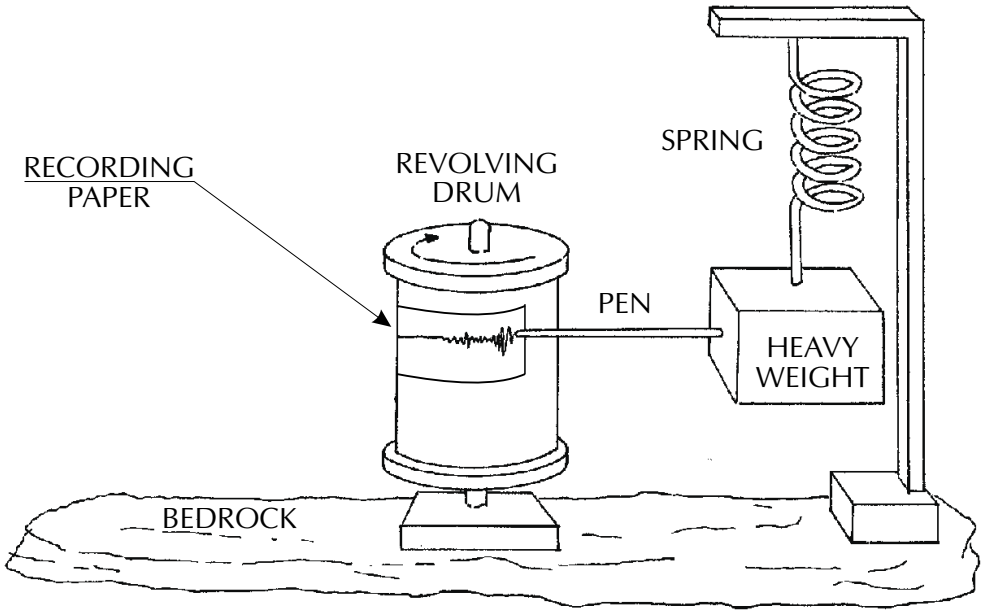


THE BOTTOM OF THE OCEAN SHOWS RIDGES IN THE MIDDLE OF THE OCEANS (MID-OCEANIC) AND MARINE TRENCHES CLOSE TO THE CONTINENTS.

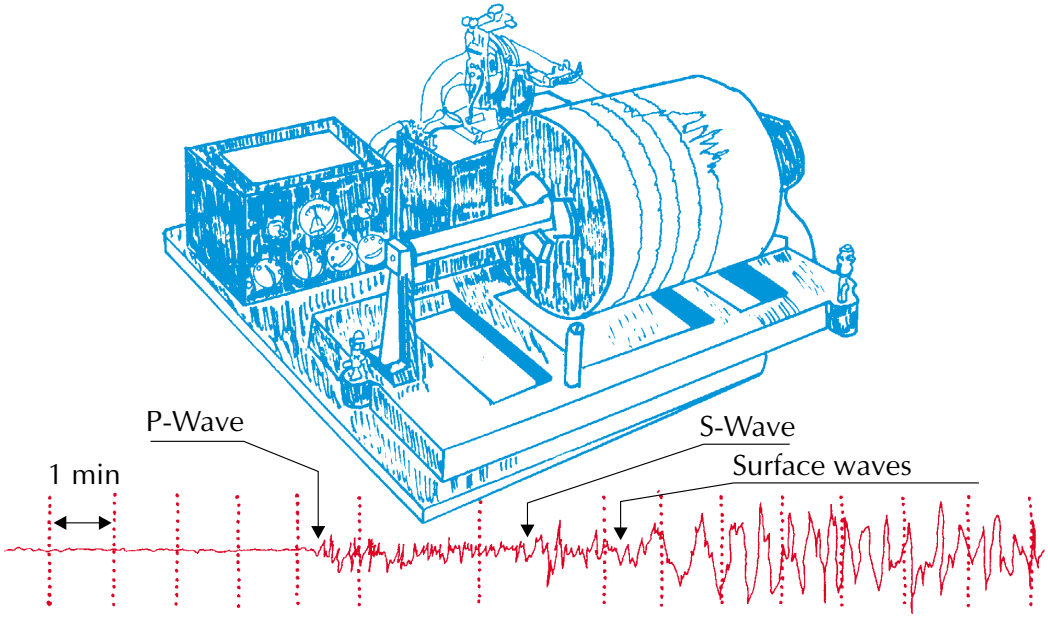
UNIT II



THE INTERIOR OF THE EARTH



Seismograph



Seismograph and seismogram.

COULD WE KNOW THE INTERIOR OF THE EARTH?

DO YOU KNOW?

Every year, ten or more big earthquakes shake our planet. The smallest of these eartquakes releases energy equivalent to one thousand times the energy released by an atomic bomb.

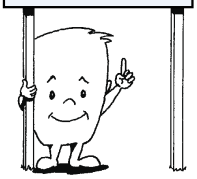
Nobody can make a trip to the center of our planet to discover its internal structure, that is, the material it is made of. However, today we know the internal structure thanks to instruments that record the waves produced by earthquakes.

Seismic waves go through the different layers of the earth and we can learn the characteristics of the areas they cross by their propagation velocities.

Whenever a fault is activated, three types of seismic waves are produced: P waves corresponding to primary or longitudinal waves, S or secondary waves, and surface waves.

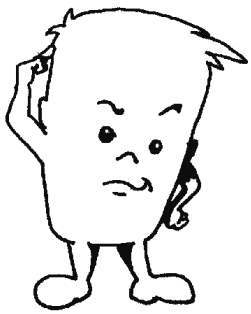
ACTIVITY:

With your class, visit an institution that has seismic instrument and observe these instruments in operation.

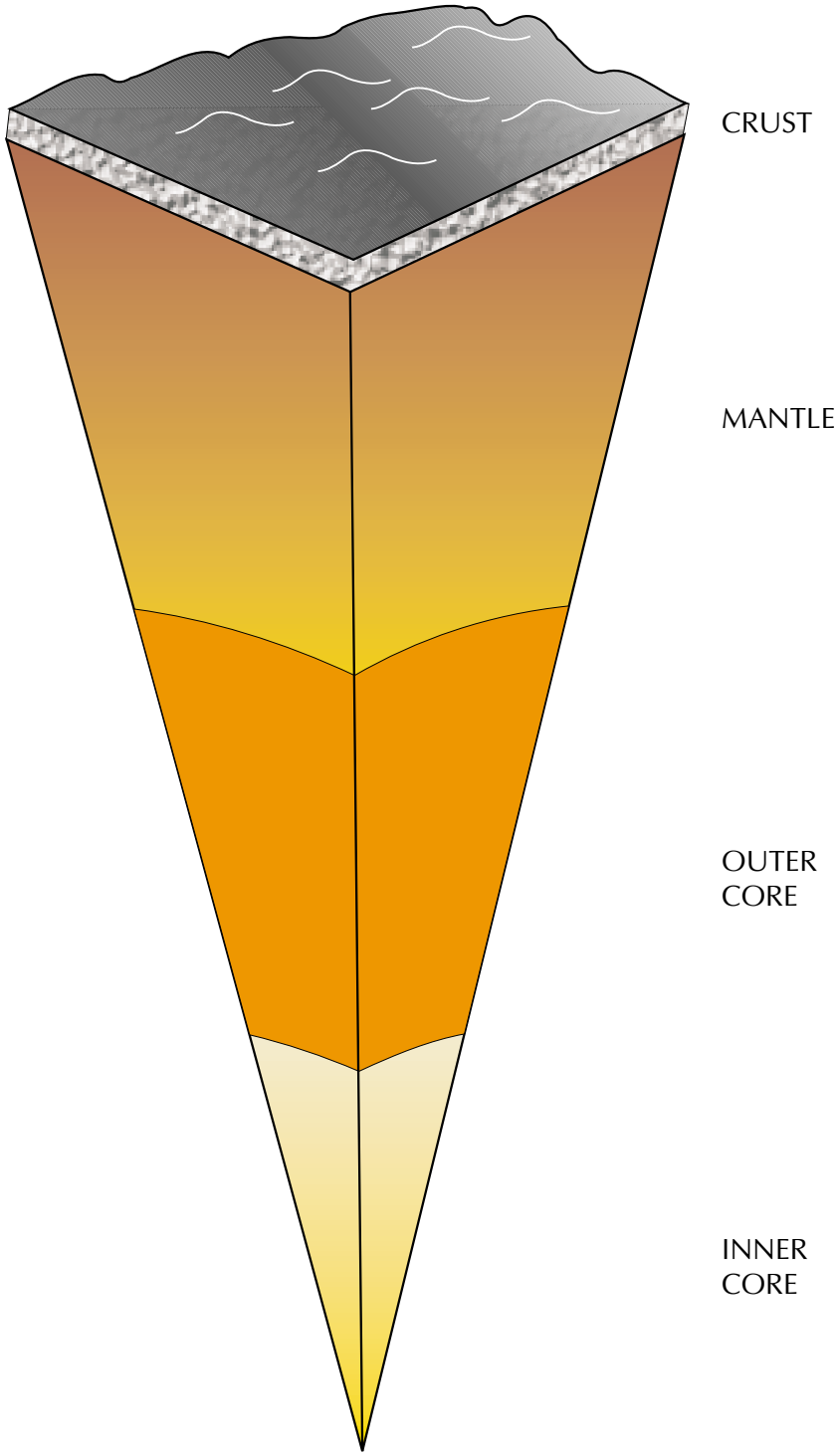


These waves are recorded using an instrument called a seismograph, through which we can determine the magnitude and location of the earthquake.

