New Vision IAS Academy
....wings to aspirations

CLASS NOTES
LITHOSPHERE

THE CONSTITUENTS OF THE EARTH CRUST

- The earth's crust is the upper most part in the arrangement of layers or spheres spread over the earth's surface.
- It is a part of lithosphere which is made up of several rocks and minerals.
- Its average thickness is about 35-40 kilometres.

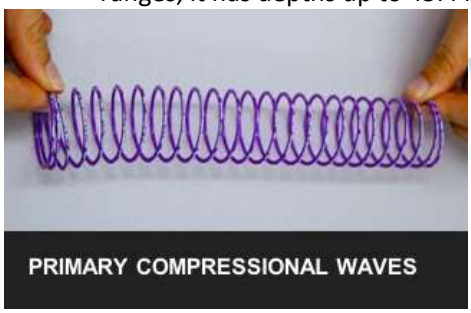
CONCEPT OF EARTH'S CRUST

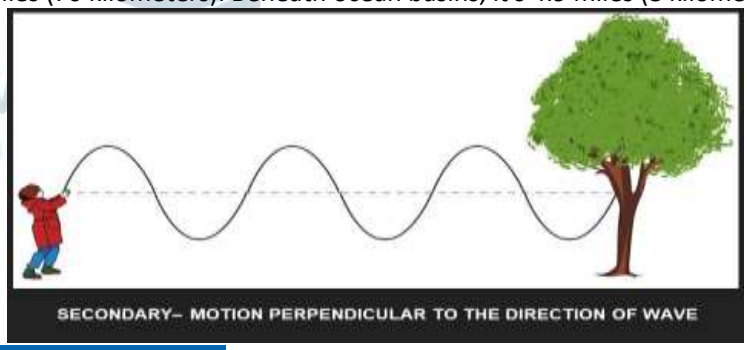
FORMATION OF EARTH'S CRUST

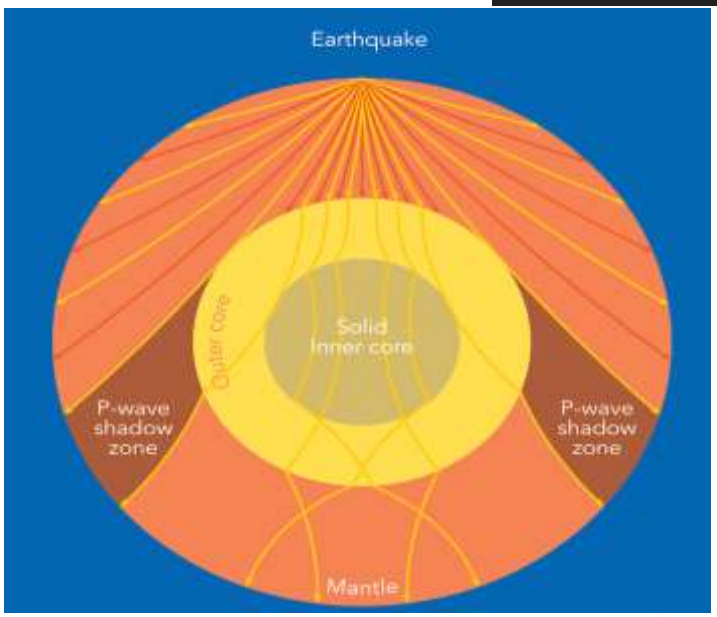
- Long ago, after its origin, the earth was in very hot state and everything was in its molten state.
- Slowly the temperature started reducing & a solid layer has formed in the outer part of Earth. It is known as 'Earth's crust'.
- Earth's crust is the top most part which is relatively rigid part like the shell of an egg.
- The crust is formed by a combination of several rocks and minerals and there are several layers in it.
- All of these layers are together known as 'lithosphere'.

