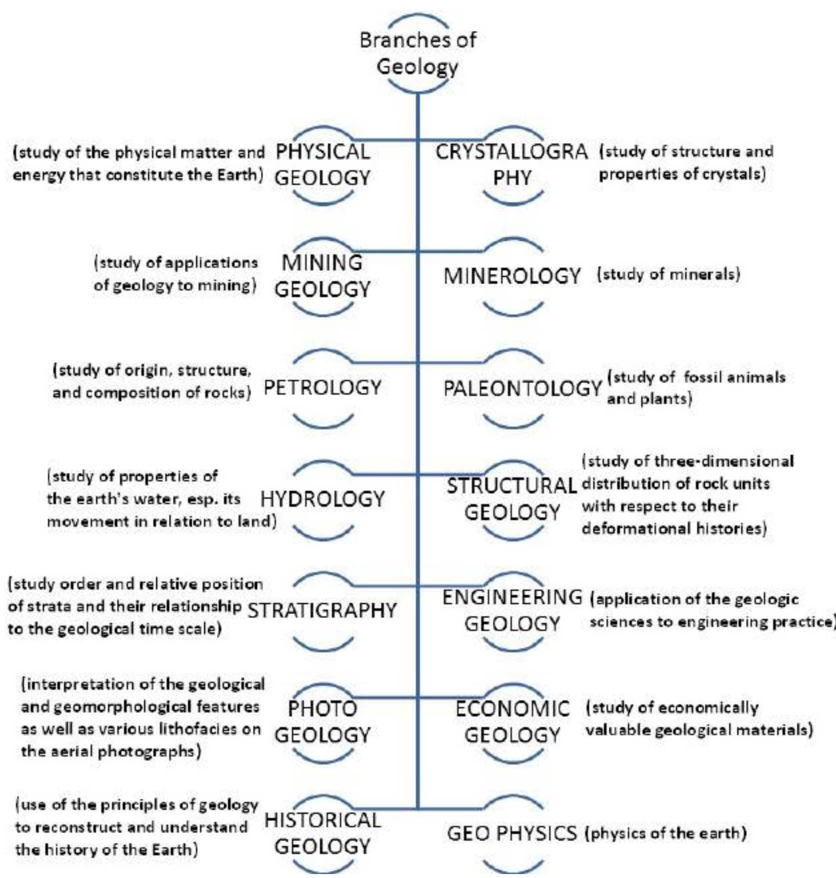
Topic 1: Introduction

INTRODUCTION: (Importance to a Civil Engineer):

The earlier studies of Civil Engineering couldn't see the design of a structure should be preceded by a careful study of its environment, particularly foundations material on which the structure was to be placed. When the St. Francis Dam in Southern California failed in 1928 with a loss of many lives and damages in millions of dollars, the civil engineering profession awoke to the idea that the careful design of a structure itself is not all that is required for the safety of structures. After the failure of St. Francis Dam, the need of environment exploration with proper interpretation of the results was understood by all.

Geology (in Greek, Geo means Earth, logos means study of or Science of) is a branch of science dealing with the study of the Earth. It is also known as earth science. The study of the earth comprises of the whole earth, its origin, structure, composition and history (including the development of life) and the nature of the processes.

Branches of Geology:



Relevance of geology to civil engineering:

Most civil engineering projects involve some excavation of soils and rocks, or involve loading the Earth by building on it. In some cases, the excavated rocks may be used as constructional material, and in others, rocks may form a major part of the finished product, such as a motorway cutting of the site or a reservoir. The feasibility, the planning and design, the construction and costing, and the safety of a project may depend critically on the geological conditions where the construction will take place. This is especially the case in extended 'greenfield' sites, where the area affected by the project stretches for kilometers, across comparatively undeveloped ground. In modest projects or in those involving the redevelopment of a limited site, the demands on the geological knowledge of the engineer or the need for geological advice will be less, but are never negligible. Site investigation by boring and by testing samples may be an adequate preliminary to construction in such cases. The long term economics depends on the engineering safety of the manmade constructions. Durability and maintenance free service of the dams, canals, structures like aqueduct etc. is only possible if engineering safety of them is assured. As every structure is related to rock beneath, proper geological investigations are of utmost importance.

Engineering geology importance:

Engineering geology provides a systematic knowledge of construction material, its occurrence, composition, durability, and other properties. Examples of such construction materials are building-stones, road materials, clays, limestone, and laterite.

The knowledge of the geological work of natural agencies such as water, wind, ice and earthquake helps in planning and carrying out major civil engineering works. For examples, the knowledge of erosion, transportation, and deposition helps greatly in solving the expensive problems of river control, coastal and harbour work and soil conservation.

The knowledge about groundwater that occurs in the subsurface rocks and about its quantity and depth of occurrence is required in connection with water supply irrigation, excavation and may other civil engineering works.

The foundation problems of dams, bridges, and buildings are directly concerned with the geology of the area where they are to be built. In these works, drilling is commonly undertaken to explore the ground conditions. Geology helps greatly in interpreting the drilling data.

In tunnelling, constructing roads, canals, and docks and in determining the stability of cuts and slopes, the knowledge about the nature and structure of rocks is very necessary.

Before starting a major engineering project at a place a detailed geological report, which is accompanied by geological maps and sections, is prepared. Such a report helps in planning and constructing the project.

The stability of the civil engineering structures is considerably increased if the geological features like faults,[1] joints,[2] folding,[3] and solution channels etc. in the rock beds are properly located and suitably treated.

In the study of soil mechanics, it is necessary to know how the soil materials are formed in nature.

For a major engineering project, precise geological survey is carried out and results thus obtained are used in solving engineering problems at hand. The cost of engineering works will considerably be reduced if the geological survey of the area concerned is done before hand.

1- fault: a fracture or fracture zone in rock along which movement has occurred. 2- joint: a fracture in rock along which there has been no displacement. 3- fold: a bend or flexure in a rock unit or series of rock units that has been caused by crustal movements.

Engineering Geologist Vs Civil Engineer:

The engineering geologist presents geological data and interpretations for use by the civil engineer. The civil engineers have to deal mostly with soil and rocks, timbers, steel, and concrete. In a great majority of civil engineering, projects and the designs, involve the soils and rocks almost directly.

Civil engineering is to construct the structure and facilities for transport, water supply, hydropower, flood control, environmental protection, sewage and waste disposal, urban development and more. In above fields, civil engineers construct and maintain waterways, highways, railway, pipelines, dam and reservoirs and tunnels.

BRIEF STUDY OF CASE HISTORIES OF FAILURE OF SOME CIVIL ENGINEERING CONSTRUCTIONS DUE TO GEOLOGICAL DRAW BACKS:

Brief study of case histories of failure of some civil engineering constructions:

With reference to Dams

1. St. Francis Dam
2. Austin Dam
3. Lafayette Dam

Note: Geological studies at the dam site will also suggest which design is suitable for a given geological context. For example, Gravity dam needs very strong and competent foundation rocks; for buttress dams, relatively less strong foundation rocks are enough; arch dam need very strong and stable abutment rocks; for earth dams, even weak foundation rocks meets the requirement.

With reference to Reservoir

1. Jerome reservoir of Idaho
2. Hondo reservoir of Mexico

Note: intense weathering in the rocks upstream causes silting problem. Porosity and permeability of rocks, occurrence of faults, joints and other weak planes cause leakage problems. Ground water conditions also play a major role in influencing leakage. Thus proper studies of geological conditions at any proposed reservoir site will forewarn an engineer of the problems, if any.

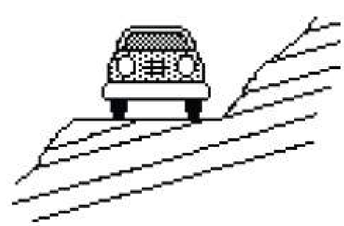
With reference to Tunnels

1. Ram-ganga diversion tunnel (Himalaya)
2. Umiam-Barapani tunnel (Meghalaya)
3. Koyna Tunnel (Bombay)

Note: Competence of rocks, associated geological structures like bedding, faults, joints, porosity and permeability of rocks, and ground water conditions are the geological conditions which need to be thoroughly studied to solve such problems.

GEOLOGICAL CONSTRAINTS IN CIVIL ENGINEERING

The geology of an area dictates the location and nature of any civil engineering structures.
Roads and Railways
Problems for a road or railway project may be caused by any of the following geological features:



- Faults
- Junctions between hard and soft formations
- Boundaries between porous and impermeable formations
- Spring-lines
- Fractured granites
- weathered schists[2]
- Landslip areas
- Areas where beds dip towards the road or railway, as shown in the adjacent diagram.

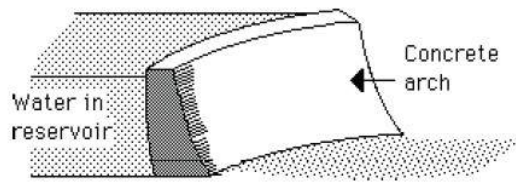
1 - A passage for surplus water from a dam.

2 - A coarse-grained metamorphic rock that consists of layers of different minerals and can be split into thin irregular plates.

Dams:

Geological investigations of a site proposed for construction of a dam must be complete and detailed. Features such as rock-types, geological structures, weathering, fractures and fissures must all be considered. The main considerations are that the material on which the dam rests must be able to carry the weight of the structure without failing. The geology upon which the dam is built must also be impervious[1] to water. The abutments[2], (the rock faces to which the dam wall is attached) must also be impervious and strong enough to support the dam wall, especially in the case of an arch dam (where more force is transmitted to the abutments).

Left: Cross-section through an arch dam.



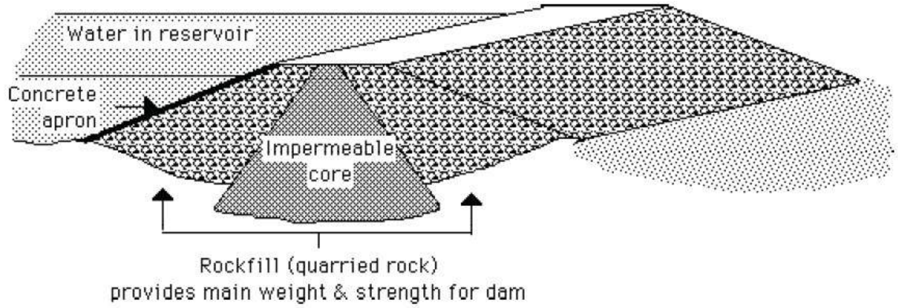
Failure of a dam can be due to many factors including:

- Earthquakes
- A sudden drop in water level
- Inadequate protection of the reservoir side of the dam from wave action
- Insufficient spillway capacity, so that water flows over the whole of the dam surface, with consequent erosion

1 - Not allowing something to pass through; not penetrable. 2 - A structure built to support the lateral pressure of an arch or span, e.g., at the ends of a bridge.

The type of dam selected depends largely on the nature of the surrounding rocks. If they are strong and stable, an arch dam, such as the one shown below can be constructed. This type of dam requires a minimum of construction materials, but the concrete must be of high quality. The Barossa Reservoir Dam (the Whispering Wall), The Roosevelt Dam are examples of an arch dams.

An earth and rock fill embankment dam, as shown in the diagram below must be constructed where the surrounding rocks are not strong enough to support an arch dam. This type of dam is more expensive to build, requiring much more material. The main weight and strength of the dam is provided by compacted quarried rock. The core is made of impermeable material, such as clay, bitumen[1] or concrete.



Cross-section through an embankment dam.

1 - A black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation.

IMPORTANCE OF PHYSICAL GEOLOGY

This is also variously described as dynamic geology, geomorphology, etc. As the name suggests it deals with:

(i) Different physical features of the earth, such as mountains, plateaus, valleys, rivers, lakes, glaciers, and volcanoes in terms of their origin and development,

(ii) The different changes occurring on the earth's surface, like marine transgression, marine regression, formation or disappearance of rivers, springs and lakes,

(iii) Geological work of wind, glaciers, rivers, oceans, ground water, and their role in constantly molding the earth's surface features, and

(iv) Natural phenomena like landslides, earthquakes, and weathering.

The main cause for surface changes is weathering. This is a natural phenomenon resulting directly or indirectly due to changes in the atmosphere. It disintegrates and decomposes rocks. This aspect is of special importance from the civil engineering point of view, because color, appearance, strength and durability of rocks are adversely affected by weathering. Thus even granite which is considered ideal for most of the civil engineering works becomes weak and friable on thorough weathering, rendering it useless.

Civil engineers deal with structures like dams which are artificial barriers to the natural flow of rivers. Proper understanding of the geological work of a river and its features will lead to their better utilization for engineering applications

IMPORTANCE OF PETROLOGY

Petrology (Petro = rock, logos = study) deals with the study of rocks. The earth's crust, also called lithosphere, is made up of different petrology types of rocks. Petrology deals with mode of formation, structure, texture, composition, occurrence, types, etc., of rocks. The composition and textural characters of rocks primarily contribute to their inherent strength and durability. Rocks based on their suitability can be used as foundation for dams, for tunneling and materials of construction. Hence this is the most important branch of geology from the civil as engineering point of view.

IMPORTANCE OF STRUCTURAL GEOLOGY

Structural Geology the rocks which form the earth's crust undergo various deformations, dislocations and disturbances under the influence of tectonic forces. The result is the occurrence of different geological structures like folds, faults, joints and unconforimities in rocks. The details of mode of formation. Causes. Types, classification, importance, etc., of these geological structures form the subject matter of structural geology. From the civil engineering point of view, it is as important as petrology because these geological structures modify the inherent physical characters of rocks rendering them more suitable or unsuitable for civil engineering purposes. For example, at a dam site sedimentary rocks with upstream dip provide a desirable geological set-up, while the same rocks with downstream dip make the geological set-up most undesirable.

Weathering

Weathering

Weathering is the breakdown of rocks at the Earth's surface, by the action of rainwater, extremes of temperature, and biological activity. It does not involve the removal of rock material.

There are three types of weathering, physical, chemical and biological.

How is erosion different to weathering?

Erosion is the process by which soil and rock particles are worn away and moved elsewhere by wind, water or ice. Weathering involves no moving agent of transport.

Physical Weathering

Physical weathering is caused by the effects of changing temperature on rocks, causing the rock to break apart. The process is sometimes assisted by water.

There are two main types of physical weathering:

- 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.

Where does it occur?

Physical weathering happens especially in places places where there is little soil and few plants grow, such as in mountain regions and hot deserts.

How does it occur?

Either through repeated melting and freezing of water (mountains and tundra) or through expansion and contraction of the surface layer of rocks that are baked by the sun (hot deserts).

Freeze-thaw

Find out more about freeze-thaw

Exfoliation

Find out more about exfoliation.

Freeze-thaw

Where does it occur?

In mountainous regions like the Alps or Snowdonia.

How does it occur?

Rainwater or snow-melt collects in cracks in the rocks.

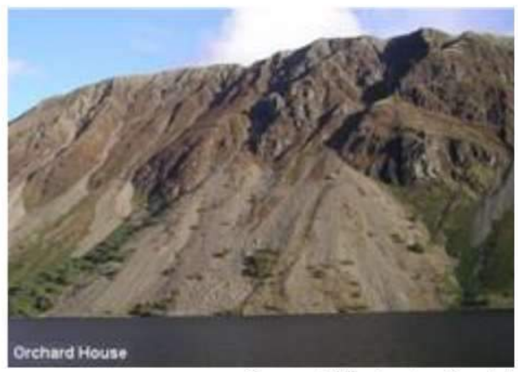
At night the temperatures drops and the water freezes and expands.

The increases in volume of the ice exerts pressure on the cracks in the rock, causing them to split further open.

During the day the ice melts and the water seeps deeper into the cracks.

Rocks broken by freeze-thaw action, Snowdoni

When the rock is finally broken in to small pieces they collect at the bottom of the mountain. The piles of broken rock are calle scree.



Scree at Wastwater, Cumbri

View an animated version of the freeze-thaw process.

Exfoliation

Where does it occur?

Typically in upland areas where there are exposures of uniform coarsely crystalline igneous rocks.

How does it occur?

The rock mass at depth is under high pressure from underlying rocks. It tends to be uniform and lack fractures.

↓

As progressive erosion occurs, the rock mass is subjected to progressively lower pressure of overlying rocks which leads to tension in directions at right angles to the land surface.

↓

This tension is relieved by formation of cracks which follow the land surface - they are relatively flat on plateaus, but can be steep on the flanks of mountains which are called exfoliation domes.

↓

Once the cracks develop, water enters and causes chemical weathering leading to the formation of new low-density minerals. This enhances the cracks and encourages slabs of rock to detach from the surface.

Chemical Weathering

Chemical weathering is caused by rain water reacting with the mineral grains in rocks to form new minerals (clays) and soluble salts. These reactions occur particularly when the water is slightly acidic.

Where does it occur?

These chemical processes need water, and occur more rapidly at higher temperature, so warm, damp climates are best. Chemical weathering (especially hydrolysis and oxidation) is the first stage in the production of soils.

How does it occur?

There are different types of chemical weathering, the most important are:

Solution - removal of rock in solution by acidic rainwater. In particular, limestone is weathered by rainwater containing dissolved CO2, (this process is sometimes called carbonation).

Hydrolysis - the breakdown of rock by acidic water to produce clay and soluble salts.

Oxidation - the breakdown of rock by oxygen and water, often giving iron-rich rocks a rusty-coloured weathered surface.

Solution

Malham Cove, Yorks

Find out more on 'Solution'.

Hydrolysis

Anglesey, N. W

Find out more on 'Hydrolysis'.

Solution

Carbonation

Carbon dioxide in the air dissolves in rainwater and becomes weakly acidic.

This weak "carbonic acid" is able to dissolve limestone as it seeps into cracks and cavities. Over many years, solution of the rock can form spectacular cave systems (see photo).

Note: Stalagmites and stalactites form in caves as water drips from the roof, depositing some of its dissolved calcium carbonate, as carbon dioxide is released into the air.

Cheddar caves, Somers

Acid rain

Polluting gases, like sulphur dioxide and nitrogen oxide dissolve in rainwater to make stronger acids. When this rainwater falls, we get acid rain. This acid attacks many rock types, both by solution and hydrolysis, seriously damaging buildings and monuments.

Damage to stonework caused by acid rain at Ephes
Turk

Hydrolysis

Hydrolysis takes place when acid rain reacts with rock-forming minerals such as feldspar to produce clay and salts that are removed in solution.

The only common rock-forming mineral that is not affected is quartz, which is a chemically resistant mineral. This is why quartz and clay are the two of the most common minerals in sedimentary rocks.

Spheroidal weathering

The weird shapes form as water attacks the rock along joints and cracks, leaving rounded lumps of un-weathered rock.

The iron-rich minerals in the rock have also oxidised to a brown "rusty" colour.

Spheroidal weathering by hydrolysis, Holy Island, Anglesey.


Church carving showing effects of hydrolysis.

Biological Weathering

Living organisms contribute to the weathering process in many ways:

Trees put down roots through joints or cracks in the rock in order to find moisture. As the tree grows, the roots gradually prize the rock apart.

Many animals, such as these Piddock shells, bore into rocks for protection either by scraping away the grains or secreting acid to dissolve the rock.

Even the tiniest bacteria, algae and lichens produce chemicals that help break down the rock on which they live, so they can get the nutrients they need.

Effects of weathering on granite:

Granite is an igneous rock that injects, or intrudes, as magma into Earth's crust and then cools. It consists of four main mineral compounds. Two of these are types of feldspar, a group of silica compounds that constitute the most abundant mineral group on Earth. Plagioclase feldspar is a compound of sodium and silica; potassic feldspar is a compound of potassium and silica. Granite also contains quartz, the second most abundant rock-forming mineral after feldspar. The fourth main mineral compound is mica, which in granite is a silica compound with a crystalline appearance resembling sheets of paper. Muscovite is mica with a high concentration of potassium. Biotite is mica with iron and magnesium. Each of these mineral groups weathers according to its own chemical properties.

1. Cooling

Granite cools slowly within the Earth's crust. Feldspar, quartz and mica crystals form during the cooling. Vertical and horizontal fissures form within the rock mass as it contracts. The fissures expand to larger fractures as the rock cools further.

2. Wind

Wind, water and ice denude the soil and Earth's crust overlying the granite mass, exposing it to the atmosphere. The rock expands and contracts in reaction to changes in temperature. It shatters on the surface and the fractures widen to form crevices.

3. Hydrolysis

Hydrolysis is the chemical weathering of minerals by a mildly acidic water that forms when rains dissolves trace gases in the atmosphere. The reaction of feldspar minerals in granite with rainwater produces kaolinite, white clay known as "China clay" used in the production of porcelain, paper and glass. Kaolinite is most abundant over weathered granite in hot and moist tropical climates. Biotite and muscovite micas also weather by hydrolysis into kaolinite and release iron, potassium and magnesium into the surrounding soil as nutrients.

Topic 2: MINERALOGY

Mineral:

A mineral may be defined as a natural, inorganic, homogeneous, solid substance having a definite chemical composition and regular atomic structure.
To call any substance a mineral, the requirements to be fulfilled are:

1. It must have been formed by natural process
2. It must be homogeneous, i.e. All parts of the minerals should possess the same physical and chemical characters
3. It must be inorganic substance, i.e., substances of wood or any other organic material cannot be called mineral
4. It must be solid, i.e. gaseous, liquid or semisolid substances are not minerals.
5. It must have a definite chemical composition.
6. It must be crystalline.

Importance of study of minerals:

From civil engineering point of view, studies of minerals are very important because:

1. The civil engineers need to know the properties of rocks precisely to enable them to consider different rocks for any purpose, i.e. foundation rocks, as road metal. As concrete aggregate, as building stones, as flooring or roofing materials , as decorative material etc.
2. The economic minerals, since they are scarce, do not influence the properties of their constituent minerals, and hence irrelevant from the civil engineering point of view. But, if they happen to occur in large quantities, their economic value will not permit them to be used as construction materials or as foundation sites.

Thus properties of civil engineering importance such as strength, durability and appearance of rocks can be assessed only with the knowledge of the minerals that form rocks.

Engineering Significance of Rock Forming Minerals

The civil engineers need to know the properties of rocks precisely to enable them to consider different rocks for any required purpose, i.e., as foundation rocks, as road meta, as concrete aggregate, as building stones, as flooring or roofing material, as decorative material etc. All properties of rocks are, in turn, depended on the properties of their constituent minerals. Thus, properties of civil engineering importance such as their strength, durability and appearance of rocks can be assessed only with the knowledge of the minerals that form rocks i.e. rock-forming minerals.
The economic minerals, since they are scare, do not influence the properties of rocks and are hence irrelevant from the civil engineering point of view. However, if they happen to occur in large quantities, their economic value will not permit them to be used either as construction materials or as foundation sites.

Different methods of study of minerals

1. *Study of physical properties*
2. *Study of chemical composition*
3. *Study of optical properties*
4. *X-ray analysis*

Physical Properties

Over 4,000 minerals are known to man, and these minerals are identified by their physical and chemical properties. The physical properties of minerals are determined by the atomic structure and crystal chemistry of the minerals. The most common physical properties are crystal form, color, hardness, cleavage, and specific gravity.

Crystals
Cleavage and Fracture
Color
Hardness
Streak
Luster
Specific Gravity
Tenacity
Acid Test
Magnetism
Fluorescence

Crystals

One of the best aids in the identification of a mineral is its crystal form (external shape). A crystal is defined as a homogenous solid possessing a three-dimensional internal order defined by the lattice structure.
Crystals developed under favorable conditions often exhibit characteristic geometric forms (which are outward expressions of the internal arrangements of atoms), crystal class, and cleavage. Large, well-developed crystals are not common because of unfavorable growth conditions, but small crystals recognizable with a hand lens or microscope are common. Minerals that show no external crystal form but possess an internal crystalline structure are said to be massive. A few minerals, such as limonite and opal, have no orderly arrangement of atoms and are said to be amorphous.
Crystals are divided into six major classes based on their geometric form: isometric, tetragonal, hexagonal, orthorhombic, monoclinic, and triclinic. The hexagonal system also has a rhombohedral subdivision, which applies mainly to carbonates.

Cleavage and Fracture

After minerals are formed, they have a tendency to split or break along definite planes of weakness. This property is called cleavage. These planes of weakness are closely related to the internal structure of the mineral, and are usually, but not always, parallel to crystal faces or possible crystal faces. Minerals may have one, two, three, four, or six directions of cleavage. These cleavage forms are (1) cubic, (2) octahedral, (3) dodecahedral, (4) rhombohedral, (5) prismatic, and (6) pinacoidal. Minerals that break easily along these lines of weakness yield shiny surfaces. Many crystals do not cleave, but fracture or break instead. Quartz, for example, forms well-developed crystal faces but does not cleave at all; instead it fractures or breaks randomly with a conchoidal fracture.

Color

The color of a mineral is the most important identifying characteristic for the amateur mineralogist. Many minerals exhibit various colors; the varieties are mainly due to impurities or a slight change in chemical composition. For example, calcite can be white, blue, yellow, pink, or fluorescent. Surface tarnish may have changed the color of the specimen; therefore, a fresh surface should be examined.

Hardness

The hardness (scratchability) of a mineral can be measured by its resistance to scratching or abrasion. Mohs scale is a set of 10 common minerals chosen for comparative hardness. The minerals are arranged in order of increasing hardness; each mineral will scratch all that precede it, and be scratched by all that follow it. Mohs scale (1-10) is as follows:

- *talc*
- *gypsum*
- *calcite*
- *fluorite*
- *apatite*
- *orthoclase*
- *quartz*
- *topaz*
- *corundum*
- *diamond*

Streak

The streak of a mineral is the color of the powder produced when the mineral is rubbed against an unglazed porcelain plate or other fine-grained, hard, abrasive surface. The color of a particular mineral may vary, but the streak is generally constant. The streak may be the same color as the mineral or an entirely different color, but the streak of all white minerals, including calcite, is white.

Luster

Luster refers to the brightness of light reflected from the mineral's surface. The main types of luster are metallic and nonmetallic. Some of the more important nonmetallic lusters are:

Adamantine: brilliant, like that of a diamond.

Earthy: dull, like kaolin.

Silky: having the sheen of silk, like satin spar, a variety of gypsum.

Greasy: oily appearance.

Resinous: waxy appearance, like sphalerite.

Vitreous: the appearance of broken glass, like quartz.

Nacreous (pearly): like mother of pearl; for example, pearly luster on fossil gastropods and cephalopods.

Specific Gravity

The specific gravity (relative density) of a mineral is its weight compared to the weight of an equal volume of water; thus, a mineral with a specific gravity of 4 is four times heavier than water. Special instruments are needed to measure the specific gravity.

Tenacity

Tenacity is the measure of a mineral's cohesiveness or toughness. Tenacity terms are:

Brittle: breaks or powders easily; for example, pyrite or marcasite.

Ductile: can be drawn into a wire; for example, copper.

Elastic: bends and resumes its original position or shape when pressure is released; for example, biotite or muscovite.

Malleable: can be hammered into thin plates or sheets; for example, gold or copper.

Sectile: can be cut or shaved with a knife; for example, gypsum or galena.

Acid Test

When carbonates (especially calcite) are treated with cold, dilute hydrochloric acid, they will effervesce, foam, and bubble, and give off carbon dioxide gas. When sulfides, such as galena, pyrite, and sphalerite, are treated with dilute hydrochloric acid, they will give off the rotten-egg odor of hydrogen sulfide.

