INTERIOR OF THE EARTH

Analysis of the behavior of seismic waves as they pass through the earth from the focus to seismograph stations has yielded basic information about the architecture of the earth.

3 km -mines	1. granites buried
11 km-oil drilling	2. metamorphism
40-700 km-volcano and fragments	3. geophysics

PRESSURE AND TEMPERATURE IN THE EARTH'S INTERIOR

All matters tend to be drawn or held together by gravitational attraction.
In case of spherical earth gravitational attraction is directed approximately towards the earth's centre of directed approximately towards the earth's centre of mass and gives the quality of weight to all substance.

Weight = m x g

where, m = quantity of matter in the object or mass.
g = acceleration of gravity

A weight is equal to the force with which it presses vertically down upon a horizontal surface on which it is resting.

Pressure = Force/unit area

It will go on increasing as we go toward the centre of the earth.

The metallic state is one in which the ions are much more tightly packed than in the crystals of rock forming minerals , so tightly that some of the electrons are forced of their orbit, so tightly that some of the electrons are forced out of their orbit so that they are free to move through the crystal lattices.

Rocks at surface are strong and brittle and at great pressure it would shatter into fragments rather than flow as air and water does.

However, under extremely greatly confining pressure and high temperature rocks can flow like a thick tar and at some time come to rest at hydrostatic pressure.

Depth km	Pressure K bar	Atmospheric Pressure
0	0.00 approx.	1
8	2.4	2,400

16	4.8	4,800
24	7.2	7,200
40	12.0	12,000
1/3 distance to centre		1 million atmosphere
Centre		3.5 million atmosphere

Matter at the earth's centre has no weight because it is being attracted outward equally in all directions by the mass of the sphere that surrounds it.

But confining pressure is greatest here because of the combined weight of the entire earth mass is directed towards that one point.

Temperature

Temperature also increases greatly into the earth's interior.
Measurements of rock temperature in mines and bore holes show that the rate of temperature rise or geothermal gradient, average:

1 °F per 50 ft. Or
1 °c per 30 m
But rate of temperature increase observed near the surface falls rapidly with depth.

Estimate of temperature from surface to core is as under:

Molten iron from a Blast furnace reaches 2000°c, and this is not far from representing the earth's interior temperature. But at high pressure.

Earth's Mass and Density:

Mass can be measured by Newton's law of gravitation and mechanics.
Mass is quantity of matter and is one of the fundamental properties of the physical universe.

Mass of the Earth

6.6×10^{21} tons or
5.975×10^{27} gm

Volume of the Earth

Depth (km)	Temp °c	°F
30	500	900
100	1100	2000
200	1400	2600
1000	1700	3200
3000	2300	4200
6000	2500	4600

By computing the volume of the earth from its ellipsoid dimension:

$V = 1.08 \times 10^{27}$

Average Density

Mass/ Volume = 5.53g/cc
Iron has density of nearly 8 g/cc

Earth's outermost zone is of density: 2.6 gm/cc (e.g. granite)
or 3.0 gm/cc for Basalt.

which are much less than average of 5.53. Therefore density must increase towards centre. Therefore core is 11.0 g/cc composed of iron.
Because if iron were compressed in the earth's interior under 2-3 million atmosphere of pressure, density of iron will change from of 8 to 11.

Meteorites also indicate evidence for iron core. Between outermost layer and earth's core, density must range between 4.6 and 6.0. Rock that fits this requirement is dunite, an ultramafic rock with average density of 3.0 gm/cc. But at pressure it will increase to a density of 4 to 6.

The CRUST

Mohorovicic Discontinuity
It is a seismic interface between Crust and the Mantle. It was discovered in 1909 by Yugoslav geophysicist named Andrija Mohorovicic (1857-1936).

He found that below depths of few tens of km P and S waves travel faster than at shallow depths. The speed of P wave (7 km/sec) increased to 8.2 km/see.

This discontinuity was named in honor of Mohorovicic. It was later found to be a world wide phenomena.
Moho is therefore a boundary between the crust and the mantle.

The earth's crust

The outermost zone of the earth, the crust, consists of a layer varying from 5-25 miles (10-40 km) in thickness.

It averages 17 km (10 miles) in thickness when calculated as uniformly spread over the globe.

The crust is distinguished from the mantle by the presence of rather abrupt and clearly defined change in the velocity of seismic waves.

Generally speaking, rigidity of crust and mantle rocks increases with depth. Two possibilities are considered:

1. gradual increase in the rock rigidity with depth
2. there exists layers of rocks each of uniform rigidity within itself but with each successive deeper layer changing abruptly to higher rigidity.

Waves of both shallow earthquakes and surface explosions show quite definitely that the continents consists of plate-like crust, averaging about 33 km (20 miles) thicjk resting upon quite different rock of the mantle.

The continental crust consists of largely granitic rock in the upper part and of largely basaltic rock in the lower part.

It is known that the P-waves near the surface travel at about 6.3 km/sec, which is expected in granitic rockm and that this velocity increases gradually or abruptly to the base of the crust where it is about 7 km/sec. a velocity expected in basaltic rock at this depth.

At about 33 km depth, on the average, the velocith increases abruptly to more than 8 km/ sec, a speed to be expected of an ultrabasic rock, such as peridotite. S-waves undergo a corresponding velocity increase with depth.

This surface of sudden increase in wave velocity, whcih separates the crust above from the mantle below is named as Mohorovicic discontinuity or M-discontinuity or Moho.

At the margins of the continents the crust thins rapidly and at the same time its base, marked by Moho, becomes much shallower.

The basaltic rock of the lower part of the continental plate extends out over the ocean basin floors as a layer of 5-8 km thick, but there is no granitic material above it.