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 a lot about the structure of the earth.



The internal structure of the earth has been determined thanks to seismology. Seismic waves cross the different layers of the earth. There are 3 types of waves: P or primary waves, S or secondary waves, and surface waves.



Layers of the earth.

LET'S LEARN ABOUT THE INTERIOR OF THE EARTH...

DO YOU KNOW?

Pressure at the border between the inner and the outer core is 3.3 million atmospheres.

That is equivalent to the pressure of a pile of 3,300 medium size car on the surface of a fingernail.

The interior of the earth is made of layers with different characteristics. These layers are classified in different ways. We are going to learn only one of this classifications at the moment.

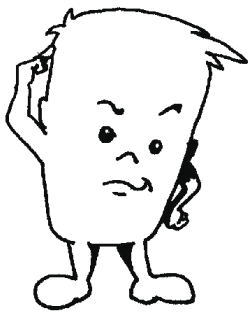
We will divide the earth into three basic layers:

CRUST, is the layer covering the earth's ground. It is composed of solid rock and has more rigidity than the next layer. its thickness varies between 5 and 60 kilometers and averages 33 kilometers. The continental crust is where we live, and the oceanic crust covers the bottom of the oceans.

MANTLE, this layer is under the crust and goes down to a depth of 2,900 kilometers. It is divided into two regions: the upper mantle from the base of the crust to a depth of 700 kilometers, and the lower mantle from that point down to the surface of the core.

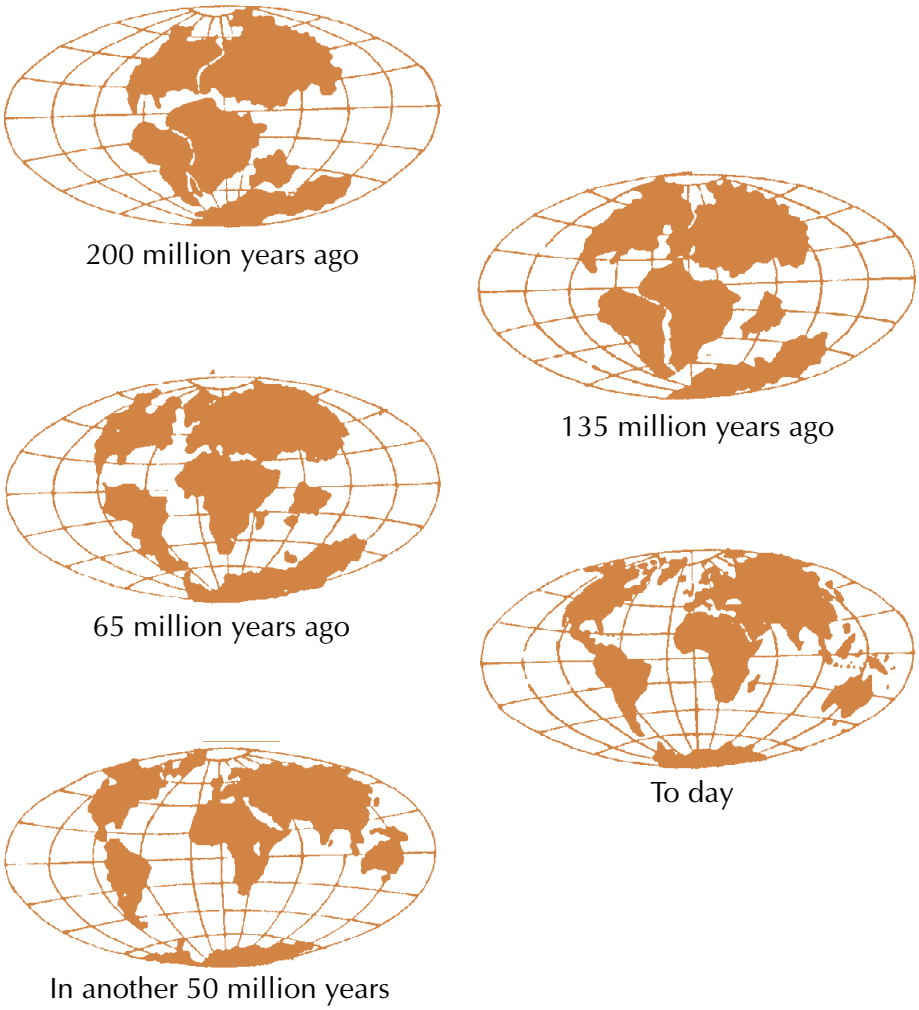
CORE, composed of the liquid outer core located between depths of 2,880 and 5,000 kilometers, and the inner core that is solid and has a radius of 1,200 kilometers.

Although the crust and the mantle are composed by several kinds of rocks, the inner core is made mainly of iron and nickel.

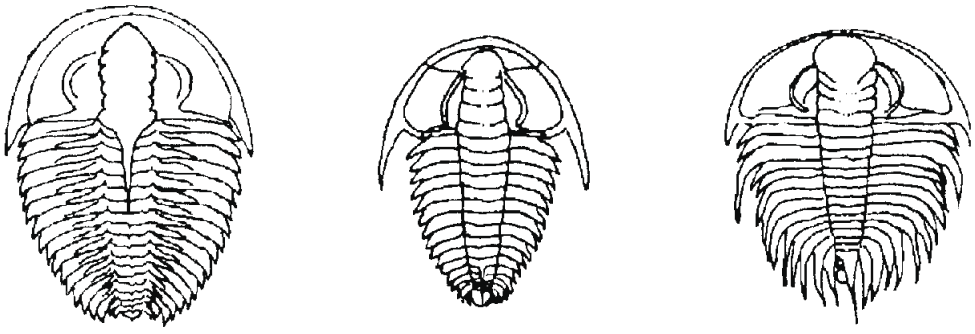


REVIEW:

The earth is divided into three layers: Crust (continental and oceanic crust), Mantle (upper and lower mantle) and Core (outer and inner core).



Formation and Breakup of Pangea.



Trilobite (200 million year fosils).

... AND THE ORIGIN OF THE CONTINENTS?

DO YOU KNOW...?

Wegener's theory is known as the theory of

"CONTINENTAL DRIFT".

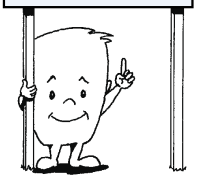
Many mysteries about our planet have stirred the curiosity of observant people. Earlier in this century, explorers were amazed to find rocks with fossil imprints of ferns in the frozen lands of the Arctic and the Antarctic. How could plants that thrive in warm, moist climates exist in what is now a harsh climate? What changes had taken place?

In 1912, Alfred WEGENER, a German scientist proposed a theory that all the continents where joined in the past in a huge megacontinent called "PANGAEA", which means "every lands" in Greek.

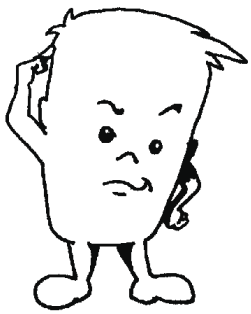
Wegener believed that Pangaea began breaking up and drifting a art many millions of ears ago. He insisted that C jigsaw puzzle fit Y1the continents was not an accident, but the result of the splitting of Pangaea. He said that the continents slowly drifted over the ocean floor until they reached their present positions.

ACTIVITY:

Find out... What other type of fossils can be found in the rocks of the mountains?



If you look at the shape of the eastern coastline of South America you will see that it fits very well with Africa, as if they were joined sometime in the past. Although Wegener's theory is not completely correct, it allowed scientist to understand that the earth's crust is not static, and to make other important discoveries.



Alfred Wegener established that at the beginning there was just one continent that split apart to start the origin of the continents you know. They drifted slowly to their present positions, and are still drifting: this is the theory of Continental Drift.

