

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

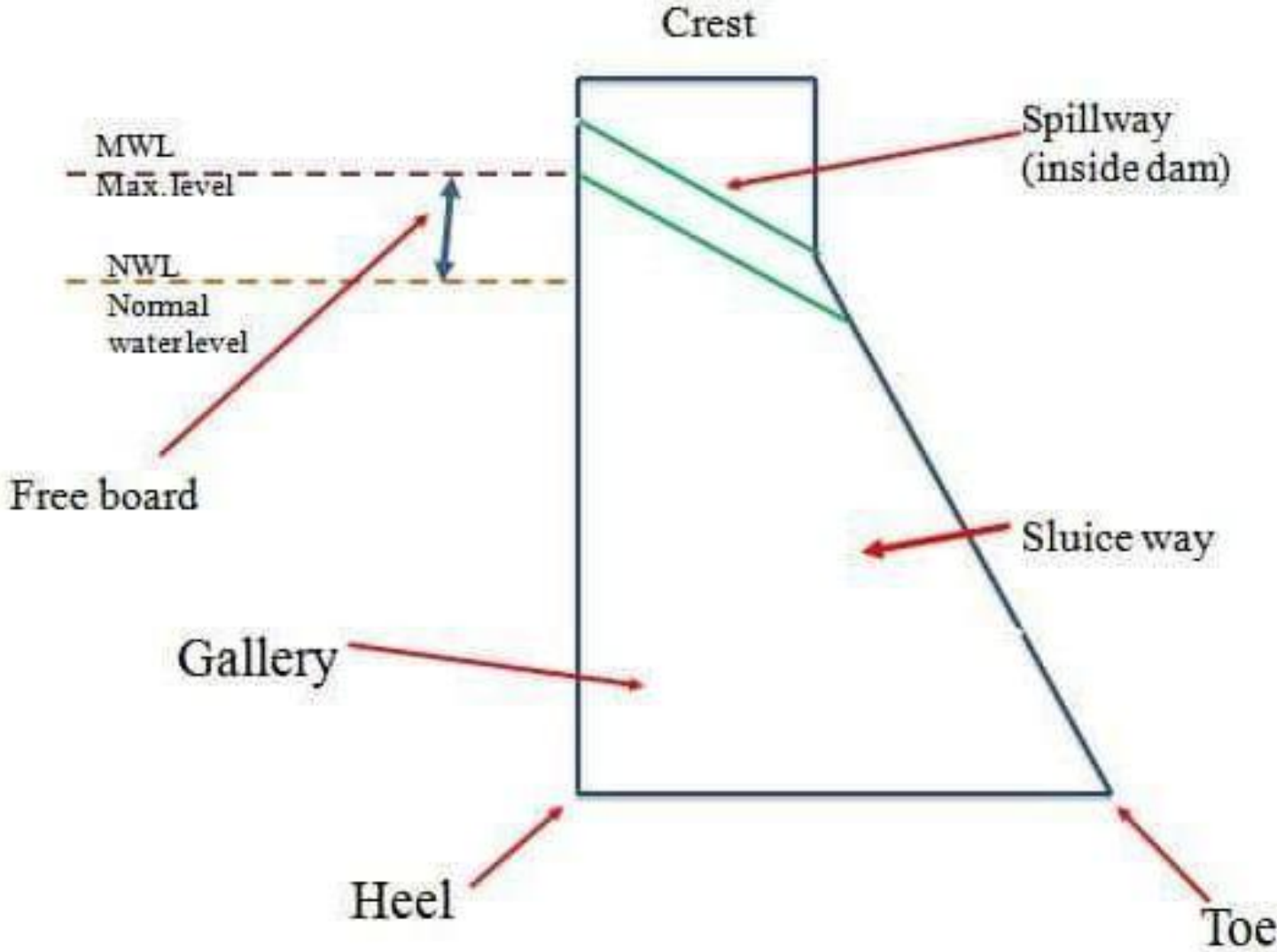


Based on structure and design

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.



