



Geophysical Investigations



Unit-II





SYLLABUS

- Geophysical methods of groundwater exploration
- Electrical resistivity method, Seismic refraction method, determination of aquifer thickness, determination of top of the sloping aquifer

Geophysical Investigations

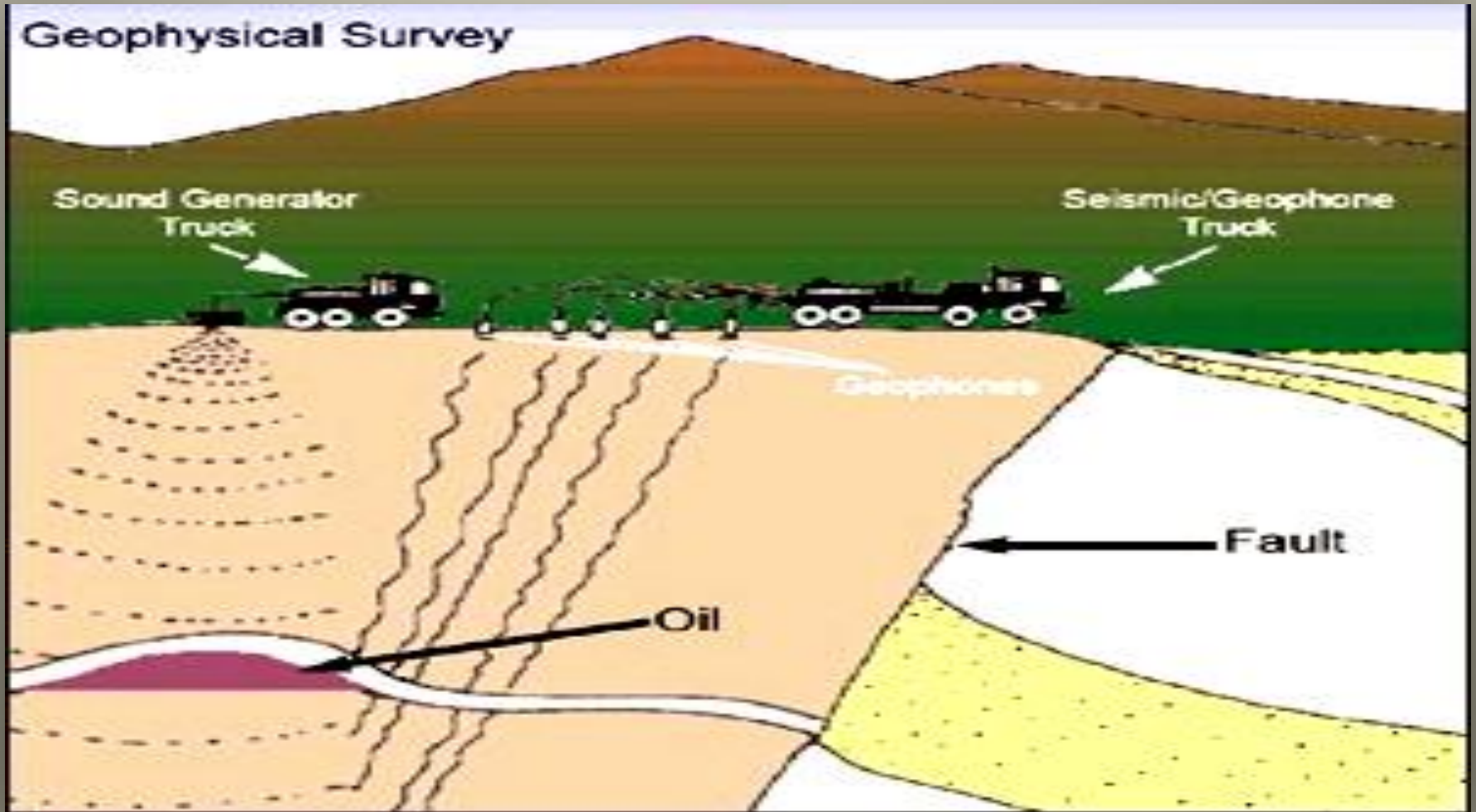
- Geophysical investigations involve simple methods of study made on the surface with the aim of ascertaining subsurface detail. This is achieved by measuring certain physical properties and interpreting them mainly in terms of subsurface geology.