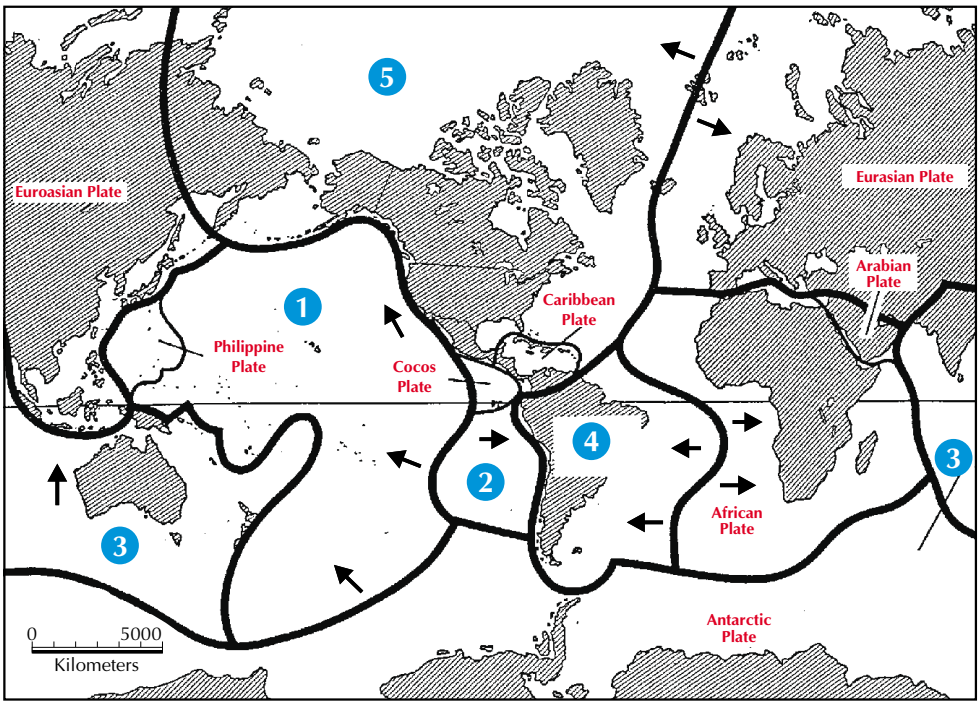
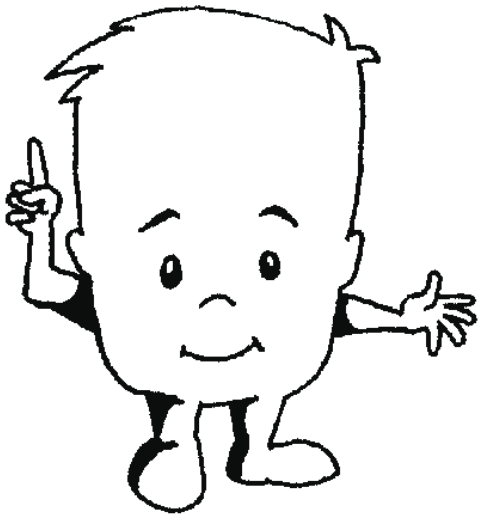


Plate boundaries map.

LOCATE!



WHAT IS PLATE TECTONICS?

DO YOU KNOW...?

Plates move at speeds of up to 15 centimeters per year at most.
The plate with the greatest velocity is the Pacific plate.

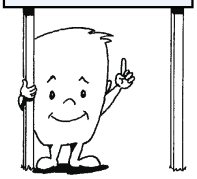
Scientific discoveries in the 1960's and Wegener's theory of continental drift suggested that the Atlantic Ocean was growing. Can an ocean grow? Is the earth's crust moving? Answer these question after reading the text.

In this map you can see the earth is divided into about 20 big sections called "plates". These plates have an average thickness of 70 kilometers. The map shows that a plate can contain both continental and oceanic crusts.

Plates can spread, collide or slide with each other. Arrows in the map show present direction of movement of each plate. Probably in the past the directions of movement were different.

ACTIVITY:

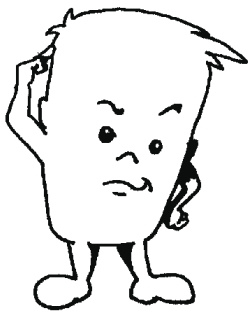
Find out the names of the plates number 1, 2, 3, 4 and 5 on the map.



The region where plates come in contact with each other is call a "plate boundary ". The way one plate moves with respect to another one determines what happens in their boundary.

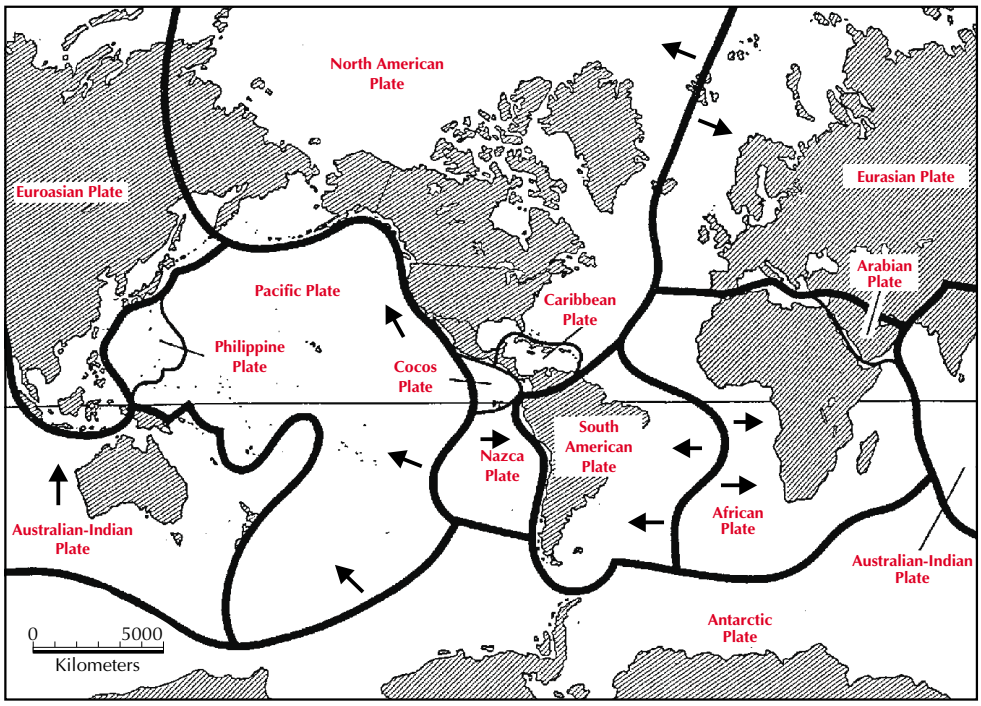
After this answer the questions.

	YES	NO
Could oceans grow?	☐	☐
Is the crust of the earth moving?	☐	☐



OVERVIEW

The earth is divided into about 20 huge plates, each of which can contain both continental and oceanic crust. The place where plates meet is called a "Plate Boundary".



Displacement of the tectonics plates.

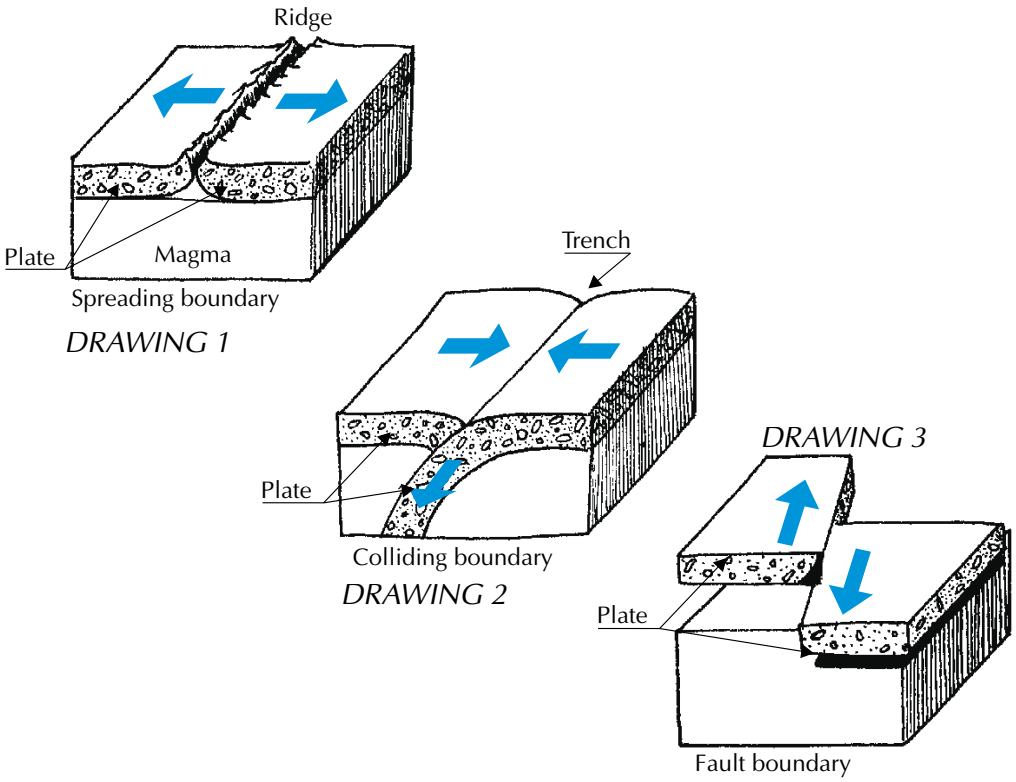


Plate boundaries.

WHAT ARE PLATE BOUNDARIES?

DO YOU KNOW?

Iceland, and island in the north Atlantic, emerged from the spreading in the Mid-Atlantic Ridge.

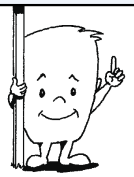
SPREADING BOUNDARIES are found where plates are moving apart at mid-ocean ridges (drawing 1). New crust forms at spreading boundaries. Volcanoes steam and the earth trembles with great regularity along this mid-ocean ridge. When Pangaea broke, it separated along the Mid-Atlantic Ridge. It took 200 million years for the Atlantic to grow to its present size.