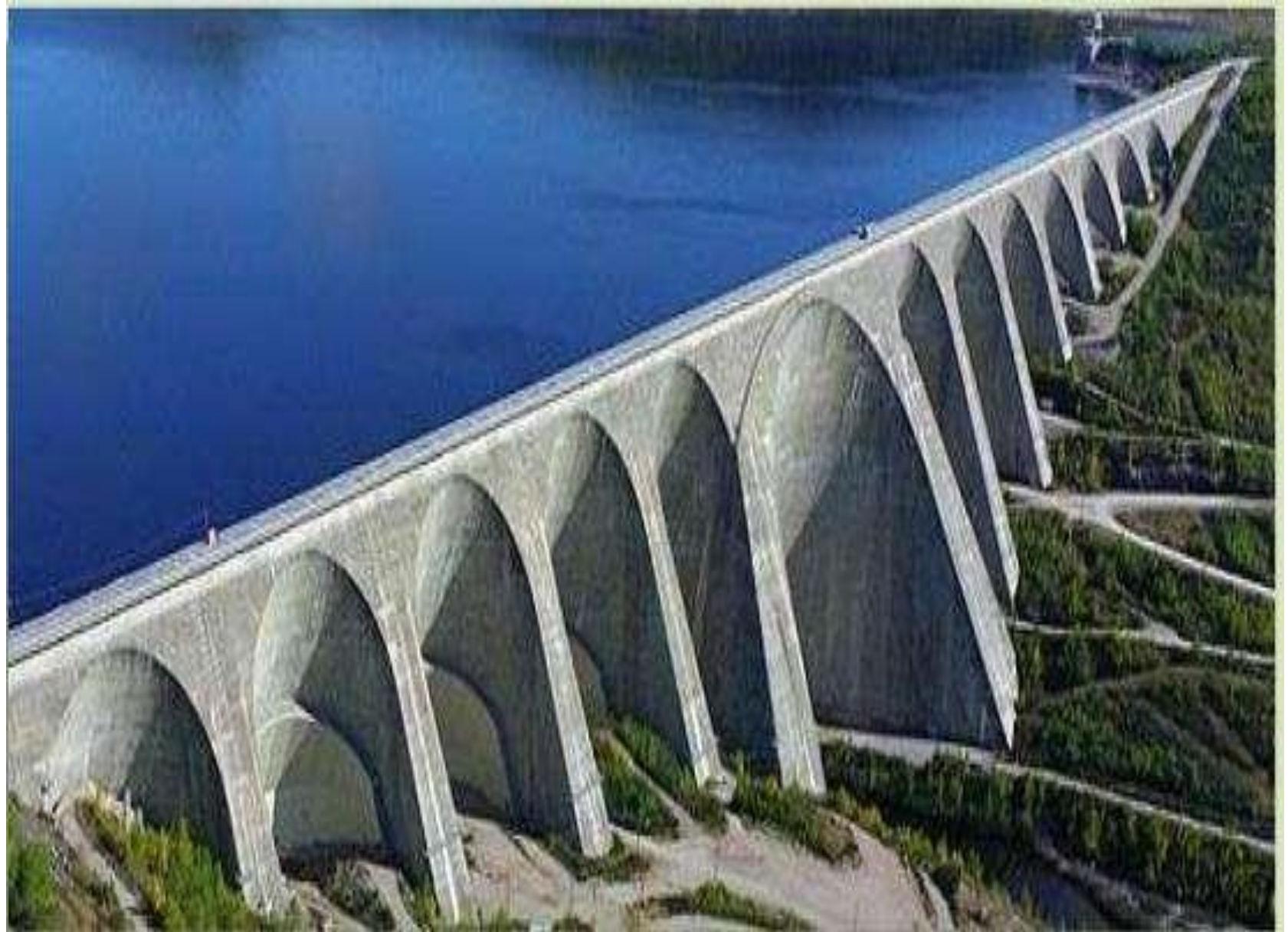
Construction
Photography





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

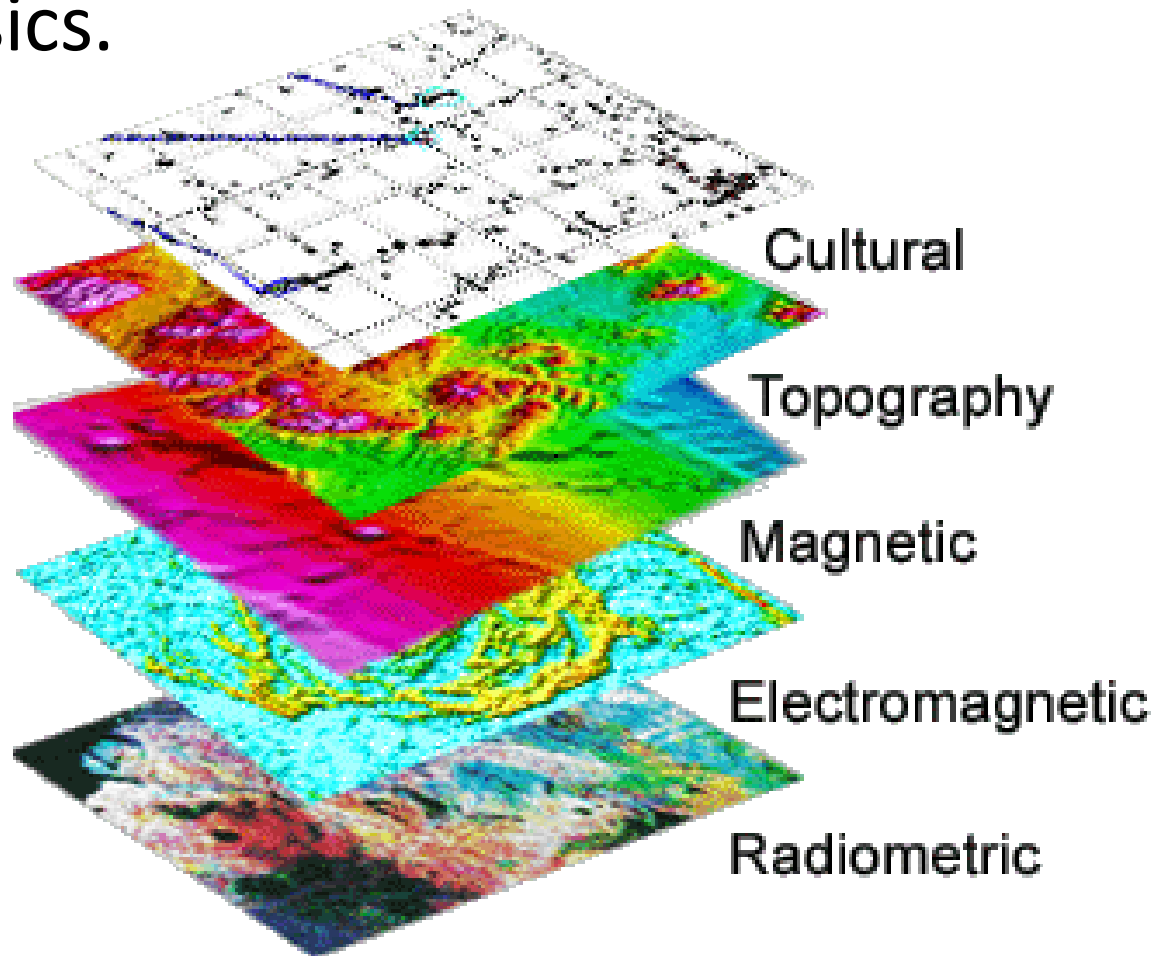
- **Silting**
- **Evaporation**

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

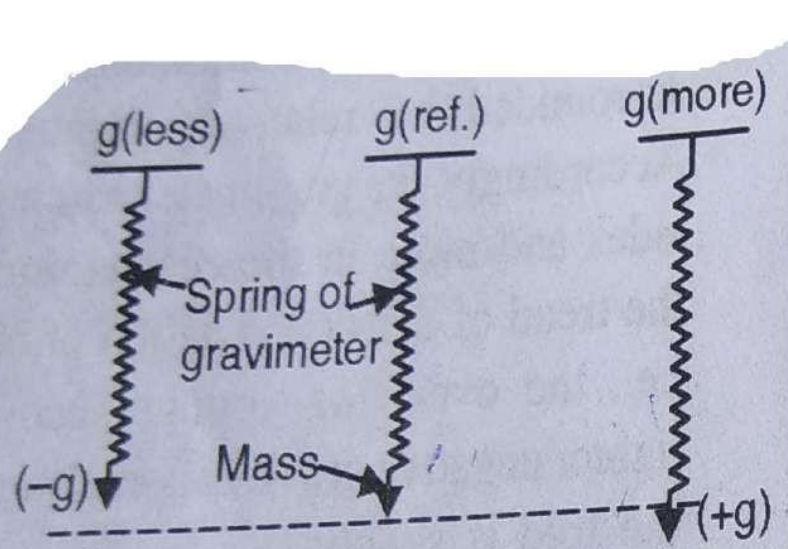
- There are many kinds of geophysical investigation.
- All of them can be classified logically into six major groups based on the type of physical field measured or physical property of subsurface formations which controls the measured physical quantities.

These methods are:

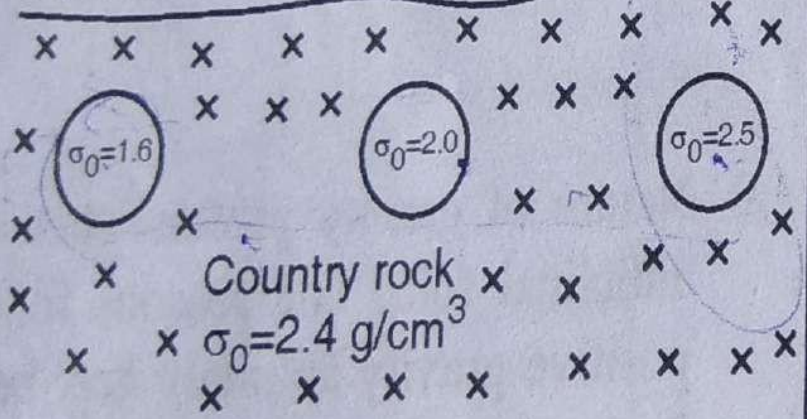
- 1. Gravity method.**
- 2. Magnetic method**
- 3. Electrical method.**
- 4. Geothermal method**
- 5. Radiometric method.**

GRAVITY METHOD

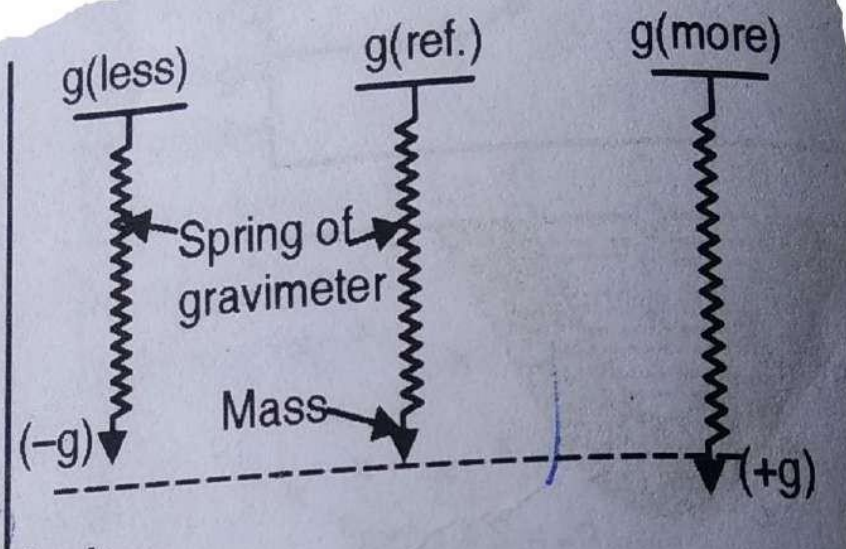
- Gravity method represents a set of geophysical methods which make use of the natural gravity field of the earth.
- Physical Property: **Density** of the materials is the controlling property