Study of chemical compositions:

According to the definition, every mineral is expected to have its own distinctive chemical composition, which is not to be found in any other mineral.
Therefore, by chemical analysis, if the composition is known it should be possible to identify the mineral.
This principle is the basis for this type of study of minerals. For example, if the chemical composition of an unknown mineral is found to be lead sulphide, then that mineral must only be Gelena, because it only has the composition of lead sulphide and no other mineral has this composition.

Study of Optical properties:

In this method, the minerals are ground very fine and fixed over glass slides by means of *CANADA BALSAM.* Such skillfully prepared slides are called thin sections.
They are studied under a petrlogical microscope.
The properties of minerals like colour, their order, interference figures, cleavage, shape, etc are studied under crossed nicols, with the help of some other accessories, if necessary.

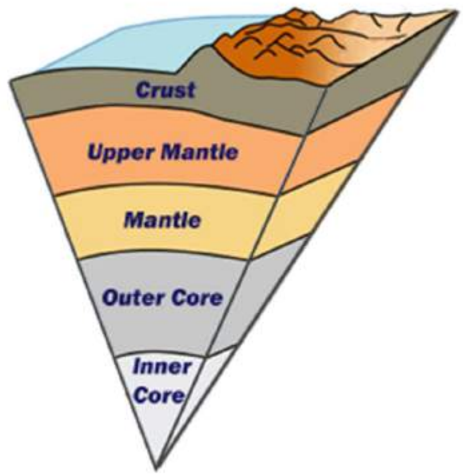
X-ray Analysis:

X-ray analysis makes use of the definite atomic structure, found in every mineral, X-rays are similar to light waves but have a much shorter wave length, comparable to the distances between atoms in a crystalline mineral. When a beam of X-rays falls on crystal, it is diffracted by layers of atoms within the crystal. In making an x-ray analysis of atomic structure of the crystal, the diffracted x-rays are allowed to fall on photographic plate, and the resulting photograph shows a series of spots or lines which form more or less symmetrical pattern. X-ray analysis of minerals reveals their actual atomic structures, which is distinctive for each mineral. This enables the accurate identification of minerals.

Petrology:

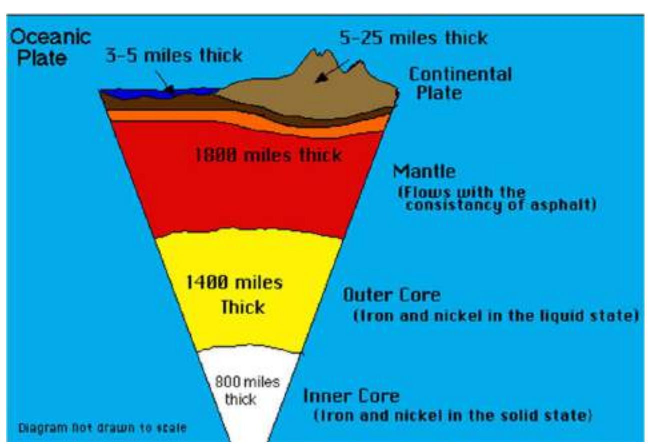
Shell structure of earth:

The interior structure of the Earth is layered in spherical shells. These layers can be defined by their chemical and their rheological properties. Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core.



Structure of earth:

The crust of earth is made up of different kinds of rocks. The thickness of crust is approximately 35Km. this rocky crust is known as **Lithosphere.**
The earth crust is uneven with many depressions and elevations.
These depressions are filled with water and are called lakes, seas and oceans. This discontinuous body of water in association with the lithosphere is called the **Hydrosphere**.
On land masses of the lithosphere and in water bodies of hydrosphere, all living creatures exist, this is called **Biosphere**. All these, in turn are enveloped by a layer of air which is called the **Atmosphere.**



Definition of a Rock:

Rock or stone is a natural substance, a solid aggregate of one or more minerals or mineraloids. The solid mineral material forming part of the surface of the earth and other similar planets, exposed on the surface or underlying the soil.

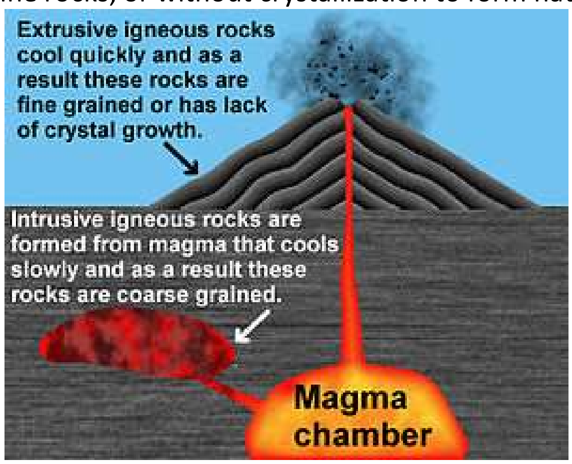
A rock can be simply defined as *"an aggregate of minerals"*.

Classification of Rocks:

Using color, texture, and mineral composition, geologists can classify a rock according to its origin. A rock's origin is how the rock formed. Geologists classify rocks into three major groups: **igneous rock, sedimentary rock,** and **metamorphic rock**.

Igneous rock:

Igneous rock is formed through the cooling and solidification of magma or lava. The magma can be derived from partial melts of existing rocks in either a planet's mantle or crust. Typically, the melting is caused by one or more of three processes: an increase in temperature, a decrease in pressure, or a change in composition. Solidification into rock occurs either below the surface as intrusive rocks or on the surface as extrusive rocks. Igneous rock may form with crystallization to form granular, crystalline rocks, or without crystallization to form natural glasses.



Igneous rocks are also geologically important because:

- Their minerals and global chemistry give information about the composition of the mantle, from which some igneous rocks are extracted, and the temperature and pressure conditions that allowed this extraction, and/or of other pre-existing rock that melted;
- Their absolute ages can be obtained from various forms of radiometric dating and thus can be compared to adjacent geological strata, allowing a time sequence of events;
- Their features are usually characteristic of a specific tectonic environment, allowing tectonic reconstitutions in some special circumstances they host important mineral deposits (ores): for example, tungsten, tin, and uranium are commonly associated with granites and diorites, whereas ores of chromium and platinum are commonly associated with gabbros.

Sedimentary Rocks:

Sedimentary rocks are types of rock that are formed by the deposition and subsequent cementation of that material at the Earth's surface and within bodies of water. Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to settle in place. The particles that form a sedimentary rock by accumulating are called sediment. Before being deposited, the sediment was formed by weathering and erosion from the source area, and then transported to the place of deposition by water, wind, ice, mass movement or glaciers, which are called agents of denudation.

Sedimentation may also occur as minerals precipitate from water solution or shells of aquatic creatures settle out of suspension.

The sedimentary rock cover of the continents of the Earth's crust is extensive (73% of the Earth's current land surface, but the total contribution of sedimentary rocks is estimated to be only 8% of the total volume of the crust. Sedimentary rocks are only a thin veneer over a crust consisting mainly of igneous and metamorphic rocks. Sedimentary rocks are deposited in layers as strata, forming a structure called bedding. The study of sedimentary rocks and rock strata provides information about the subsurface that is useful for civil engineering, for example in the construction of roads, houses, tunnels, canals or other structures. Sedimentary rocks are also important sources of natural resources like coal, fossil fuels, drinking water or ores.

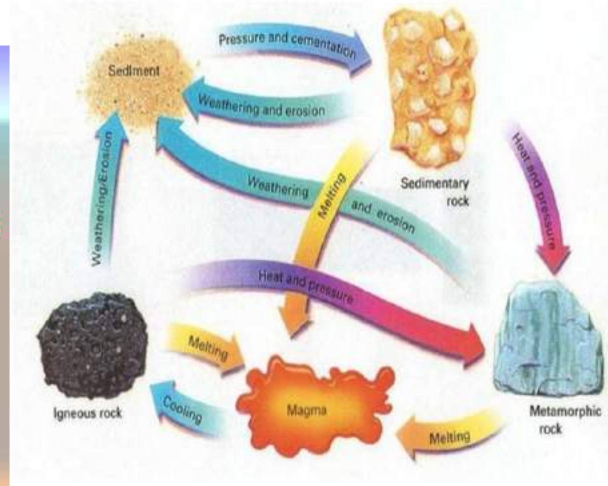
Metamorphic rocks:

Metamorphic rocks arise from the transformation of existing rock types, in a process called metamorphism, which means "change in form". The original rock (protolith) is subjected to heat (temperatures greater than 150 to 200 °C) and pressure (150 megapascals (1,500 bar))[clarify],causing profound physical and/or chemical change. The protolith may be a sedimentary, an igneous, or even an existing type of metamorphic rock.

Metamorphic rocks make up a large part of the Earth's crust and form 12% of the Earth's current land surface. They are classified by texture and by chemical and mineral assemblage (metamorphic facies). They may be formed simply by being deep beneath the Earth's surface, subjected to high temperatures and the great pressure of the rock layers above it. They can form from tectonic processes such as continental collisions, which cause horizontal pressure, friction and distortion. They are also formed when rock is heated up by the intrusion of hot molten rock called magma from the Earth's interior. The study of metamorphic rocks (now exposed at the Earth's surface following erosion and uplift) provides information about the temperatures and pressures that occur at great depths within the Earth's crust. Some examples of metamorphic rocks are gneiss, slate, marble, schist, and quartzite.

Rock Cycle:

The rock cycle is a basic concept in geology that describes the time-consuming transitions through geologic time among the three main rock types: sedimentary, metamorphic, and igneous. As the adjacent diagram illustrates, each of the types of rocks is altered or destroyed when it is forced out of its equilibrium conditions. An igneous rock such as basalt may break down and dissolve when exposed to the atmosphere, or melt as it is subducted under a continent. Due to the driving forces of the rock cycle, plate tectonics and the water cycle, rocks do not remain in equilibrium and are forced to change as they encounter new environments. The rock cycle is an illustration that explains how the three rock types are related to each other, and how processes change from one type to another over time. This cyclical aspect makes rock change a geologic cycle and, on planets containing life, a biogeochemical cycle.



A diagram of the rock cycle.

1 = magma; 2 = crystallization (freezing of rock); 3 = igneous rocks; 4 = erosion; 5 = sedimentation; 6 = sediments & sedimentary rocks; 7 = tectonic burial and metamorphism; 8 = metamorphic rocks; 9 = melting.

Forms of Igneous rock:

Igneous rocks are formed in two forms

1. Intrusive igneous rocks
2. Extrusive igneous rocks

Intrusive igneous rocks:

Intrusive, or plutonic, igneous rocks form when magma cools slowly below the Earth's surface. Most intrusive rocks have large, well-formed crystals.
Examples: granite, gabbro, diorite and dunite.

The most common forms of intrusive igneous bodies as observed in the field are:
Dyke, sill, laccolith, lopolith, bysmalith, phacolith, chonolith,volcanic neck or plug, batholiths etc.,.

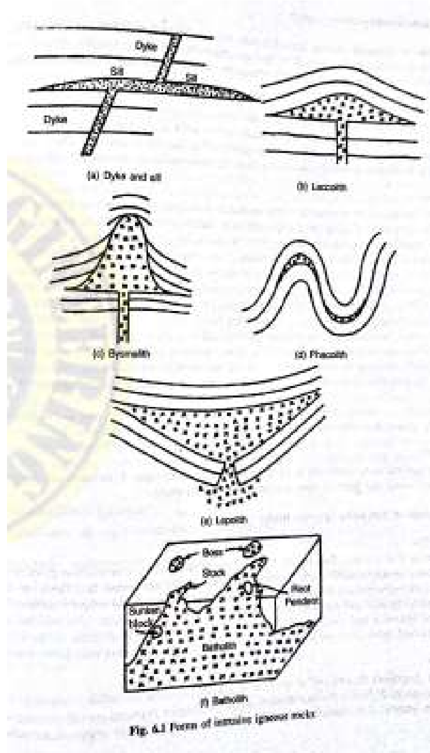
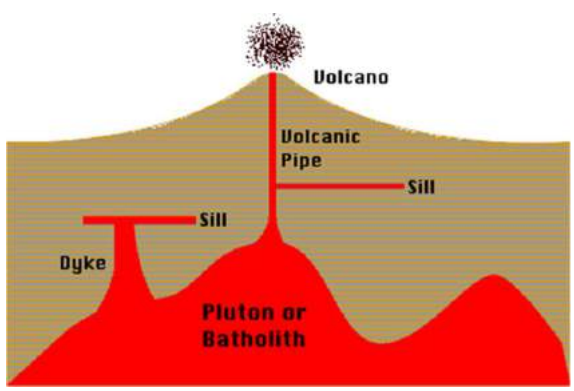


Fig. 6.1 Forms of intrusive igneous rocks

Dykes:

A dyke (or dike) in geology is a type of later vertical rock between older layers of rock. Technically, it is any geologic body which cuts across: flat wall rock structures, such as bedding. Massive rock formations, usually igneous in origin.

Dikes can be either magmatic or sedimentary in origin. Magmatic dikes form when magma intrudes into a crack then crystallizes as a sheet intrusion, either cutting across layers of rock or through an un-layered mass of rock. Clastic dikes are formed when sediment fills a pre-existing crack.



Sills:

A sill is a sheet-like intrusion that is concordant with external layering such as bedding or metamorphic foliation. Sills are formed from magma injected along planes of weakness represented by layering in rocks and are distinct from dykes that cut across layering (i.e. are discordant).

An intrusive mass of igneous rock which consolidated beneath the surface and has a large horizontal extent in comparison with its thickness.

FORMS OF EXTRUSIVE IGNEOUS ROCKS:

Lava Flows

On eruption of a volcano, lava simply flows on the surface and on consolidation gives rise to lava flows. These closely resemble sills in shape. Based on surface appearance, lava flows are described as block lava and ropy lava. Block lava is less mobile and has a rough and irregular surface. The ropy lava is more mobile and has a wrinkled but smooth and shining surface. The vesicles are more numerous, spherical and small in ropy lava flow and they are few and irregular in block lava flow. These physical differences occur because ropy lava comes out hotter and with lesser volatiles.

Pyroclasts

The rock fragments thrown out at the time of volcanic eruption are called pyroclasts. These are described variously, based on size and shape. Bigger and angular fragments are called volcanic blocks. If they are somewhat rounded they are known as volcanic bombs. Smaller fragments are called lapilli.

Classification of Igneous rocks:

- **i) Classification based on silica percentage**
- **ii) Classification based on silica saturation**
- **iii) Classification based on depth of formation**

Classification based on silica percentage:

The chemical composition of a rock is generally expressed in terms of different (oxides like SiO2 AL2O3, Fe2O3, FeO, Mg0 and C20. Among different oxides silicon dioxide is always predominant in rocks. Since silica percentage is also responsible for the formation of different minerals and their associations, it serves as a suitable basis for the classification of igneous rocks. When silica content exceeds 66%. The igneous rock is called as **acidic;** when it is 52-66%, the rocks are called **intermediate**. **The basic rocks** have 45-52%. In **ultrabasic rocks**, the silica content is less than 45%.

Acidic rocks

1. These rocks are compositionally rich in silica, alumina & alkalies, but poor in calcium, magnesium & iron (Mafic)
2. They are composed of quartz, alkali feldspar & muscovite mica – representing late stage of crystallization of magma.
3. They are leucocratic because these are rich in pale coloured minerals & poor in dark coloured Mafic minerals.
4. They have characteristically free primary quartz & are always devoid of unsaturated minerals like olivines & feldspathoids.
5. They are relatively lighter & have high melting points.
6. Granites & many Pegmatites are typical examples of this group: Granites have 70% (or) more of silica content. Sometimes, pure white primary quartz veins composed of 100% silica also occurs in nature.

Intermediate Rocks

1. These rocks may be lacking in free quartz completely (or) may be having very little of it.
2. These are mainly composed of alkali feldspars with a few accessory minerals of the mafic kind.
3. These are leucocratic (or) mesocratic
4. Syenite is a typical example of this group - potash feldspar is the predominant constituent of this rock.

Basic Rocks

i) In these rocks, mafic minerals occur as essential minerals, i.e., they occur as important constituents.
ii) Quartz and olivine are generally absent, or any one of them may occur in small quantities.
iii) Feldspars are of the plagioclase type
iv) Silica + alkalies are less + calcium, magnesium + ferrous iron are more in content when compared with acidic rocks.
v) Dolerite + gabbro, belonging to this group, are typical melanocratic i.e., black coloured, Basalt, another typical

basic rock, is, however, is generally some what cement coloured. (24)

6. The dominant occurrence of mafic minerals makes these rocks to have a slightly higher specific gravity (roughly (3.1))

7. Gabbro, norite, dolerite & basalt are typical examples.

Ultra basic Rocks

1. Free quartz are absent
2. Unsaturated minerals and/or mafic minerals occur as essential minerals.
3. These are typical melanocratic
4. These have the highest density among the different rock types (sp. gravity = 3.6)
5. These are usually formed as differential products of early formation minerals like Olivine, calcium rich plagioclase & magnesium rich pyroxenes.
6. Dunites, ~~periodotites~~ Periodotites, picrites & pyroxenites are typical examples of this category.
7. Compositionally, these are the poorest in silica & richest in magnesium.

Classification based on silica saturation

1. Saturated
2. Unsaturated
3. Over saturated
4. Under saturated

Classification based on Depth of formation

1. Volcanic rocks — Surface (low temp & low Pressure)
   (less coarse grained)
2. Hypabyssal rocks — Shallow depth
   (more coarse grained compare to volcanic) (moderate temp & pressure)
3. Plutonic rocks — deeper depth
   (high coarse grained) (high temp & pressure)

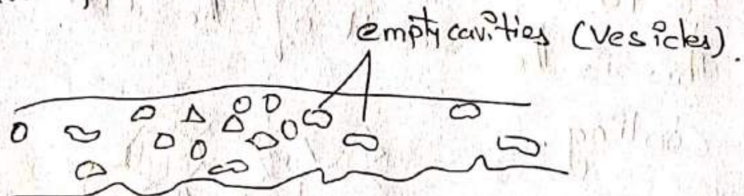
Structure & Texture of Igneous rocks

Structure

Vesicular structure

This structure is due to the porous nature, commonly observed in volcanic rocks, & is attributed to the following reasons.

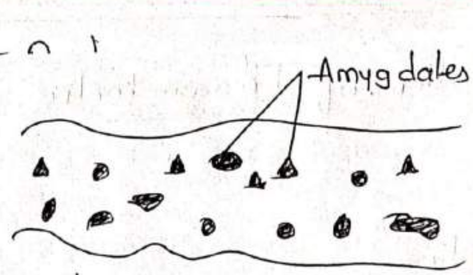
- Magma is an intimated mixture of rock melt and gases.
- Eruption of any volcano is accompanied by the flow of such melt on the surface.
- Then, the gases being lighter, move upwards and as they escape into the atmosphere create cavities of various sizes & shapes near the surface of lava flow. These cavities are called Vesicles.



- Vesicles if plenty, make rock hollow & less strong
- Vesicles are interconnected with fractures, the rock becomes permeable too & behave like aquifer.

Amygdaloidal structure

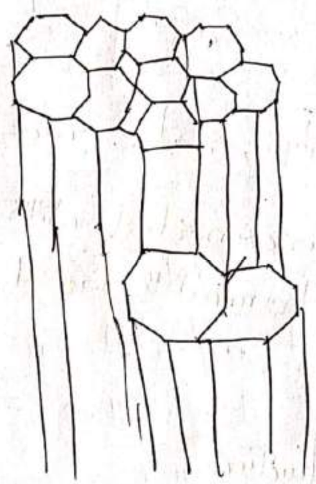
The vesicles, which are empty to start with in vesicular structure, are subsequently filled up by the deposits of surface waters or hydrothermal solutions. Such infillings are called amygdales.



When cavities filled with amygdales the Vesicular structure is known as Amygdaloidal structure.

Columnar Structure

In this structure, the volcanic igneous rock appears to be made up of numerous parallel polygonal prismatic columns, bundled together. This is the result of the contraction of lava during cooling.



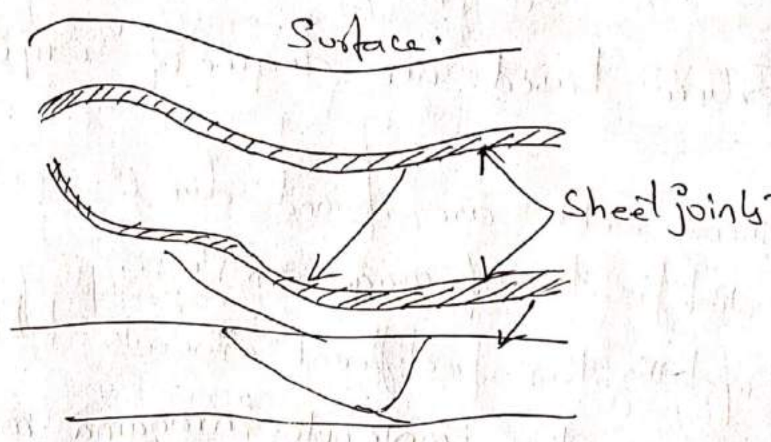
columnar structure.

Ideal conditions produce hexagonal columns. But irregularities in the spacing of cooling centres produce ~~hexagonal~~ Prisms ~~columns~~ of three or four or more number of sides. This feature bears a resemblance to mud cracks.

Sheet structure

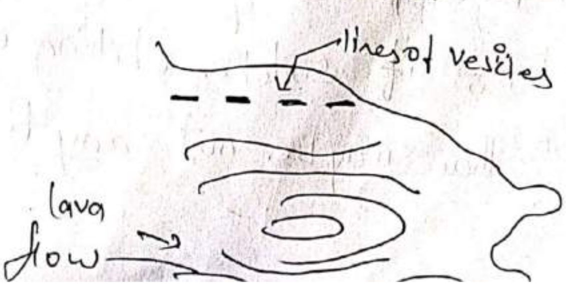
In this structure, the rock appears to be made up of a no. of sheets, because of the development of nearly horizontal cracks. This is the effect of erosion over rocks formed at depth.

When erosion takes place, the overlying rocks (or) strata disappear, ultimately exposing plutonic rocks on the surface. In this process the earlier pressure no longer remain & this release (or) disappearance of pressure results in the development of joints or cracks, roughly parallel to the surface. These are sheet joints.



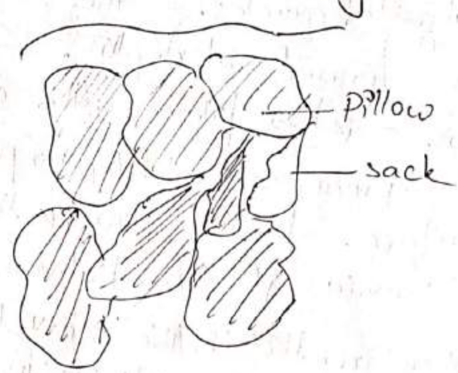
Flow structure

This structure refers to linear and nearly parallel feature occuring in volcanic rocks which develop ~~as a consequence~~ as a consequence of the lava flow.



Pillow structure

In this structure, the volcanic igneous body appears as a pile of numerous overlapping pillow(or)sacks.



Common Texture of Igneous rocks

Texture based on degree of crystallinity.

Igneous rocks are formed due to cooling & solidification of magma (or) lava.
Crystallization of different minerals takes place when the respective molecules in magma move to their centres of crystallization & arrange themselves in a definite pattern. If reasonable time is available, crystallization of different minerals takes place from the melt giving rise to a rock. But if sudden chilling of lava occurs, then there may be not any time for crystallization.

(27)

i) Holocrystalline → holo – complete
ii) Holo hyaline – glassy (or) ~~amphor~~ amorphous
iii) Hemi crystalline → hemi – half (Partly crystalline & Partly glassy)

Thus preceding three crystallization give rise to three textures of igneous rocks.

Texture based on Granularity

Depending on the physical conditions that had prevailed during the crystallization of magma, mineral grains occur in different sizes.
The presence of volatiles, low viscosity, slow cooling & great pressure help to grow large minerals. The absolute sizes of minerals vary widely.
If minerals in the rocks are big enough to be seen by naked eye, then the texture is described as phaneric texture.
If minerals in the rock are too fine to be seen seperately by naked eye, the texture is described as aphanitic texture.

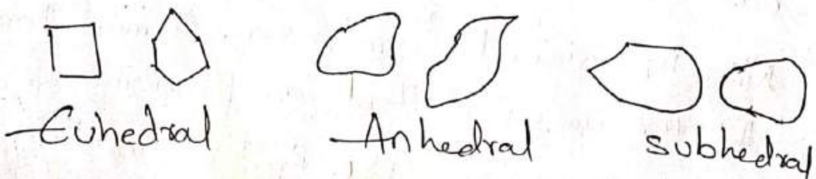
When the mineral grain size is more than 5mm, the texture is called as phaneric - coarse.
When the grain size is less than 1mm & 5mm the texture is called phaneric - medium.
When the grain size is recognizable as less than 1mm then phaneric – fine.

Similarly, the aphanitic texture is also classified as micro-crystalline, cryptocrystalline & glassy.

When grain is recognizable under microscope, the texture is called aphanitic - microcrystalline.
if the rock is amorphous & minerals are not recognizable under the microscope then the texture is aphanitic glassy.
If the minerals had undergone only very incipient growth, & are not distiguishable under the microscope but affect the polarized light giving hazy outlook under crossed Nicols, the texture is called aphanitic - cryptocrystalline.

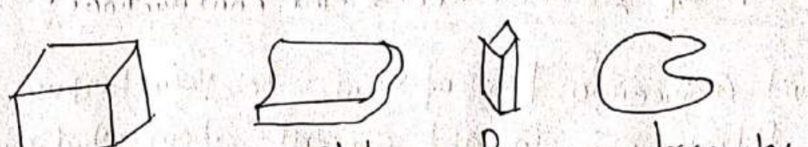
Texture based on shapes of crystals

When the minerals are completly bounded by crystal faces, it is called "euhedral", when crystal faces are absent, it is called "anhedral", & when only a part of the mineral is bound by crystal faces it is called "subhedral".



Minerals based on their shapes are described as equidimensional (or) platy (or) Prismatic (or) irregular.

(28)



Equidimensional Platy Prismatic Irregular

Texture based on Mutual relation of Constituent minerals of Rock

Equigranular texture: minerals present are approx. of same size

Inequigranular texture: rocks having this type of texture are not composed of same sized minerals.

Porphyritic texture: In this two sizes (larger + smaller) (Phenocrysts and ground mass) minerals grains occur. rock is known as Phorphyry.

Poikilitic texture: In this type smaller mineral grains are enclosed in b/w or in the larger ones without any order.

Ophitic texture: This type commonly occurs in dolerites, under microscope. In this augite mineral grains enclose small laths (regular grains) of Plagioclase-feldspar

Seriate texture: This is uncommon inequigranular texture in which grain sizes of minerals vary gradually from smallest to largest.

Intergranular texture: This is also observed under microscope in rocks like basalts. In this Intergranular (or) regular shaped Plagioclase feldspar grains form a network & polygonal shaped spaces left are filled with augite, olivine & iron oxides

~~Graphic texture~~

Interlocking texture: In this texture, the different minerals are closely interlinked (or) mutually locked with one another. It develops when a melt solidifies. only igneous rocks have this type of texture.

Graphic texture: This is an intergrowth texture formed due to eutectic crystallization in which two minerals are formed simultaneously.

... texture is also classified

Suitability of Igneous Rocks for constructions:

From Civil Engineering point of view, the very purpose of studying Petrology is to get concept about what makes some rocks very competent & other less competent.
– Among various types of rocks, igneous rocks are inherently very competent & desirable for different civil engg. purposes.

No rock possesses all the desirable properties so as to make it ideally suitable for various types of construction.

