Chapter 1 rocks and minerals and their exploitation

Structure of the interior Earth

- The earth is an almost spherical body with a radius of 6,400 km
- **Crust** – the topmost layer
- **Mantle** – the middle layer
- **Core** – the innermost layer

Crust:

- It is the thinnest layer of the earth, also called the lithosphere
- Because it is a sphere of solid rocks
- 'Lithos' meaning stones or rocks in Greek

  There are two types of crust

- The **continental crust** (below the landmass), which is about 35 km thick
- The **oceanic crust** (below the ocean), which is about 5 km thick
- The main elements that make up the continental crusts are silica and alumina and it is thus called sial
- The main elements that make up the oceanic crust are silica and magnesium (sima)

Mantle:

- Mantle lies just below the crust
- It is positioned between the crust and the core
- The mantle is 2,900 km thick
- It is made up of dense and heavy materials such as Mg, Fe, Si
- The mantle consists of two layers – the upper mantle and the lower mantle
- Magma is found in this layer (outer mantle)
- The molten magma comes out from the interior of the earth through volcanoes (during volcanic eruptions) in the form of lava
- Lava is rich in metals and minerals

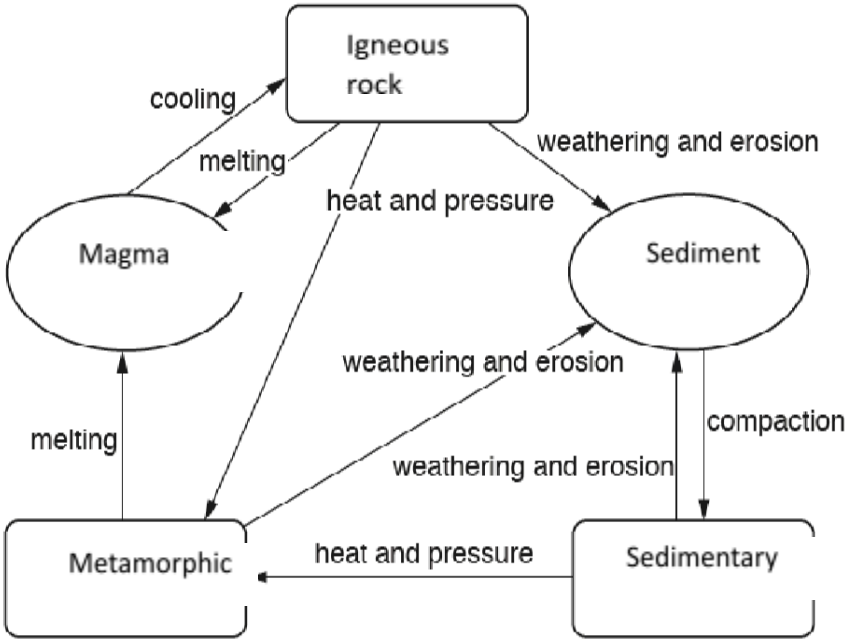
Core:

- It is situated below the mantle
- It is made of heavy metals such as nickel and iron. Therefore, it is called 'nife'
- The temperature of the inner core is 5000 deg cel (extremely high)

Formation of rocks:

- When volcanoes erupt, the magma release onto the surface as lava and ash cool to form new rock
- Rocks are made up of minerals
- Rocks vary in physical properties – colour, structure, variety of shape, size, texture, weight, consistency, permeability, composition, hardness, etc.