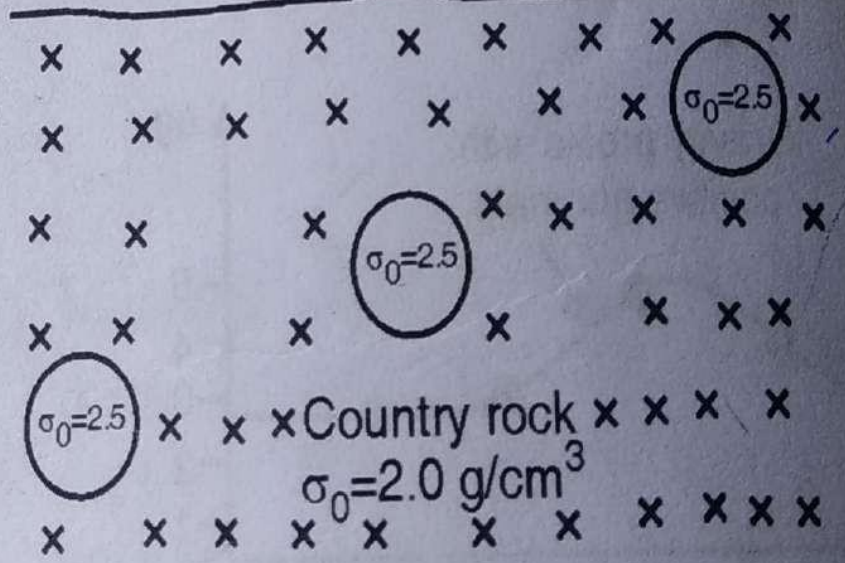
Surface



(a)



Surface



(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

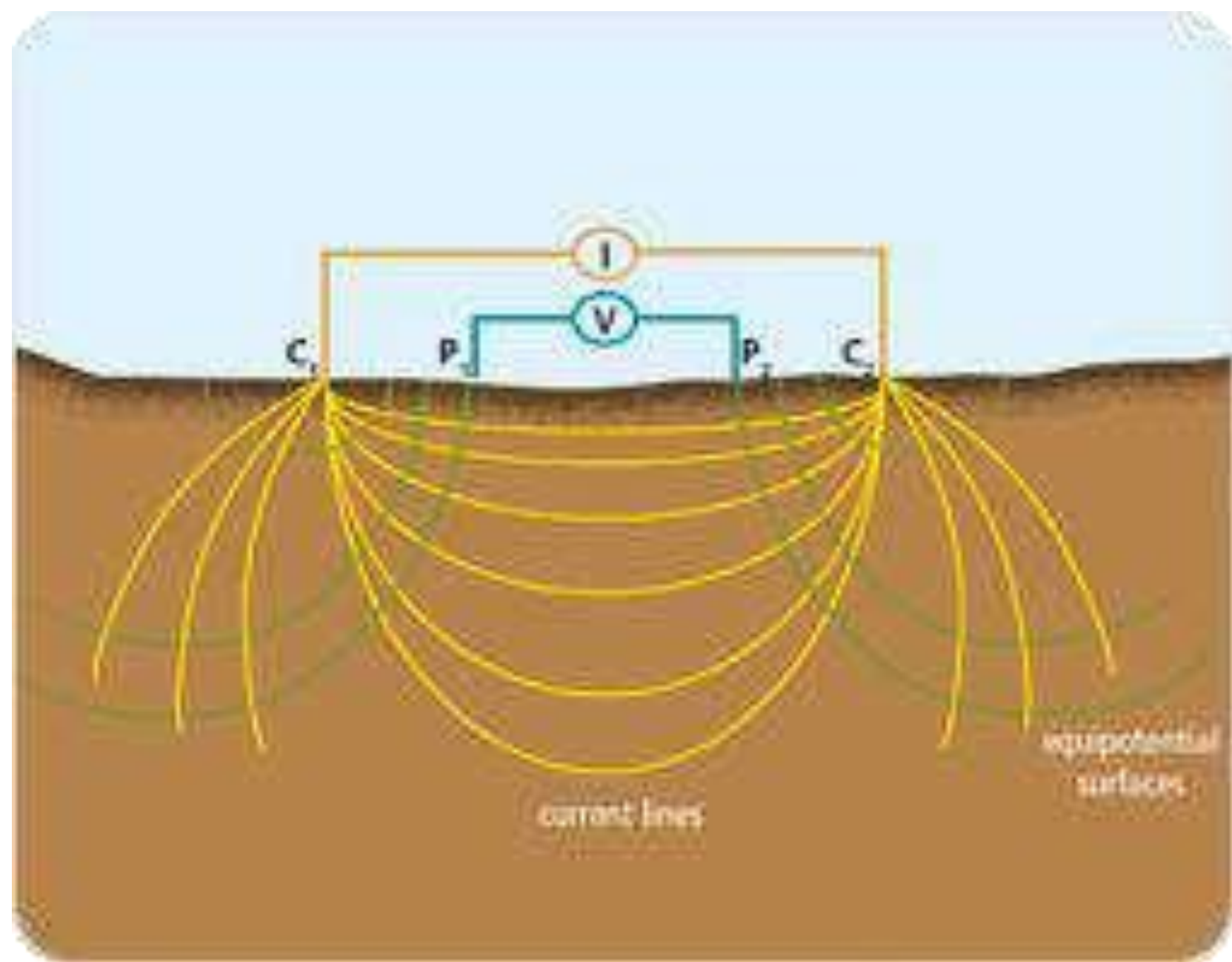
Electrical Method

Controlling properties:

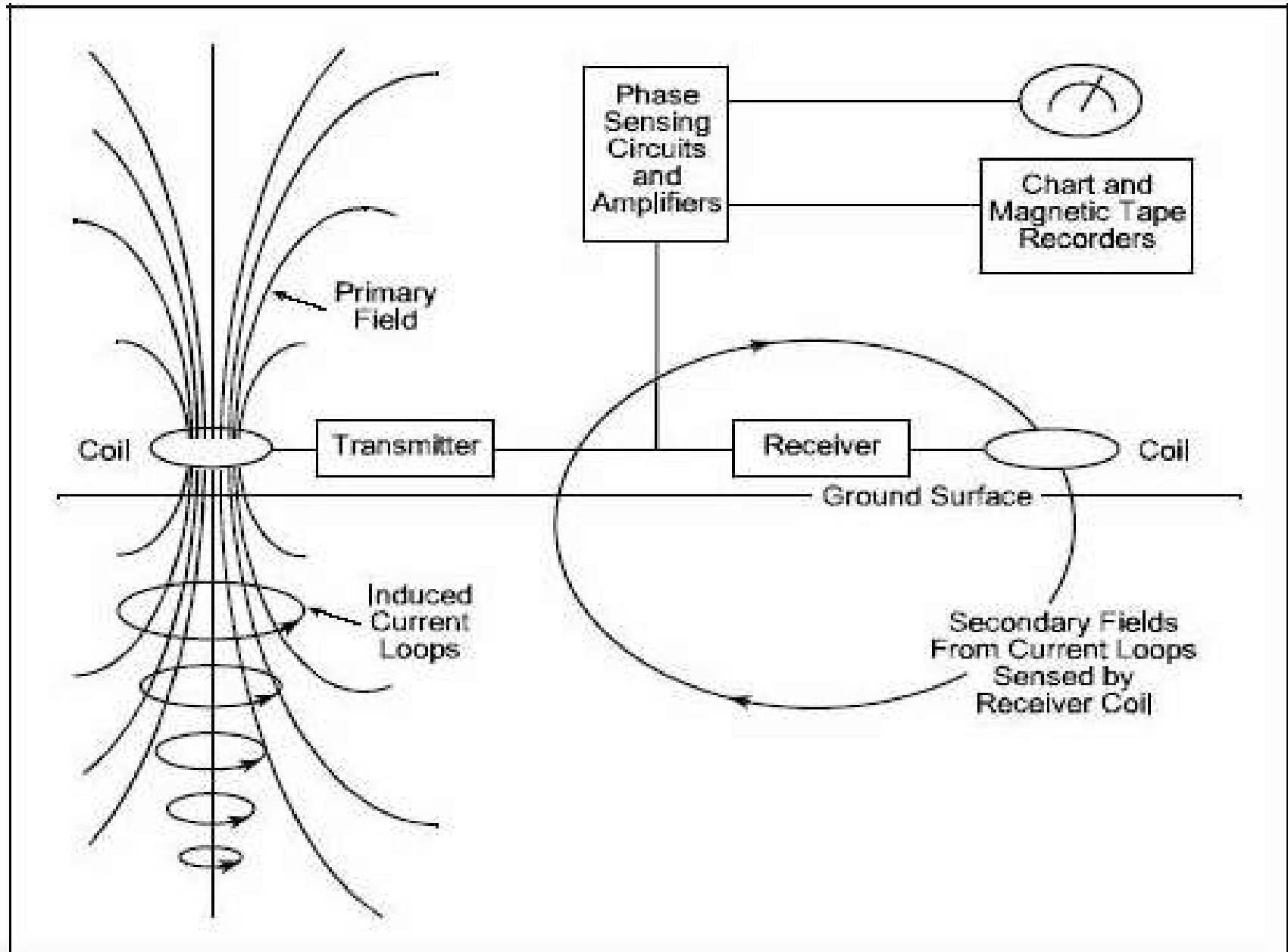
1. Electrical resistivity- **Electrical Method**
2. Dielectric constant- **Electro-magnetic Method**
3. Electrochemical activity- **Electrochemical Method**