Importance of Geophysical Investigations

- Geophysical methods are gaining importance very rapidly because of their success in solving a vast variety of problems.
- These investigations are carried out quickly. This means large area can be investigated in a reasonable short period and hence time is saved.
- The geophysical instruments used in the field are simple, portable and can be operated easily. This means fieldwork is not laborious.
- Since the work is carried out quickly and only physical observations are made. Without the use of consumables (like Chemicals), it is economical too.

Importance of Geophysical Investigations



Importance of Geophysical Investigations

- Different interpretations to suit different purposes can be drawn from the same field data, for example electric resistivity data can be interpreted for knowing subsurface of rock types, geological structures, groundwater conditions, ore deposits depth to the bed rock, etc. Hence the investigations are multipurpose.

Applications of Geophysical Investigations

- Geophysical explorations are numerous, important and widely varied.
- Investigations aimed in solving problems of **regional geology**.
- Investigations aimed at locating and estimating economically important **mineral deposits**.
- Investigations aimed at locating and assessing **groundwater potential** and its **quality**
- Investigations aimed at solving problems connected with geology.

Classification of Geophysical Methods

- There are many kinds of geophysical methods of investigation. These methods are
- **Gravimetric method**
- **Magnetic method**
- **Electrical method**
- **Seismic method**
- **Radiometric method**
- **Geothermal method**