For foundation purposes of heavy construction – rock should be very strong & be able to withstand substantial loads.

For superstructure of considerable magnitude, rocks should be easily workable & be ~~able~~ available in plenty, & should be durable.

For Roofing purposes, rocks should be resistant to weathering

For flooring purposes, rocks should be able to withstand wear & tear, i.e., they should be resistant to abrasion.

For face work, rocks should have pleasant color, attractive appearance & ability to take good polish.

Igneous rocks in general 'Granite' in particular meets these requirements to a very satisfactory extent

Sedimentary Rocks

Sedimentary rocks are those which have formed out of Sediments. Sediments are rocks fragments which are Product of weathering.
Weathering has already been defined as a natural process of disintegration & decomposition of rocks.
Sediments which have formed out of disintegration are loose materials of various sizes like clay, sand & pebbles. These sediments on subsequent cementation (or) compaction (or) both gives rise to hard, cohesive sedimentary rocks.
Since sediments represent secondary (or) derived materials from the pre-existing rocks, rocks formed out of them are also called Secondary rocks.

Classification of Sedimentary rocks

i) Detrial (ii) Non Detrial.

Detrial rocks are also known as ~~clasts~~ clastic rocks, which are formed out of physically broken and transported rock fragments.
Coarser rock fragments are cemented by a finer matrix & give rise to rudaceous & arnaceous rocks.
Non-Detrial rocks are formed either by

Precipitation, evaporation (or) by accumulation (3) of hard parts of plants & animals.
Coals, various types of limestones, springs deposits flint, salt beds etc., are formed.
In another classification sedimentary rocks are classified as
(1) Detrial (2) Residual (3) chemical deposits
(4) Organic deposits.

Any rock which is subjected to altering dry and wet climates over a considerable length of time, undergoes through decay and decomposition.
As a consequence, all readily soluble as well as difficult to dissolve material is dissolved and leached. This ultimately leaves behind chemically inert & insoluble residual matter. This makes up a group of sedimentary rocks known as Residual Rocks.
Due to prolonged disintegration, rocks are broken down into smaller & smaller particles. when large bodies of rocks are reduced to convenient size in this manner, they are transported mechanically. Thus, rivers & streams both physically & chemically transport rock matter. The mechanically transported sediments subsequently cemented or compacted to give rise to another group called Detrial rocks.

The rest of the river transported matter, carried as solution, is also deposited sometimes, under favorable conditions due to chemical process like precepitation & evaporation, which are called as chemical deposits.

Due to accumulation of hard parts of plants & animals. Under favorable conditions, a part of the dissolved matter is extracted by growing plants and trees & utilized as food material. These plants & trees may subsequently form coal deposits. The remaining dissolved materials ultimately reach sea (or) oceans and get extracted by various marine organisms to develop hard parts. These hard parts after the death of organisms accumulate over the sea floor & become shell lime stones, oozes etc,. Further under favourable conditions secondary deposits which are formed out of active involvement of plants & other organisms are called organic deposits.

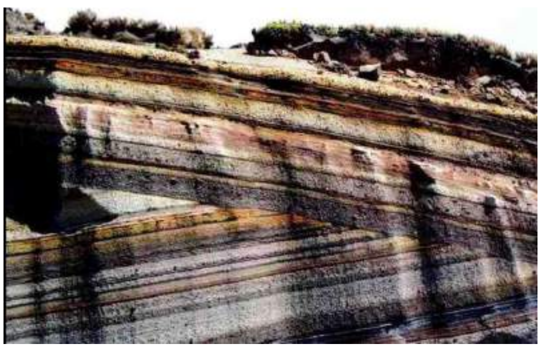
STRUCTURE AND TEXTURE OF SEDIMENTARY ROCKS

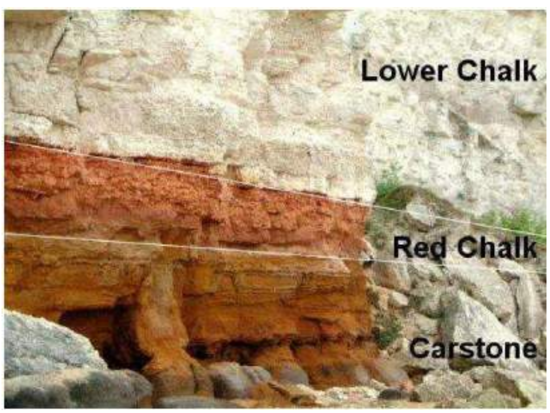
- *STRATIFICATION*
- *CEMENTING MATERIAL*
- *FOSSIL OCCURRENCE*
- *RIPPLE MARKS*
- *MUD CRACKS OR SUN CRACKS*
- *RAIN PRINTS OR MARKS*

- *TRACKS AND TRAILS*
- *PECULIAR FORMS*
- *CONCOIDAL FRACTURE*

STRATIFICATION

• STRATIFICATION refers to the way sediment layers are stacked over each other, and can occur on the scale of hundreds of meters, and down to sub-millimeter scale. It is a fundamental feature of sedimentary rocks.





- Stratum- bed, strata means beds
- Stratification is also known as bedding
- When the thickness of individual beds is very thin then it is known as Lamination
- Bedding plane is the plane of contact between two adjacent beds of strata.

Cementing material

Cementation, in geology, hardening and welding of clastic sediments (those formed from pre-existing rock fragments) by the precipitation of mineral matter in the pore spaces. It is the last stage in the formation of a sedimentary rock. The cement forms an integral and important part of the rock, and its precipitation affects the porosity and permeability of the rock. Many minerals may become cements; the most common is silica (generally quartz), but calcite and other carbonates also undergo the process, as well as iron oxides, barite, anhydrite, zeolites, and clay minerals.

Fossil occurrence

• Fossils have been defined as "relicts and remnants of ancient plants and animals preserved inside the rocks by natural processes"

• Remains of plants and animals, when they get buried under sediments, become fossilized.

• Not all animals and plants become fossils, only with hard parts become fossils under favourable conditions.

Mud cracks

• Water or sea or lake, depending on different conditions covers the gently sloping sides on and off.

• When such a wet surface is not covered, it dries up and develops vertical polygonal cracks which are wedge-shaped downwards.

Ripple marks

• In shallow bodies, the waves and currents on the surface of water produce impressions in the form of minor undulations on the loose and soft sediments which lie at the bottom. These are known as ripple marks.

Rain prints or marks

• Rain prints or marks develop under the same conditions as those of mud cracks and are preserved on surface of some rocks.

Tracks and trails

• Tracks and trails are the markings indicating the paths of some animals or organisms, over a soft sediment, which is able to take and retain the impression.

• Footprints of animals or birds may occur the same way.

Peculiar forms

• Nodular , concretionary, pisolitic, oolitic, stalactitic.

• These forms occurs only in sedimentary rocks.

NODULAR

CONCRETIONARY

PISOLITIC

OOLITIC

STALACTITIC

Metamorphic Rocks

Metamorphic rocks are geologically classified as one of the major groups of rocks which have been formed out of metamorphism of Pre-existing Igneous & sedimentary rocks.

Orthometamorphic — from Igneous rocks
Parametamorphic — from Sedimentary rocks
Polymetamorphic — Metamorphism of Metamorphic rock

Note:
When a rock undergoes metamorphism more than once, the process is called Polymetamorphism.

(Meta – change
Morph – form)

In petrology, it indicates the effect of temp., pressure & chemically active solutions over the texture, minerals & composition of parent rocks.

Igneous & Sedimentary rocks which serve as parent rocks are formed under a certain physico-chemical environment, i.e., at the time of their formation, they were in equilibrium with their surroundings in terms of temperature, pressure & chemically active fluids.

Granite —changes→ Granite gneiss
Peridotite → Serpentine & talc schist
Gabbro → hornblende schist
Sandstone → quartzite, limestone → marble
Shale → Slate.

* Metamorphic Agents

Temperature, Pressure & chemically active fluids are the agents of metamorphism.

Generally all these act together & cause Metamorphism. But some times, any one or two of them may dominate & Play an active role.

Temperature :

The source of temperature which is responsible for metamorphism is either due to depth (or) contact with magma. The metamorphic changes mainly take place in the temperature range of 350–850°C. The temperature rise also increases the chemically activity in rocks & facilitates rxn's during metamorphism.

Pressure :

The Pressure which causes metamorphism is of two different kinds, namely, uniform Pressure & direct pressure.

Chemically Active fluids :

Chemically active fluids play a key role in different ways in causing metamorphism.

i) Since metamorphism of any type cannot take place for solid minerals in a perfect dry state, the presence of a liquid medium of some kind is indispensable. Thus liquids act as carriers of chemical components that actually take part in chemical rxns to take place. The most common liquid plays such role is water.

(ii) The huge quantities of volatiles that are associated with magmatic bodies ultimately permeate through the surrounding rocks by means of diffusion & cause compositional changes even in rocks far off from magma

(iii) The magma (or) the hot juvenile hydro-thermal solutions may react directly with those rocks with which they come in contact. The heat that is generally associated with the preceding contents plays a positive role in accelerating the rxns.

Types of Metamorphism

Metamorphism of rocks occurs due to the combined effect of temperature, Pressure & chemically active fluids. But sometimes one (or) two of these metamorphic agents play a more active role in bringing about metamorphism. Based on this factor different types of Metamorphism are recognized. Some important types along with relevant details are as follows:

i) Thermal Metamorphism
ii) Dynamic Metamorphism (Directed pressure Predominant)
iii) Geothermal Metamorphism (uniform pressure Predominant)
iv) Metasomatic Metamorphism (chemically Active fluids Predominant)
v) Dynamothermal metamorphism (Direct Pressure + Heat)
vi) Plutonic Metamorphism (Uniform Pressure + Heat)

Structure of Metamorphic rocks

- **Gneissose Structure**

- If the rock consists of **equi-dimentional** minerals ***along with platy and prismatic minerals***, which can **easily be segregated** and **altering bands** are formed.
- Foliation and lineation of **platy and prismatic minerals** take place.
- Such a texture or arrangement of minerals is called **Gneissose structure**.

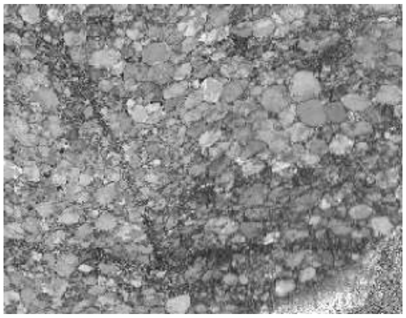
Schistose Structure

- If the rock consists of **only prismatic or platy minerals**, then **no segregation takes place.**
- **Only foliation or only lineation** occurs.
- Such a texture or arrangement of minerals is known as **Schistose structure**

Granulose Structure

- If the rock is **composed predominantly of equidimensional minerals**, then **neither segregation nor foliation** takes place, **absence of platy or prismatic minerals**.
- Such a texture is called G**ranulose structure.**

Cataclastic Structure



- It is produced under the influence of direct pressure in the upper zones of earth's crust.
- In some rocks, more resistant minerals may remain unaffected, while the softer minerals are powdered to fine material.
- This result in appearance similar to porphyritic texture and is called **Porphyroclastic structure**.

Classification of Metamorphic rocks

- Metamorphic rocks are classified as para-metamorphic or ortho-metamorphic rocks based on whether they have been formed out of sedimentary or igneous rocks.
- In different way, metamorphic rocks can be classified on their physical appearance, i.e., as massive or foliated.
- This is independent of kind of metamorphism or parent rock involved.
- However this classification reflects the mineral content and structure clearly.

Foliated rocks

- The process of metamorphism which is accompanied by pressure, induces alignment of constituent minerals in rock.
- The alignment or orientation of minerals takes place perpendicular to the direction of the greatest stress.
- When platy, lamellar, bladed or flaky minerals occurs in rocks, they orient themselves parallel to each other and obviously perpendicular to the direction of the greatest stress.

Such rocks are called as foliated rocks, the process is known as foliation.

Massive or non-foliated rocks

The three important type of rocks which come in this type of category are:

- Quartzite
- Marble
- Hornfels

Of these quartzite is formed out of thermal, dynamic or dynamo-thermal metamorphism.

Hornfels is formed through thermal metamorphism.

Marble is a result of thermal metamorphism of limestone**.**

TOPIC 3

Structural Geology

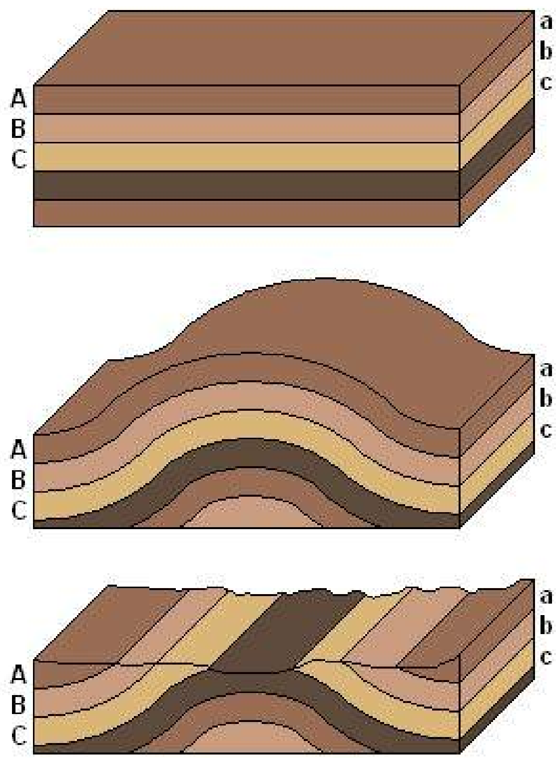
- Structural geology is the study of factors such as origin , occurrence, classification, types and effects of various secondary structures like folds, faults, rock cleavage and unconformities.
- All these structures are those which develop and occur in rock after their formation and different from those primary structures such as bedding and vesicular structure, which develop in rocks at the time of their formation itself.

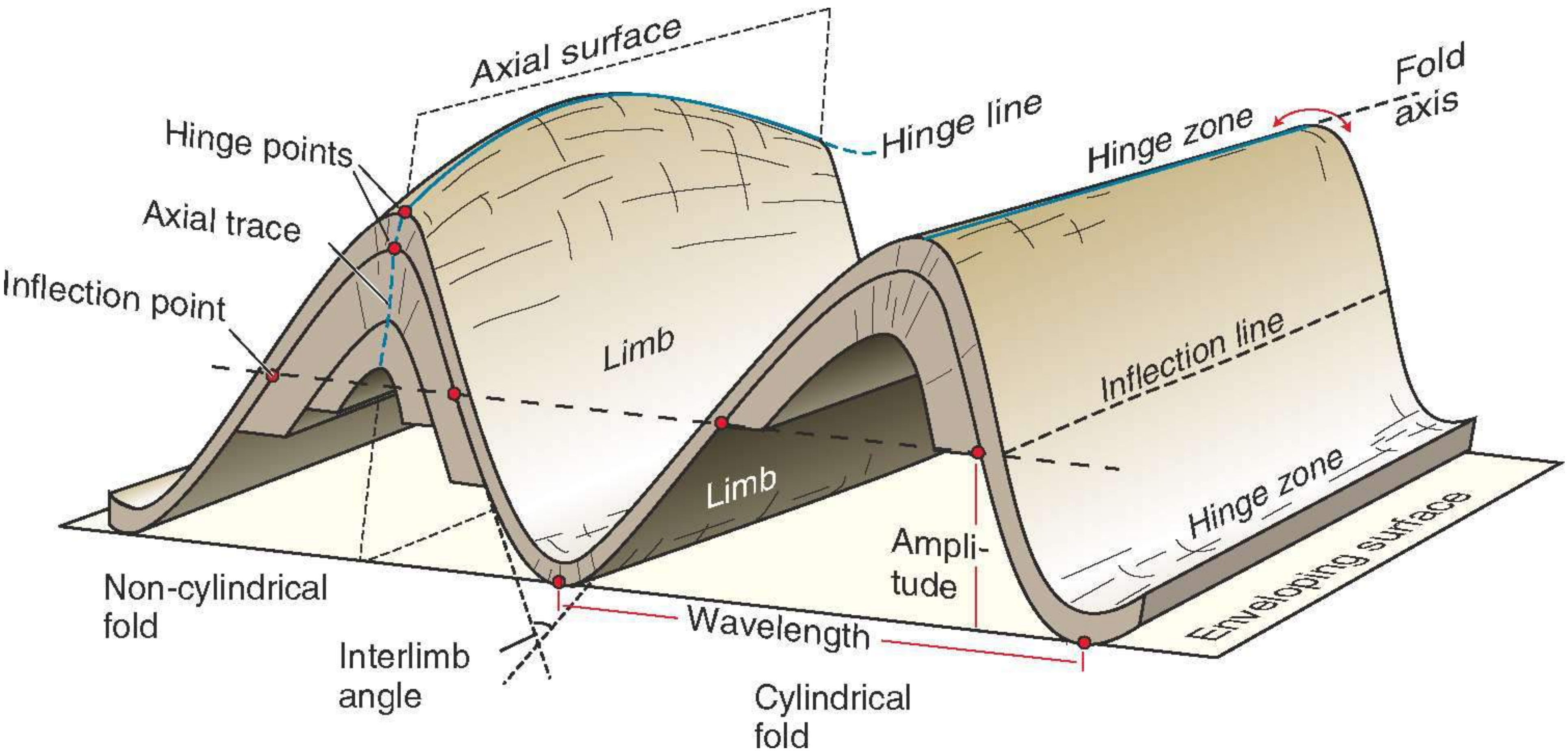
Outcrop

- Any geological formation exposed on the surface is called an outcrop.
- It is used as a general term to refer to exposed folds, faults, joints, etc.

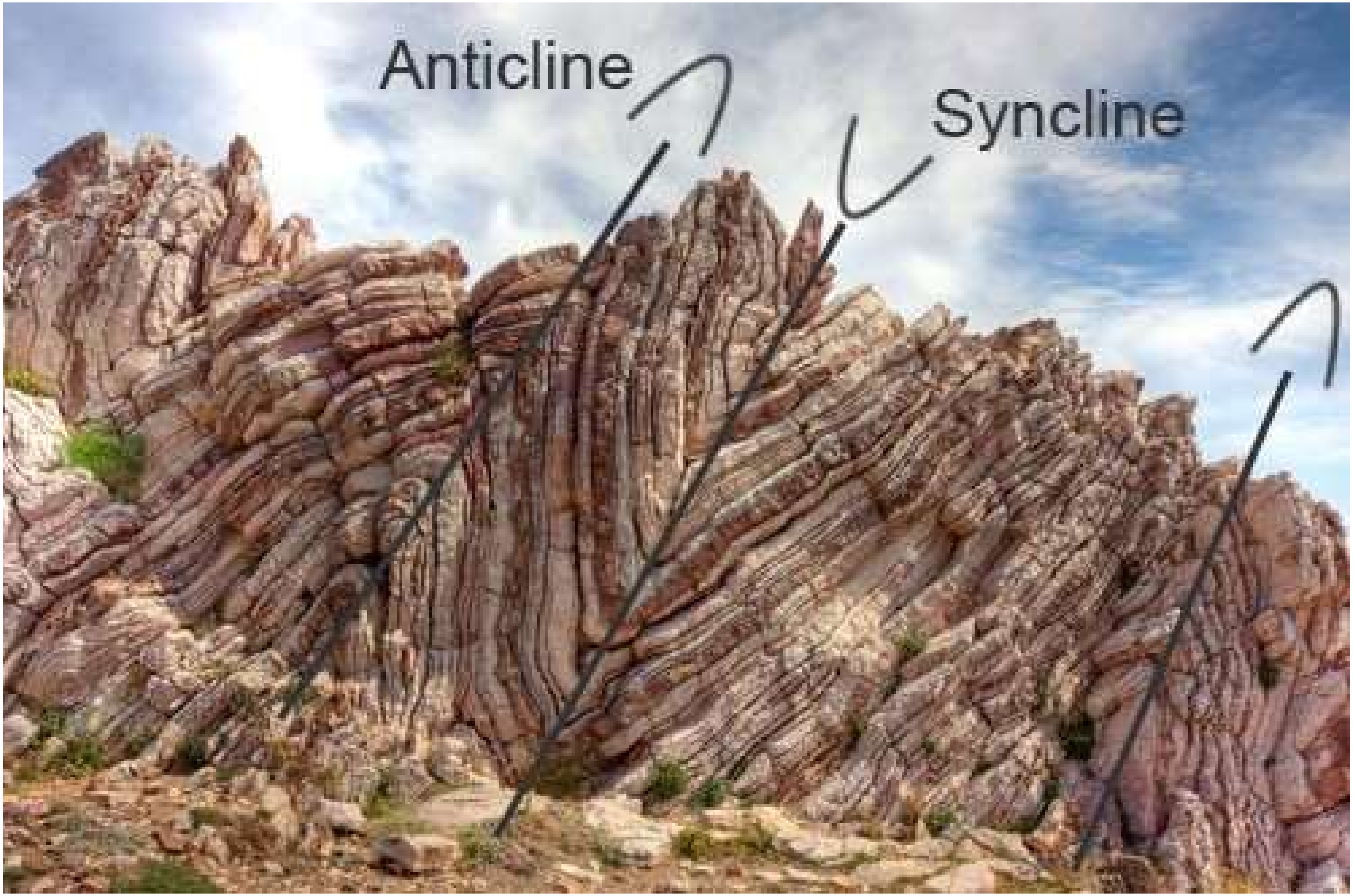
FOLDS

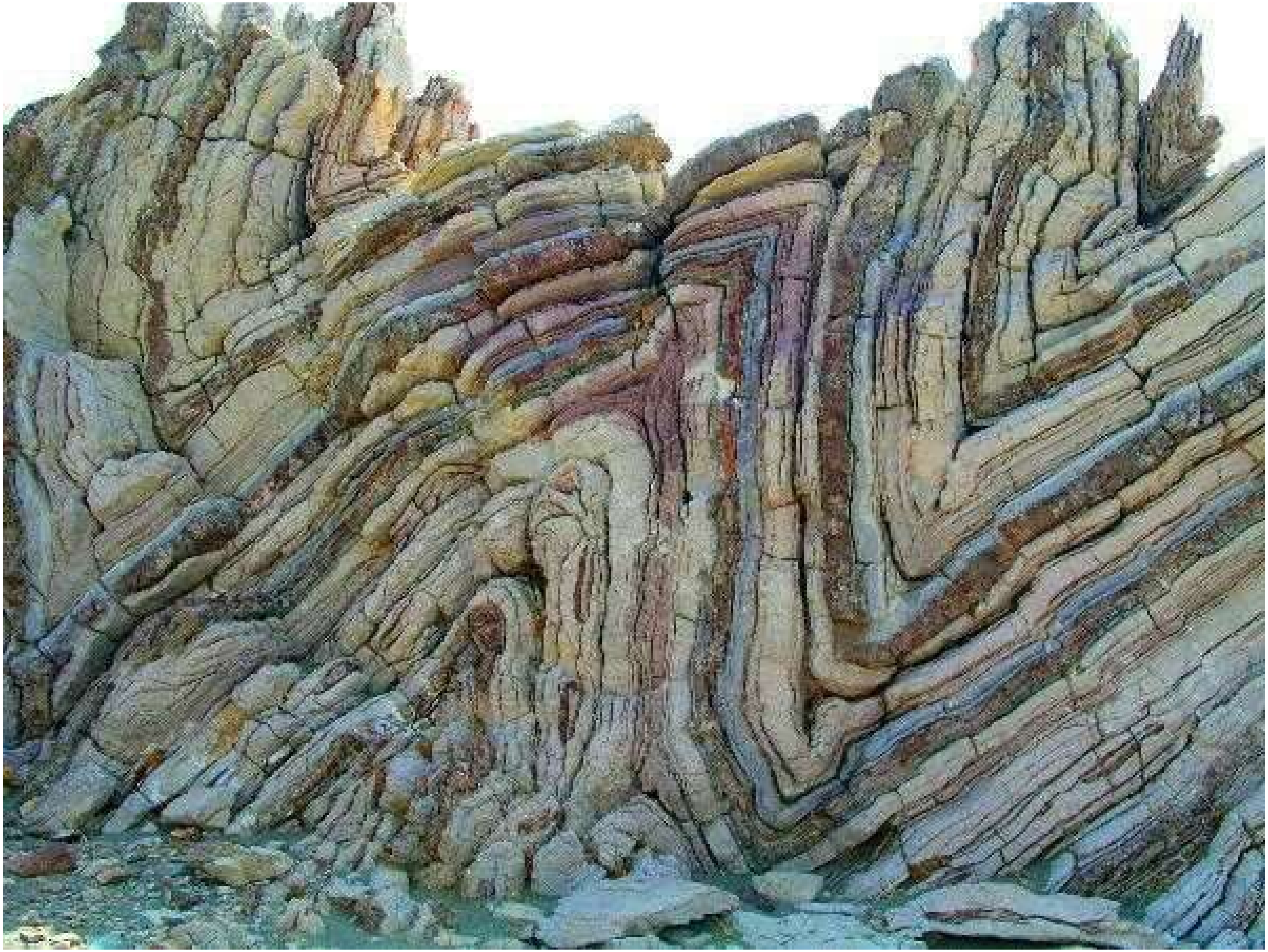
- Folds are one of the most common geological structures found in rocks.
- When a set of horizontal layers are subjected to compressive forces, the bend either upwards or downwards.