Principle:

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



Schematic Drawing Of Electromagnetic Operating Principles



Applications

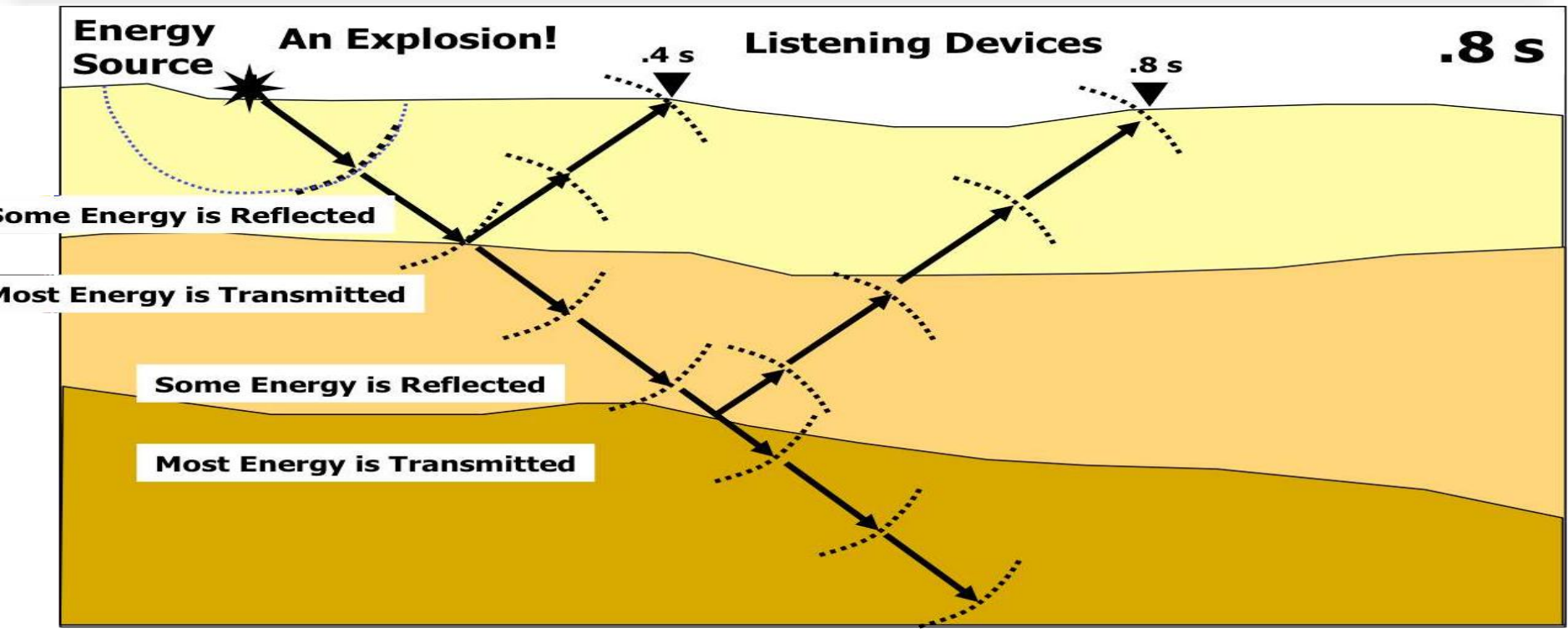
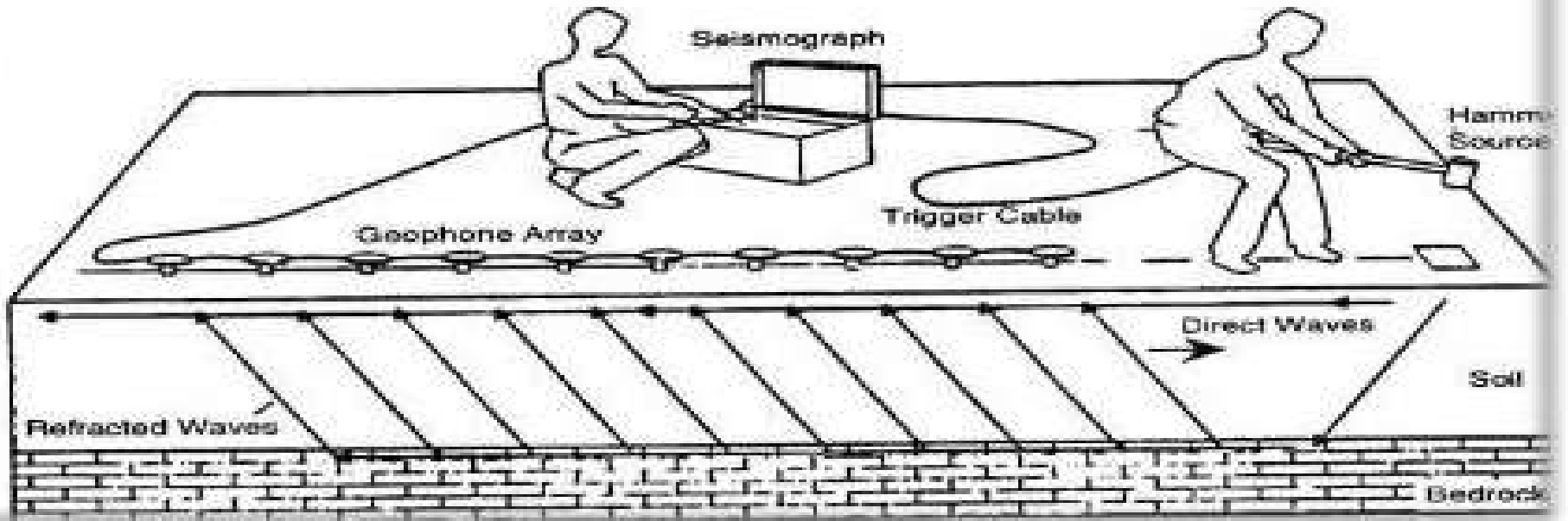
These methods are particularly successful in ground water exploration.