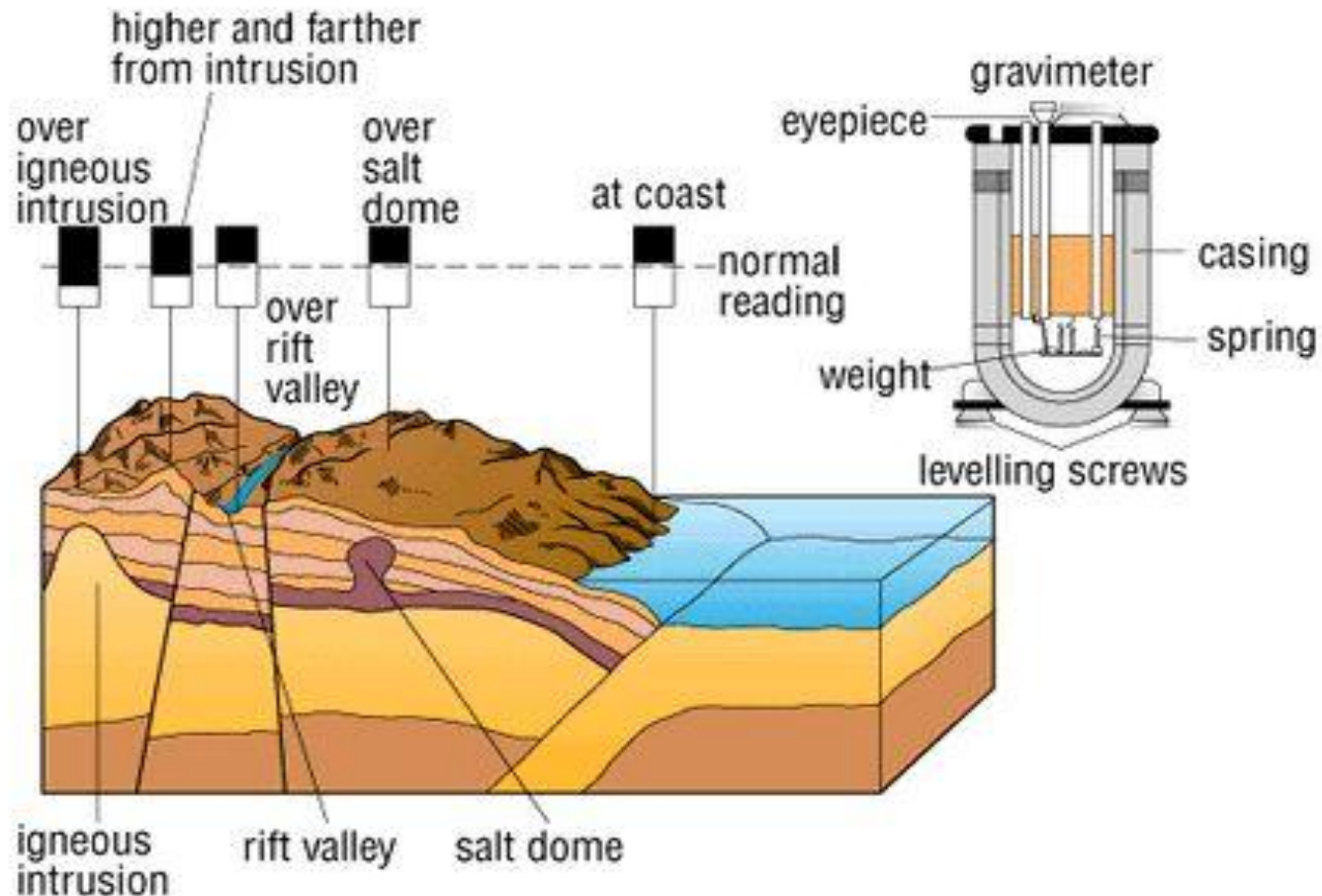
Gravity Methods

- Gravity method represent a set of geophysical methods which make use of the natural gravity field of the earth.
- **Physical Property**
- **Density** of the material is the controlling physical property.
- **Principle**
- In gravimetric method, **the nature of distribution of gravity g on the surface is analyzed.** The gravity is influenced positively if the causative body is heavier, larger and occurs at a shallow depth.
- The **gravimeter, used in relative gravity measurement is a mass loaded spring.** If the subsurface has a relatively heavier body, the gravity pull is more there ($+g$) and the spring extends becoming longer. If the subsurface has relatively a lighter body there the gravity pull is less ($-g$) and the spring contracts and become shorter.