The Mantle

The same method used by Moho could be used to examine deeper parts of the earth. Other methods of learning about the mantle is:

1) examination of exotic block thrown out of volcanoes
2) study of depth distribution of earthquake foci

The evidences from the first method indicate that the mantle contains mafic silicate rocks including garnets.

2) Around Pacific ocean, earthquake foci are concentrated along planes that dip 45°away from ocean. Such inclined zones of earthquake foci have been named Benioff zones. The maximum depth of such foci are 700 km.

Variations in the seismic properties of upper mantle

First nobody believed.

A zone was found in which the speeds of S and P waves did not increase regularly with depth, as they should if the properties of the mantle are changing gradually.

At one depth: the speed decreased before they resumed their usual pattern of increase with depth.

This zone lies in the depth range of about 100 to 200 km. Together, the mantle and crust above this zone where speed of seismic waves reverse constitute the lithosphere.

This reversal of speeds of seismic waves is taken to indicate the existence of a zone of low strength and easy flow, which has been named as **Asthenosphere.**

Another boundary within the mantle lies at a depth of 700 km. This makes the lower limit of deep focus earthquakes. The depth of 700 km divides the upper mantle and lower mantle. Within the mantle no other boundary is found.

At 2900 km lies the mantle core boundary.

The Mantle
P and S wave travel faster in more rigid and denser material.
Rigidity: It is the resistance of elastic body to a change of shape.

For example rubber and steel both are elastic but iron has higher rigidity.
Rocks in general has high rigidity whether composed of crystallized or glassy material. Rigidity determines the velocity of seismic waves.

Mantle
Physical properties of the outer mantle

At first seismologists supposed that earthquakes are set off by fault movements near the earth's surface at depths down to little more than 55 km (< 55 km shallow earthquakes). Further study led them to realise that many shocks have a focus very muc deeper.

Intermediate depth: 55-240 km
Deep earthquakes: 300-650 km
A few originate below 720 km

Thus the earth seems to have an outer most layer which has great strenth, but which will break by faulting when unequal stress are too strong.

Below brittle zone, estimated about 60 km thick, and entering the mantle,the rock has less strength and brittleness.

Increasingly plastic quality of it enables to undergo very show flowage.

As early as 1914 Joseph Barrell, an American geologist, proposed that the plastic zone of the mantle be called Asthenosphere (Greek meaning weak) to distinguish it from the overlying rigid zone or lithosphere. The lower lomit of therigid zone represents not a change in rock composition but instead a change in physical properties.

For example an iron bar is heated on one side.
The rigid zone extends to equal depth unde both continents and ocean basis.

Elasto-viscous substance: Means brittle and plastic at the same time.

Physical properties of the upper mantle

A layer within theupper mantle, in the depth range from 60-200 km is of particular interest, because here the mantle rock is at a temperature very close to its melting point, It is called plastic layer or soft layer.

Composition of the mantle:
Two views are presnt:

Conventional hypothesis considers that the M- discontinuity represents achemical change from rock of basaltic composition at the base of the crust to an underlying ultrabasic rock like dunite and peridotite.

Basalt
-- Moho
Dunite and peridotite (transition layer:
heterogeneous mixture of dunite and peridotite)

Pyrolite (py+oliv) ultrabasic rock (gabbro 1 part and dunite 3 part)

2. The alternative hypothesis prposes that the rock immediately below the Moho is of essentially of the same chemical composition but the minerals exist in a physical state of a higher density.

Eclogite : garnet+pyroxene has the same chemical composition as basalt and gabbro. But the density of eclogite is 3.4-3.6 gm/cc where as the density of gabbro is 3.0 only.

Phase change

At a increasing depth the mantle rock is transformed into a mineral matter of increased density. At about 1000 km the rock would have a density of 3.9 gm/cc. below this depth in the lower mantle, the rock is thought to be hoghly homogeneous silicate of Mg and Fe.

At 1000 km a slight seismic discontinuity indicates a beginning of lower homogeneous layer.

The earth's core

It is a smooth, dense sphere that forms the innermost portion of the earth.
Temperature at the centre is 4500 $^{\circ}$c and the density about 13.5 gm/cc.

Movement of the liquid outer core are thought to generate the earth's magnetic field. The factors that could make the liquid part of the core to move are:

a) Earth's rotation
b) Thermal convection current
c) Other source of energy

The liquid which is molten iron is an electric conductor. The flow of an electric conductor is capable of creating of magnetic field.

The total volume of mantle is 68 percent of the of the mass or 83 percent of the volume of the earth.
The mass of the core is 32 percent of the earth or 16 percent of the volume.

Density of the core is double than that of the mantle.

Spherical core

From the extent of shadow zone, the core is calculated to have 2160 miles (3475 km) more than half the total radius of the earth.
The outer core is composed of liquid iron of great density and at high temperature.

The inner core has a radius of 780 miles (1255 km).

The earth consists of spherical core at the earth's centre. If earth were in a solid state entirely, the P and S waves would travel through the centre and they can be received on the opposite side. It has great density and enormous pressure at the centre.

Study of earthquake waes has confirmed the existence of a spherical core at the earth's centre.

Radius: 3475 km a little more than the half of earth's total radius. it is a smooth dense sphere.

Density information: Outer region of the core is composed of liquid iron of great deinsity. it is under enormous pressure and at high temperature.

The radius of the inner part of the core is 1255 km and behaves differently to seismic waves. It is a solid core.

Density: 13.5 times that of water
temperature: 4500 ^{0} C

Earth's magnetic field

The movements of the liquid of outer core

The factors that could make the liquid part of the core move are:

1. earth's rotation
2. thermal convection current
3. possibly other sources of energy

The liquid of iron is electrical conductro. The flow of an electical conductor is capable of creating a magnetic field.