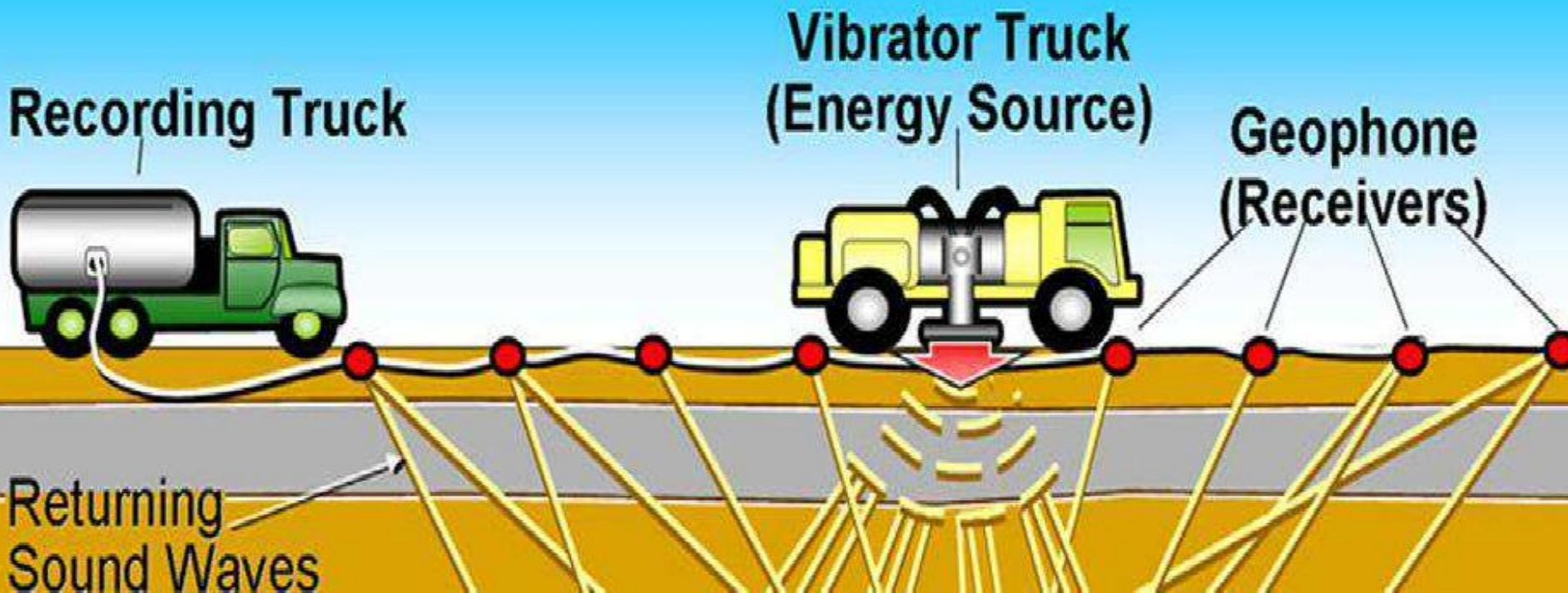
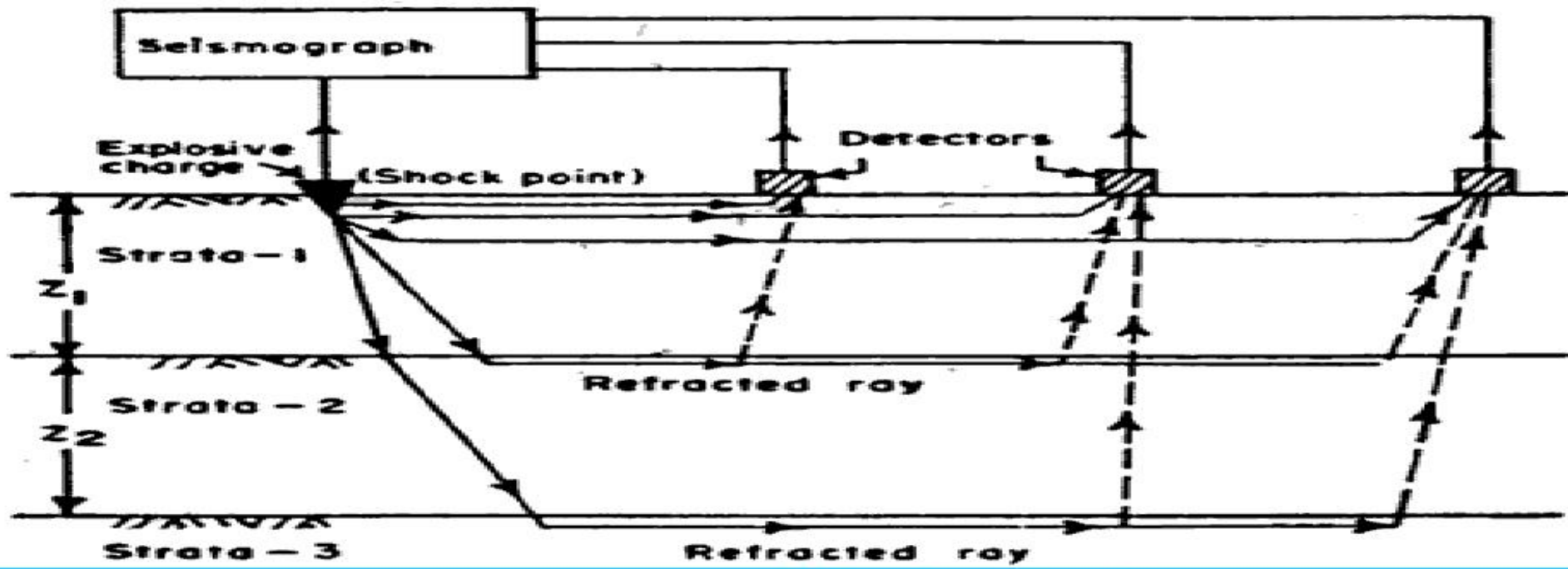
- For locating highly conductive bodies (sulphide ore and graphite)
- Oil exploration
- Economic mineral deposit exploration

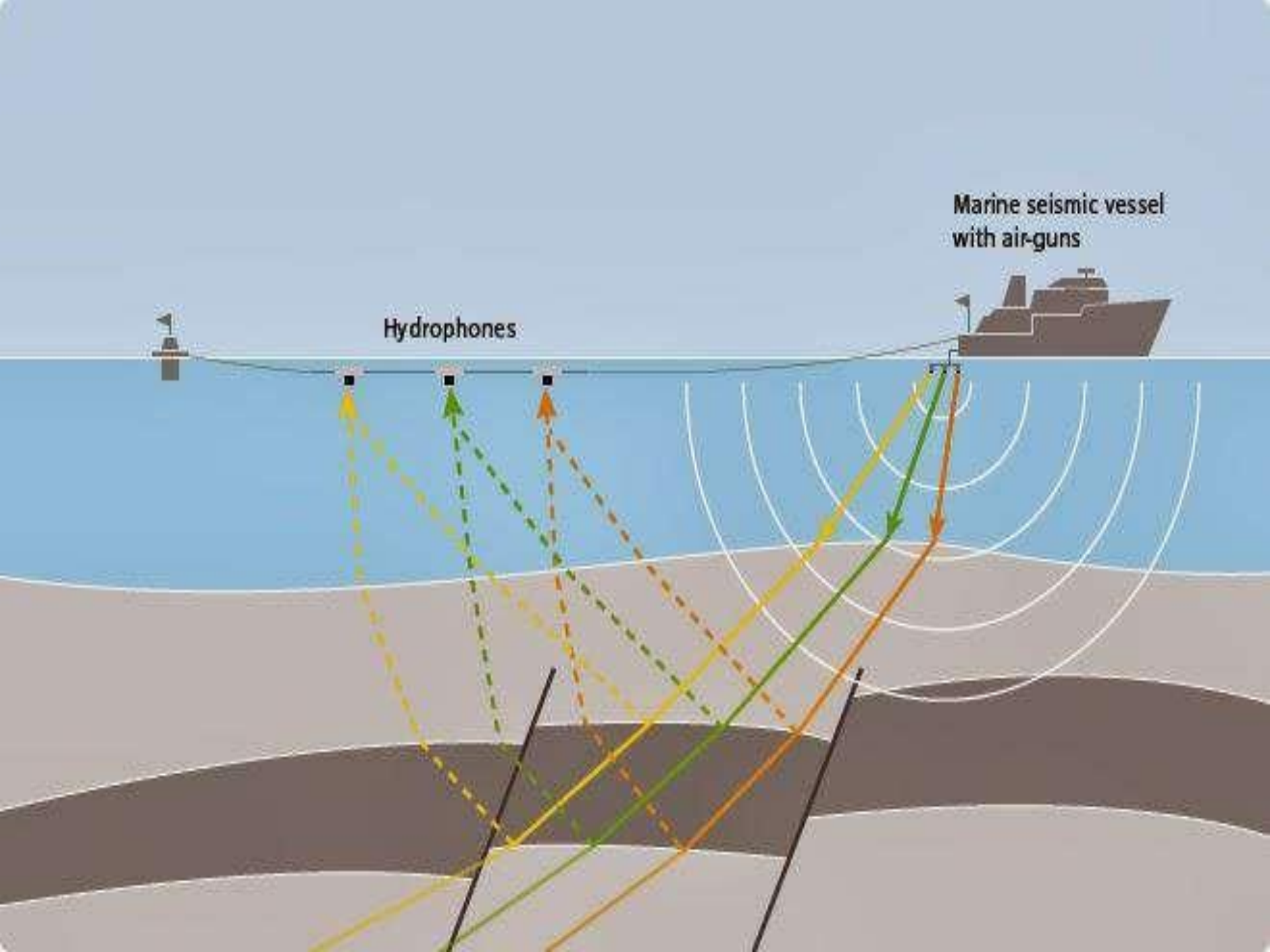
Seismic Method

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.