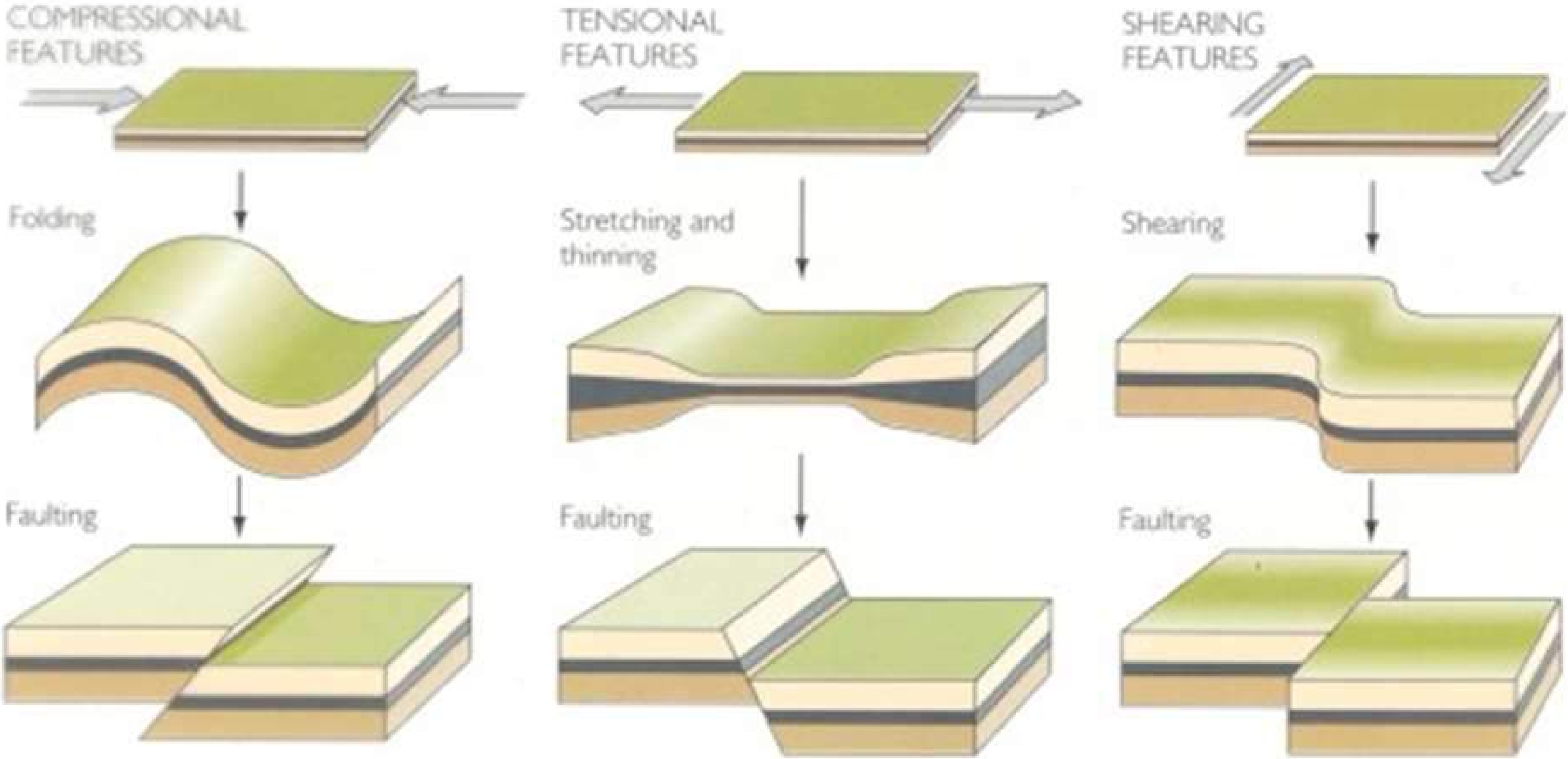




Axial surface
Fold
axis
Hinge line
Hinge zone
Hinge points
Axial trace
Inflection point
Limb
Inflection line
Limb
Hinge zone
Enveloping surface
Ampli-
tude
Non-cylindrical
fold
Wavelength
Interlimb
angle
Cylindrical
fold


Anticline
Syncline



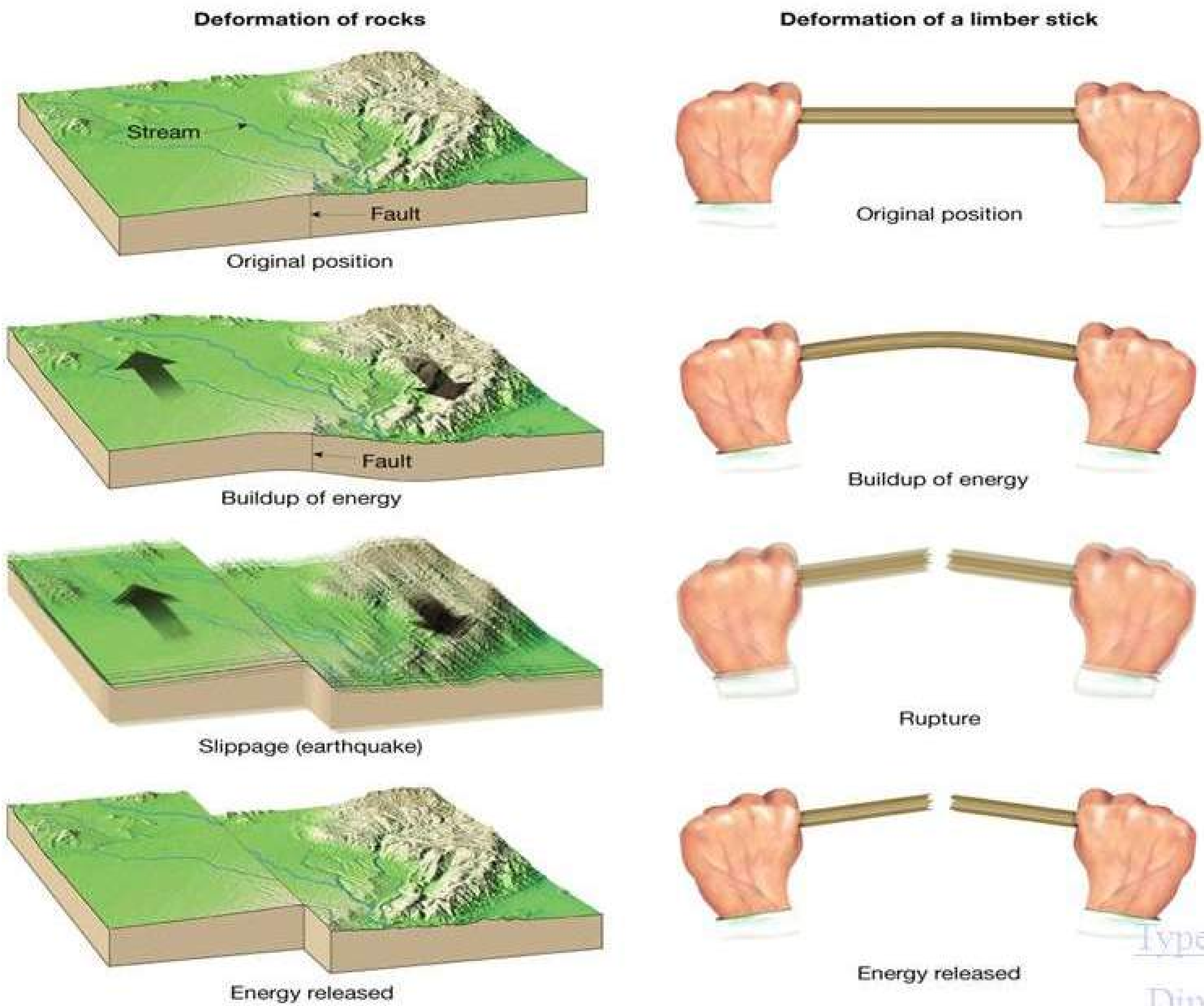


COMPRESSIONAL FEATURES
TENSIONAL FEATURES
SHEARING FEATURES
Folding
Stretching and thinning
Shearing
Faulting
Faulting
Faulting

FAULTS

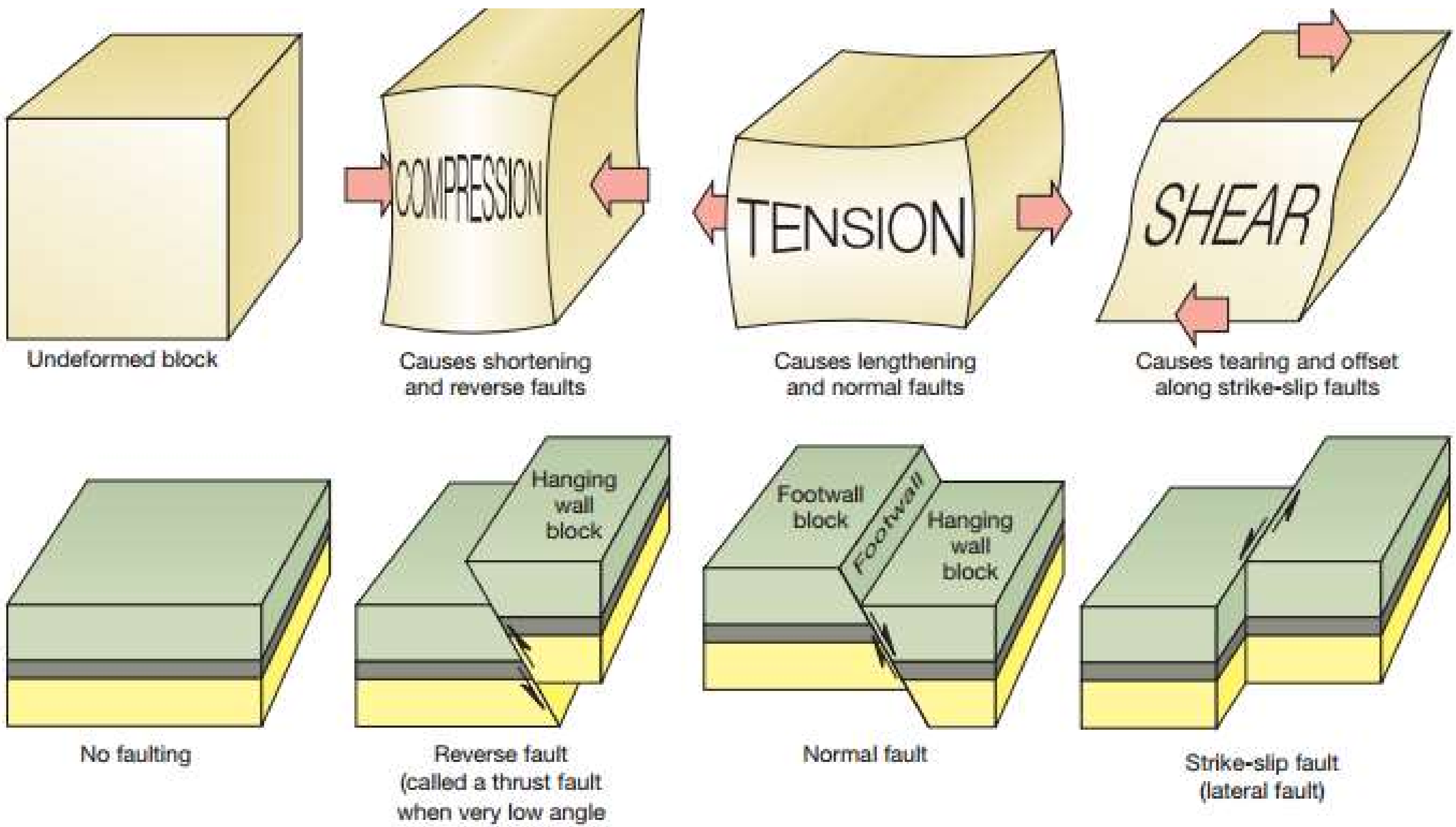
- From civil engineering point of view, faults are the most unfavourable and undesirable geological structures at the site for any given purpose, i.e., for location of reservoirs: as a foundation site for construction of dams, important bridges or huge buildings, for tunnelling; for laying roads or railway tracks etc.

Note : Folds leads to form faults.



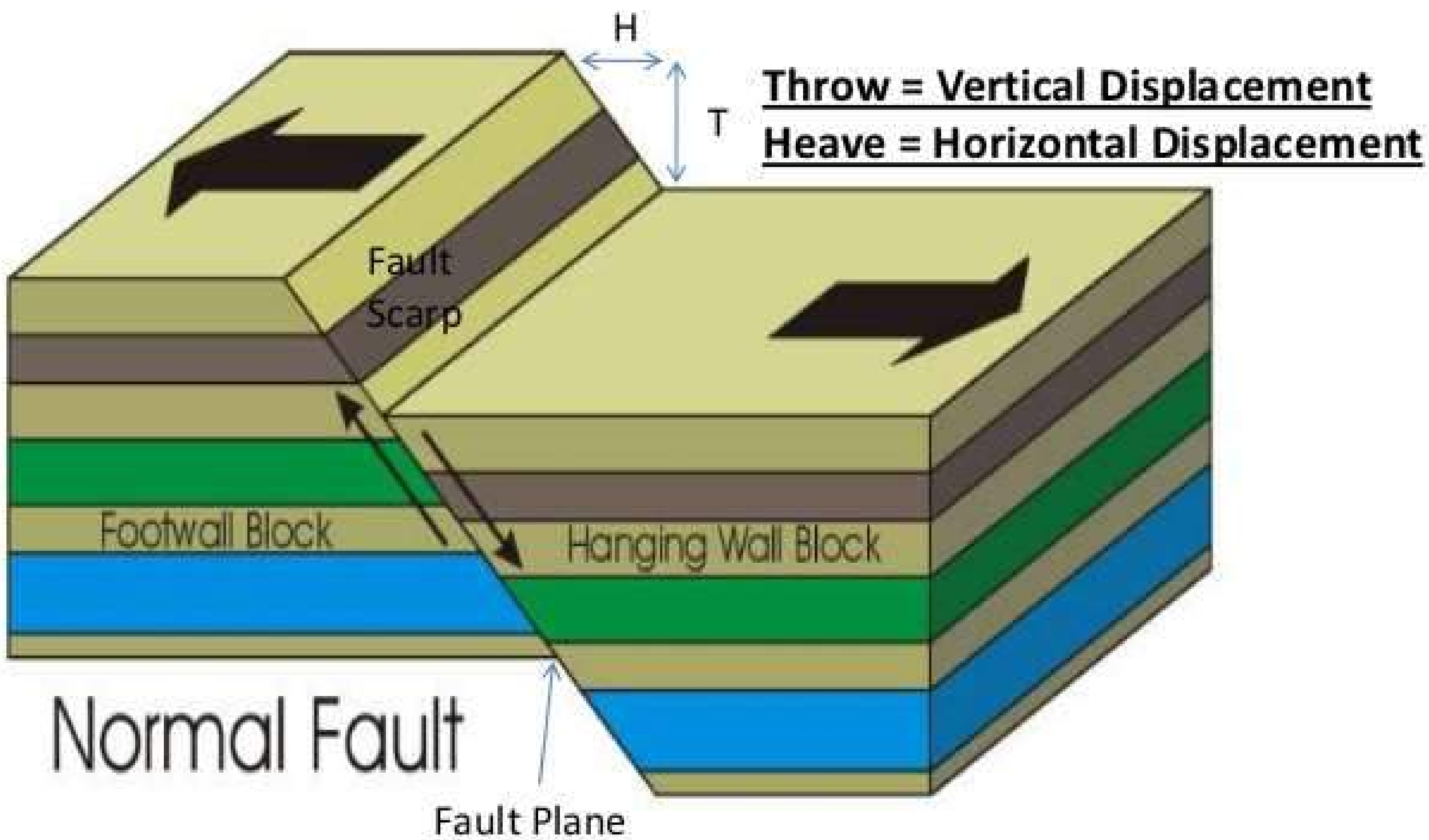
Types of Faults

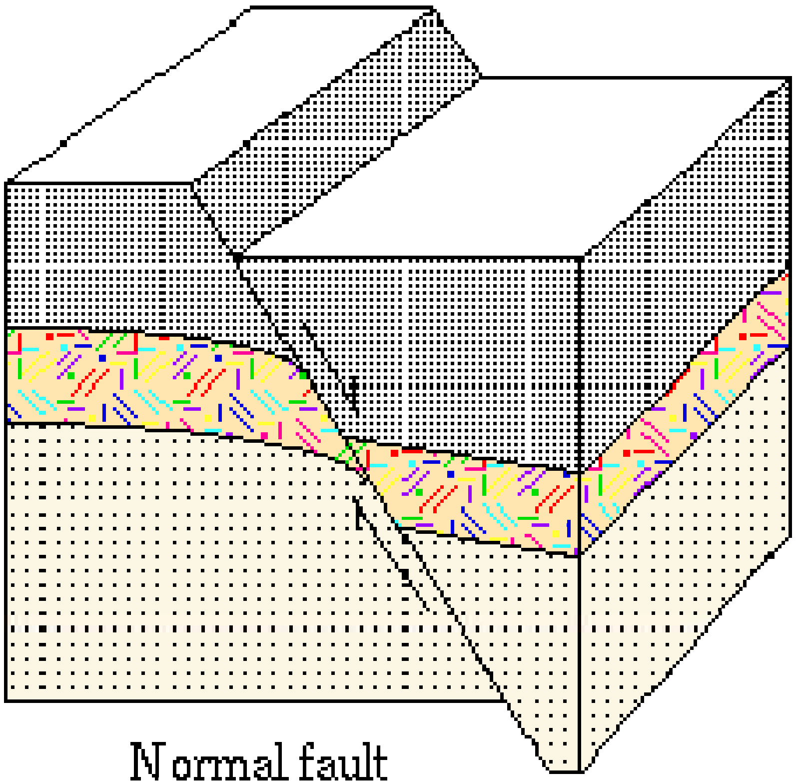
Dip-Slip Fault


COMPRESSION
TENSION
SHEAR
Undeformed block
Causes shortening and reverse faults
Causes lengthening and normal faults
Causes tearing and offset along strike-slip faults
Hanging wall block
Footwall block
Footwall
Hanging wall block
No faulting
Reverse fault (called a thrust fault when very low angle
Normal fault
Strike-slip fault (lateral fault)

Normal Faults

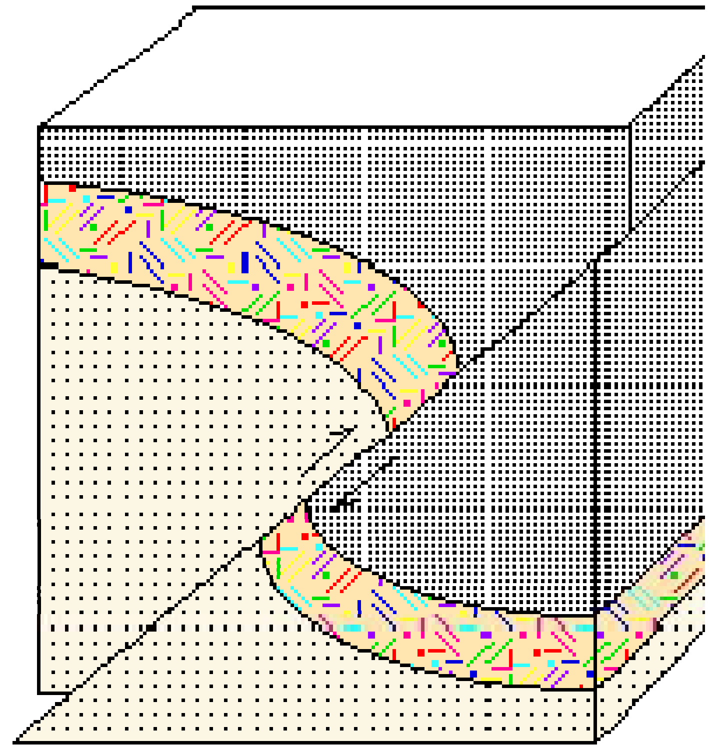
TENSION / Pulling motion = LENGTHENING





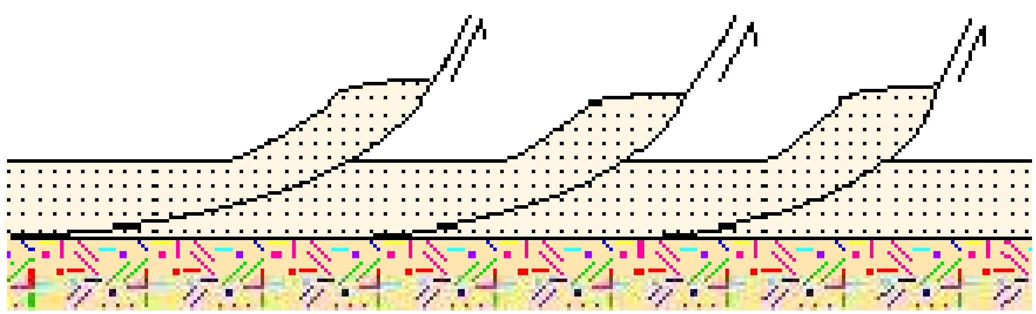
Normal fault

Extension

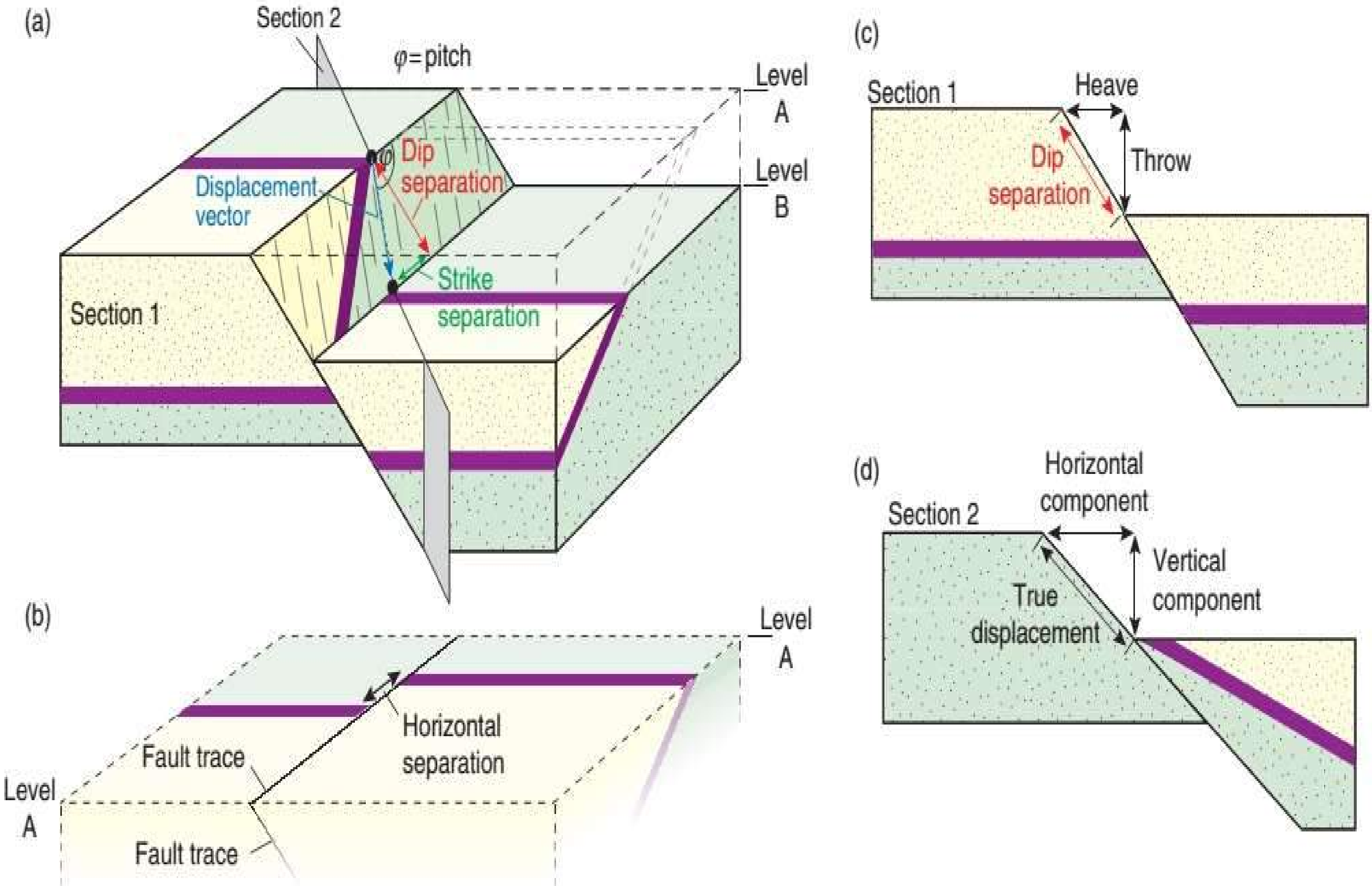


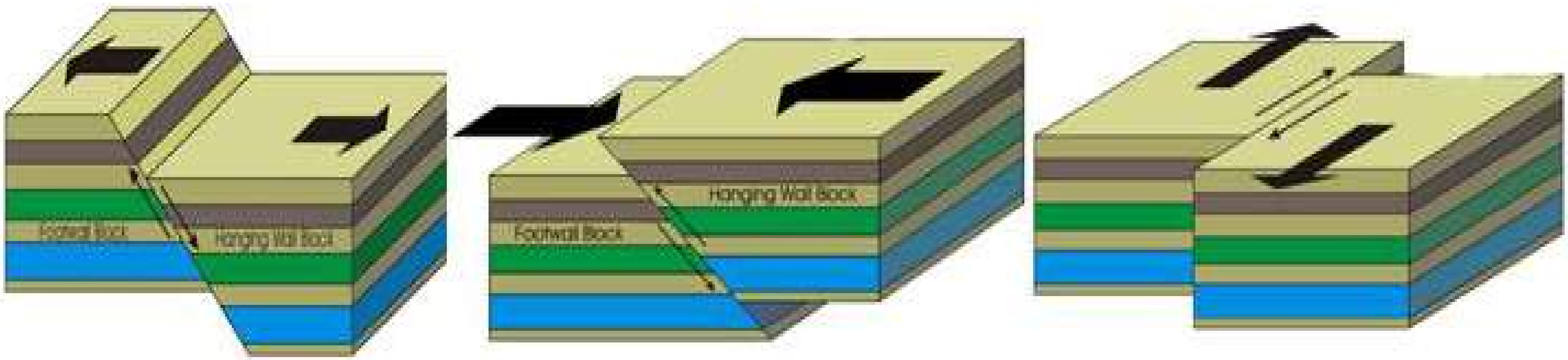
Reverse fault

Compression



Thrust faults

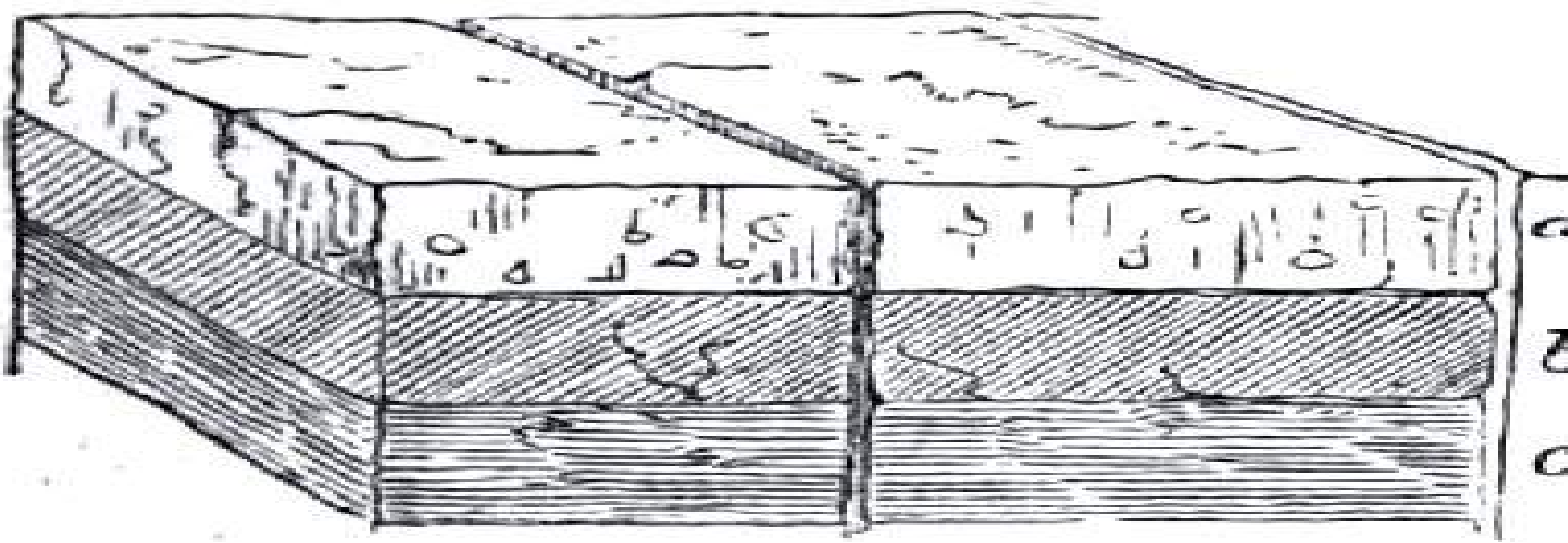

(a)
Section 2
φ= pitch
Level A
Level B
Dip separation
Displacement vector
Strike separation
Section 1
(b)
Level A
Horizontal separation
Fault trace
Level A
Fault trace
(c)
Section 1
Heave
Throw
Dip separation
(d)
Section 2
Horizontal component
Vertical component
True displacement

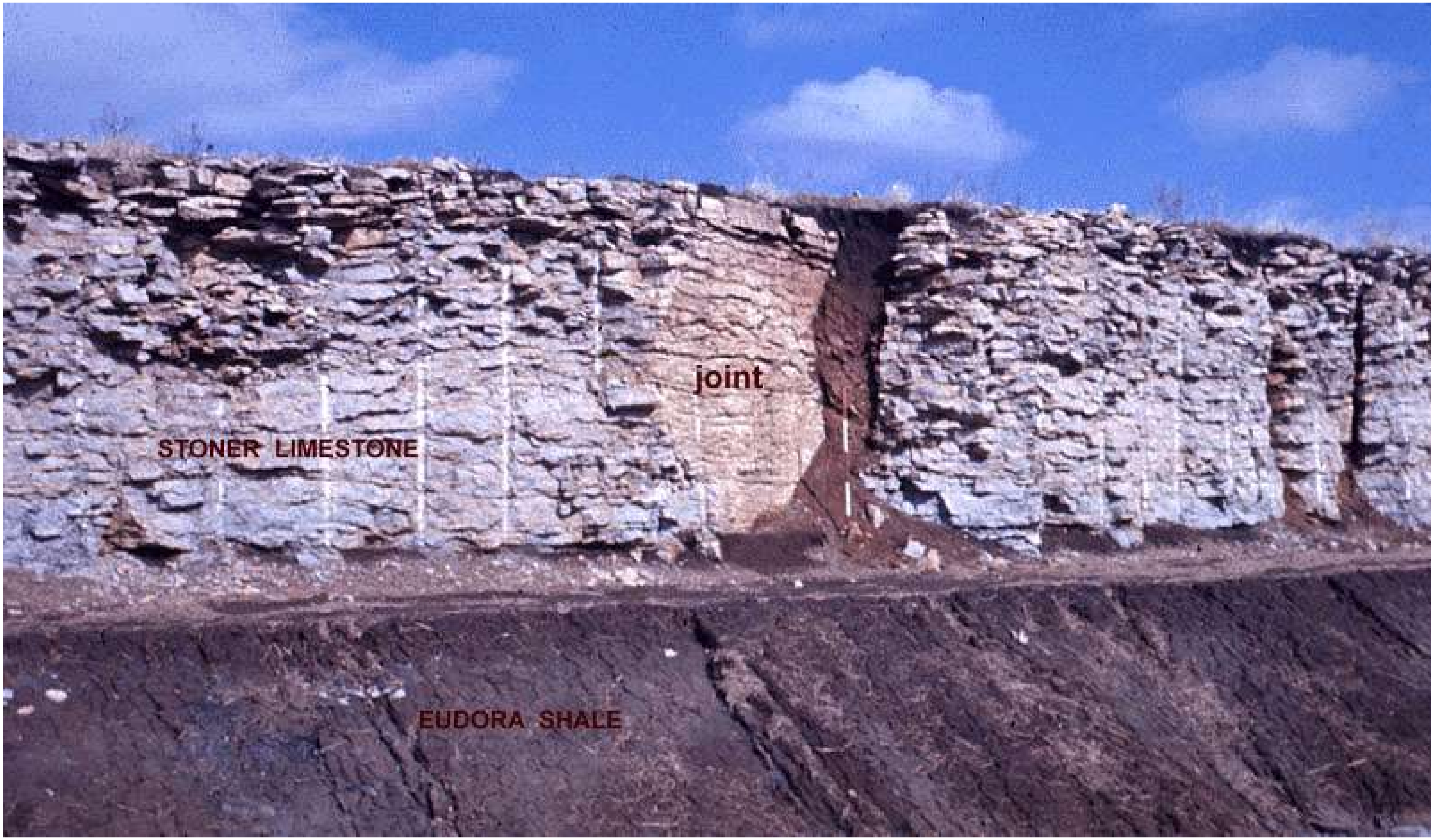


Normal fault Reverse fault Strike-slip fault

JOINTS

- Joints are fractures found in all type of rocks.
- They are cracks or openings formed due to various reasons.
- The presence of joints divides the rock into a number of parts or blocks.