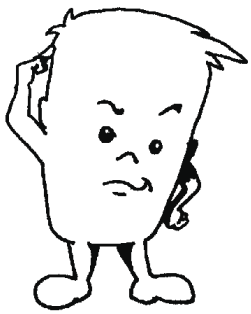
ACTIVITY:

Look carefully at the tectonic plates map and mark with colored pencils the different plate boundaries.
Mark them as follows:
Colliding boundaries= red
Spreading boundaries= green
Fault boundaries= blue

COLLIDING BOUNDARIES form where two plates bump into each other. The leading edge of one plate sinks into the mantle under the edge of another plate (drawing 2). Trenches bordering the Pacific Ocean are regions where the Pacific plate is sinking ... this is why this ocean is slowly shrinking.

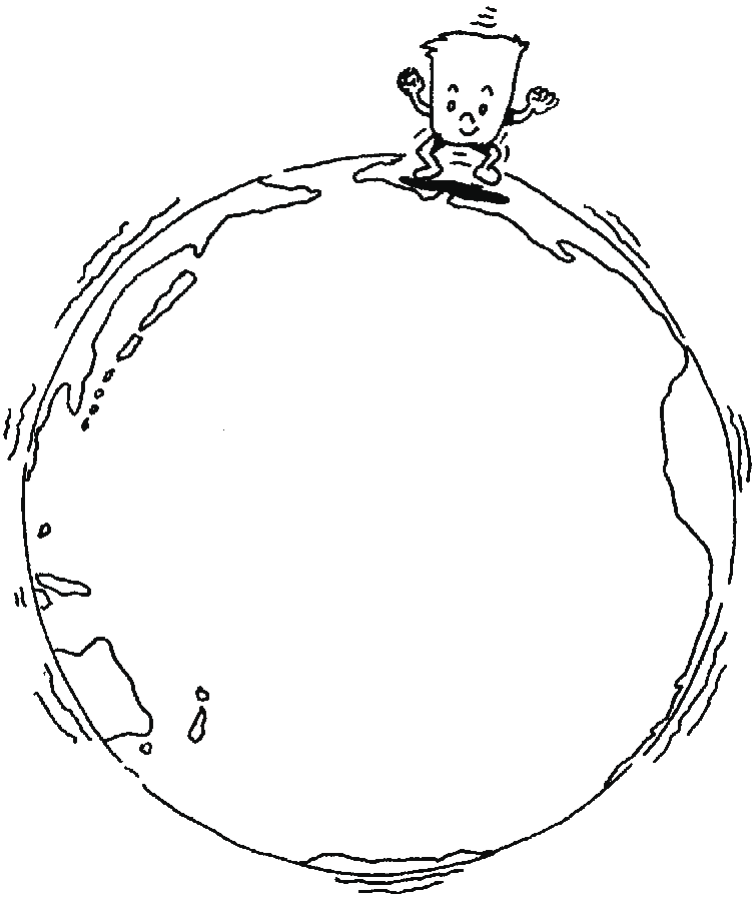
SLIDING BOUNDARIES occur where two plates rub past each other (drawing 3).



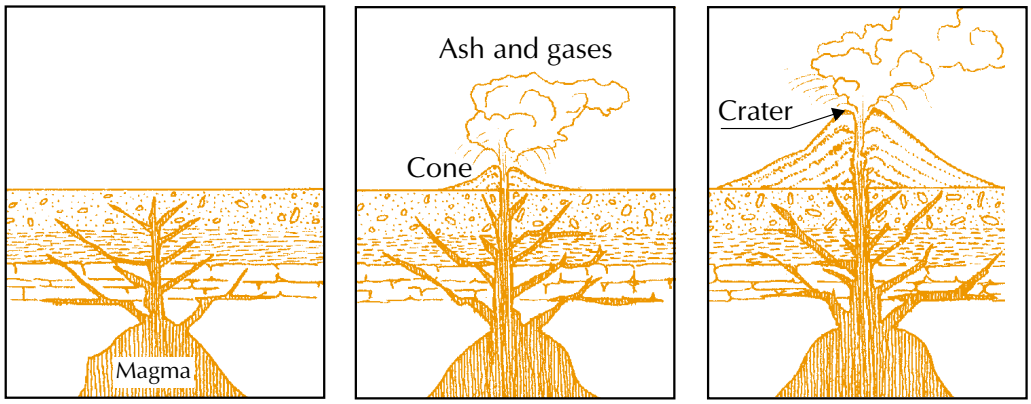


There are three types of plate boundaries: spreading boundaries forming mid-oceanic ridges, colliding boundaries where plates bump into each other and fault boundaries where plates rub past each other.

UNIT III



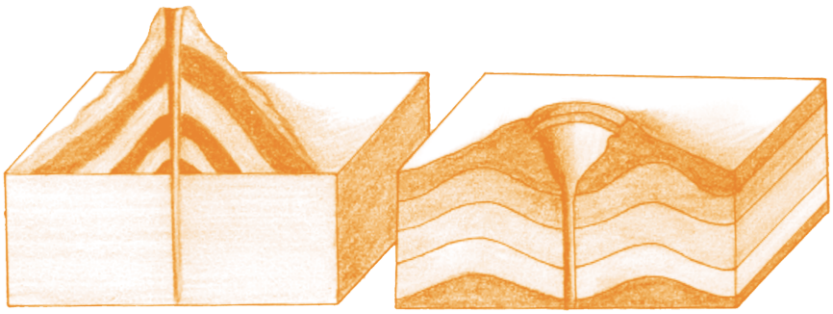
EARTHQUAKES AND VOLCANOES



How volcanoes are born.

CINDER CONE:
Forms when eruptions throw out mostly rocks and ash but very little lava.

SHIELD CONE:
Created by non-explosive eruptions with easy flowing lava.



COMPOSITE CONE:
Originates with alternating eruptions of dust, ash, and rock followed by quiet lava flows.

VOLCANIC DOME:
Results from violent eruptions of lava so thick that it barely flows.

HOW ARE VOLCANOES BORN?

DO YOU KNOW?

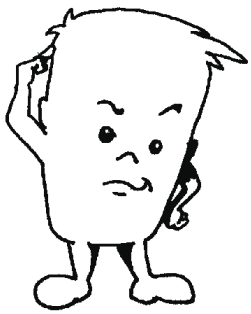
MAGMA is molten rock of very high temperature which is in the interior of the earth. When magma flows to the exterior through volcanoes it is called LAVA.

As we already know volcanoes are openings of the earth's crust that could originate at the oceanic crust by sinking under another oceanic plate, giving rise to volcanoes in islands that are called island arcs as the Japanese Islands. Volcanoes can also form on the continents where an oceanic plate is sinking under a continental plate, as in South America. Volcanoes differ in appearance and behavior. Some volcanoes shoot water vapor and other gases, dust, ash, and rocks explosively.

Visualize the effects of shaking a warm soda pop. The bottle may explode, releasing the soda and carbon dioxide, the dissolved gas in the soda. Cases and water vapor, which are under pressure inside a volcano, may also explode. One of the biggest volcanic explosions that ever took place was the eruption of the volcano Krakatau, a volcanic island in the strait between Java and Sumatra. In 1883 it exploded so violently that people heard the explosion 3,200 kilometers away. Most of the island disappeared. Volcanic dust remained in the air around the world for two years. A giant sea wave created by the explosion killed more than 36,000 people on nearby islands.

Volcanoes often give warnings before they erupt. These warnings include gas and smoke from the volcano. Earthquakes may signal the rise of magma inside the volcano. The ground around or on the volcano may bulge or tilt slightly.

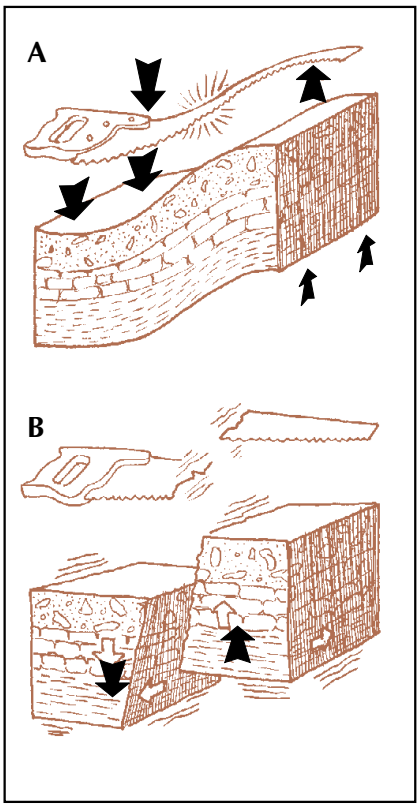
If a volcano has erupted in the recent past, it is called an active volcano. A dormant volcano is one that erupted in the past but has been quiet for many years. An extinct volcano is one that is not expected to erupt again. Most of the volcanoes in the Hawaiian Islands are extinct.



REVIEW

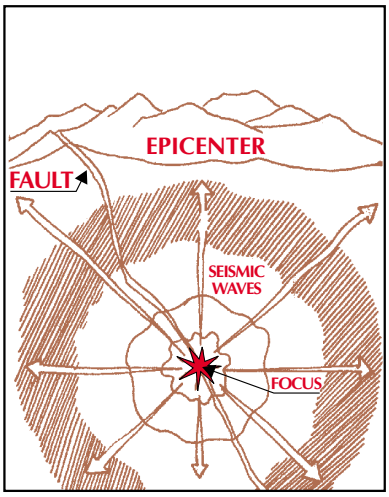
Volcanoes can originate at either oceanic or continental crust and vary both in their appearance and material they throw away. They can quietly ooze lava or explode under the pressure of gas and water vapor within the magma. Earthquakes may signal the rise of magma inside the volcano.