MOHO DISCONTINUITY

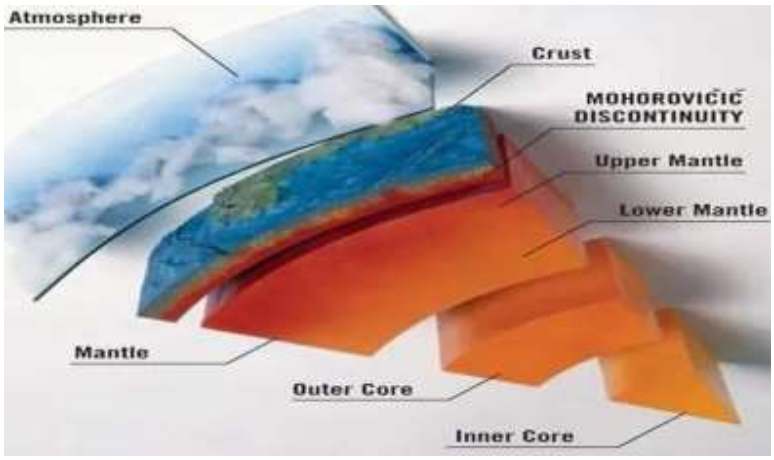
- The crust is separated from the lower layer called Mantle.
- The process of separation of different layers depends upon the chemical composition, density, temperature of the constituting rocks and minerals
- The line that separates crust from the mantle is known as 'Moho Discontinuity'.
- It was discovered in 1909 by A. Mohorovicic which marks the boundary between lower crust and upper mantle
- The Moho was initially defined as a seismic discontinuity—a marked change in propagation velocity of compressional P waves.
- As per the Snell's law, Mohorovicic hypothesized that , Different types of seismic waves—P (primary) waves and S (secondary) waves—travel at varying speeds through different materials & a different material must be below Earth's crust that caused the refraction of the seismic waves.
- On average, the Moho is 19.8 miles (32 kilometers) below continental surfaces, i.e. land, though beneath mountain ranges, it has depths up to 43.4 miles (70 kilometers). Beneath ocean basins, it's 4.9 miles (8 kilometers) deep.





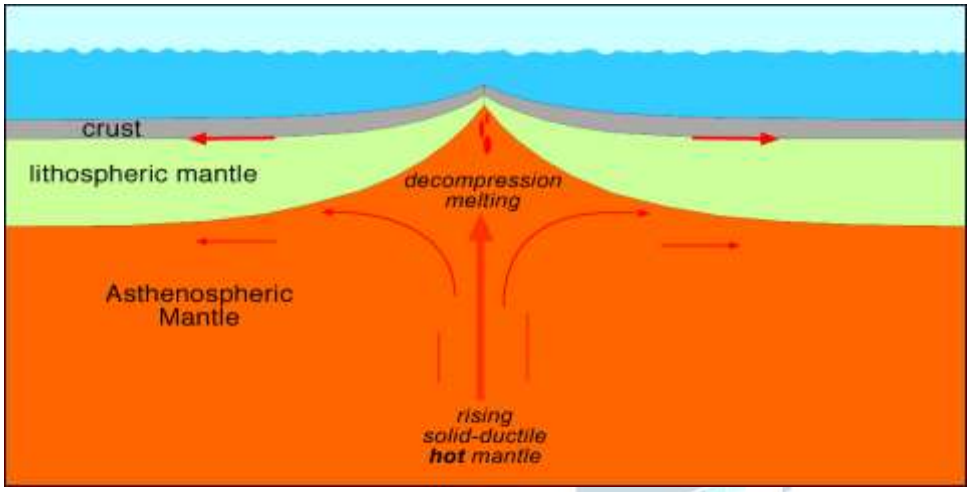


- Its depth differs depending on whether it's beneath the oceanic or continental crust or offset by thrust faults. Because of its depth, the Moho has never been confirmed.
- Heat at that depth ranges from 1,000 to 3,700 degrees Celsius.
- To date, humans couldn't dug beyond 40,230 feet (12,262 meters). The hole is called the Kola Superdeep Borehole — a 20-year project initiated by the Soviets in the 1970s and was ceased when temperatures reached 356 degrees Fahrenheit (180 degrees Celsius), making it impossible to keep going.
- The International Ocean Discovery Program has begun the M2M or "Moho to Mantle" project to collect samples from Earth's mantle. If they succeed, it will be humankind's first (and deepest) step ever taken into Earth.