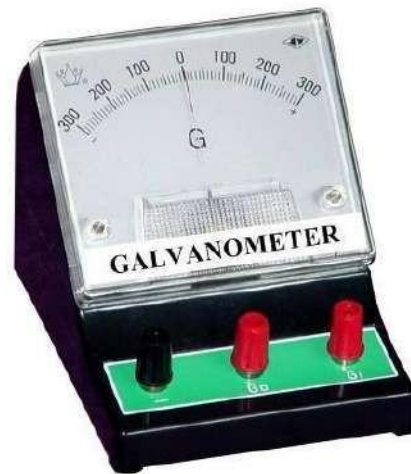


Method

- 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

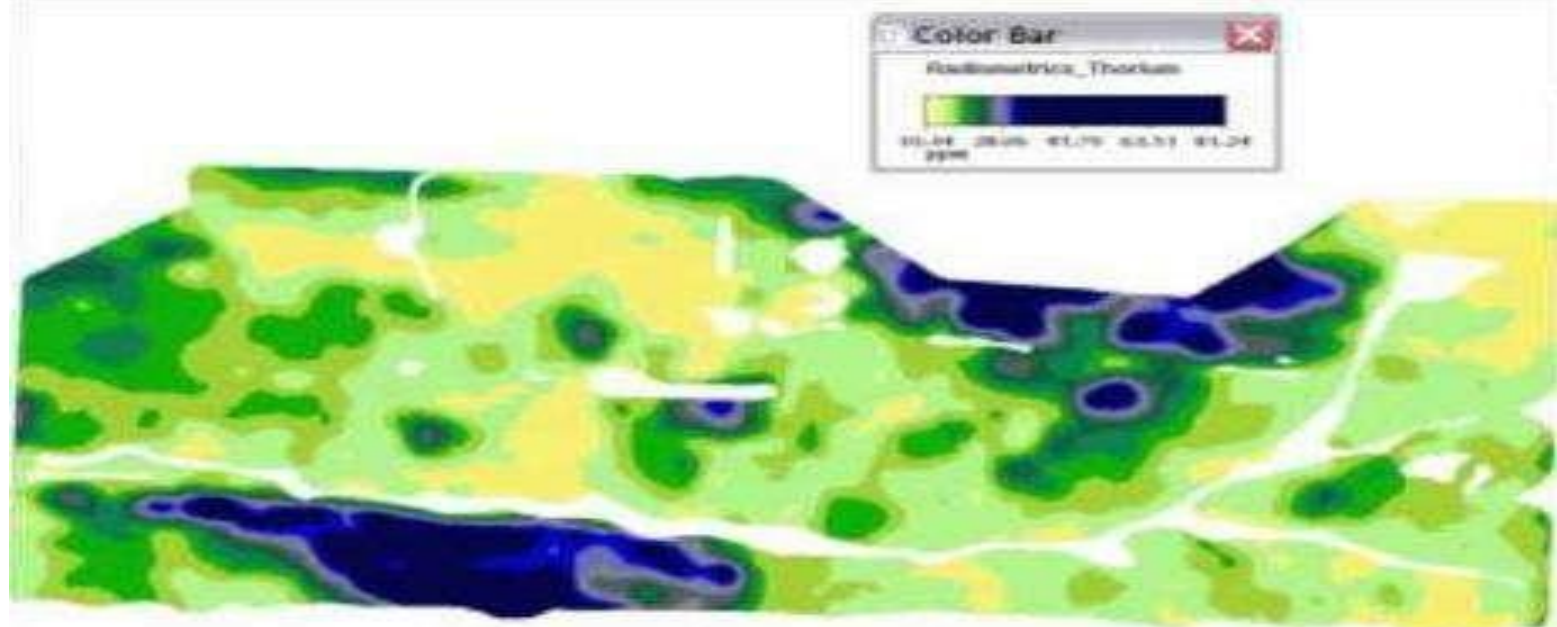
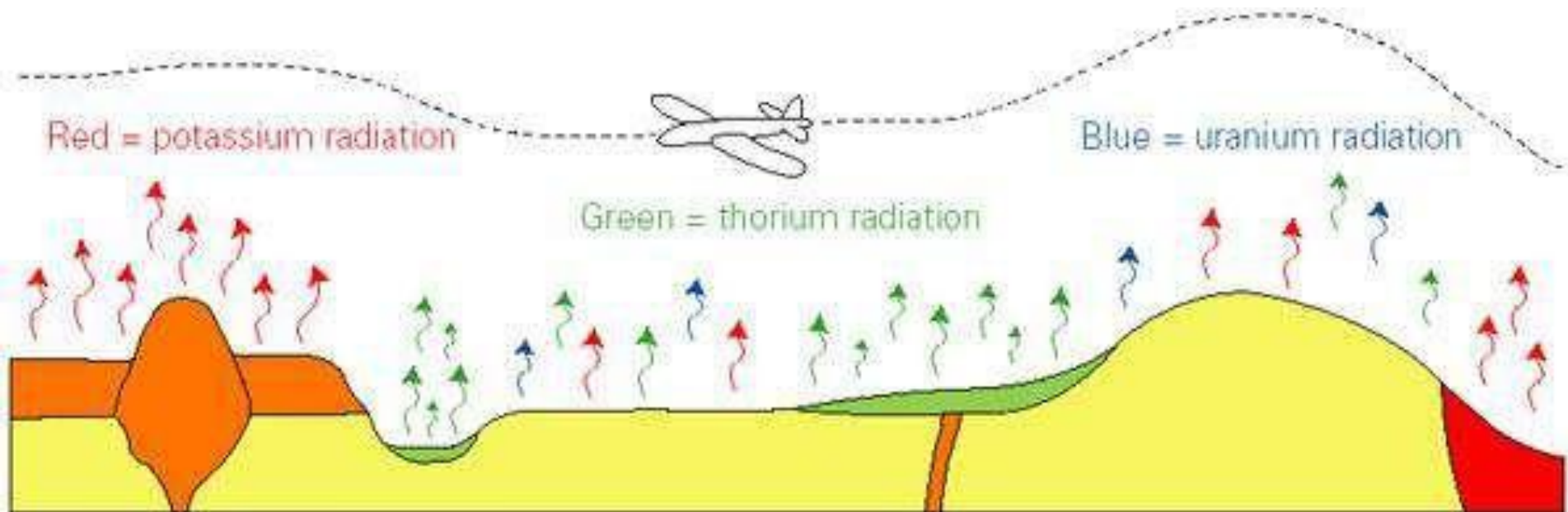
Controlling property: **Natural radioactivity** of rocks.