DRAWING 1



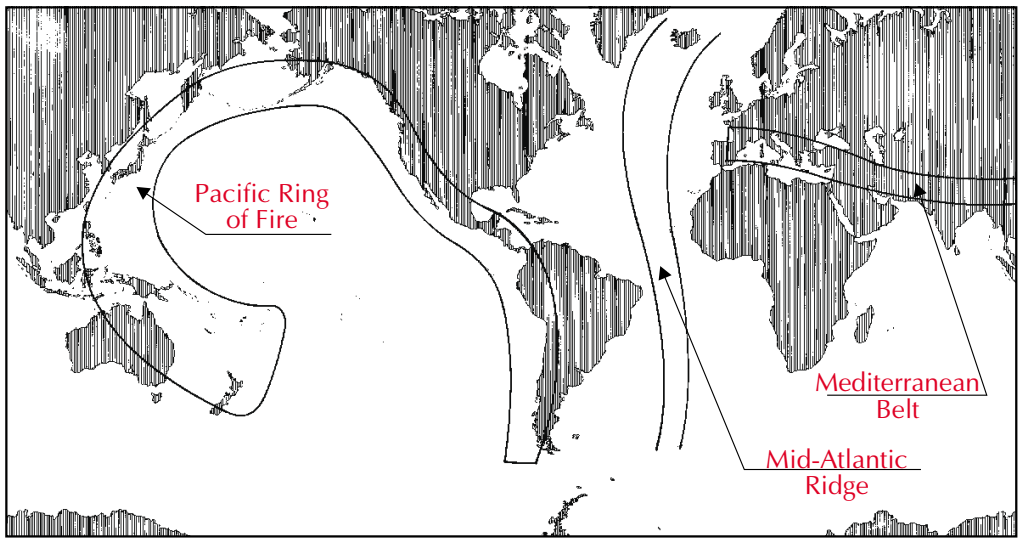
Seismic waves are generated by the break of the rocks.

DRAWING 2



Focus of an earthquake.

DRAWING 3



Areas of high seismicity.

WHAT ARE THE EARTHQUAKES AND HOW ARE THEY PRODUCED?

ACTIVITY:

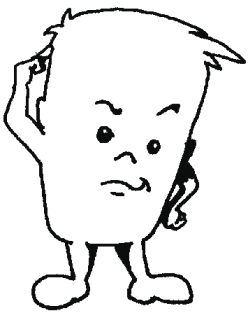
Compare the map (drawing 3) with the plate tectonics maps of page 18 and 20.
Can you explain why there is a zone called the "Ring of Fire of the Pacific"? Discuss this with your classmates.

An earthquake is a trembling or shaking of the earth. A big earthquake is one of the strongest forces of nature and it produces large scale destruction.

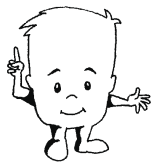
HOW ARE THEY ORIGINATED? Some earthquakes are caused by volcanic activity. During a volcanic eruption, magma ascending through the volcano's interior shakes the crust producing an earthquake. However, most of the earthquakes are produced by the movement of rocks along a fault and by the energy released at plate boundaries.

See drawing 1: rocks have a certain amount of elasticity and when they are under pressure they fold, but if the pressure is very high they finally brake and go back to their original position. A FAULT is a brake in the earth's rocks along which the two sides have been displaced relative to each other. When a brake occurs a big amount of energy is released as SEISMIC WAVES, as seen in drawing 2. The place where the earthquake originated is called the FOCUS or HYPOCENTER, and the place on the surface of the earth located over the focus is called the EPICENTER.

With highly sensitive seismographs installed around the world, it's easy to record seismic events, even if they are not felt by man. Once the seismic waves have been detected and recorded at several seismic stations, it is possible to determine the place where they have come from and the time they were produced.



An earthquake can be originated by volcanic activity, however, most of them are produced by movements of rocks along a fault or at a plate boundary. The FOCUS is the point where the seismic waves originated at first in the interior of the earth. The same point projected onto surface is called the EPICENTER.



MODIFIED MERCALLI INTENSITY SCALE

I	Not felt except by a very few persons under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeable indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake.
IV	During the day, felt indoors by many people. Dishes, windows and doors, disturbed; walls make cracking sound; liquids in open vessels disturbed.
V	Felt by nearly everyone. Some dishes, windows, etc., broken. Unstable objects overturned.
VI	Felt by everyone. Some heavy furniture moved. A few instances of fallen plaster or damaged chimneys.
VII	Everyone frightened. Overturned furniture in many instances. Trees and bushes shaken strongly. Noticed by persons driving cars. Cornices, brickwork, tiles and stones dislodged.
VIII	Damage slight in specially designed structures. Great in poorly built structures. Chimneys, factory stacks, columns, monuments and walls collapse.
IX	Every building damaged and partially collapsed. Ground cracked conspicuously. Underground pipes broken. Several landslides reported.
X	Some well-built wooden structures destroyed. Most masonry and frame structures destroyed along with their foundations.
XI	Few, if any structures remain standing. Bridges destroyed. Damage great to dams, dikes, and embankments. Rails bent greatly.
XII	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rocks may move.

HOW ARE EARTHQUAKES MEASURED?

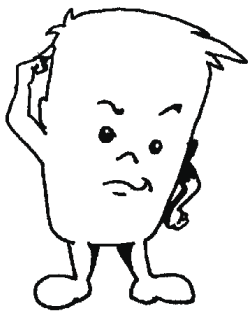
DO YOU KNOW?

The strongest recorded earthquakes in history occurred in 1960 off coast of southern Chile, and in 1964 off the coast of Alaska. Both had magnitudes over 9.1 in the Richter scale.

To measure an earthquake, two scales are used to determine its intensity and magnitude. The intensity of an earthquake is the violence with which the earthquake is felt at different locations in the affected area. Its value is determined by assessing the damage produced, the effect on objects, buildings and grounds, and the impact on people.

The intensity value of an earthquake is determined according to a previously established intensity scale, which is different for different countries. In several countries of America it is determined using the Modified Mercalli Intensity Scale, graded in 12 levels.

The magnitude of an earthquake is the energy released at the focus of the earthquake. It is measured with the help of an instrument called seismograph. The instrument's reading (amplitude of seismic waves) indicates the amount of energy released by an earthquake. The greater the wave amplitude, the greater the magnitude. A magnitude scale was devised by the American seismologist Charles Richter in 1935. It uses Arabic numerals. Richter's scale is open-ended; that is, there is no upper or lower limit to Richter magnitudes. Each whole-number increase in the magnitude of an earthquake represents about a thirty-fold increase in the amount of energy released.



SUMMARY:

Earthquakes are measured using the intensity (Modified Mercalli) and magnitude(Richter) scales.

EARTHQUAKE WARNING SIGNS

Warning Sign	Detected by
Foreshocks - a series of small tremors.	Seismograph
Local variations in the earth's magnetic field due to changes in rock under pressure.	Magnetometer (measures magnetism)
Tilting of the earth's surface due to movements caused by a buildup of stress.	Tiltmeter (detects tilt)
Increased levels of radon, a radioactive gas, in deep wells. Gas is released into the water by rocks under pressure.	Scintillation Counter (detects radioactivity)
Movement along a fault.	Creepmeter - a wire or rod stretched across fault
Rising or failing of the land.	Gravity meter
Expansion or contraction of rocks.	Strainmeter
Changes in the ability of rocks to conduct electricity.	Resistivity gauge
Changes in the level, temperature, and murkiness of water in wells, especially deep wells.	Direct observation, thermometers
Spreading apart of land along a fault.	Laser Range - measures round-trip travel time of a light beam bounced across a fault.

TO DRAW OR STICK (Page 49)

CAN EARTHQUAKES BE FORECAST?

Where and when will the next earthquake occur? How strong will it be? Scientists are trying to answer these questions.

People all over the world who watch faults find that certain "signs" often occur before earthquakes. The ground sometime bulges or tilts near a fault before an earthquake. An increasing number of small earthquakes on a fault could mean that a strong earthquake is coming. Also, change in the water level in a well near a fault is often an earthquake sign. These changes might last for several months before smaller destructive earthquakes or for years before large ones.

Using these signs and many others, scientists have been able to correctly predict some destructive earthquakes. Perhaps in your lifetime earthquake forecasts will become accurate enough to save lives.

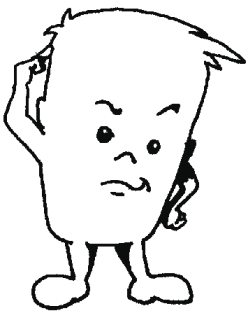
ACTIVITY:

Draw or stick drawings of three of the instruments named on page 30.

DO YOU KNOW ANIMALS CAN PREDICT EARTHQUAKES?