MID OCEANIC RIDGE & CONRAD DISCONTINUITY

- Continental crust is not continuous and is separated by very large water bodies.
- Oceanic crust is continuous and lies beneath the continental crust and extends up to mid-oceanic ridges.
- Mid-Oceanic Ridges are the volcanic mountain system under the oceans.
- Here magma is coming out to form oceanic crust and spreads towards the continents.
- It is at this point i.e. mid-oceanic ridges, the earth's crust originates . These two layers are separated by a line of discontinuity known as 'Conrad Discontinuity'.



CONRAD DISCONTINUITY

- The Conrad discontinuity corresponds to the sub-horizontal boundary between Continental and Oceanic Crust.
- This boundary is observed in various continental regions at a depth of 15 to 20 kilometres. However, it is not found in Oceanic regions.

CONTINENTAL CRUST

- The 7 billion cubic kilometres of continental crust lie above the mean sea level.
- It supports the life, settlement, agriculture and provide drinking water.
- It is fragmented to form various major geographical features like continents, oceans and islands
- About 3.7 billion years ago, due to the volcanic activities over the very thin heavier oceanic crust, the continental shields started to form.
- The processes of formation of continental crust from volcanic activities are visible in different parts of the World till today
- It it is because of volcanic activities that gave birth to Igneous rocks which subsequently after erosion gets transported and deposited to form Sedimentary rocks.
- All the above rocks later on under tremendous heat and pressure gets modified to become Metamorphic rocks.
- It is a continuous and repetitive process known as rock cycle.
- The continental crust is made up of all the three types of rocks.
- The continental crust is less dense than all the layers of the earth's interior
- Its density is 2.7g/cm3 whereas the density of the oceanic crust is 3.0 g/cm3 and that of the earth's mantle is 3.3 g/cm3.
- Main mineral composition of continental crust is Silica and Aluminium.
- This layer is also commonly known as Sial layer.

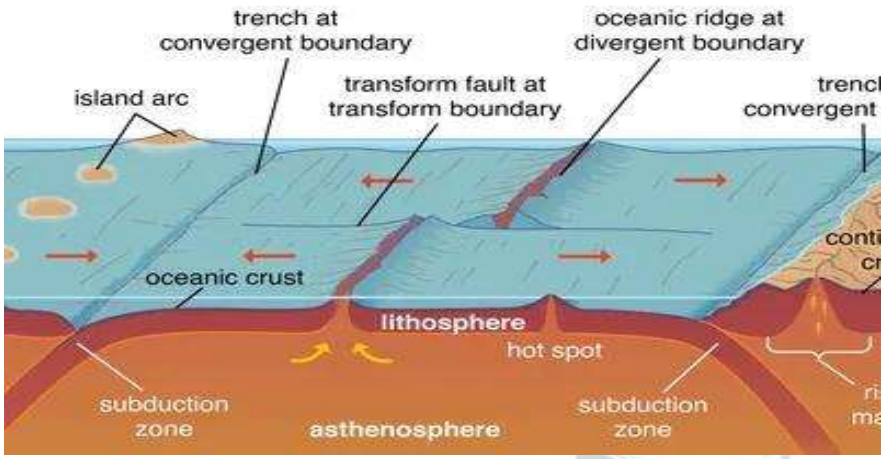
HOW COASTAL LANDFORMS ARE FORMED ?

- The continental crusts are drifting over the heavier oceanic crust and the collision between two continental crusts or continent and oceanic crust give rise to several landforms and associated features.
- The oceanic crust being heavier subducts back into mantle and melts down.
- It is the collision zone of two continents that gives rise to taller and heavier mountain chain systems like the Himalayas.
- Furthermore the greatest thickness of the continental crusts is also found there
- Since the height of the mountain is always determined by the thickness of the continental crust.
- On account of high temperature, pressure conditions and distortion leads to the modification of the continental crust to that of metamorphic rocks.

CONCEPT OF OCEANIC CRUST

- About 70% of the earth's crust is covered by oceans.
- The oceanic crust originates from the Mid-oceanic Ridges and spreads towards the continents and then it goes down to magma again and it melts.