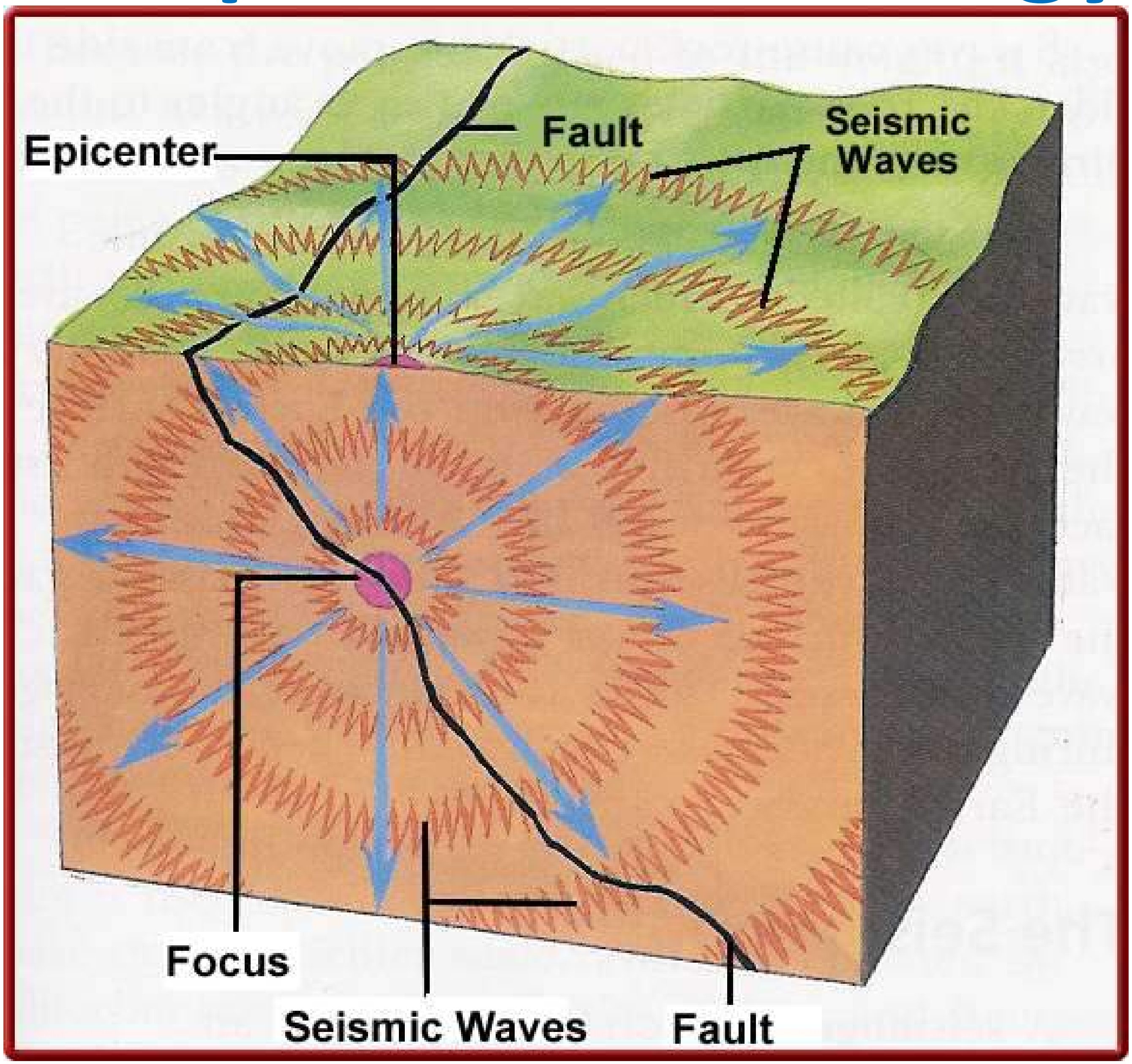

joint
STONER LIMESTONE
EUDORA SHALE


JOINT
Bedding Plane

EARTHQUAKES

- An earthquake may be simply described as a **sudden shaking phenomenon of the earth's surface** for some reason or the other.
- It is also variously described as a sudden **vibrating** or **jerking** or **jolting** or **trembling** or **shivering** phenomenon of the earth's surface.

Earthquake terminology



Classification of earthquakes

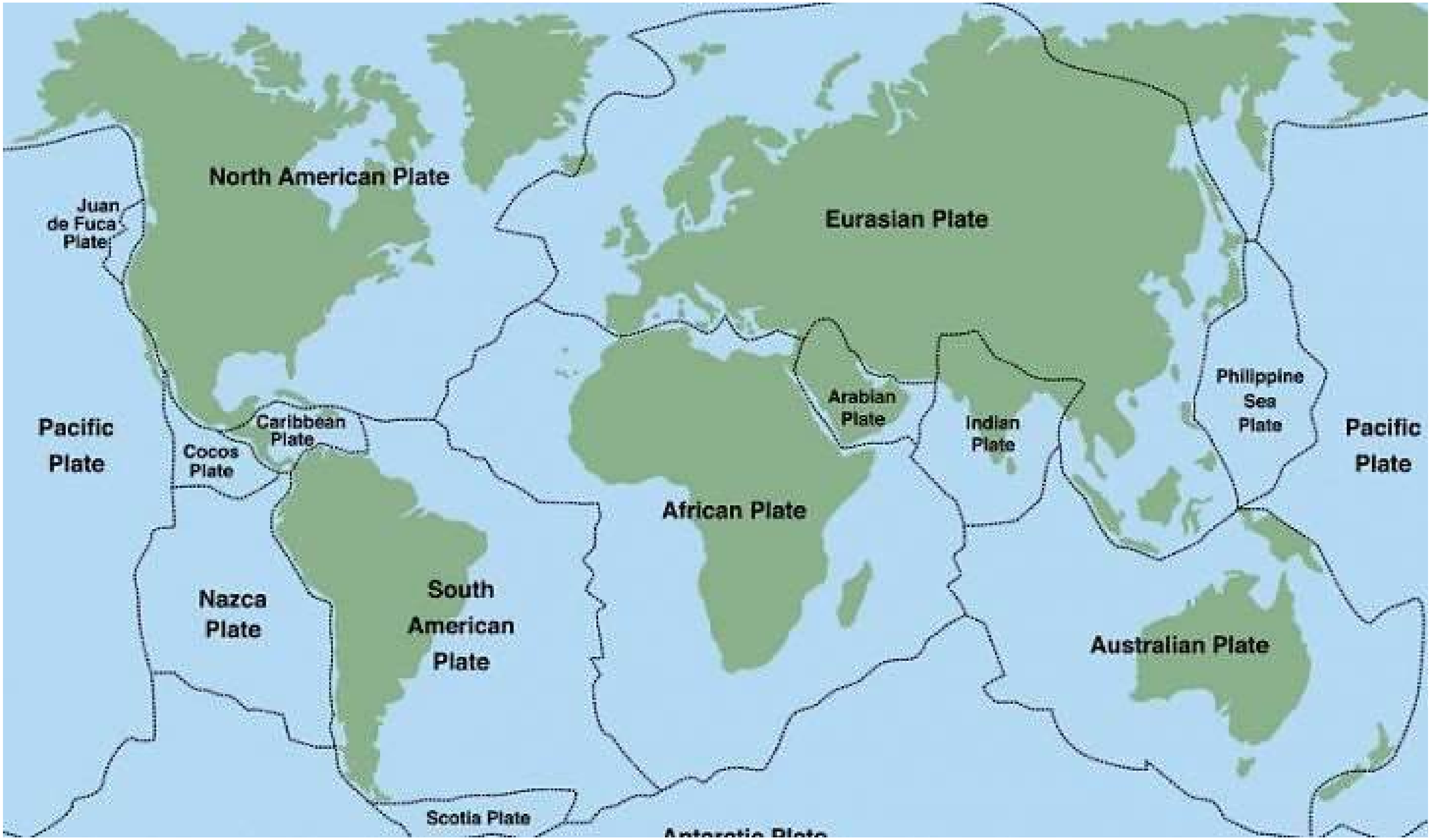
- Based on depth of their origin, earthquakes are described as

1. **SHALLOW (<60KM)**
2. **INTERMEDIATE (>60KM AND <300KM)**
3. **EXTREME DEEP (>300KM)**

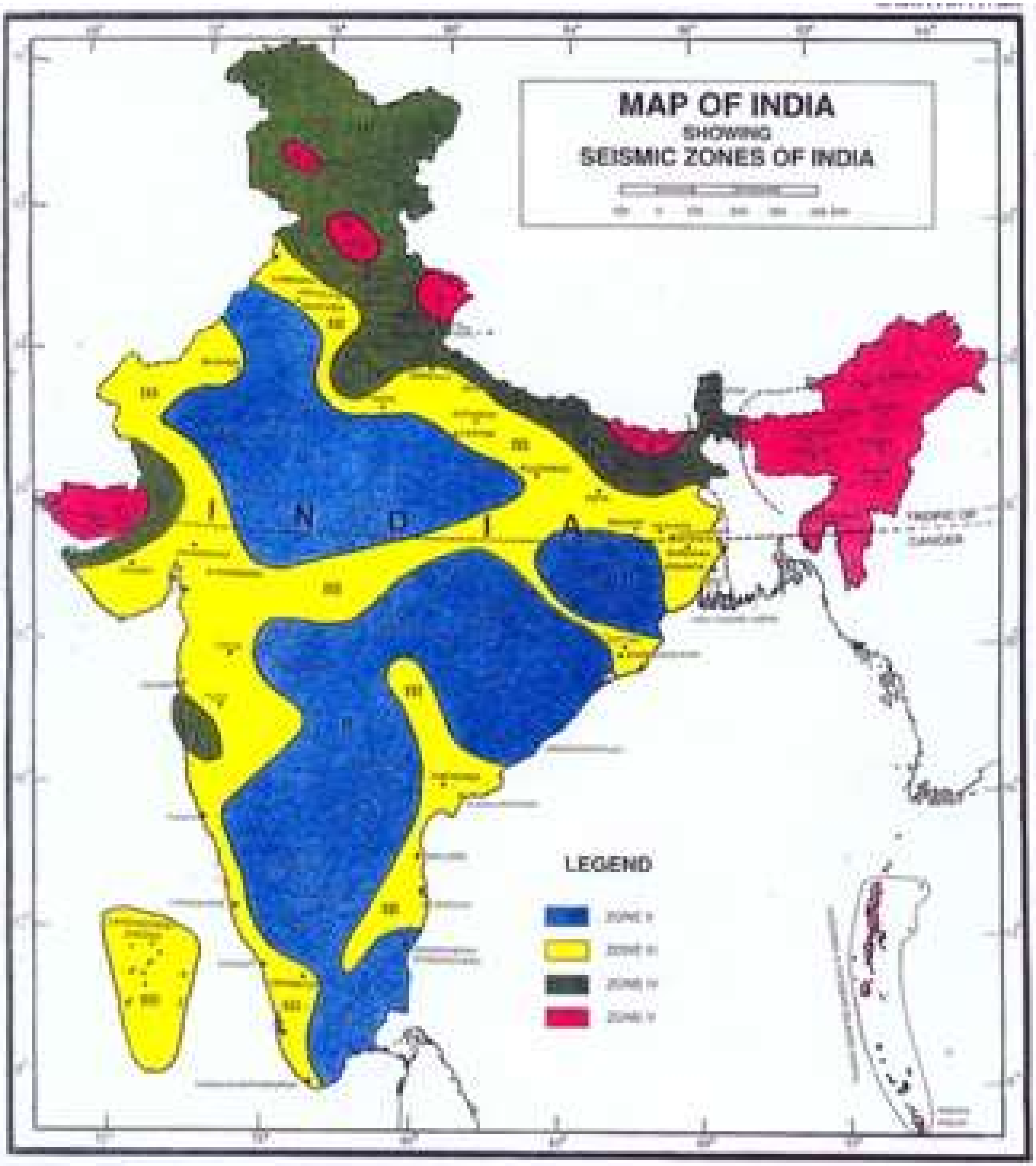
- Based on depth of their occurrence, earthquakes are described as

1. **Tectonic**
2. **Non-tectonic**

Tectonic plates



Afghanistan
EURASIAN PLATE
Islamabad
Tibetan Plateau
Pakistan
China
Himalayas
Nepal
Delhi
Kathmandu
Bhutan
Ganges Plain
Bangladesh
INDIAN PLATE
Bay of Bengal


MAP OF INDIA
SHOWING
SEISMIC ZONES OF INDIA
I N D I A
TROPIC OF CANCER
LEGEND

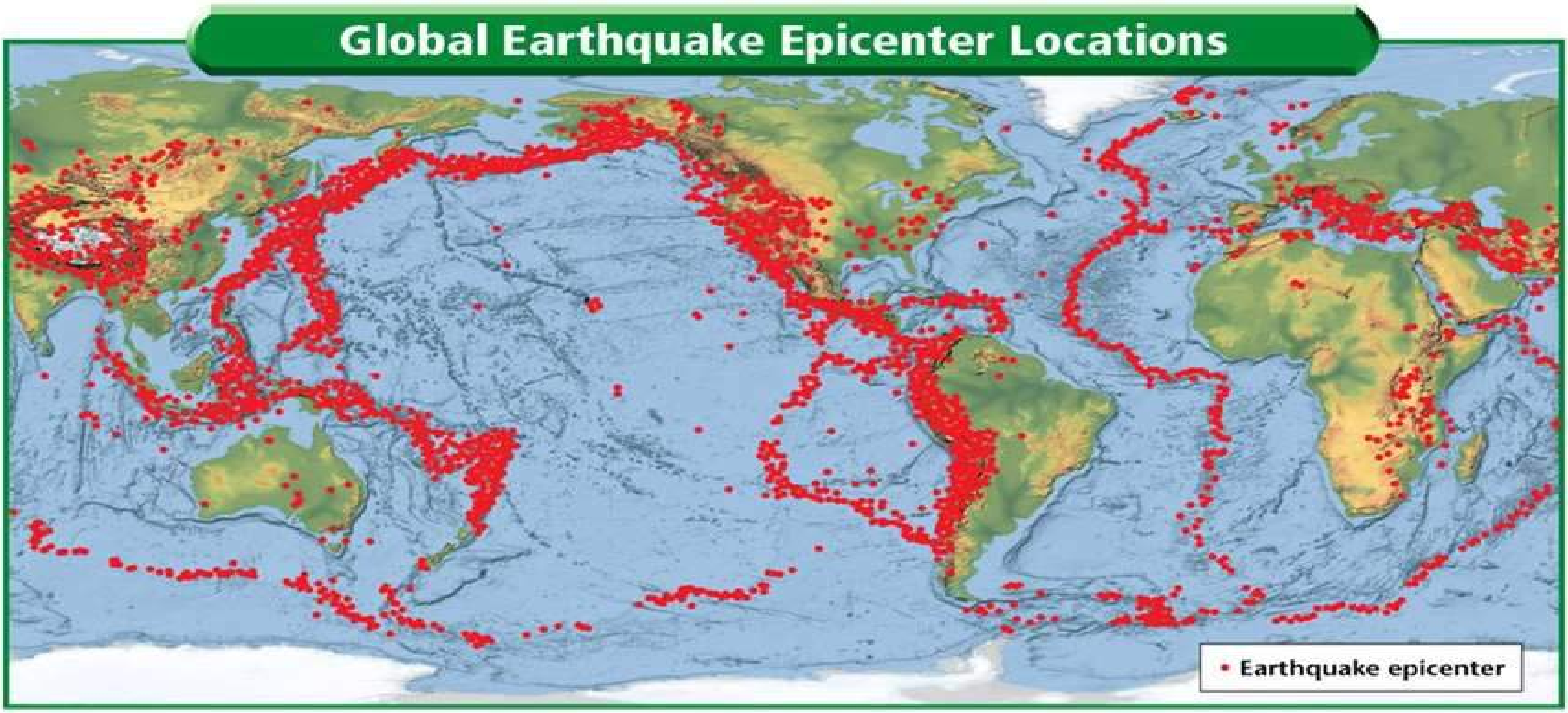
- **Tectonic earthquakes** are exclusively due to internal causes, i.e.., due to disturbances or adjustments of geological formations taking place in the earth’s interior.
- Generally these are less frequent and more intensive and hence more destructive in nature.
- **Non-Tectonic earthquakes** are due to external or surficial causes.
- These type of earthquakes are very frequent but less destructive.

- Non-tectonic earthquakes, occur due to variety of reasons, some of which are as follows.

1. Due to huge water falls
2. Avalanches
3. Meteorites
4. Landslides
5. Volcanic eruptions
6. Tsunamis
7. Man-made explosions

Seismic belts and shield areas

Seismic Belts



Seismic belts are those areas where earthquakes occur frequently and shield areas are those places where earthquakes occur either rarely or very mildly.

Earthquake waves

- Earthquake vibrations originate from focus and are propagated in all directions.
- These vibrations through the rocks in the form of elastic waves.
- There are three types of waves called as

1. **Primary waves (P-waves)**
2. **Secondary waves (S-waves)**
3. **Love waves. (L-waves)**

P-WAVES

- These are also called as **primary waves**, ***push-pull waves, preliminary waves, longitudinal waves***
- These are the fastest waves among all the seismic waves.
- They travel as fast as 8 to 13 Km/s.
- The P waves resemble sound waves because these too are compressional waves in nature.
- These waves can travel through solids, semi-liquids and gases.

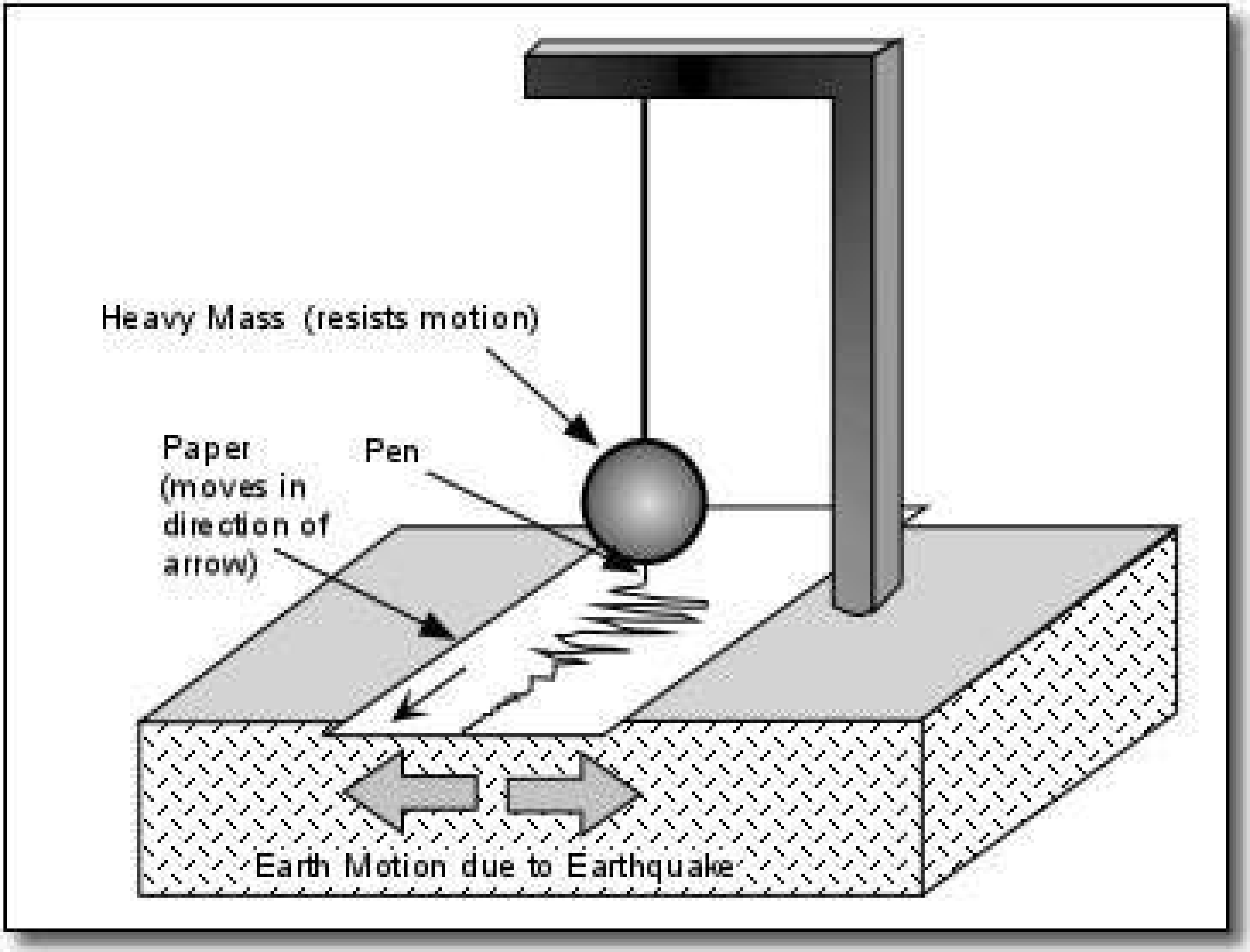
S-WAVES

- These are also called as secondary waves or traverse waves or shear waves.
- Compared to P waves, these are relatively slow.
- These can travel at a speed of 5 to 7 Km/s.
- These are like light waves.
- These waves are capable of travelling only through solids.

L-WAVES

- These are also called as love waves or long waves or surface waves.
- These ae the slowest among the seismic waves.
- These can travel at a speed of 4 to 5Km/s.
- These waves are capable of travelling through solids and liquids.

Richter scale



Effects of earthquakes

Most of the earthquakes are minor and go unnoticed. But the major ones, though occasional, are responsible for heavy loss of life and property.