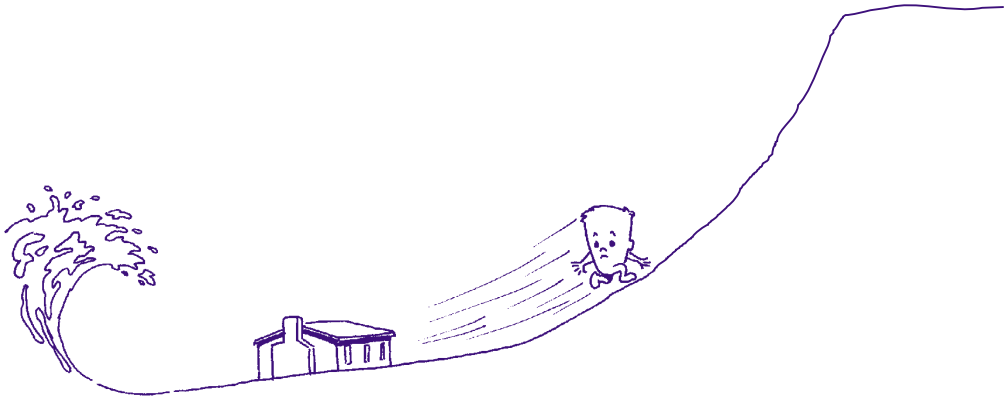
A government agency in China has reported that strange animal behaviors were observed just hours before an earthquake. Cattle, sheep, mules, and horses would not enter corrals. Rats fled their homes. Hibernating snakes left their burrows early. Pigeons flew continuously and did not return to their nests. Rabbits raised their ears, jumped about aimlessly, and bumped into things. Fish jumped above water surfaces.

China was not the only country to report such unusual animal behavior. Late on May 6, 1976, an earthquake shook a town in Italy. Before the earthquake, pet birds flapped their wings and shrieked. Mice and rats ran in circles. Dogs barked and howled. Perhaps the animals sensed the coming earthquake?

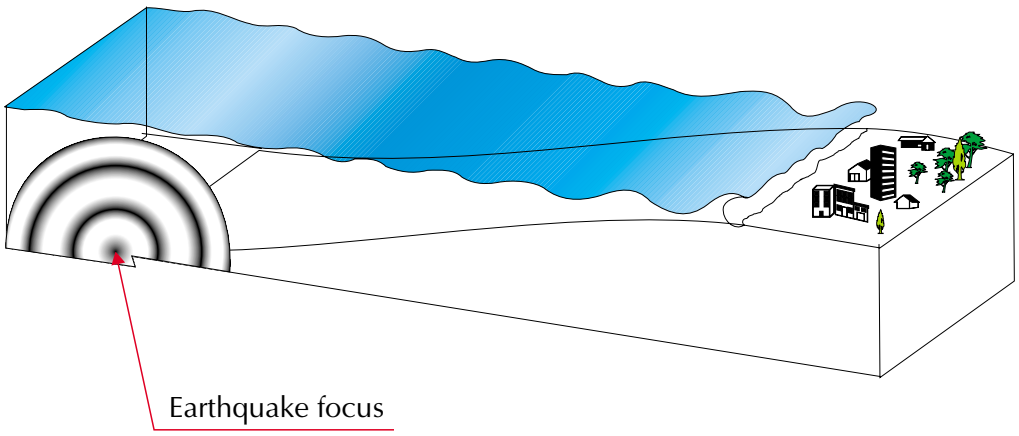


Presently, scientists are able to recognize some premonitory "signs" of earthquakes... Someday they will be able to forecast earthquakes without fail.

UNIT IV



TSUNAMIS



Origin and propagation of a tsunami.

LET'S LEARN ABOUT TSUNAMIS

DO YOU KNOW?

In 1883 a series of volcanic eruptions in Krakatau (Indonesia) produced a powerful tsunami with waves as high as a 12 story building.

The word tsunami is of Japanese origin. If we break the word in half we see that "tsu" means harbor and "nami' means wave.

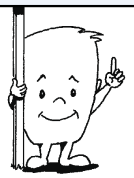
A tsunami is a series of sea waves spreading rapidly in all directions from the area on the sea bottom where a large earthquake, volcanic eruption, or coastal landslide has occurred.

As a tsunami reaches the coast, the first thing that may happen is a withdrawal of water. More shore may be exposed than even at the lowest tides. This major withdrawal of sea water should be taken as a warning of the tsunami wave that will follow. No one would want to try to outrun a fast-moving ten-meter wave that could smash the shore with great impact.

Another tsunamis begin with a rise of the sea level. As the tsunami wave of the maximum height appears as 2nd. or 3rd. wave, you should not think to be safe just after the first tsunami wave attack.

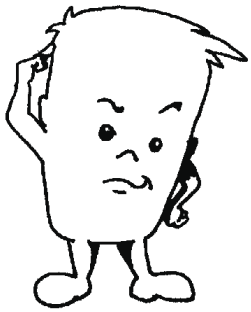
ACTIVITY:

Find out what countries have suffered destructive tsunamis in the last 50 years.



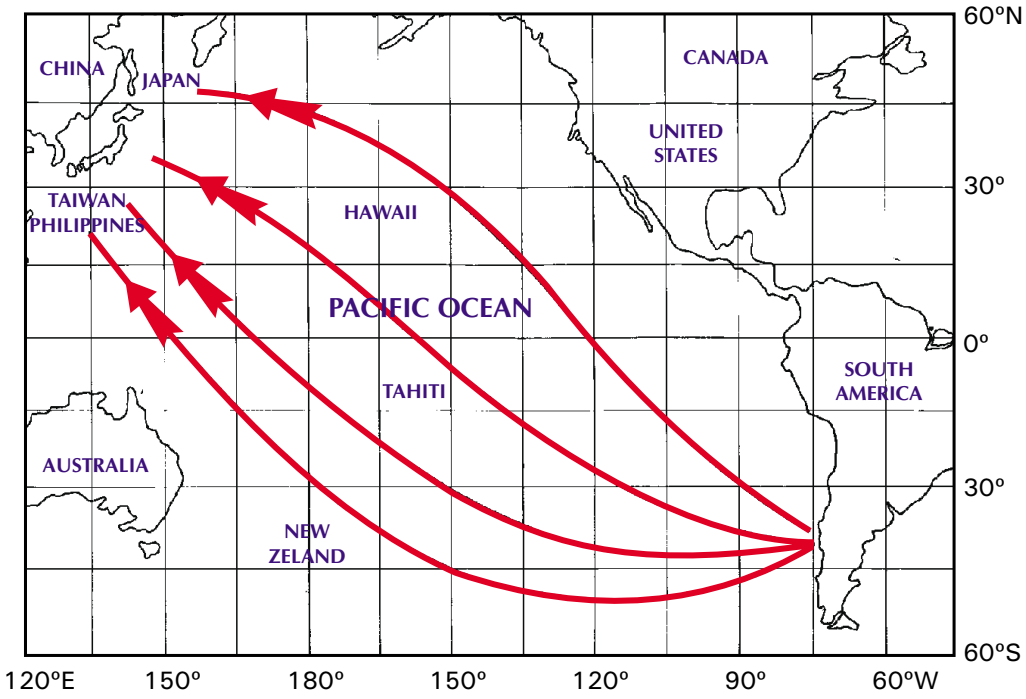
HOW IS A TSUNAMI CREATED?

Most tsunamis occur after a large earthquake under the ocean, and are due to changes in the sea bottom at faults or plate boundaries.



SUMMARY:

A tsunami is a natural disaster occurring after a large earthquake. It is a series of long waves moving at great speed over the ocean. At the coast they can be as high as 30 meters, causing damage to cities and people.



Propagation of the tsunami waves fron the Chilean 1960 earthquake.

TSUNAMI PROPAGATION

ACTIVITY:

Find out the latitude and longitude of Chile and Japan. Relate them to the drawing.

The return of sea level to its normal position generates a series of waves propagating in all directions. These waves are not uniform. They can be modified by different phenomena:

When a tsunami travels a long distance across the ocean, the sphericity of the Earth must be considered to determine the effects of the tsunami on a distant shoreline. Waves that diverge near their source may converge again at a point on the opposite side of the ocean.