Rock cycle:



On the basis of their formation, rocks are classified into three types

- Igneous rocks
- Sedimentary rocks
- Metamorphic rocks

Igneous rocks

- The word 'igneous' is derived from the latin word 'ignis' meaning fire
- They are formed by the cooling of molten magma inside the earth crust or on the surface of the earth
- Igneous rocks are also known as primary rocks since they were the first to be formed
- They form the basis of formation of other types of rocks

Igneous rocks are of two types –

- Intrusive igneous rock
- Extrusive igneous rocks

Intrusive igneous rocks

- The rocks that cool below the surface are called intrusive igneous rocks
- The rate of cooling is slow inside the earth, they take thousands of years to form and develop large crystals
- These rocks are hard and compact
- Dolerite, gabro, dolomite and granite are the examples because the forms with in the crust
- Intrusive igneous rocks are also called **plutonicrocks** because of slow cooling of magma which leads to the formation of crystals of large size

Extrusive igneous rocks

- They are formed by the cooling of molten magma on the **earth's surface**
- The magma which is brought to the surface through fissures or volcanic eruptions, solidify at a **faster rate** (rapid cooling)
- Hence, such rocks are smooth, crystalline and fine grained
- So, crystals are not very large, small in size
- Basalt and obsidian are good examples

Sedimentary Rocks

- Rocks roll down, crack and hit each other and are broken down into small fragments
- Running water, wind, moving ice, plants and animals also break down the rocks into small particles. These particles are called **sediments**
- These sediments are carried away by winds and rivers and are deposited in lowlands, lakes and ocean beds.
- These sediments are deposited in layers
- With the passage of time, these layers are hardened to form rocks. These rocks are called sedimentary rocks
- Sandstone, limestone, shale, chalk and conglomerate are some examples of sedimentary Rocks

Metamorphic rocks

- The word metamorphic is derived from 'metamorphose' which means **change in form**
- Under very high temperature and pressure, igneous and sedimentary rocks change their form
- Such changed rocks are called metamorphic rocks

- These rocks are very hard
- The process of metamorphism takes thousands of years
- **Marble** (formed by the action of heat on lime stone or chalk or dolomite)
- **Gnesis**(formed from granite)
- **slate** (formed from mudstone or shale) and
- **quartzite** (formed from sandstone)
- **Schist** formed from basalt
- **Graphite** formed from coal

Weathering:

- It is the process of breaking down of rocks
- It is described as disintegration or decomposition of rock in size by natural agents
- It is change in weather conditions like temperature, moisture, precipitation that disintegrates or break down the rock
- Weathering causes formation of soil

Physical weathering:

Two main types

- **Freeze-thaw** occurs when water continually seeps into cracks, freezes and expands, eventually breaking the rock apart
- **Exfoliation** occurs as cracks develop parallel to the land surface a consequence of the reduction in pressure during uplift and erosion

Chemical weathering:

The weathering of rocks by chemicals is called chemical weathering.

Rainwater is naturally slightly acidic because **carbon dioxide** from the air dissolves in it. Minerals in rocks may react with the rainwater, causing the rock to be weathered.

Some types of rock are easily weathered by chemicals. For example, **limestone** and **chalk** are made of a mineral called calcium carbonate. When acidic rainwater falls on limestone or chalk, a chemical reaction happens. New soluble substances are formed in the reaction. These are washed away and the rock is weathered.

Chemical weathering can hollow out caves form and make cliffs fall away.

Some types of rock are **not** easily weathered by chemicals.

For example, **granite** and **gabbro** are hard rocks that are weathered only slowly. Still some of their minerals do react with the acids in rainwater to form new, weaker substances that crumble and fall away.

Biological weathering:

Animals and plants can wear away rocks. This is called **biological** weathering.