1. **Destruction of various civil engineering constructions like dams, bridges, tunnels, roads and railway tracks**
2. **Creation of irregularities and cracks in the ground.**
3. **Causing landslides, blocking of roads and railway lines.**
4. **Changes in courses of rive due to faulting across them.**
5. **Formation of new lakes, springs and water falls.**
6. **Submarine earthquakes causes Tsunamis**
7. **Heavy loss of life and property**

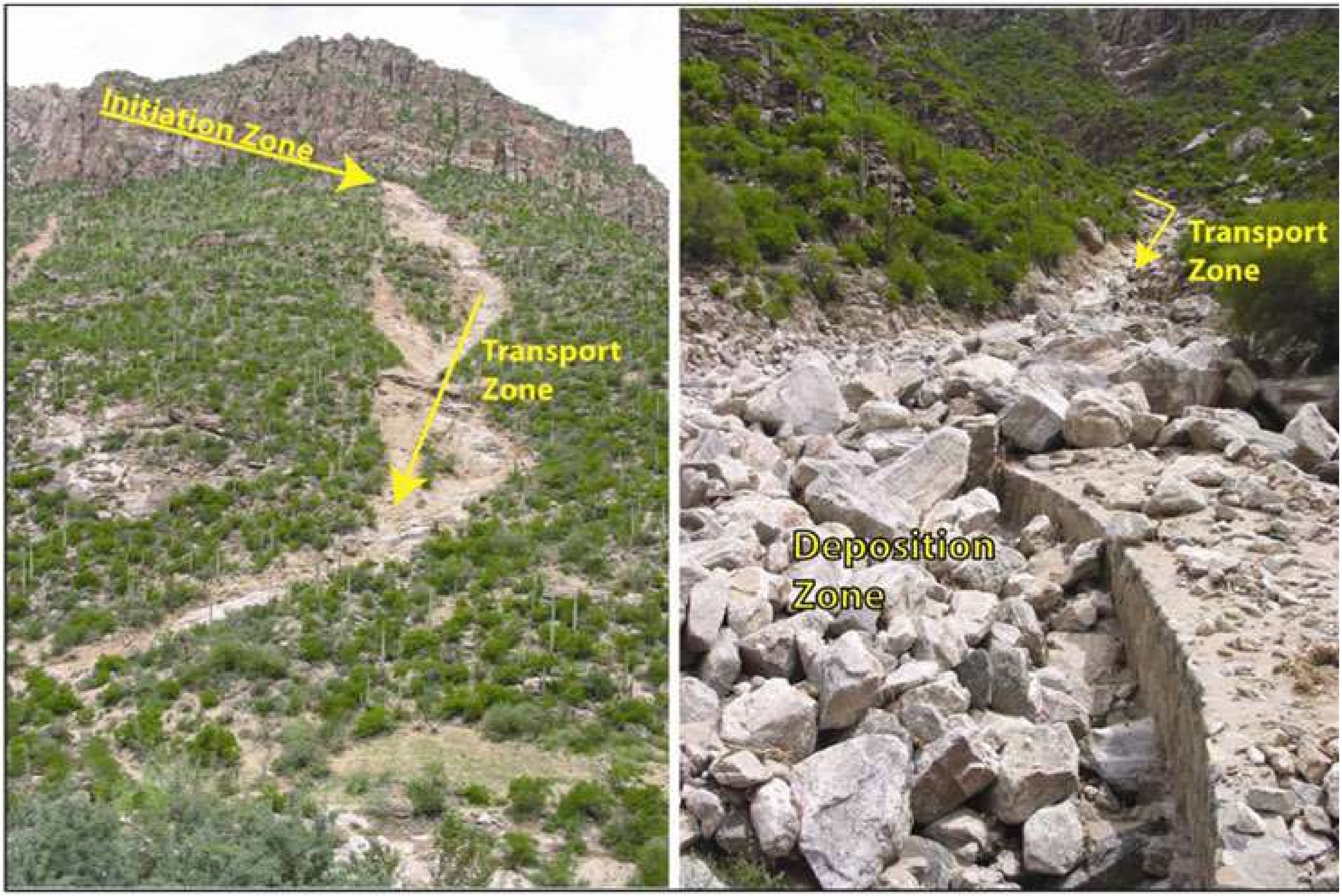
LAND SLIDES

- If a mass of earth or rock moves along a definite zone or surface, the failure is called a landslide
- There are three types

1. DEBRIS SLIDES
2. ROCK SLIDES
3. ROCK FALLS

ROCK SLIDES

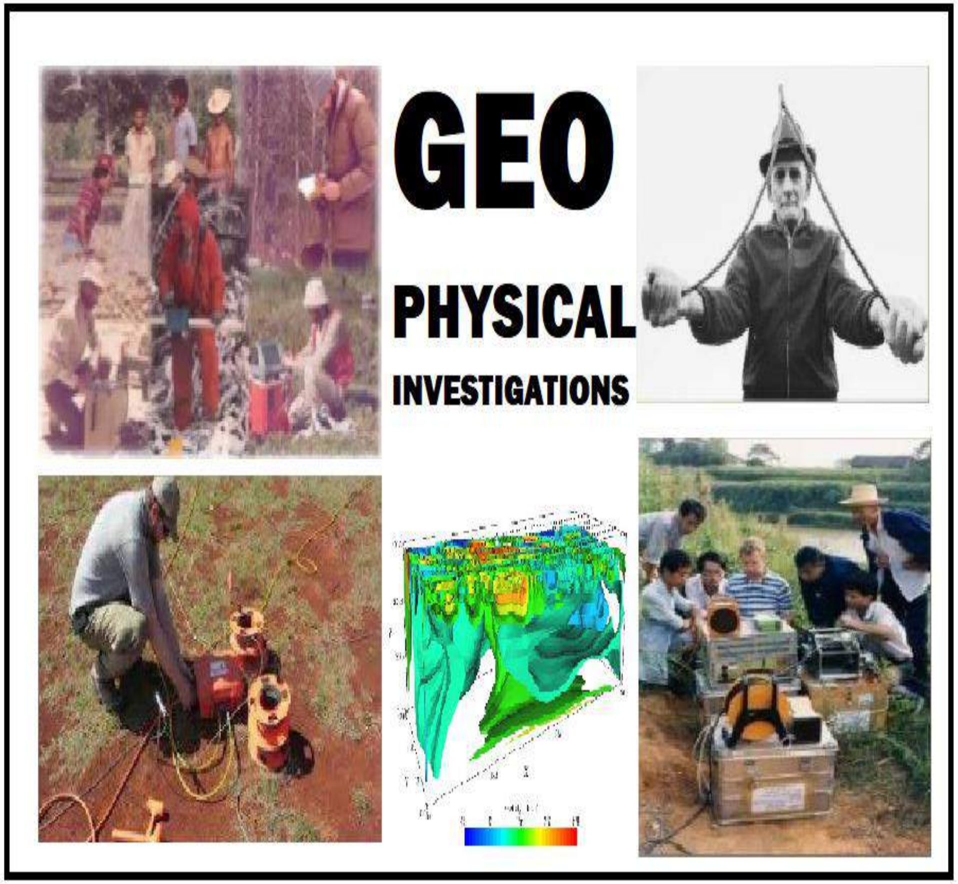
DEBRIS SLIDES


Initiation Zone
Transport Zone
Transport Zone
Deposition Zone

ROCK FALLS

TOPIC 4

- Geology of dams and reservoirs
- Geophysical investigations



GEOLOGY OF DAMS & RESERVOIRS

- Types of Dams
- Geological considerations in the selection of dam site
- Analysis of dam failures of the past
- Factors contributing to the success of reservoir
- Geological factors influencing water tightness and life of reservoirs.

DAM

- A dam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. These purposes may be Irrigation, Hydropower, Water-supply, Flood Control, Navigation, Fishing and Recreation.
- Dams may be built to meet the one of the above purposes or they may be constructed fulfilling more than one.
- Dam can be classified as: **Single-purpose** and **Multipurpose Dam**.

TYPES OF DAMS

Dams can be classified in number of ways. But most usual ways of classification of dams are mentioned below:

1. **Based on the functions of dam**
2. **Based on structure and design**

Based on the functions of dam

- **Storage dam**
- **Diversion dam**
- **Detention dam**
- **Debris dam**
- **Coffer dam**

Based on structure and design

- **Gravity dam**
- **Arch dam**
- **Buttress dam**
- **Earth dam**

Storage dam

These are constructed to store water during the rainy season when there is a large flow in the river. Many small dams impound the spring runoff for later use in dry summers. Storage dams may also provide a water supply, or improved habitat for fish and wildlife. They may store water for hydroelectric power generation, irrigation or for a flood control project.

Shasta dam on the Sacramento River

Bilaspur Dam, Rajasthan

Koyna Dam, Maharashtra

Mettur Dam, Tamil Nadu

Diversion dams

A diversion dam is constructed for the purpose of diverting water of the river into an off-taking canal (or a conduit). They provide sufficient pressure for pushing water into ditches, canals, or other conveyance systems. Such shorter dams are used for irrigation, and for diversion from a stream to a distant storage reservoir.

A diversion dam is usually of low height and has a small storage reservoir on its upstream. The diversion dam is a sort of storage weir which also diverts water and has a small storage. Sometimes, the terms weirs and diversion dams are used synonymously.

Palo Verde Diversion Dam

Red Bluff Diversion Dam

Detention dams

Detention dams are constructed for flood control.

A detention dam retards the flow in the river on its downstream during floods by storing some flood water. Thus the effect of sudden floods is reduced to some extent. The water retained in the reservoir is later released gradually at a controlled rate according to the carrying capacity of the channel downstream of the detention dam.

Thus the area downstream of the dam is protected against flood.

CHERUTHONI DAM, KERALA

Debris dams

A debris dam is constructed to retain debris such as sand, gravel, and drift wood flowing in the river with water.

The water after passing over a debris dam is relatively clear.

Coffer dams

- It is an enclosure constructed around the construction site to exclude water so that the construction can be done in dry.
- A cofferdam is thus a temporary dam constructed for facilitating construction.
- A coffer dam is usually constructed on the upstream of the main dam to divert water into a diversion tunnel (or channel) during the construction of the dam.
- When the flow in the river during construction of the dam is not much, the site is usually enclosed by the coffer dam and pumped dry.
- Sometimes a coffer dam on the downstream of the dam is also required.

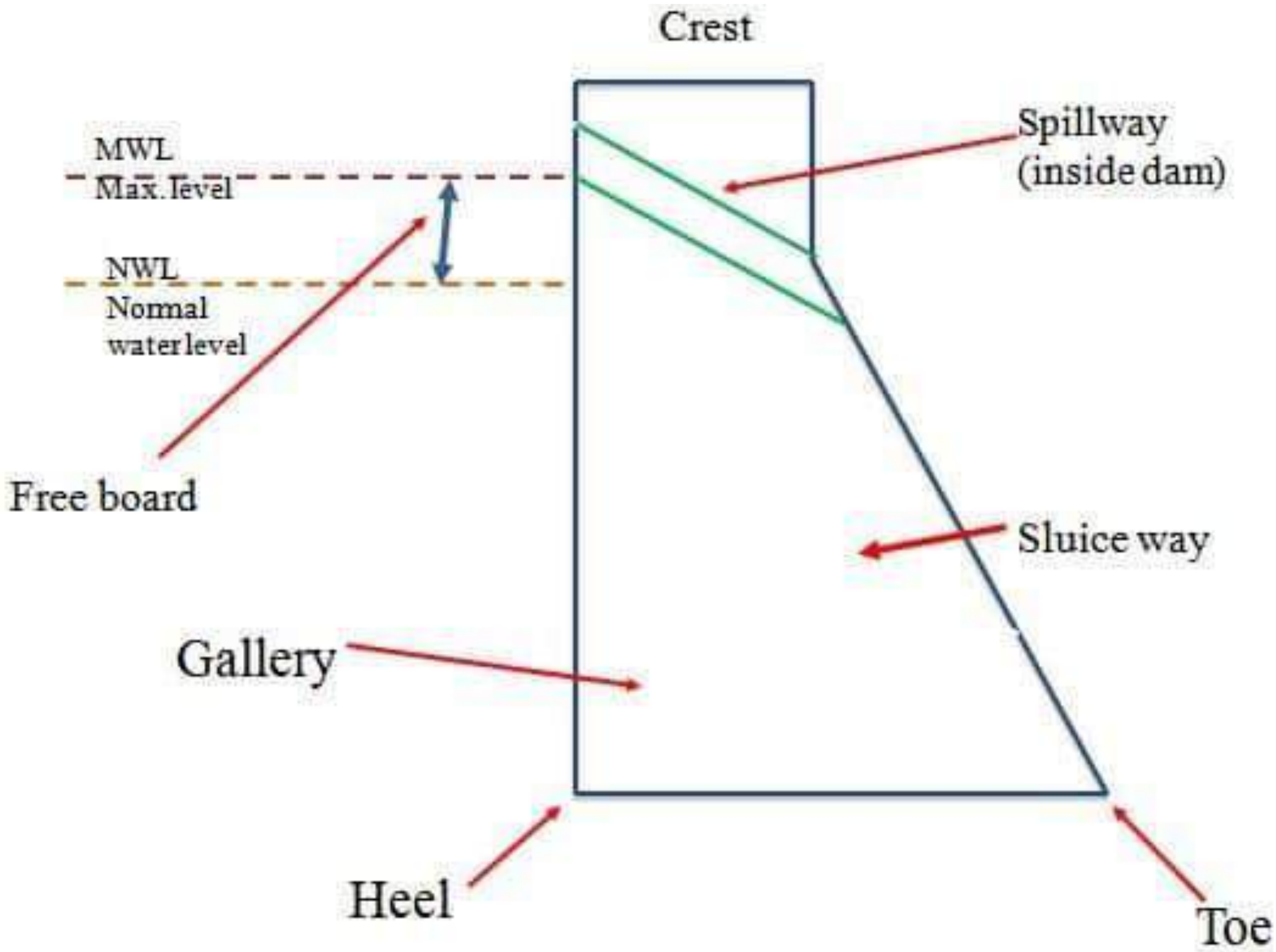

COFFER DAM

Based on structure and design

GRAVITY DAM

A gravity dam is a massive sized dam fabricated from concrete or stone masonry. They are designed to hold back large volumes of water. By using concrete, the weight of the dam is actually able to resist the horizontal thrust of water pushing against it. This is why it is called a gravity dam. Gravity essentially holds the dam down to the ground, stopping water from toppling it over.

PARTS OF DAMS



EARTH DAM

An earth dam is made of earth (or soil) built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides. A facing of crushed stone prevents erosion by wind or rain, and an ample spillway, usually of concrete, protects against catastrophic washout should the water overtop the dam. Earth dam resists the forces exerted upon it mainly due to shear strength of the soil.

ARCH DAMS

An arch dam is curved in plan, with its convexity towards the upstream side.

An arch dam transfers the water pressure and other forces mainly to the abutments by arch action.

An arch dam is quite suitable for narrow canyons with strong flanks which are capable of resisting the thrust produced by the arch action.


Construction
Photography

BUTTRESS DAMS

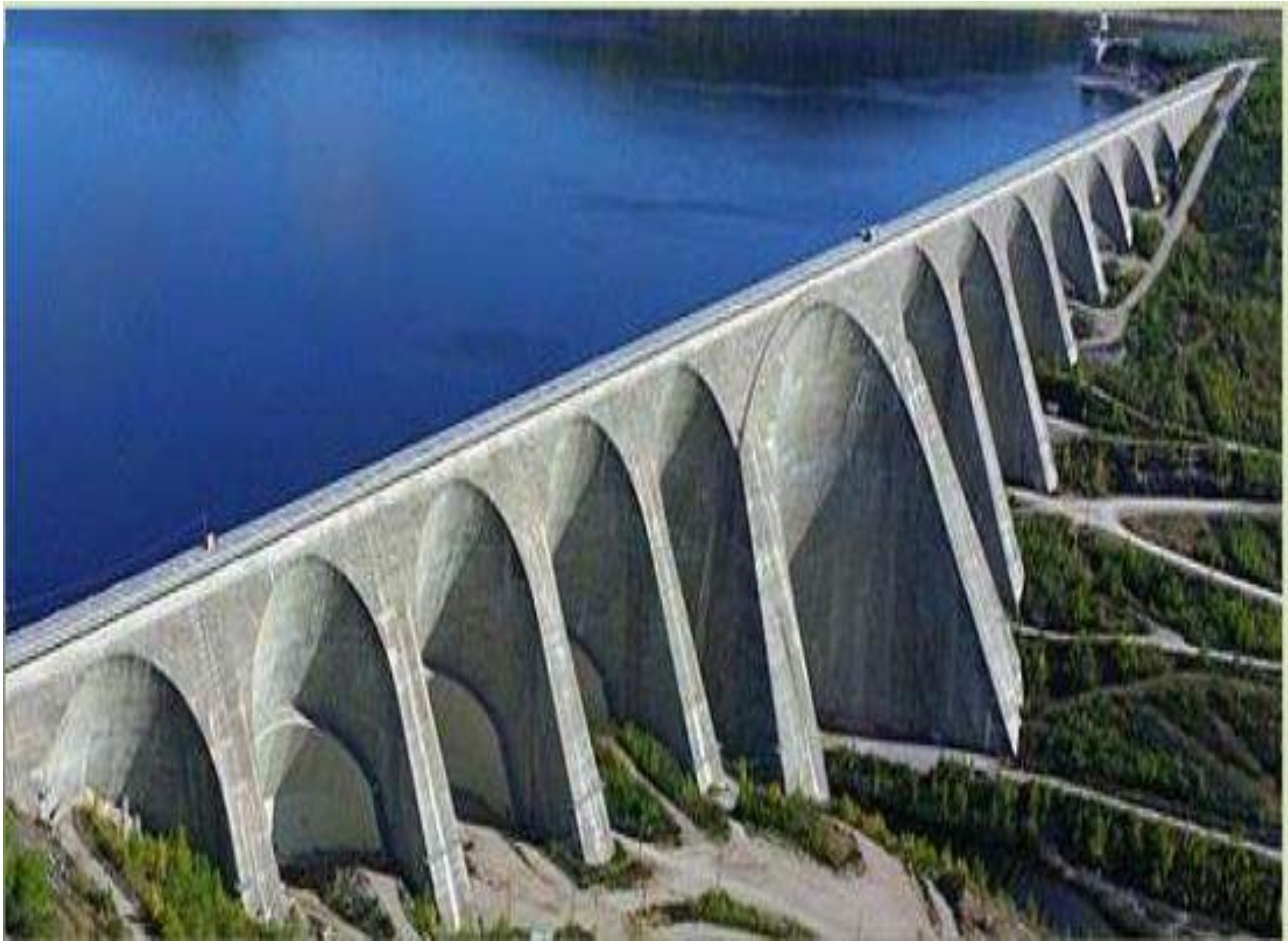
- Buttress dams are of three types :

(i) Deck type,

(ii) Multiple-arch type, and

(iii) Massive-head type.

- A deck type buttress dam consists of a sloping deck supported by buttresses.
- In a multiple-arch type buttress dam the deck slab is replaced by horizontal arches supported by buttresses.
- In a massive-head type buttress dam, there is no deck slab. Instead of the deck, the upstream edges of the buttresses are flared to form massive heads which span the distance between the buttresses.



Geological considerations in the selection of dam site

Careful geological studies bring out the inherent advantages of any site selected for the dam, and it also reduce the cost of the dam considerably.

The important geological requirements that should be considered in the selection of a dam site are as followed:

1. **Narrow River Valley.**
2. **Occurrence of the bedrock at a shallow depth.**
3. **Competent rocks to offer a stable foundation.**
4. **Proper geological structures**

Narrow River Valley

If the proposed site contains a narrow river valley, only a small dam is required, which means the cost of the dam construction is also will be less.

On the other hand if the valley is wider, construction cost will be very high and maintenance of the dam will also be high.

Occurrence of bed rock at shallow depths

If the dam rest on very strong and stable rocks, the stability and safety of the dam will be very high. This also reduces the cost of the dam. On the other hand the dam cost will be high and the work of excavation will be overburden. This also requires heavy concrete refilling.

Competent rocks for Safe Dam

If the dam site consists of igneous rocks, they will offer a safe basis. If sedimentary rocks, particularly shales, poorly cemented sandstones and cavernous limestones, they are undesirable.

Though igneous rocks along with metamorphic rocks occupy 95% earth crust, on the surface igneous rocks occur only 30% and in them granites and basalts are most common ones.

So location containing granites and basalts will be much competent for the site of the dam.

Proper geological structures

The Structural study gives information on the strike and dip of the beds. It also reveals the occurrence of geological structures like folds, faults, joints, unconformities and foliation. Details of these features are very important because they have a great influence on the suitability of site for dam.

RESERVIOR

- A reservoir usually means an enlarged natural or artificial lake, storage pond or impoundment created using a dam to store water.
- Reservoirs can be created by controlling a stream that drains an existing body of water.
- They can also be constructed in river valleys using a dam.

Capacity of the Reservoir

- Reservoir capacity depends on the existing topography and the proposed top water level (TWL) of the reservoir.

- **Effect of Evaporation:** The natural process of evaporation reduces the quantity of water in the reservoir. Through unwanted, this process is unavoidable. Since reservoirs are open and extended over larger areas. The magnitude of evaporation will be extensive. of course, such loss shall be less if the topography is such that a reservoir covers a small area but has a great depth to provide adequate capacity.

Water Tightness

- When a river flows over such loose soil or fractured ground, it is natural that some water of the river percolates (or leaks) underground.
- Before the construction of the dam, this leakage shall be less and limited only to the extent over which the river flow occurs.
- But when the dam is constructed, the impounding water accumulates in large quantity in a reservoir which covers a very large area.
- This means percolation occurs over a large area.
- Due to the height of the water in reservoir, significant hydrostatic forces develops which will make the leakage more effective on the sides and the floor of the reservoir.
- Thus, the extent of leakage may become alarmingly great.

Life of reservoir

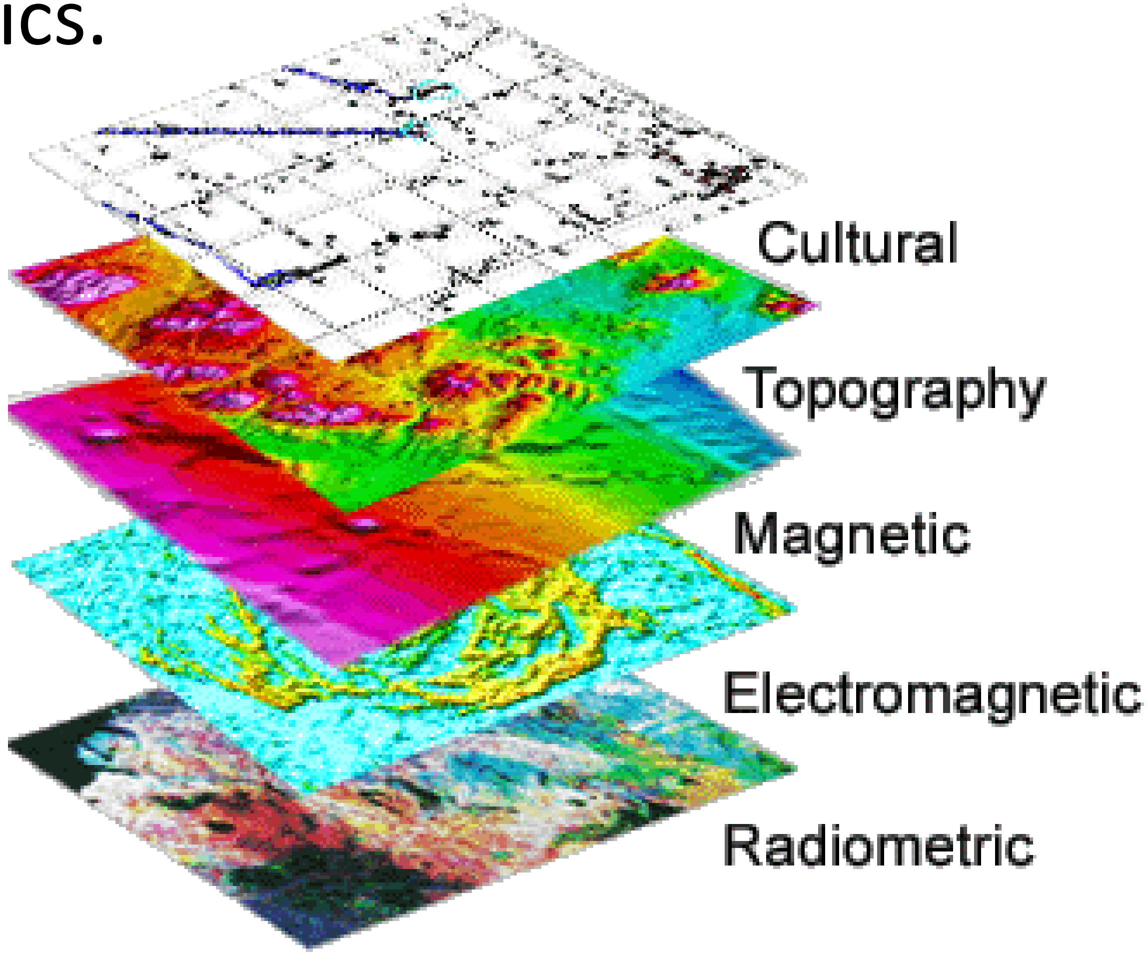
- **Silting**
- **Evaporation**

GEOPHYSICAL INVESTIGATIONS

- Importance of geophysical studies
- Principles of geophysical studies by
    - **Magnetic method**
    - **Electrical methods**
    - **Seismic method**
    - **Radio metric methods**
    - **Geothermal methods**
    - **Electrical resistivity methods**
    - **Seismic refraction methods**
- Improvement of competence of sites by grouting.

GEOPHYSICAL INVESTIGATIONS

Geophysics is the study of the earth by making use of established principles of physics.



IMPORTANCE OF GEO-PHYSICAL INVESTIGATIONS

- To ensure safety, success and economy in construction of major civil engineering structures.
- It is necessary to be thoroughly aware of geology of the concerned site.

In order to acquire subsurface details only two approaches exist.

1. Direct observations
2. Indirect Inferences

DIRECT OBSERVATIONS

Direct observations can be made by digging, trenching or drilling the ground.

Such process are expensive, laborious and time consuming. But they give exact data of the existing subsurface.

INDIRECT OBSERVATIONS

Indirect observations can be made by means of geophysical methods of investigations.

These provide quick, inexpensive, easy and fairly reliable means to get subsurface details.

There may a chance of getting minute errors.

CLASSIFICATION OF GEOPHYSICAL INVESTIGATIONS

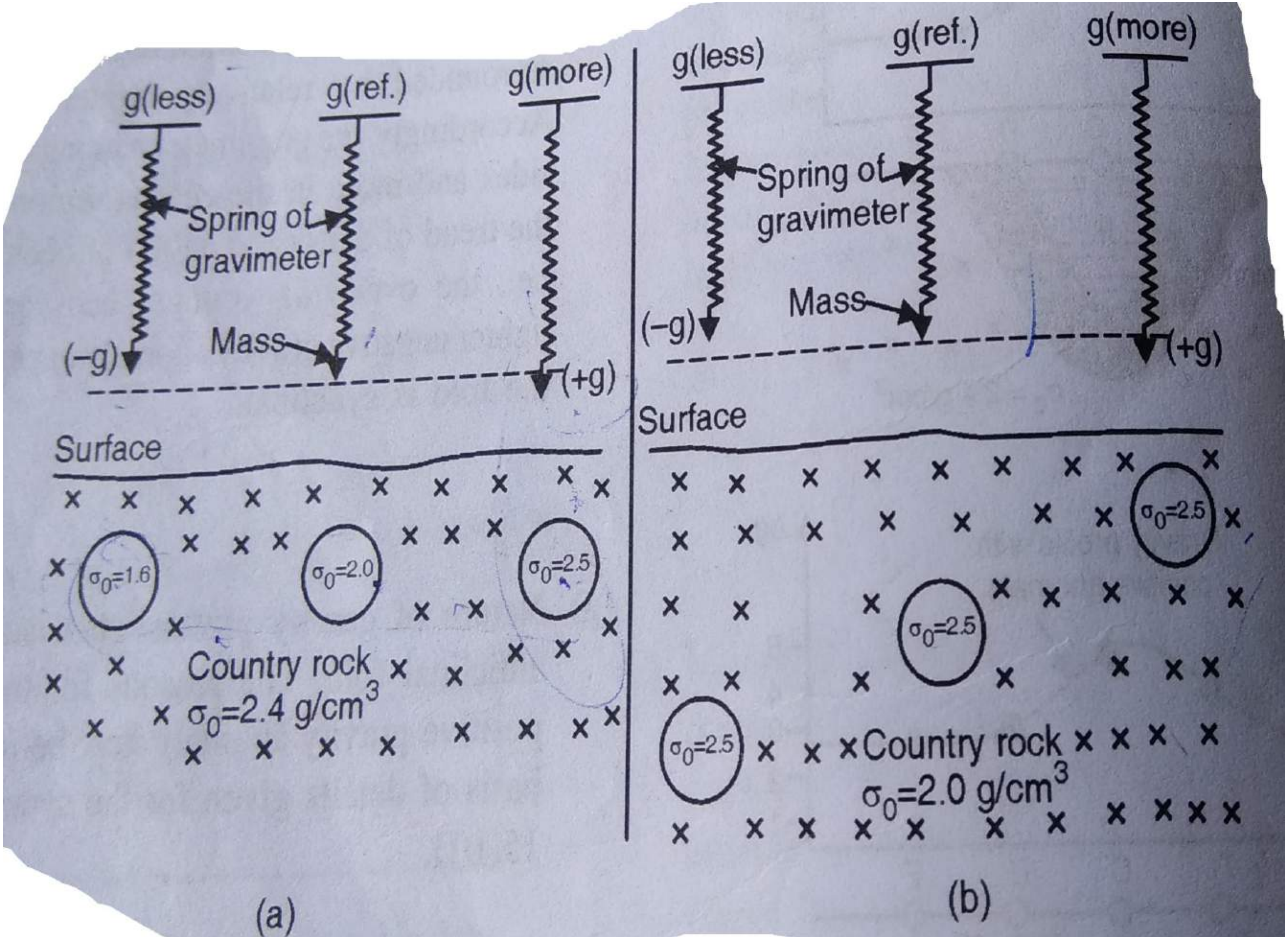
- There are many kinds of geophysical investigation.
- All of them can be classified logically into six major groups based on the type of physical field measured or physical property of subsurface formations which controls the measured physical quantities.