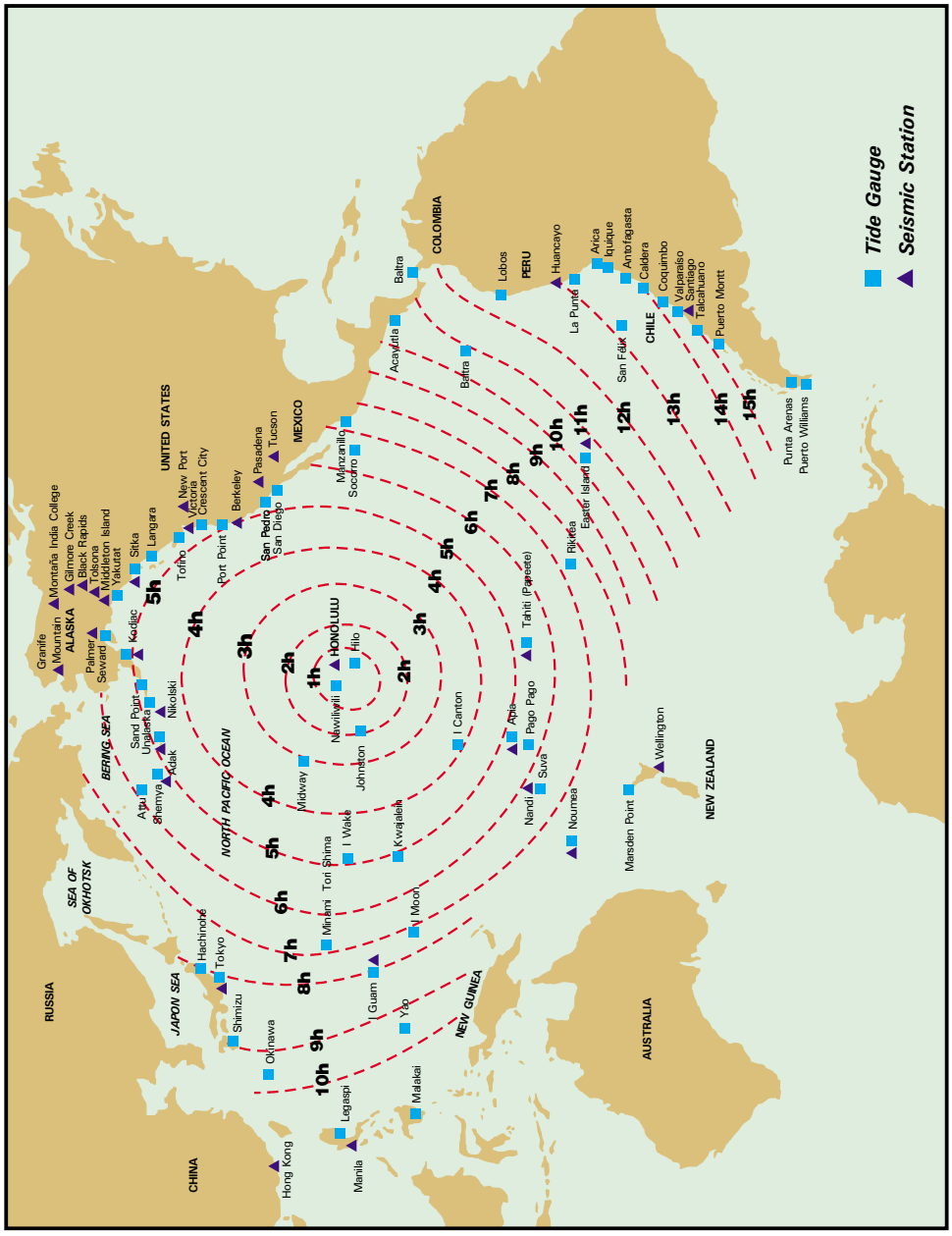
In the drawing you can see a clear example of this, where a tsunami produced in Chile affected the Japanese coast, producing much damage and many victims.

Tsunami waves can also change direction (refraction of water waves) due to shoaling, as well as due to oceanic currents moving obliquely to the tsunami direction of propagation.

As a tsunami approaches a coastline, the waves are modified by the various offshore and coastal features. Submerged ridges and reefs, continental shelves, headlands, bays of various shapes, and the steepness of the beach slopes may modify the period and height of the tsunami wave .

SUMMARY:
When a tsunami occurs, waves traveling at great speed, which can travel great distances through the oceans, change their course due to:

- ***sphericity of the earth***
- ***depth differences in the ocean***
- ***marine currents moving obliquely***
- ***costal features***



Propagation chart of tsunamis.

TSUNAMI ORIGIN

DO YOU KNOW?

A tsunami is able to travel through an entire ocean with a velocity of up to 900 kilometers per hour.

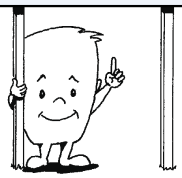
In a local tsunami, the source phenomenon (large earthquake, submarine volcanic eruption, or coastal landslide) is very close to the observer.

In this case, the tsunami effects are present almost immediately after the source phenomenon (large earthquake, etc.) is over. Lapses of time as short as 2 minutes have been observed between the occurrence of an earthquake and the arrival of the first tsunami wave to the nearest coast.

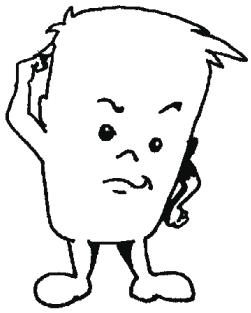
Because of this, a tsunami warning system is useless in this type of event and we should not expect instructions from an established system to react and keep us safe from the possible tsunami impact. This operational incapability of the warning systems is further increased by the possible communications and systems collapse generated by the earthquake. Hence, it is necessary to have prepared a proper response plan in case of a tsunami.

ACTIVITY:

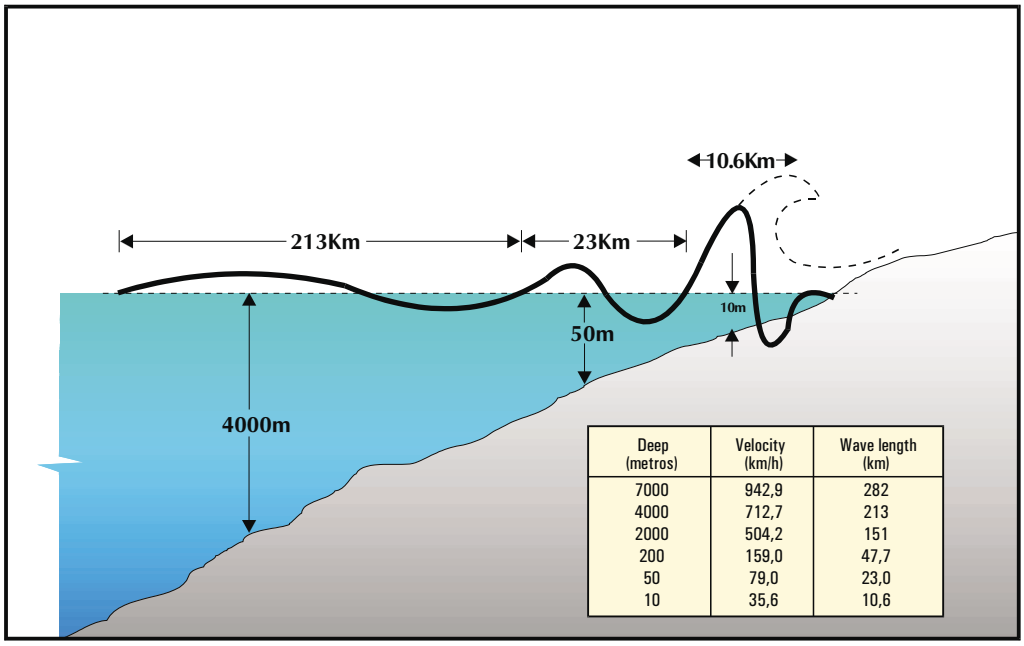
Ask your family if they remember any tsunami that have ocurred in the country. Discuss with your teacher and classmates.



With a distant tsunami, the earthquake or volcanic eruption occurs in one place, and the tsunami is registered at a different and distant place (several thousands kilometers away) several hours later.



SUMMARY:
Tsunamis are local when their effects are produced inmediately after the occurrence of the erthquake; they are distant when their effects are produced hours after the earthquake's occurrence in a very distant location.



Propagation and changes of tsunami waves near of the coast.

COASTAL EFFECTS OF A TSUNAMI

Effects produced by a tsunami at the coast are varied. They depend on the shape of the sea bottom and the shore, as well as on the tsunami wave's orientation when arriving at the coastline. As we can see in the drawing, if the sea is deep at the coast, the rise of the water level will be less violent than at a shallow coast.

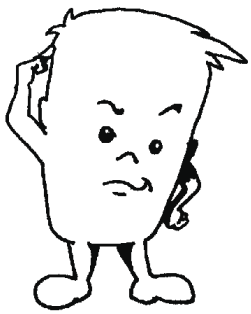
DO YOU KNOW... ?

The destruction caused by tsunamis stems mainly from the impact of the waves, the erosion of foundations of buildings, bridges and roads.

When a tsunami reaches the coast, the water level can rise several meters. In extreme cases, water levels have risen 30 meters, however, 10 meters is more common. This is called tsunami runup, and it can vary greatly from place to place.

An example of how extreme this variation can be is given by some scientists for Haena, on the island of Kauai, Hawaii, where there was a gentle rise of water level on the western side of the bay, but less than one mile to the east, waves rushed on shore, flattening groves of trees and destroying houses.

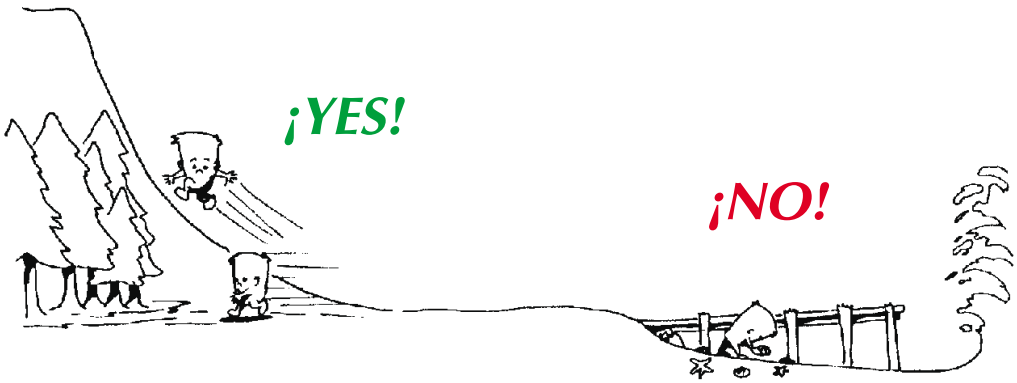
It should be noted that the characteristics of the waves may vary from one wave to another at the same coastal point. Some scientists cite a case in Hawaii where the first waves came in so gently that a man was able to wade through chest-high water ahead of the rising water. Later waves were so violent that they destroyed houses and left a line of debris against trees 150 meters inland.