- That's why the oceanic crust is younger – not more than 200 million years old.
- All of the oceanic crusts are made up of basalt rock which is a volcanic rock. Some deposits of continental sediments near the continents and organic depositions in the deep sea zone are also found there.
- Oceanic crusts are heavier and its density is 3.0 g/cm3.
- Primary wave (P) travels through this layer at a speed of 7 km/s.
- Mineral compositions of the rocks are mainly silica and magnesium. This layer is known as Sima.
- According to the Plate Tectonic Theory, the oceanic crust has its origin at the mid oceanic ridges and subducts at the convergent boundaries of two plates.
- Coastal features like Island arcs, volcanoes, oceanic trenches are formed at the subduction zone of two oceanic crusts.
- When an oceanic crust converges with a continental crust, it always subducts below the continental crust as the oceanic crust is more dense and heavy and it melts and gets subsumed into the mantle after subduction.



COMPOSITION OF EARTH CRUST

- The word 'litho' means rocks. Rocks are made up of minerals - so the earth's crust is composed of only 8 elements in varying proportions.
- Oxygen is the most common chemical element of the crust accounting 46% of the rocks. Next important mineral is Silicon (28%).
- Aluminium, iron, calcium,sodium, potassium and magnesium constitute about 24% whereas others constitute 1% only.
- The minerals vary in their structure, shape, stability, solubility, hardness, crystal structure and colour.
- Minerals are seldom found in isolation but exist in stable compound form.
- The different ratio of mixing of mineral elements generates different rock types over the earth's crust.

Element	Abundance (%)	Element	Abundance (%)
Oxygen	46.6	Vanadium	0.014
Silicon	27.7	Chromium	0.010
Aluminium	8.1	Nickel	0.0075
Iron	5.0	Copper	0.0055
Calcium	3.6	Zinc	0.0070
Sodium	2.8	Cobalt	0.0025
Magnesium	2.1	Lead	0.0013
Potassium	2.6	Uranium	0.00027
Titanium	0.44	Tin	0.0002
Manganese	0.095	Tungsten	0.00015
Barium	0.043	Mercury	$8x10^{-6}$
Strontium	0.038	Silver	$7x10^{-6}$
Rare earths	0.023	Gold	$<5x10^{-6}$
Zirconium	0.017	Platinum Metals	$<5x10^{-6}$

ROCKS & MINERALS

- Shale: it is composed mainly by clay minerals and mixed with fine quartz grains,
- Sandstone: it is composed mainly by quartz sand and mixed with feldspars,
- Granitic rocks: these are composed together from quartz and potash feldspars mixed with amphibole or biotite mica,
- Limestone and dolomite: these two are composed mainly from calcite or dolomite,
- Basaltic rocks: it is composed of plagioclase feldspars, biotite mica, pyroxenes and olivine etc.
- Together these above-mentioned five rock types constitute about 92% of the total rocks found over the earth's surface.

ORIGIN & CLASSIFICATION OF ROCKS

- Rocks can be classified on the basis of chemical and physical properties, mineral content, mineral size grains, types of elements and origin of rocks etc.
- However, rocks are most commonly classified on the basis of their origin.
- Three major well known identified rock groups are Igneous, Sedimentary and Metamorphic rocks.

IGNEOUS ROCKS

- Igneous rocks are originated in the initial stage of earth formation by the cooling of hot magma.
- Approximately, more than 80 percent of earth's crust is made up of igneous rocks.
- The oldest known igneous rocks are thought to be as old as nearly 3.6 billion years.
- The formation of youngest igneous rocks is still in progress – a repetitive natural process.
- Igneous rocks are also known as primary or parent rocks.
- All rock types are developed either directly or indirectly from the igneous rock.
- Magma is a very hot mixture of minerals and gases.
- Often, it comes out to the earth's surface through some weak points or some time gets stored under the surface.
- Classification of the igneous rocks depends on several factors.

- These factors encompass location of cooling of the hot magma, the mineral content, mineral size and acidity etc.