These methods are:

1. **Gravity method.**
2. **Magnetic method**
3. **Electrical method.**
4. **Geothermal method**
5. **Radiometric method.**

GRAVITY METHOD

- Gravity method represents a set of geophysical methods which make use of the natural gravity field of the earth.
- Physical Property: **Density** of the materials is the controlling property



g(less)
g(ref.)
g(more)
Spring of gravimeter
Mass
(−g)
(+g)
Surface
σ0=1.6
σ0=2.0
σ0=2.5
Country rock
σ0=2.4 g/cm3
(a)
g(less)
g(ref.)
g(more)
Spring of gravimeter
Mass
(−g)
(+g)
Surface
σ0=2.5
σ0=2.5
σ0=2.5
Country rock
σ0=2.0 g/cm3
(b)

MAGNETIC METHOD

- Like gravity methods, these investigations also take advantage of the natural magnetic field associated with earth and its relation to subsurface geology
- Controlling Property: **Magnetic Susceptibility**

Methods:

1. **Magnetic prospecting**
2. **Magnetic logging**
3. **Airborne magneto-metry**
4. **Shipborne magneto-metry**

Applications:

- Exploration of magnetic ores of iron
- In mining field magnetic prospecting may be applied.

  1. directly in the search for deposits of highly magnetic minerals such as magnetite, pyrrhotite and some of the manganese ores.
  2. indirectly for locating bodies of other minerals which themselves may not be magnetic minerals.
- In petroleum exploration, for determination of thickness of sediments .
- In engineering projects for locating construction materials such as granite, basalt and other building stones

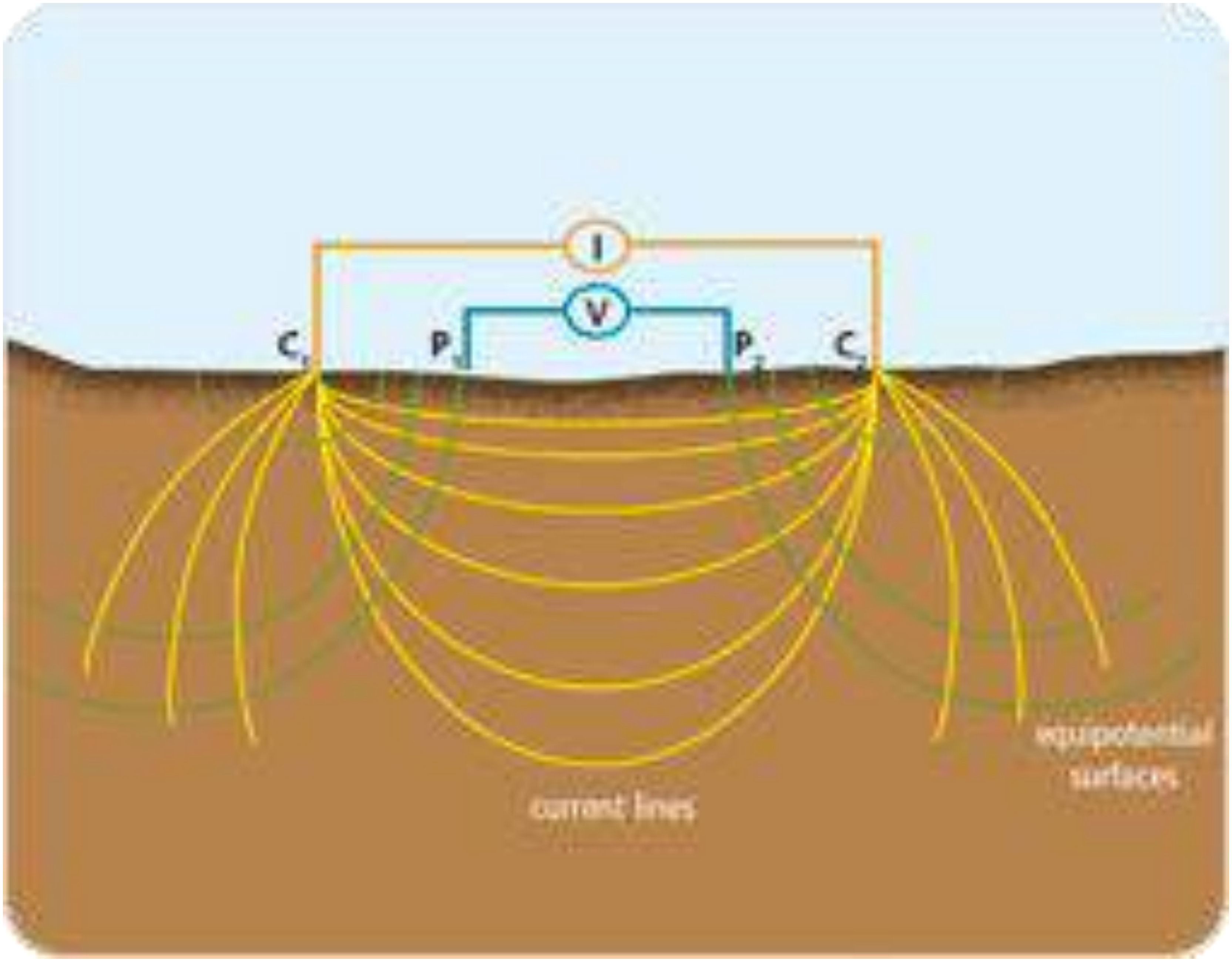
Electrical Method

Controlling properties:

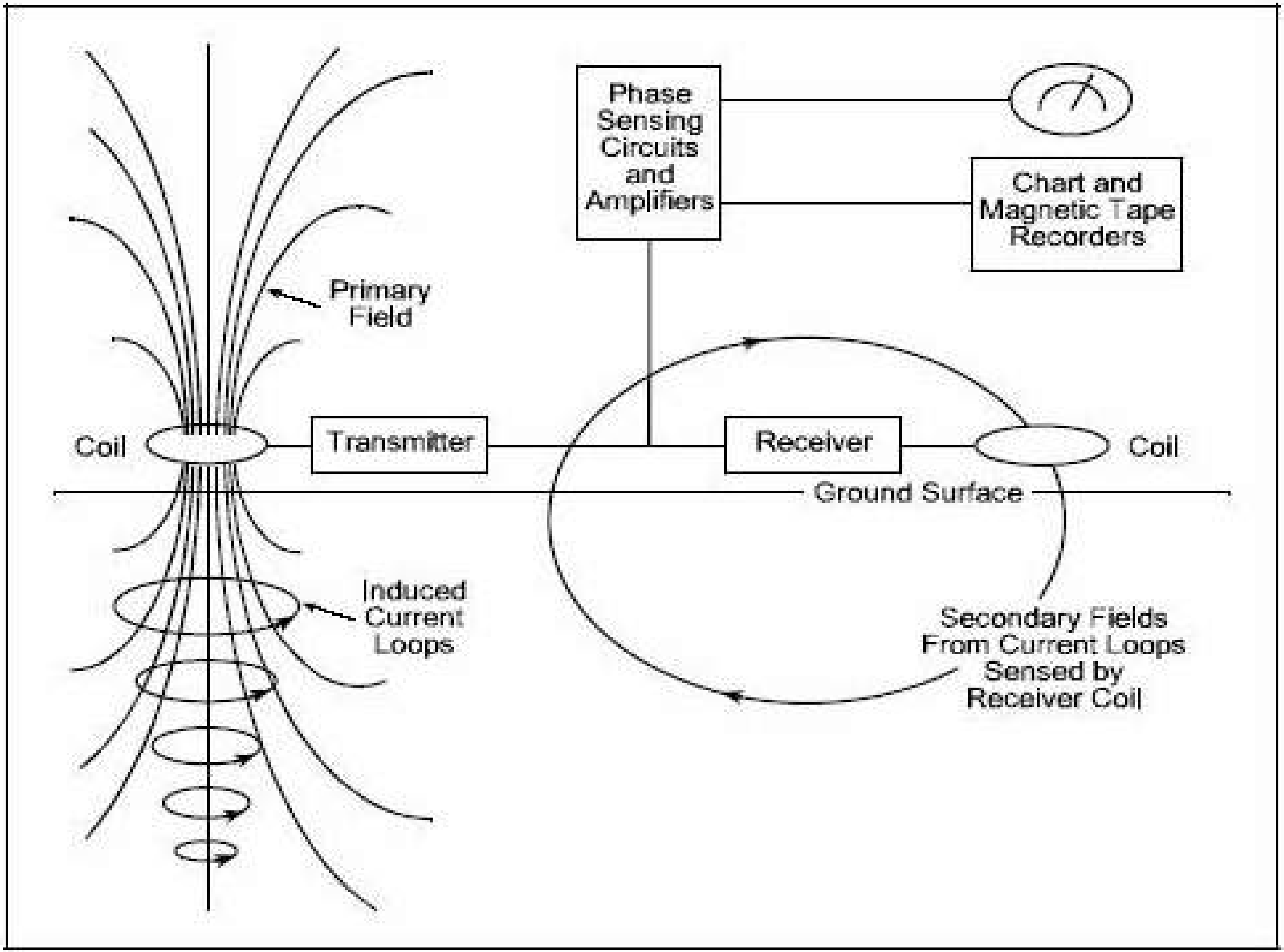
1. Electrical resistivity- **Electrical Method**
2. Dielectric constant- **Electro-magnetic Method**
3. Electrochemical activity- **Electrochemical Method**

Principle:

Electrical methods are based on the fact that the subsurface information's, structures, ore deposits, etc., posses electrical properties. These are investigated suitably and exploited to draw the necessary conditions.


I
V
C1
P1
P2
C2
current lines
equipotential surfaces

Schematic Drawing Of Electromagnetic Operating Principles



Applications

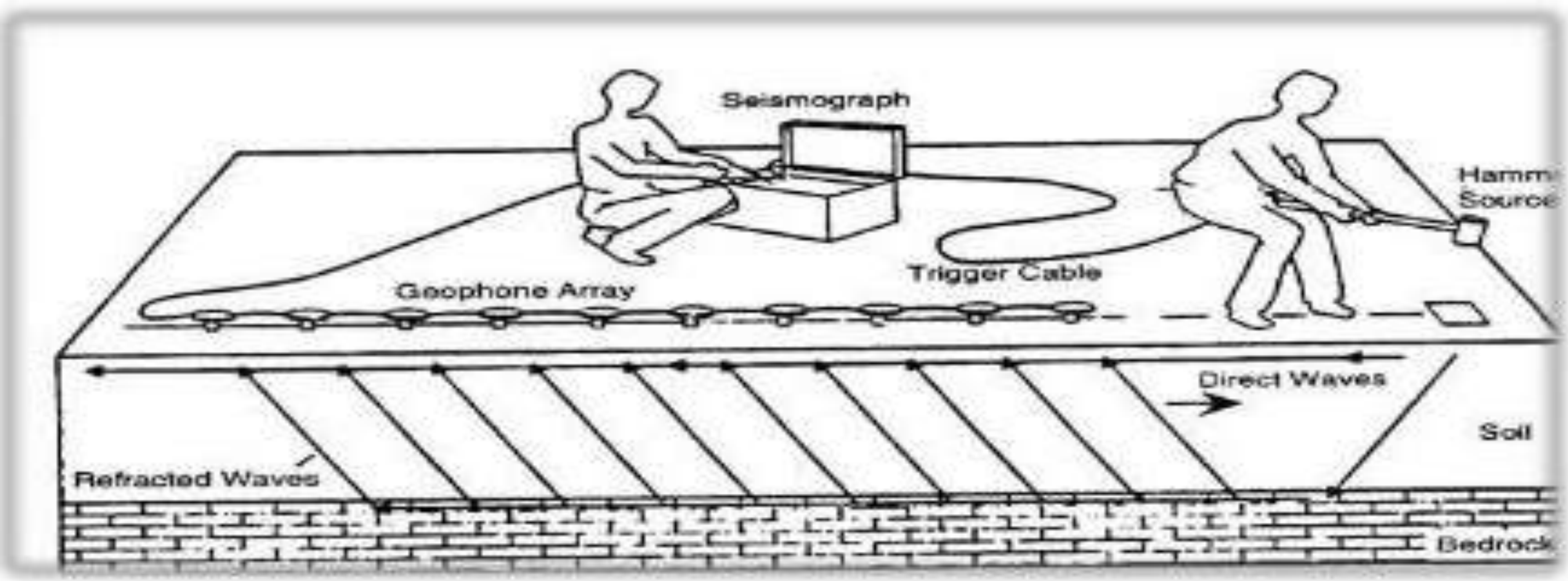
These methods are particularly successful in ground water exploration.

- For locating highly conductive bodies (sulphide ore and graphite)
- Oil exploration
- Economic mineral deposit exploration

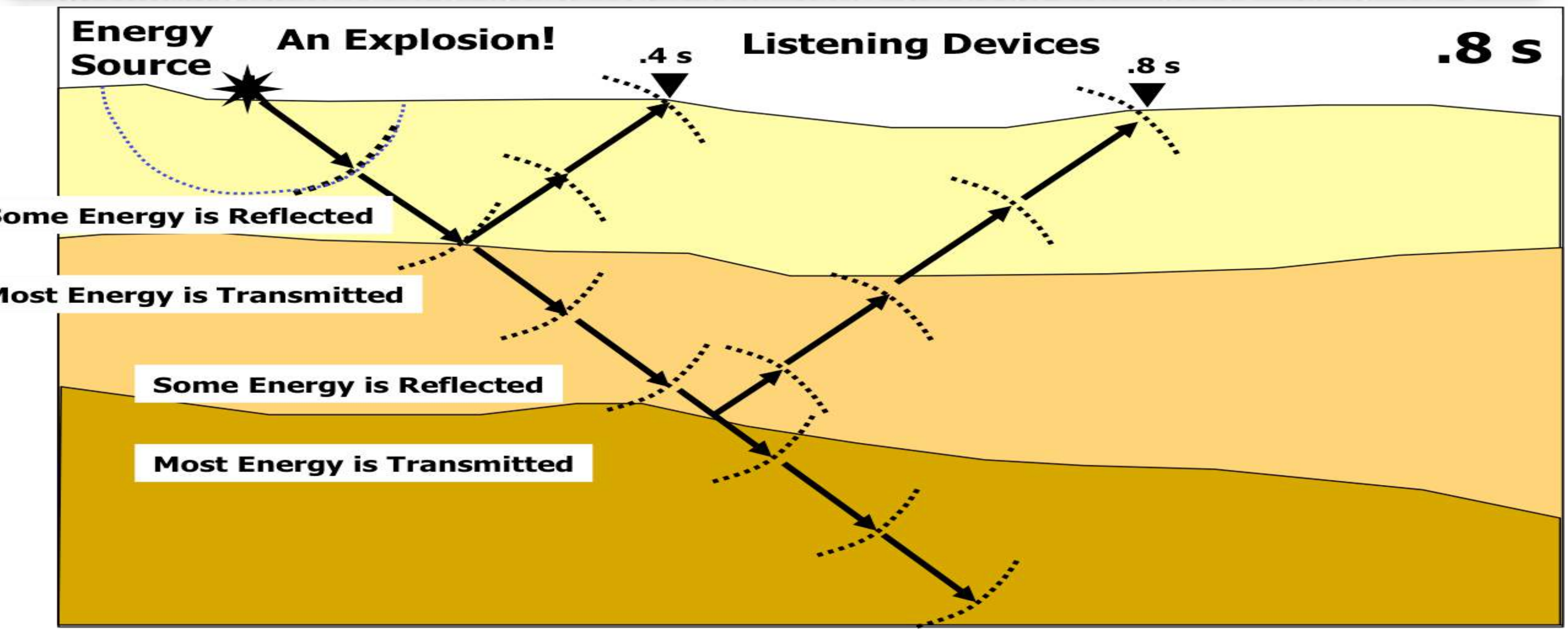
Seismic Method

Controlling property: **Elastic property** differences in the rocks

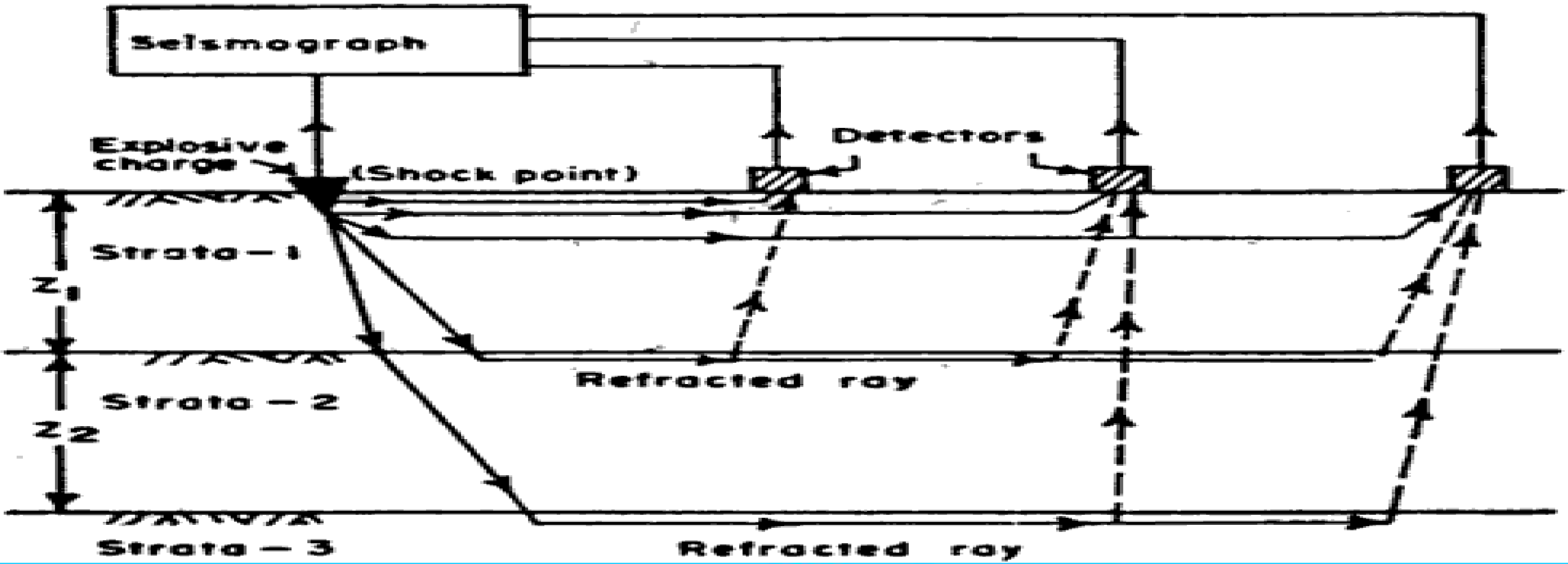
Principle: Subsurface rock formations bear different elastic properties. Because of this, the velocities of propagation of seismic wave velocities of rock formations therefore provides a scope to distinguish different subsurface lithological units.



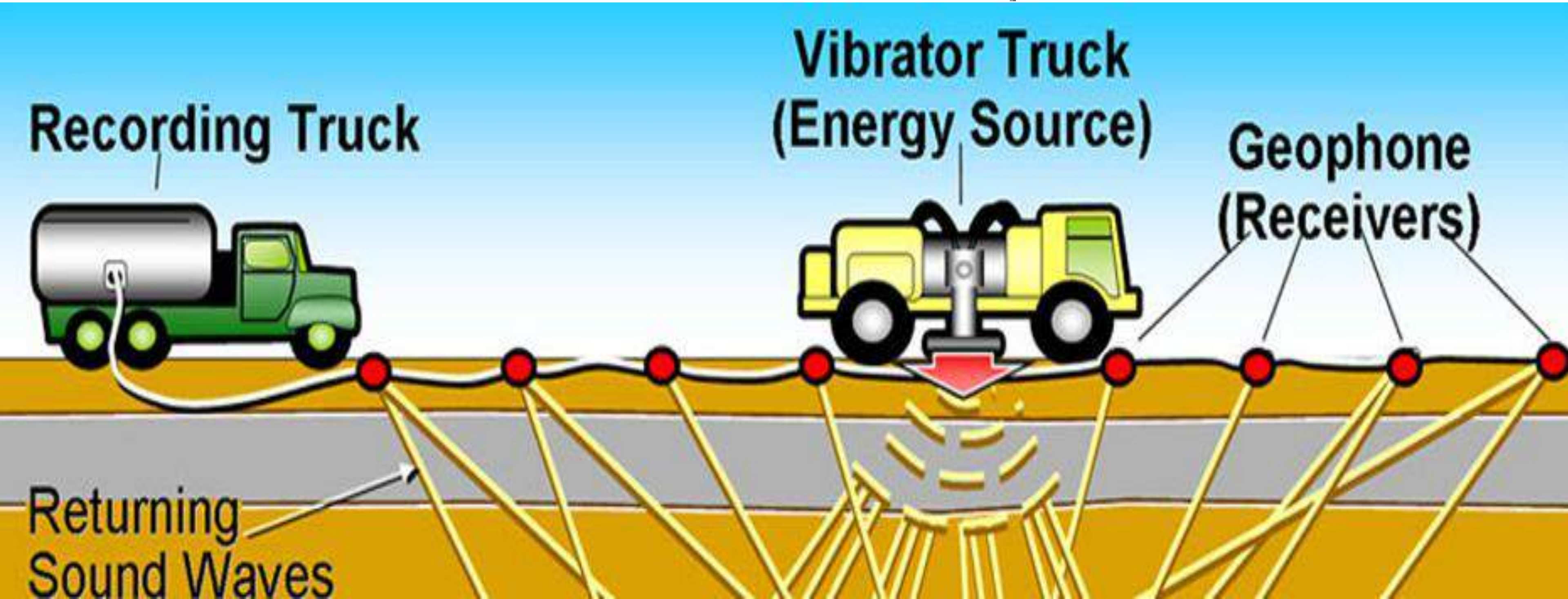
Seismograph
Hamm
Source
Trigger Cable
Geophone Array
Direct Waves
Soil
Refracted Waves
Bedrock



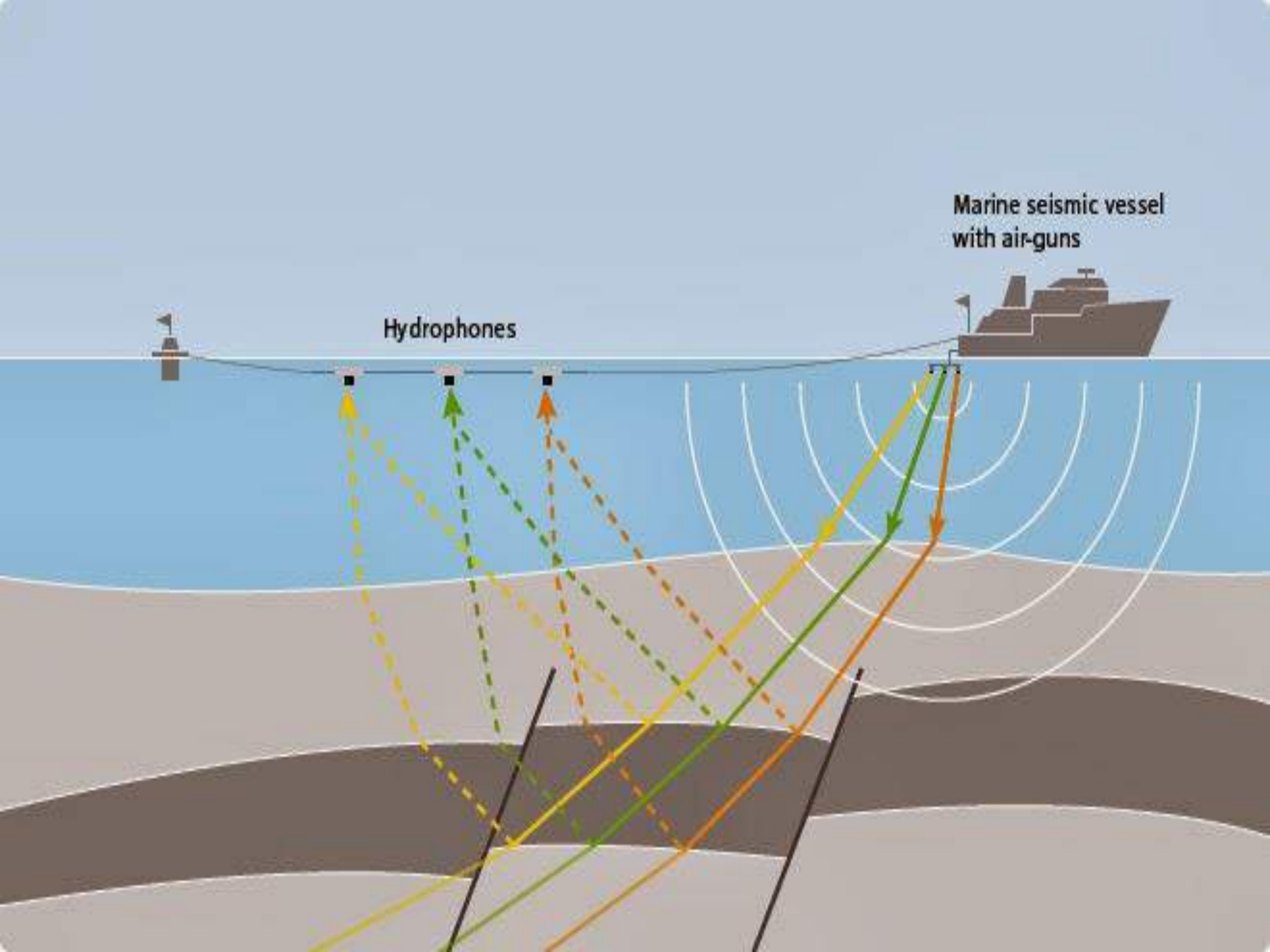
Energy Source
An Explosion!
Listening Devices
.8 s
.4 s
.8 s
Some Energy is Reflected
Most Energy is Transmitted
Some Energy is Reflected
Most Energy is Transmitted



Seismograph
Explosive charge
(Shock point)
Detectors
Strata - 1
Z_1
Refracted ray
Strata - 2
Z_2
Strata - 3
Refracted ray



Vibrator Truck
(Energy Source)
Recording Truck
Geophone
(Receivers)
Returning
Sound Waves

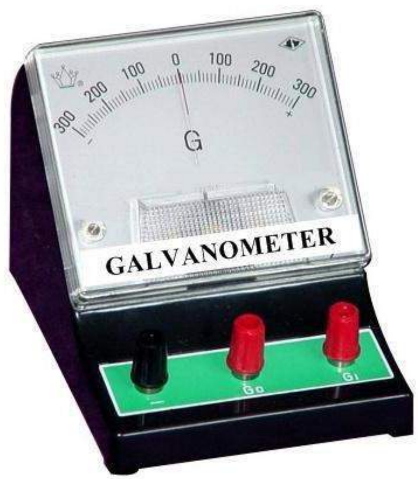

Marine seismic vessel
with air-guns
Hydrophones

Method

- Depending upon whether reflected waves or refracted waves are used in the investigation, there are two types of seismic methods, namely seismic reflection and seismic refraction methods.