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

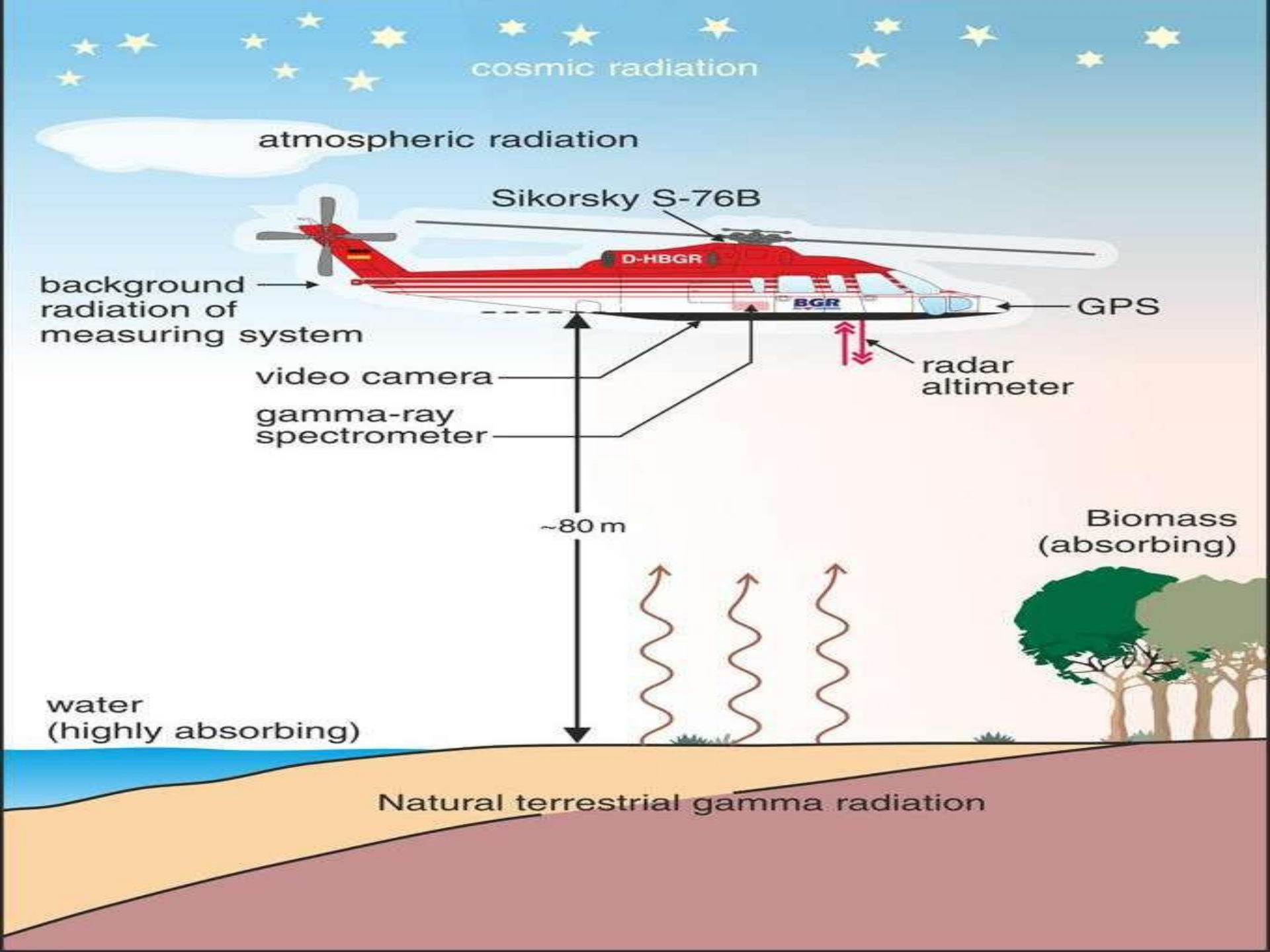
This change is accompanied by emission of radiations known as alpha and beta particles and gamma rays. This phenomenon is known as radioactivity.

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

background radiation of measuring system

GPS

video camera

radar altimeter

gamma-ray spectrometer

~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.

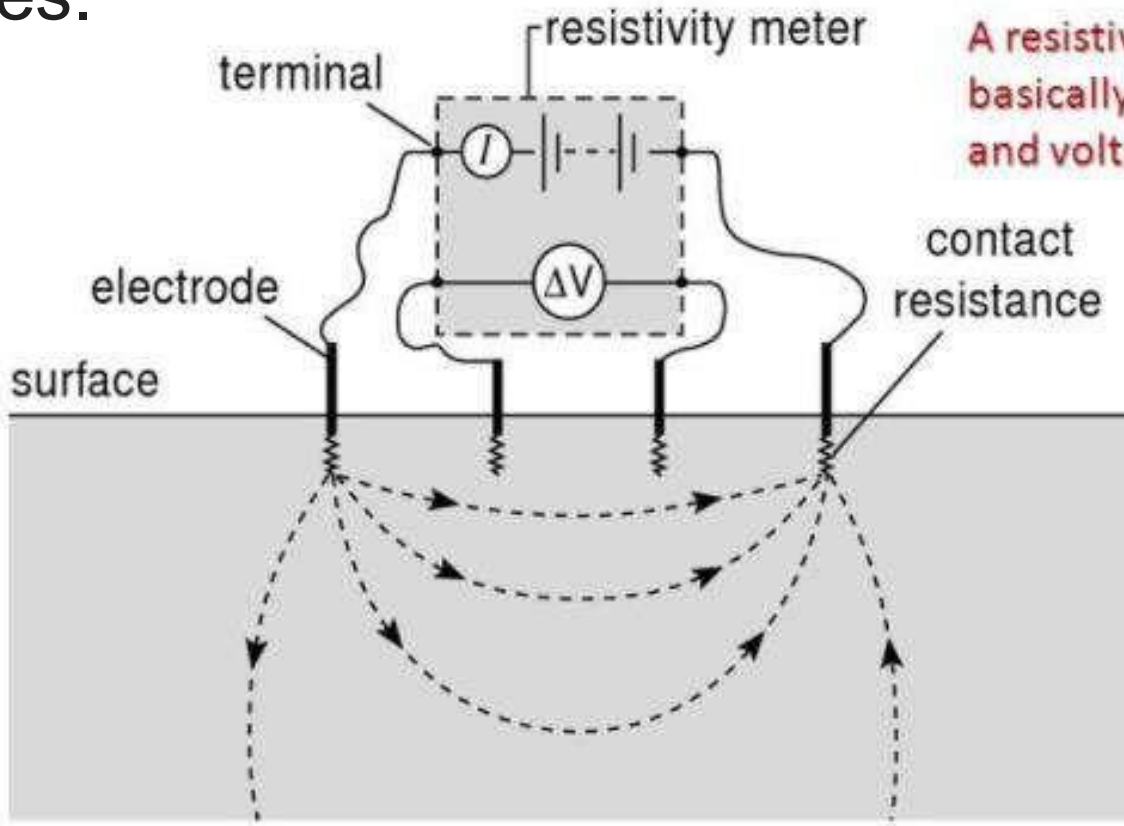
Equipment: for measurement of the temperature on the surface of the earth, in shallow holes or in deep bore holes, thermistor thermometers and platinum resistance thermometers which can achieve an accuracy of 0.01°C are used.

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 through a pair of electrodes.



A resistivity meter is basically a current meter and voltmeter all in one

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



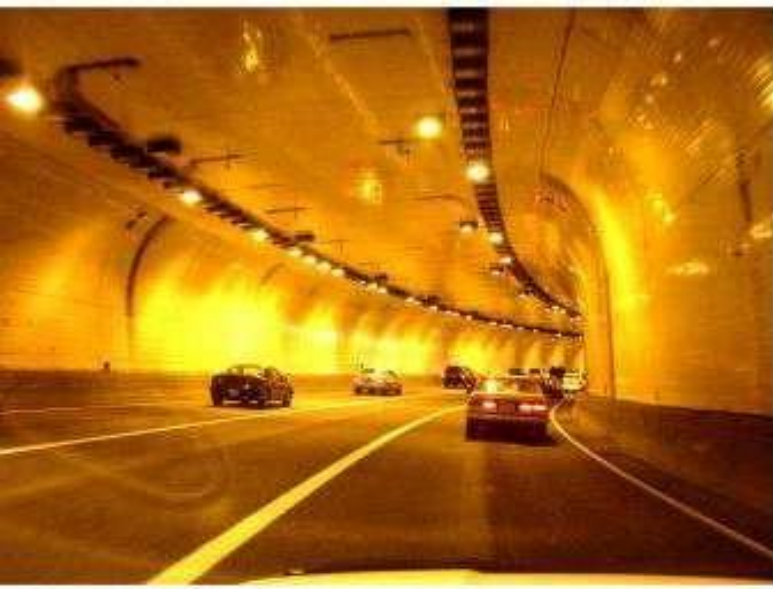
Tunnels are underground passages or passages through hills or mountains used for different purposes. They are made by excavation of rock below the surface or through hills or mountains.