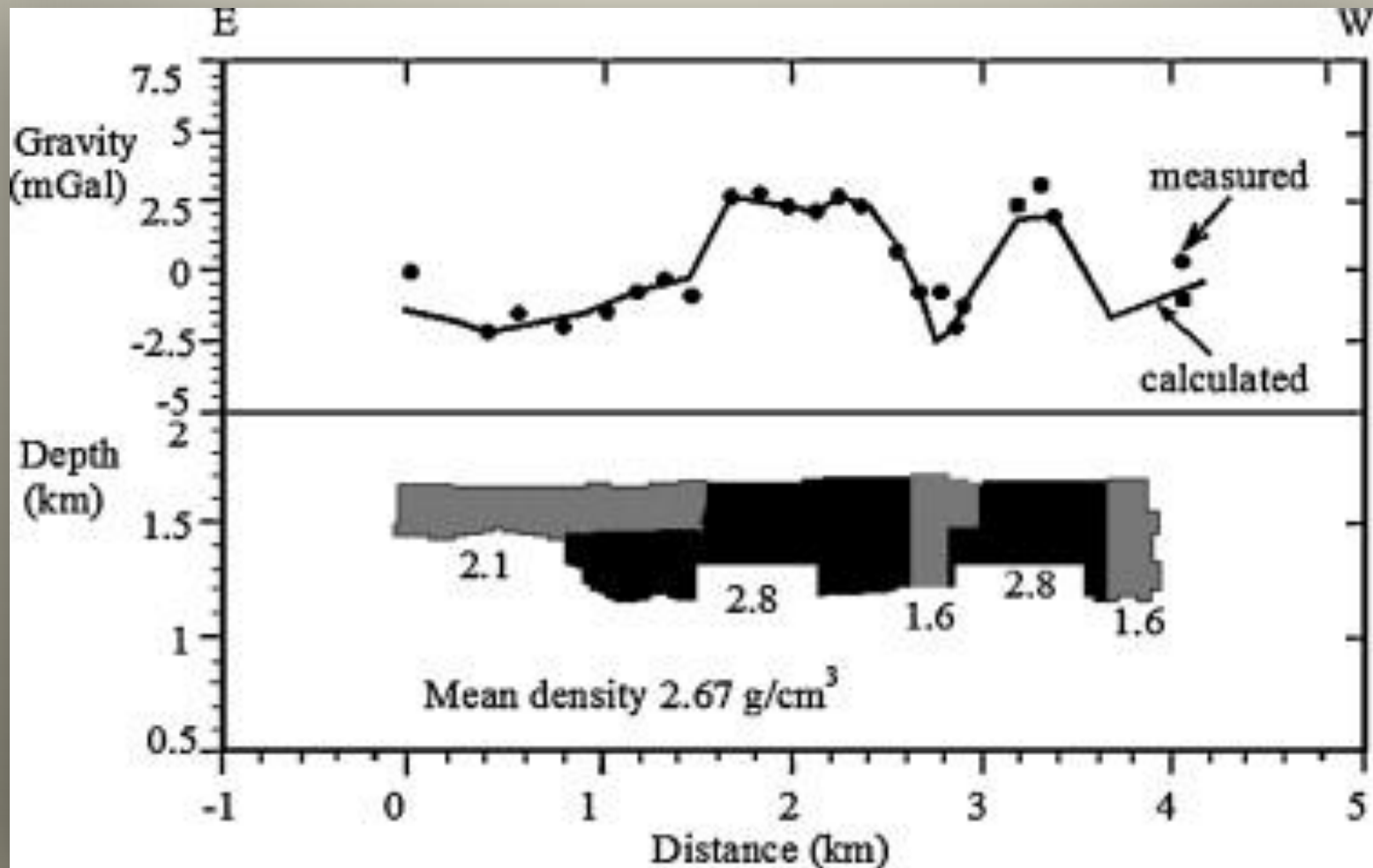
Gravity Methods

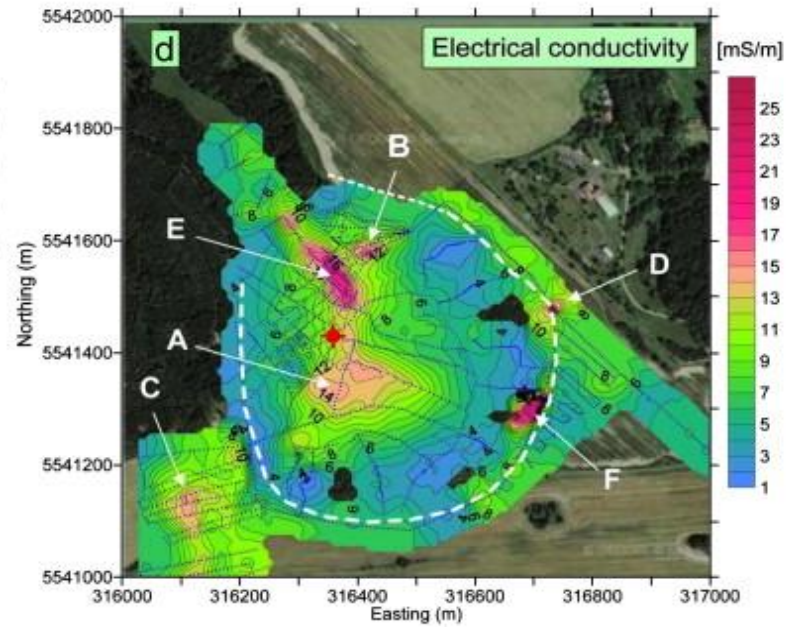
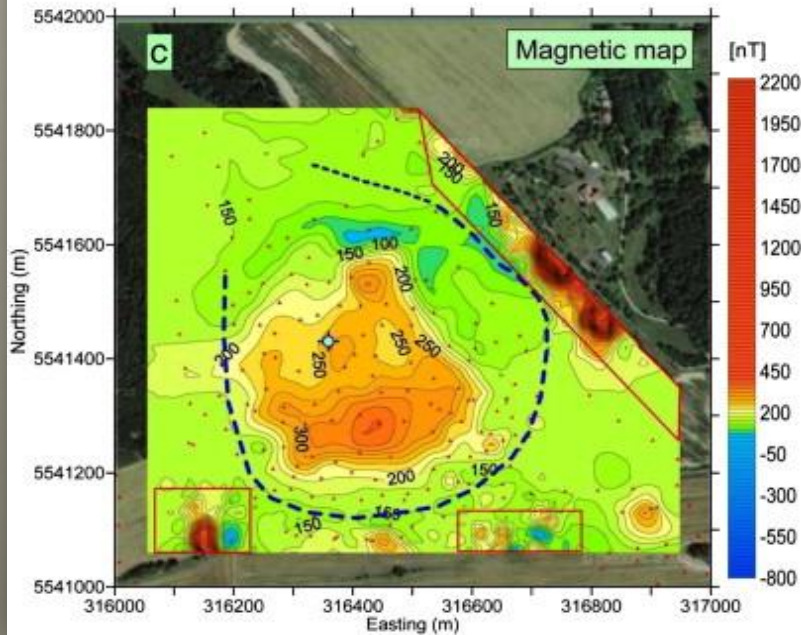