CHARACTERISTICS OF IGNEOUS ROCKS

- The rock forming elements are very compact which increases its hardness;
- The igneous rocks are very hard and heavy and therefore resistant to erosion;
- Water cannot percolate through the rocks as there is no porosity;
- There is no layer as it is seen in sedimentary rocks;
- Igneous rocks do not contain any fossil but contains crystals and may be visible to the bare eyes.
- The cooling rate gives rise & helps to shape the chemical composition and mineral size etc.
- So the igneous rocks are classified primarily based on two parameters origin and chemical composition.

BASED ON THE PLACE OF ORIGIN

- When the rocks originate deep inside the earth's crust, it is known as intrusive igneous rocks.
- Granite is an example of intrusive rock.
- Intrusive rocks are characterized by larger mineral size and may be visible with bare eyes to a keen observer.
- Some igneous rocks originate in very deep portions of the crust and are having even larger minerals – called plutonic igneous rock.
- When it originates immediate below the earth's surface, it is known as hypabyssal igneous rock having smaller mineral size. The example is Porphyry
- Magma reaches the earth's surface through the weak points like joints, fractures and faults etc.
- Subsequently it cools very fast when it comes into contact with air and generates very finer microscopic minerals.
- This type of igneous rock is known as extrusive rock.
- Basalt is an example of extrusive rock.
- Magma may come out at the earth's surface from the mantle through volcanoes and generates lava rocks and the ash and other Pyroclastic rock.
- Tuff is an example of pyroclastic rock.

BASED ON THE CHEMICAL COMPOSITION

- Silica is a very important mineral of igneous rock and determines the pH or acidity of the rocks.
- Based on the acidic condition of the igneous rock, rocks can be classified into four categories.
  i. Acidic Igneous rock: The content of silica is more than 65%. Granite is an acidic igneous rock.
  ii. Basic Igneous Rock: Basalt is an example where the content of silica lies between 45-60%. Iron content of this rock is very high.
  iii. Intermediate Igneous Rock: The pH of the rock is neutral and silica content is such that neither the rock falls in acidic nor in basic category. Diorite is an example of this type of rock.
  iv. Ultra-basic: Igneous rock is peridotite. In this rock silica content is less than 45%.

SEDIMENTARY ROCKS

- Nearly 70 percent of landmass of the planet earth is covered under thin layers of sediments or debris.
- Such huge piles of sediments eventually gets settled on the beds of major and minor water bodies like oceans and seas, lakes and rivers etc.
- With the passage of time, rock materials becomes compacted over millions of years and thereafter erosion takes place and material is carried together with older rocks by agents of erosion such as water, ice, wind or wave etc. under the influence of gravity.
- Such kind of eroded and transported sediments/debris materials are known as sedimentary rocks.
- Later on the materials come to rest and gradually gets compacted, consolidated and cemented together.
- In this way sand becomes sedimentary sandstone rock and similarly clay becomes sedimentary shale rock etc
- Although sedimentary rocks cover extensive areas but account only 8% of the total area of the earth's surface.
- Sedimentary rocks exist as layers of different rock beds. These are further separated by bedding planes.
- Sedimentary rocks are very important source of coal, natural oil, drinking water and ores.
- Such types of natural resources play an important role in the spatial and economic activities.
- The main characteristics of sedimentary rocks are as follows:

➢ sedimentary rocks are secondary formation and they have layers of beds separated by bedding plane;
➢ it is characterized by pore spaces and is lighter than the igneous rocks;
➢ it is the source of fossil fuels. They do not have any crystalline structure.

CLASSIFICATION : BASIS OF PLACE OF ORIGIN

- Sedimentary rocks are secondary rocks as it originates from the primary igneous rocks.
- The weathered and eroded materials are transported by air, water, sea or glaciers.
- Such type of material gets deposited in different depositional environment like river bed, lakes or in seas.
- The sediment characteristics vary significantly on the basis of weathering processes, natural agents of erosion along with transportation.