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

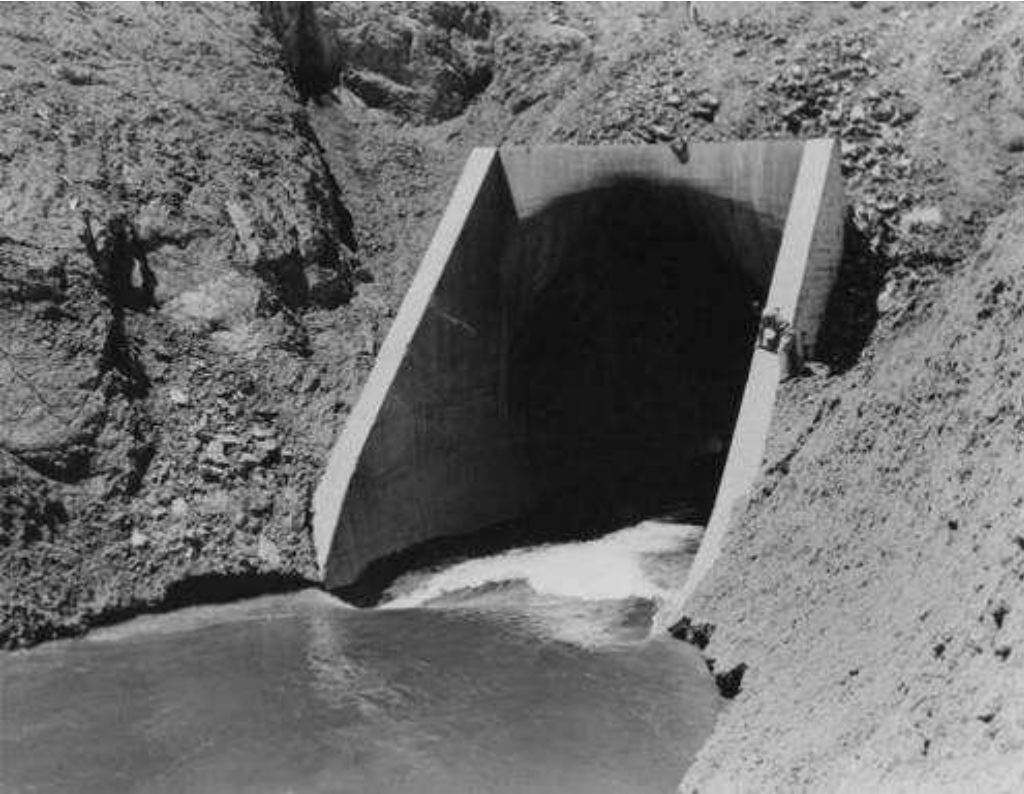


SPEED

200 km/h

124 mph

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.

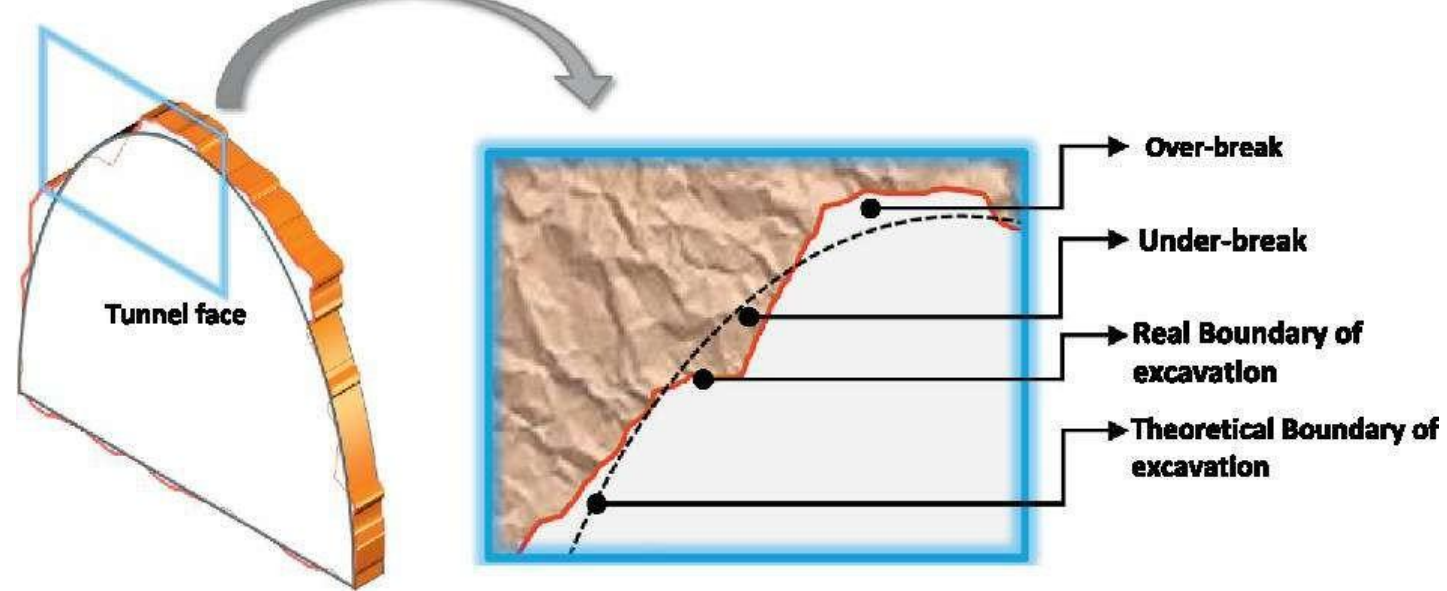
Effects of faults at the tunnel site

- Dislocation and discontinuity in the tunnel alignment is caused.
- If they 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.

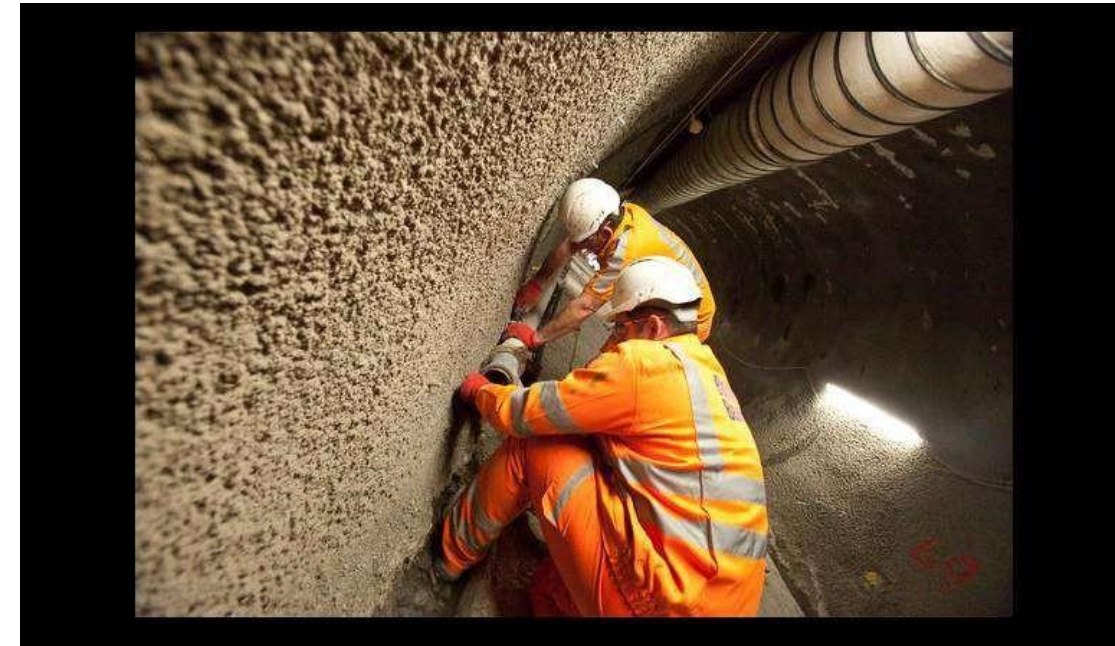
OVER BREAK



Excavations through hard rocks necessarily involve 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.