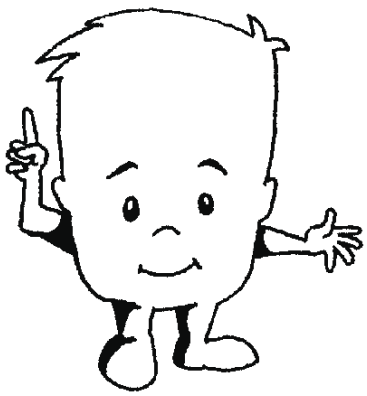


SUMMARY:
Effects produced by a tsunami on the coast depend on the shape of the sea bottom and the coastline, as well as the orientation of the incoming tsunami waves.

UNIT V

PROTECTION TSUNAMI MEASURES


¡YES!
¡NO!



HOW SHOULD WE PROTECT OURSELVES FROM TSUNAMIS?

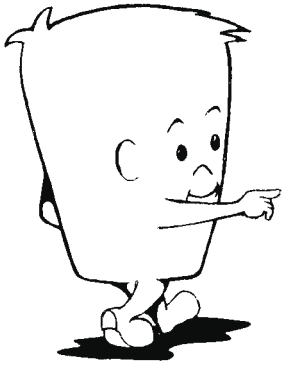
As you already know, a tsunami usually originates from a large earthquake. Therefore, if you are in a coastal area when an eartquake occurs you should quickly move to a higher land or tough building, as soon as possible.

It is impossible to fully protect any coast from the ravages of tsunamis. Countries have built breakwaters, dikes and various other structures to try to weaken the force of tsunamis and to reduce their height. In Japan, engineers have built broad embankments to protect ports and breakwaters to protect narrow harbor mouths in an effort to divert or reduce the energy of the powerful waves.

But no defense structures have been able to protect the low-lying coasts. In fact, barriers can even add to the destruction if a tsunami breaks through, hurtling chunks of cement about like missiles.

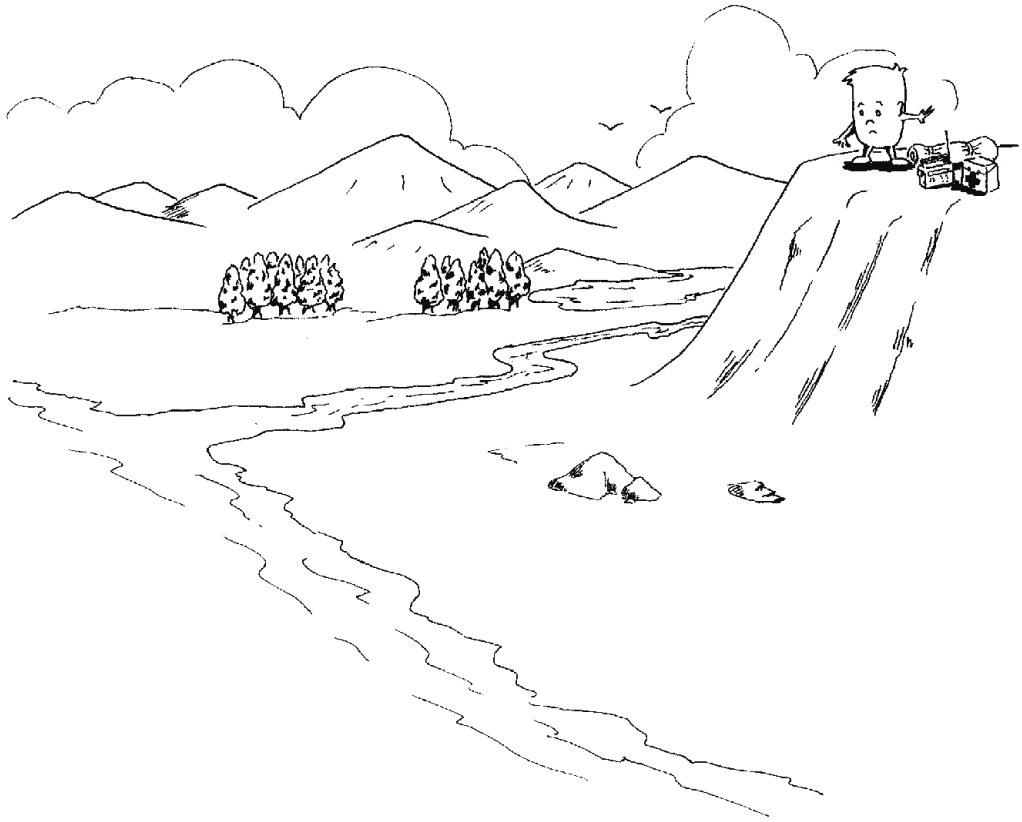
In some instances, trees may offer some protection against a tsunami surge.

The most important thing is to protect yourself and your family by following these actions:



IF YOU ARE AT THE BEACH

- If you perceive the severe shocks of an earthquake, don't stay watching or collecting shells from the beach, leave the beach and move quickly to a location that is more than 30 meters above mean sea level.
- If there is no high ground near your location, protect yourself in a forest, or a tough building.

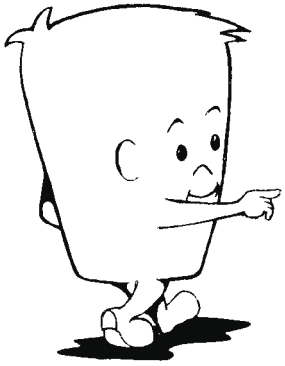


IF YOU ARE AT HOME OR AT SCHOOL

DO YOU KNOW?

If you stay calm and follow the given instructions, no damage from the tsunami will be experienced.

- Follow instructions given by the authorities on radio and TV.
- Go quickly to a place at an elevation more than 30 meters above mean sea level or to a forest.
- Keep away from rivers.
- Take with you a portable radio, a blanket, some food and water for drink. Nothing else.
- If your are with adults, remind them to take a first aid kit.
- Do not return home until authorities say that the tsunami is over.
- If you are far from your family, you should go to the previously established meeting place.



If there is a tsunami, I must:

- ***Follow instructions given by authorities.***
- ***Keep away from the beach and other low lying areas and go to a place more than 30 meters above mean sea level.***
- ***Keep away from rivers.***
- ***Take with me a portable radio, a blanket, food and drinking water.***

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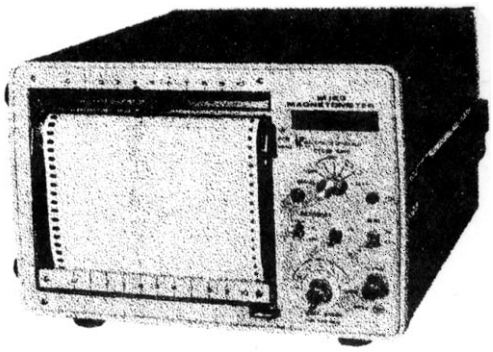
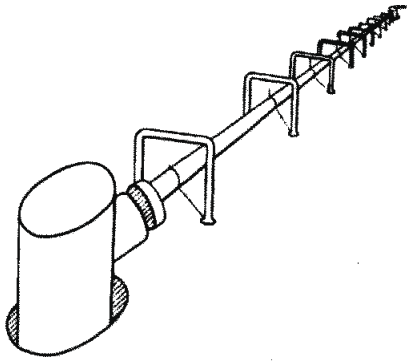
DRAWINGS OF INSTRUMENTS TO CUT OUT

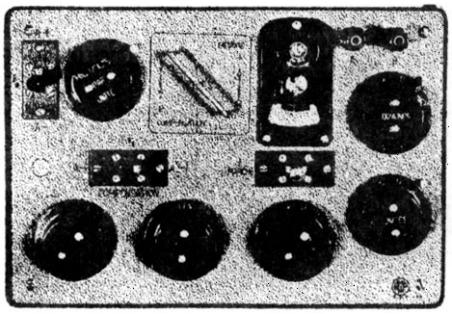
GRAVITY METER



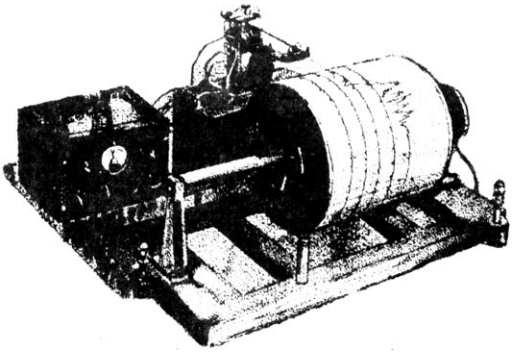
MAGNETOMETER



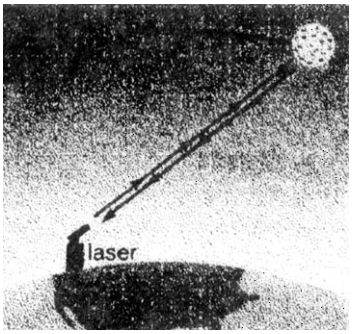
STRAINMETER



RESISTIVITY METER



SEISMOGRAPH



LASER RANGE
MEASURES