- Furthermore, the characteristics also differ on account of the particle size, mixing and sorting of particles, chemical alteration, organic character, cementing and compaction etc.
- When the parent rocks are broken up into small pieces, it starts accumulating and compacting to form new rocks known as clastic sedimentary rocks.
- Based on the depositional agency, environment and grain size, this group of sedimentary rocks can further be classified as conglomerate, sandstone, loess and clay etc.

CLASSIFICATION: BASIS OF CHEMICAL COMPOSITION

- Rock particles may be chemically altered during the process of chemical weathering and gets deposited to make chemically formed sedimentary rocks.
- This rock is commonly found in the arid and semi arid regions of the world. Gypsum is the best example of this type of rock.
- Decomposition and disintegration of organic residue sometimes leads to the cementing and compaction of the rock particles to form a type of sedimentary rocks.
- Coal, dolomite and limestone are this type of rock. Most of the sedimentary rocks originate from the marine, sea, river or lake environment.
- They can be grouped into aqueous sedimentary rocks.
- Loess sedimentary rock originated mainly due to aeolian process .It is known as aeolian sedimentary rock.
- Another type like moraine types of sedimentary rocks originated mainly due to the glacial processes.
- They can be grouped into glacial sedimentary rocks.

METAMORPHIC ROCKS

- The primary igneous and secondary sedimentary rocks may change their physical and chemical characteristics and form due to the huge pressure and heat.
- The transformed tertiary rocks are called metamorphic rocks.
- This word has its origin in the Greek word metamorphosis.
- Metamorphism makes the rocks to go through the process of recrystallization which results into the transformation of the Protolith into harder and denser rock.
- Re-crystallization destroys bedding planes and joints systems. As a result, the marble or quartz may show no stratifications in the rocks.
- The metamorphic rocks cover a significant part of the earth's crust.
- It can be classified on the basis of types of transformed rocks, transforming agents and place of transformation.

METAMORPHIC ROCKS : CHARACTERISTICS

- ➢ metamorphic rocks are denser and harder than the original Protolith.
- ➢ the recrystallization process makes bigger crystals which are prominent.
- ➢ the ores are segregated that makes it easy to mine. These rocks do not contain fossils.
- ➢ they may contain well developed foliated or lineated structure
- Metamorphism of the original igneous or sedimentary rocks may happen due to intense pressure and heat by agents of metamorphism in many places o localities.
- The original rocks may undergo intense pressure due to convergence of two plates and the rocks may get folded and transformed.
- The magma may come to the earth's surface and the heat may transform the rocks.
- Sometimes water penetrates deep into the crust and its heat, pressure and chemical reaction can alter the original rocks.
- In all the cases the effect of transformation may be very localized or regional. The metamorphism of rocks generates new texture, composition and foliation of rocks.
- These are classified based on the foliation and original rocks.

CLASSIFICATION :

- Foliated Metamorphic Rocks: They are very complex in its composition. The texture is layered, foliated, lineated, banded and the minerals are oriented. Slates and schist are examples of foliated metamorphic rocks.
- Non-Foliated Metamorphic Rocks: These rocks are simple in its composition. The texture is granular and equi-dimensional and has no definite orientation of the minerals. Quartzite and Marble are non-foliated metamorphic rocks.
- Metamorphic Rocks with an Igneous Protolith: Metamorphic rocks are considered to be derived from an original igneous protolith either because of the lithological characteristics (i.e. preservation of igneous textures and in some cases composition or mineralogy) or the lithological associations of the rock. Such rock types are classified as igneous metamorphic rocks.
- Pyroxene and hornblende are examples of this type of rocks.

- Metamorphic Rocks with a Sedimentary Protolith: If the rocks are known to be derived from original sedimentary rock i.e. protolith, either because of the lithological characteristics or the lithological associations of the rock it is classified as metamorphic rocks with sedimentary protolith.
- Phyllite and quartzite come under this type of rocks

ROCK CYCLE

- It means the change of one rock type into another rock type and vice-versa.
- The rock particles continuously alter its shape as well as structure under the conditions of pressure and heat.
- It is a gradual and long-term process which operates under the influence of natural agents.
- These include weathering and mass wasting processes, wind and water etc.
- In turn the rock cycle facilitates our understanding about the myriad inter-relationships that exists between different rock types

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