Equipment

- Geophone
- Amplifier
- Galvanometer



Radiometric Method

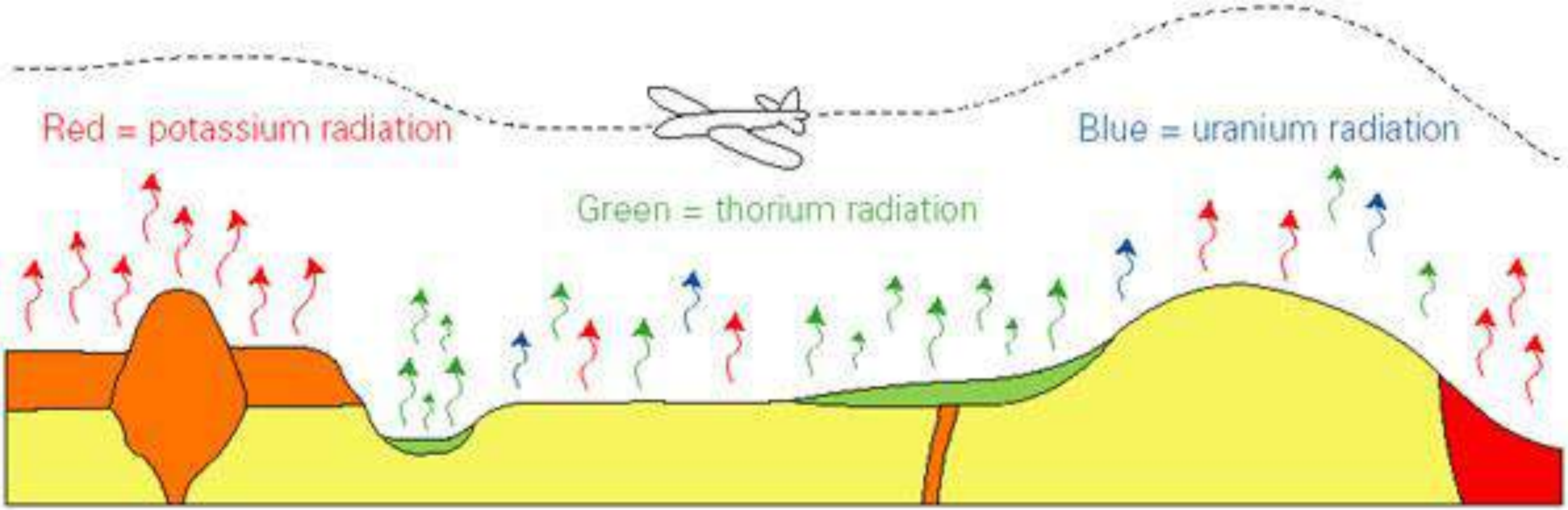
Controlling property**: Natural radioactivity** of rocks.

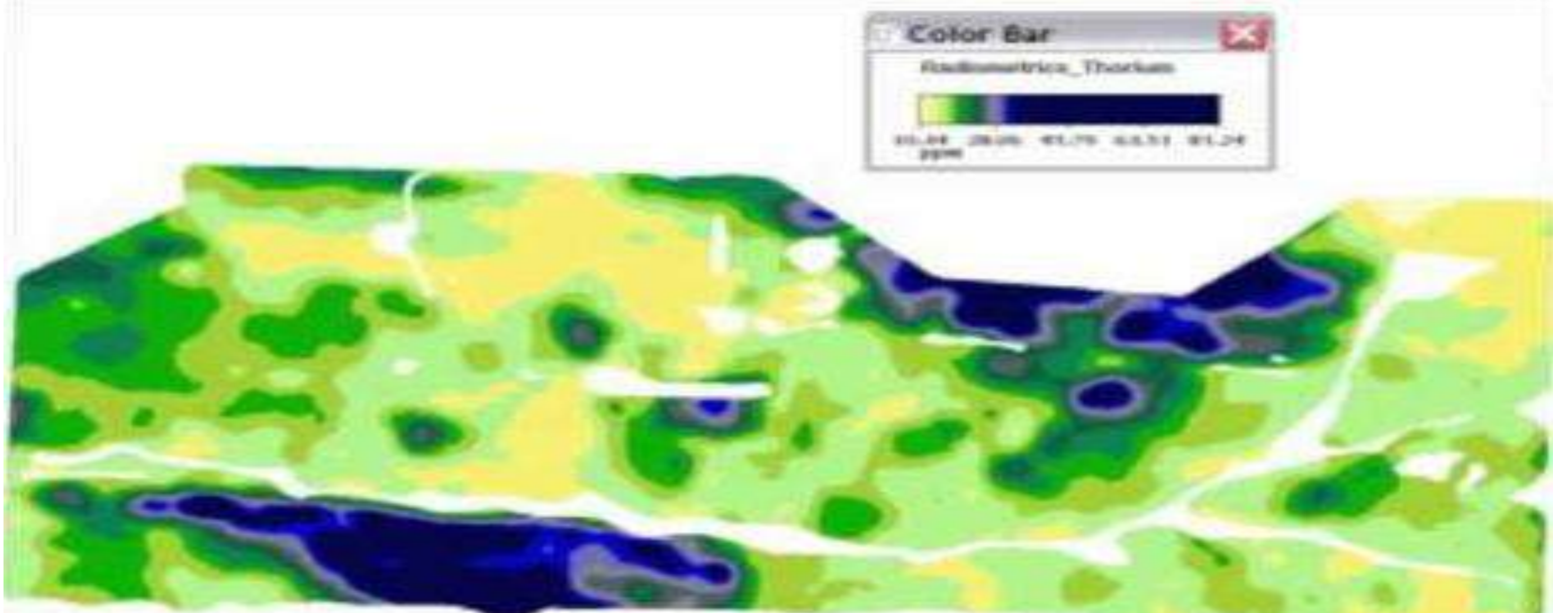
Principle: the nuclei of certain elements are unstable and change spontaneously into the nuclei of other elements.

This change is accompanied by emission of radiations known as alpha and beta particles and gamma rays. This phenomenon is known as radioactivity.

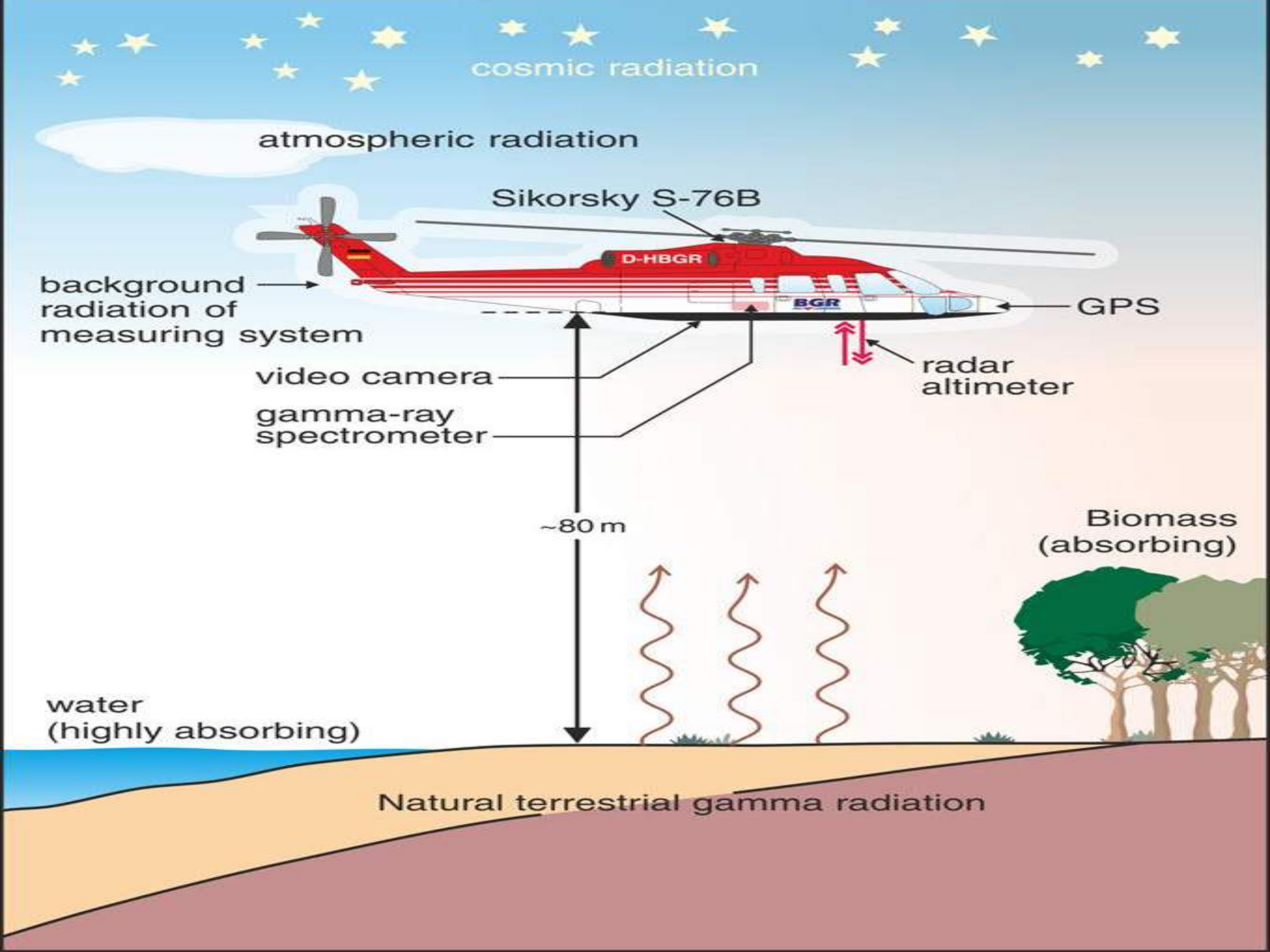
As it is associated with high energy , it can be detected easily.

The gamma rays are more powerful than alpha and beta particles are measured in the study of radiometric methods.





Radiometric Uranium Map


cosmic radiation
atmospheric radiation
Sikorsky S-76B
D-HBGR
BGR
background radiation of measuring system
GPS
video camera
gamma-ray spectrometer
radar altimeter
~80 m
Biomass (absorbing)
water (highly absorbing)
Natural terrestrial gamma radiation

Applications

- Exploration of uranium and thorium mineral deposits.
- Indirect location of some rare elements and rare earth minerals
- Scope of location of faults, shear zones etc.,
- Exploration of oil and gas
- Ground water studies
- Radioactivity tracer techniques maybe utilized for finding leakages in water storage and conveyance systems

Geothermal Methods

Controlling property: thermal conductivity

Principle: temperature distribution on the surface of the earth is due to three different sources.

i) Heat received from sun

ii) Heat conveyed from hot interior of earth

iii) Heat due to decay of radio active minerals in the earth crust.

By applying the necessary corrections, it is possible to eliminate the solar heat and heat contribution of radioactive mineral decay.

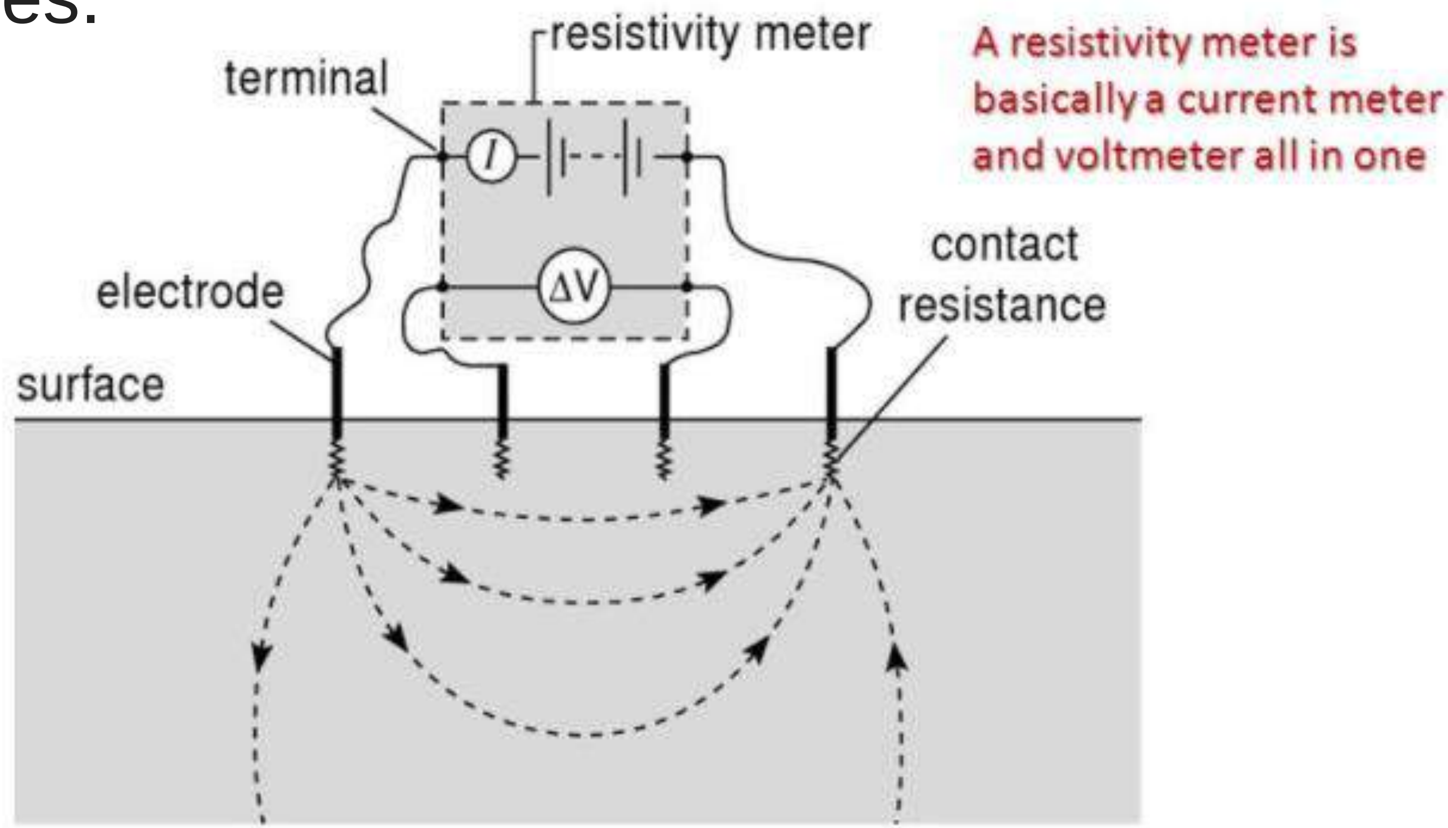
When this is done, the residual values of temperature distribution on the earths surface can be interpreted in terms of subsurface structures, rock formations and ore bodies.

Equipment: for measurement of the temperature on the surface of the earth, in shallow holes or in deep bore holes, thermistor thermometers and platinum resistance thermometers which can achieve an accuracy of 0.01°C are used.

Applications: oil and gas explorations, ore deposits, ground water studies, for delineation of salt water-fresh water interfaces, etc.

Electrical Resistivity Methods

The **electrical resistivity method** is an active geophysical **method**. It employs an artificial source which is introduced into the ground though a pair of electrodes.



Applications

- Foundation studies
- Location of suitable building material
- Ground water studies
- To determine the thickness of loose overburden or the depth of the bedrock at the foundation site
- To know the strike and dip of the rocks
- To locate place of leakage along canals or reservoir

TOPIC 5

TUNNELS

Tunnels are underground passages or passages through hills or mountains used for different purposes. They are made by excavation of rock below the surface or through hills or mountains.

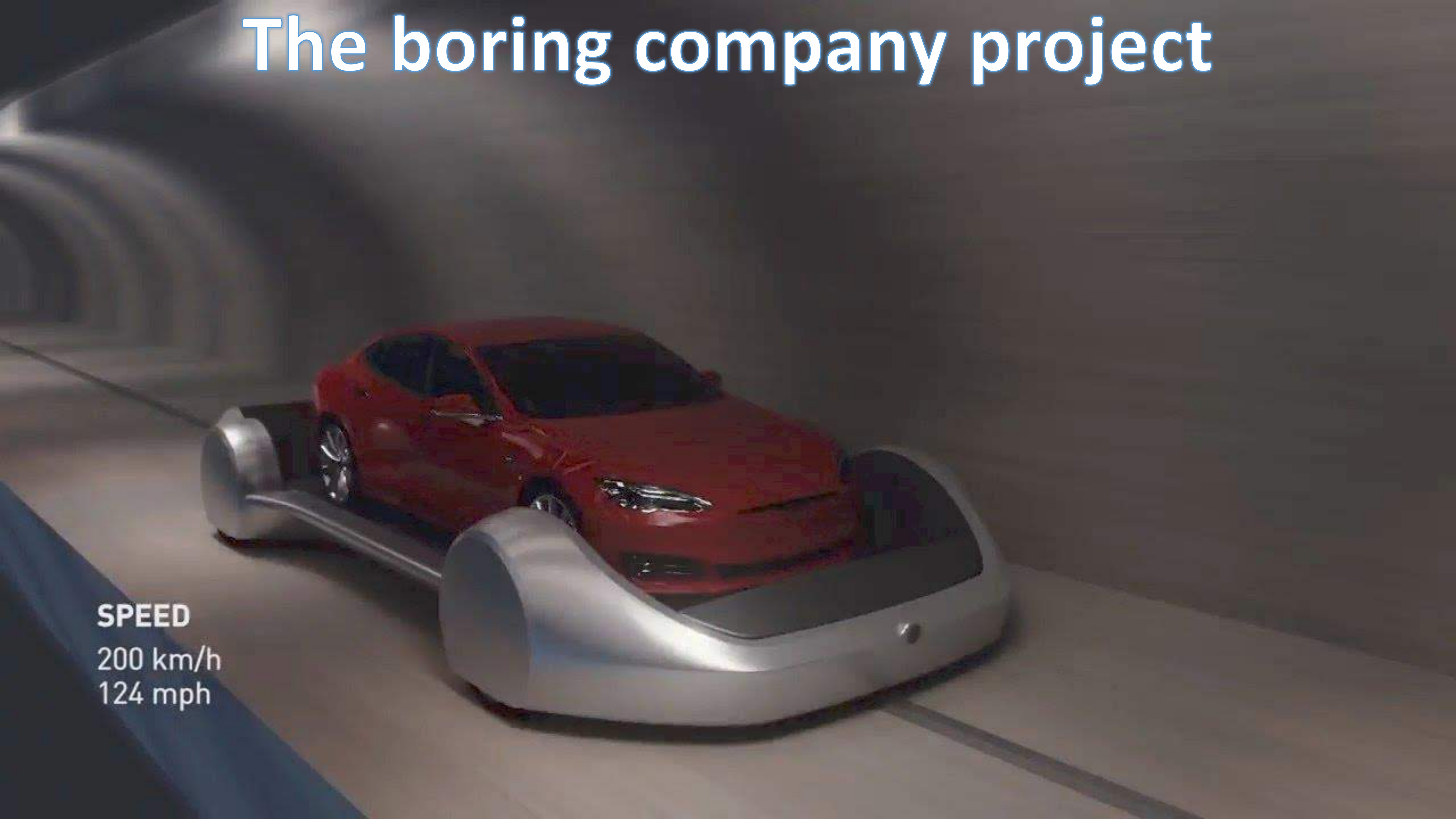
PURPOSES OF TUNNELING

Tunnels are made to serve some specific purposes.

- **For regular *traffic and transportation of goods***
- ***Diversion tunnels***
- ***Public utility tunnels***

Traffic tunnels

The boring company project



DIVERSION TUNNELS

To construct dam, the dam site should be dry and this is achieved by diverting the flow of river, dug along valley side.

Public utility tunnels

Brooklyn-to-Staten Island Drinking Water Tunnel

Sewage disposal, drinking water, oil supplying tunnels

EFFECTS OF TUNNELING ON GROUND

- The tunneling process deteriorates the physical conditions of the ground.
- Before tunneling the underground rocks which were under pressure or in a state of equilibrium in terms of prevailing stress and strain of the region. When an empty cavity is created through rocks, that equilibrium gets disturbed and as a sequence, the rocks of the roof may collapse.
- Stability of ground maybe jeopardized when the tunneled ground has unfavorable ground water conditions.
- At greater depths, high temperatures will be prevailing, making conditions for tunneling difficult. Sometimes poisonous gases may also be encountered during excavation of tunnels.

ROLE OF GEOLOGICAL CONDITIONS IN TUNNELING

- Lithological
- Structural
- Ground water

Lithological or rock types

The nature of the rock types along the tunnel alignment is very important for safety and stability of the tunnels

Structural:

Joints, faults , folds and tilted characters are the most common structural features associated with rocks.

Ground water:

Among the different problems that may occur in tunnels, the ground water problem is the most important one.

lithological

Suitability of **igneous rocks**:

- Massive igneous rocks (*plutonic and hypabyssal varieties*) are more competent but difficult to work.
- They do not need lining or any special maintenance.
- This is so because they are very strong , tough, hard, rigid, durable, impervious and after tunneling they do not collapse or bulges or any deformation.
- *The volcanic rocks* too in spite of their vesicular or amygdaloidal character are competent and suitable for tunneling.

Bhor-ghat on Bombay-Pune line of central railway about 20 tunnels were excavated through amygdaloidal basalts

Suitability of **sedimentary rocks**

In general sedimentary rock are less competent than igneous rocks. Among the different sedimentary rocks the following factors are important:

- Thick bedded, well cemented and siliceous sand stones are more competent and better suited for tunneling
- Shales, by virtue of their inherent weakness and laminations, may get badly shattered during blasting, but being soft they can be excavated but, proper lining must be provided.
- Dolomitic limestones are harder and more durable. But, in general limestones are unsuitable for tunneling.

Himalayan Ram-Ganga Diversion tunnel-poorly cemented sandstone formation, which softened with water, had caused roof fall extending about 6 m above top of tunnel

Suitability of **metamorphic rocks**

- **Gneisses** are nearly similar to granites in terms of their competence, durability and workability.
- They are capable of withstanding the tunneling process without lining.
- **Quartzite** are very hard and hence very difficult to work. They are more brittle too. They are competent and need no lining.
- **Marbles** are reasonably competent by virtue of their high compactness and granulose structure.
- **Slates** are soft, hence they are weak and require lining.

Importance of **geological structures**

- The bearing of structures in tunnels is very important for two different reasons

i) They modify the competency and suitability of rocks for tunneling

ii) They may create or prevent ground water problems. Which are of critical importance in tunneling.

Effects of joints at the tunnel site

- In igneous rocks , which are exceptionally strong the presence of suitably placed joints may be advantageous in the excavation process. Further their presence may not harm their self supporting character.
- Closely spaced joints may lead to over break.
- Due too joints ground water problem may arise.

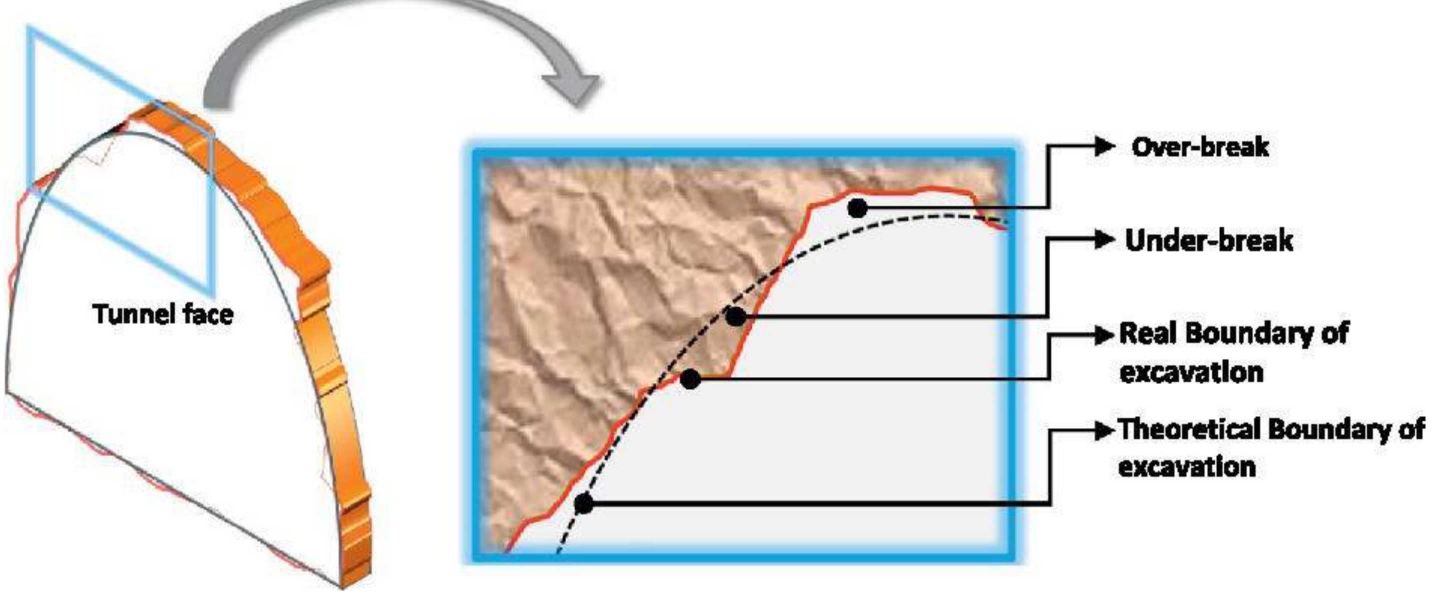
Effects of faults at the tunnel site

- Dislocation and discontinuity in the tunnel alignment is caused.
- If the occur along the course of a tunnel, it becomes necessary to provide lining.
- Being highly porous, permeable and decomposed, are the potential zones to create ground water problems.

Effects of folds at the tunnel site

- When excavations for tunnels are made in folded rocks, such rocks get the opportunity to release strain, such release may occur in the form of rock bursts or falls.

OVER BREAK



Excavations though hard rocks necessarily involves the removal of some of the rocks outside the proposed perimeter of the tunnel.

The quantity of rock broken and removed, in excess of what is required by the perimeter of the proposed tunnel, is known as overbreak.

LINING

Tunnels in loose rock and soft soils are liable to disintegrate and, therefore, a lining is provided to strengthen their sides and roofs so as to prevent them from collapsing.

The objectives of a lining are as follows:

- Strengthening the sides and roofs to withstand pressure and prevent the tunnel from collapsing.
- Providing the correct shape and cross section to the tunnel.
- Checking the leakage of water from the sides and the top.
- Binding loose rock and providing stability to the tunnel.
- Reducing the maintenance cost of the tunnel.