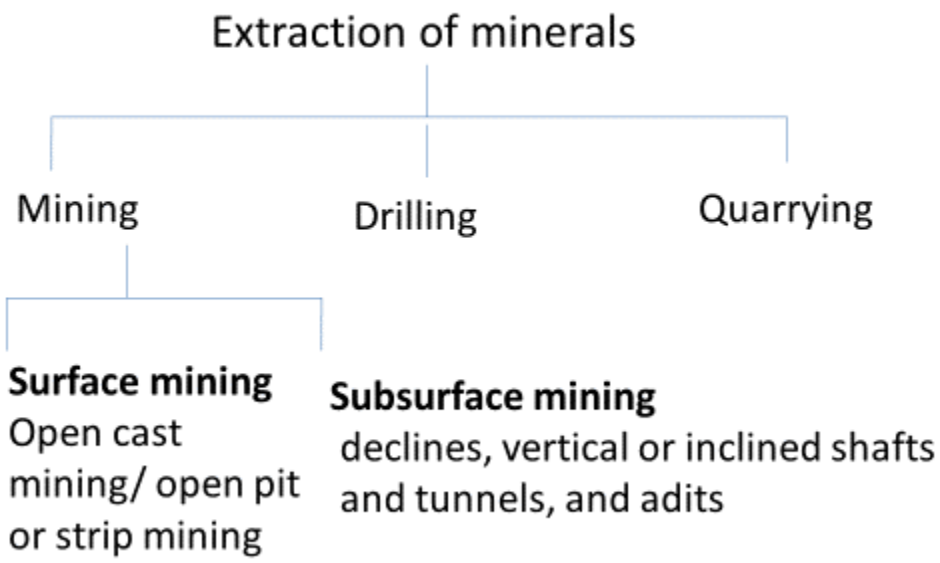
For example, burrowing animals such as rabbits can burrow into a crack in a rock, making it bigger and splitting the rock.

You may have seen weeds growing through cracks in the pavement. If you have gone for a walk in the countryside, you may even have seen bushes or trees growing from cracks in rocks or disused buildings. This is because **plant roots** can grow in cracks. As they grow bigger, the roots push open the cracks and make them wider and deeper. Eventually pieces of rock may fall away.

People can even cause biological weathering just by walking. Over time, paths in the countryside become damaged because of all the boots and shoes wearing them away.

Mining

- The process of taking out or extracting minerals from the surface of the Earth
- Mining is how minerals are removed from the ground
- There are several different ways minerals can be extracted from the Earth, but the two main methods are surface mining and subsurface mining



Subsurface mining/Open cast mining/ open- pit mining:

- Suitable for rocks and minerals that are found near the Earth's surface
- Soil and rock overlying the ore body (called the overburden) are removed by specialist Earth-moving heavy machinery
- Once exposed, the other equipment such as massive dragline and bucket wheel excavators dig out the ore body

- An open cast mine is also called a ‘quarry’

Stages/ Process involved:

- Vegetation land is cleared / topsoil or overburden are stripped away (removed)
- Soil or Rock is removed and broken and loosen by explosives
- Rocks and minerals are extracted (E.g. Coal) using diggers or mechanical shovelsand are then loaded onto trucks / railway and transported

Advantages:

- Easier access to minerals
- Open cast mines are cheaper to operate
- More minerals can be extracted quickly
- It is safer for workers compared to deep shaft mining
- Easier to transport minerals to their destination

Disadvantages

- Vegetation is stripped and a gaping hole is left
- Landslides can occur without warning
- Mining of heavy metals can cause leaching into nearby water supplies

Positive effect

- Employment opportunities
- Improvement in local or national economy
- Improvement in facilities or infrastructure

Negative effect:

Environmental impacts of open- pit (cast) mining:

Visual pollution

Waste heaps, noise pollution from blasting explosives / machinery

Loss of habitat and wildlife

Atmospheric pollution/dust

Pollutants (mining of heavy metals can cause leaching) seeps into ground water/ rivers/ lakes

Subsurface mining:

- Also called as **underground mining**

- **Declines** – they are wide tunnels that descend in a circular manner down to and around the ore body
- **Adits** – they are horizontal rather than vertical shafts excavated into side of a hill or mountain following level layers of ore
- Deep bores, called shaft have to be made to reach mineral deposits that lie at great depths. This is called **shaft mining**

Other methods:

- Petroleum and natural gas occur far below the earth's surface
- Deep wells are bored to take them out, this is called drilling
- Minerals that lie near the surface are simply dug out, by the process known as quarrying

Impact of rock and mineral extraction:

- Economic impacts
- Social impacts
- Environmental impacts
- Because mining can create the job opportunities, wealth and prosperity where it is located

Economic impacts

- For examples – in Alaska, 4400 direct jobs and a further 4300 indirect jobs have been created by mines producing gold, lead, silver and zinc
- As well as construction materials such as sand, gravel and rock
- Even jobs like catering services, cleaning and security
- This is known as Multiplier effect
- **Multiplier effect**refers to the increase in final income arising from any new injection of spending
- A belief that additional wealth gained by the richest people in society will have a good economic effect on the lives of everyone because the rich people will put the extra money into businesses, investments etc.
- This is called **trickledown effect**
- For example- working in restaurants or sports and starting new business
- **Trickle down -** gradually benefit the poorest as a result of the increasing wealth of the richest**.**

Social impact:

Social problems:

- Sudden rises in income – leads to consumption of drug and alcohol in higher rates and crime
- Divisions may rise in community between those who are benefitted from mine and those who do not (no longer work)

- Conflict can arise when the mining corporations fails to understand the cultural and spiritual importance of the environment to indigenous groups(native).
- The mine workers have to cope with noise and water pollution and power shortages

Social benefits:

- Living standard improves – e.g. being able to pay school and college fees for their children
- Employees and their families may have cheap or free access to mine facilities such as hospital, school, sports and subsidised housing
- No problem in recruiting miners

Opencast mining may have a larger environmental impact than deep mining because

Larger area of land cleared of natural vegetation; so more habitat lost;
More dust / noise / visual pollution; more polluted surface drainage;

Negative impacts on people:

- Mine dust – causes respiratory problems
- Life span is lower than other workers living in the same region
- Miners die young from lung diseases such as silicosis (caused by inhaling quartz or silica)
- Pneumonoultramicroscopicsilicovolcanoconiosis – lung disease marked by inflammation and scarring in the form of nodular lesions in the upper lobes of the lungs

Environmental impacts

- Habitat and biodiversity loss
- Water pollution
- Air pollution
- Soil erosion and sedimentation
- Visual and noise pollution

Habitat and biodiversity loss:

- The **clearing of huge areas of land** for the mine, and also adjoining areas for refineries, offices, housing, roads and railways, can cause a catastrophic decline in the range of plants, trees, birds and animals that are able to survive in surrounding aquatic and terrestrial habitats

Water pollution:

- Toxic chemicals such as **cyanide - (Au)** and **arsenic - (W)** are frequently used during refining to separate the valuable mineral elements from the waste rocks in which they are contaminated
- When water is contaminated with these pollutants and heavy metals such as **mercury, cadmium** and **lead,** this is known as **acid rock drainage** or **acid mine drainage**

- This drainage water can run off the surface into nearby rivers or seep underground until it reaches the **water table**
- Poisoned water can have devastating effects on both wildlife and humans, especially **pregnant mothers**, **babies** and the **young**

Air pollution:

- The excavation, crushing and refining of mineral ore can release huge quantities of dust containing dangerous heavy materials such as **lead** into the atmosphere
- Mining often exposes sulfide minerals such as **pyrite** that release high levels of**iron** and **sulfate** when contact is made with air or water

Soil erosion and sedimentation:

- Once soil has been disturbed to make way for the mining operation, it can be very quickly eroded by rainfall and the wind
- Soil can be carried into rivers by rainwater, where sedimentation leads to a shallowing (become less deep) of a river
- Causes – decrease in aquatic life

Visual and noise pollution:

- Local people often have to cope with floodlighting at night, noise from heavy machinery, rock is blasted out with explosives
- They are huge and noisy complexes, operating 24 hours a day, all year round

Managing the impact of rock and mineral Extraction:

- Remediation
- Restoration (mine reclamation)
- Reuse

Remediation:

- Latin - Remedium – “restoring balance”
- The process of removing dangerous or poisonous substances from the environment, or limiting the effect that they have on it
- This involves ensuring that the site is made safe by demolishing the plant, removing machinery, stabilising the ground, draining pipelines and disposing of any hazardous waste
- Waste rock that contains minerals in concentrations too low to be extracted and refined profitably will also contain toxic sulfides
- Generally, this waste will be covered in clean topsoil and planted out with vegetation
- In some cases, it may be used as underground backfill to increase the stability of mine shafts

- Tailing consist of finely ground particles of rocks and minerals that result from ore processing and contain poisonous chemicals such as arsenic
- They are usually mixed with water and disposed of in specially prepared tailing ponds enclosed by dams
- Contaminated water is often dealt with at water treatment plants set up on site
- Toxic chemicals are extracted, leaving a residue or sludge that is usually disposed of underground

Bioremediation:

- The process of using microorganisms to neutralize or remove contamination from waste.
- It used to treat contaminated media, including water, soil and subsurface material, by altering environmental conditions to stimulate growth of microorganisms and degrade the target pollutants.
- Bioremediation may also be used to treat water contamination
- This process encourages naturally occurring pollution eating single celled bacteria (prokaryotes) that already live on site to degrade contaminants in soils and water
- Although this will not work for pollutants such as cadmium, lead which are poisonous even to the microbes, it is often a safer and less expensive alternative to incineration or landfill
- Other Bioremediation are Phytoremediation, Mycoremediation, Bioleaching, landfarming

Applying successful principles to land restoration:

- Mining wastes, motorway verges and railway embankments are just three examples where colonisation by vegetation is an important means of stabilisation
- In the case of mine waste, land reclamation and land improvement are also important objectives
- Human help is needed to re-vegetate these areas
- Commonly an initial seeding will include a mix of grasses and nitrogen-fixing legumes, to enable a vegetation cover to establish quickly, but little subsequent treatment is needed
- Some wastes are often very acidic and may also be contaminated with heavy metals
- Relying on natural succession would take a very long time since few organisms can tolerate these conditions
- We can help succession in these circumstances in several ways
- **Lime** can be added to reduce acidity and top soil (very expensive) or some organic material may be added
- This material will improve water retention by the waste
- The organic material (sewage sludge, finely shredded domestic waste and farmyard manure) also provides a food source for Earthworms
- Earthworm activity will increase the aeration and mixing of the soil

- Care is taken to rebuild the ecosystem, through establishing native trees and plants close to that which existed before the environment was disturbed
- **Nature reserves** may also be created, incorporating **lakes** that have formed in open- cast mining areas and the steep rugged cliffs around quarries and open pits

Land restoration:

- making waste piles safe from collapse by re-profiling;
- creating soil;
- planting with herbs to absorb toxic substances;
- tree planting;
- use as landfill;
- use as a lake or reservoir;

These are the ways in which landscape can be restored after the opencast mining project has finished.

Reuse

- Reusing decommissioned mines and quarries contribute economically to the local community
- Some sites are used to dispose landfill waste
- Example: The new Gotline Ring 28- km motor racing circuit in sweden and Butchart gardens in canada, have both been constructed within old limestone quarries

Sustainable use of rocks and minerals

Sustainable use means use that meets the needs of the present without affecting the ability of future generations to meet their needs

Sustainable:

- Able to continue over a period of time
- To be able to maintain a decent level of resource usage

Why is being a sustainable a good thing?

- We can extend the life span of the resource we use far in the future
- Reduces release of harmful gases (E.g. CO_2) when natural resources are being converted into energy
- Rocks and minerals are not sustainable resources because they exist in fixed amounts and are non- renewable
- Supplies or sources will eventually run out

Ways to sustain mineral and rocks:

- Reduce, Recycle, Reuse

Strategies for the sustainable use of rocks:

- increased efficiency of extraction;

- increased efficiency of use;
- Legislation;
- **Increased recycling:** most metals can be recovered and refined back to clean metals to be used by industries again. This uses less energy than processing the ores or concentrates to make metals