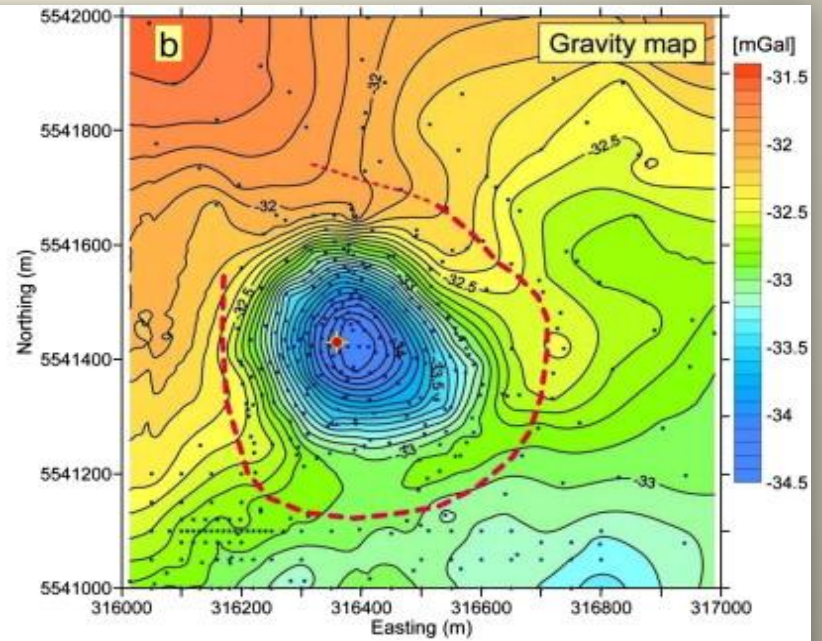
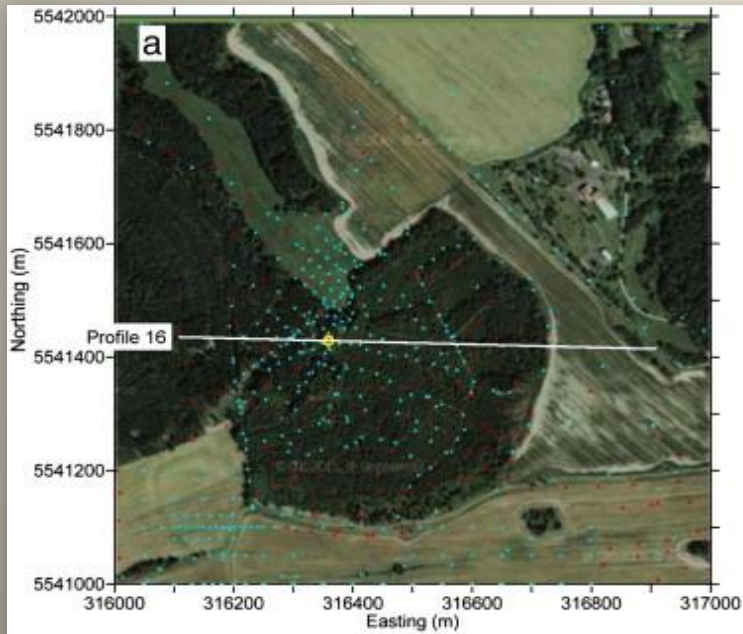


Gravity Methods



Gravity Methods





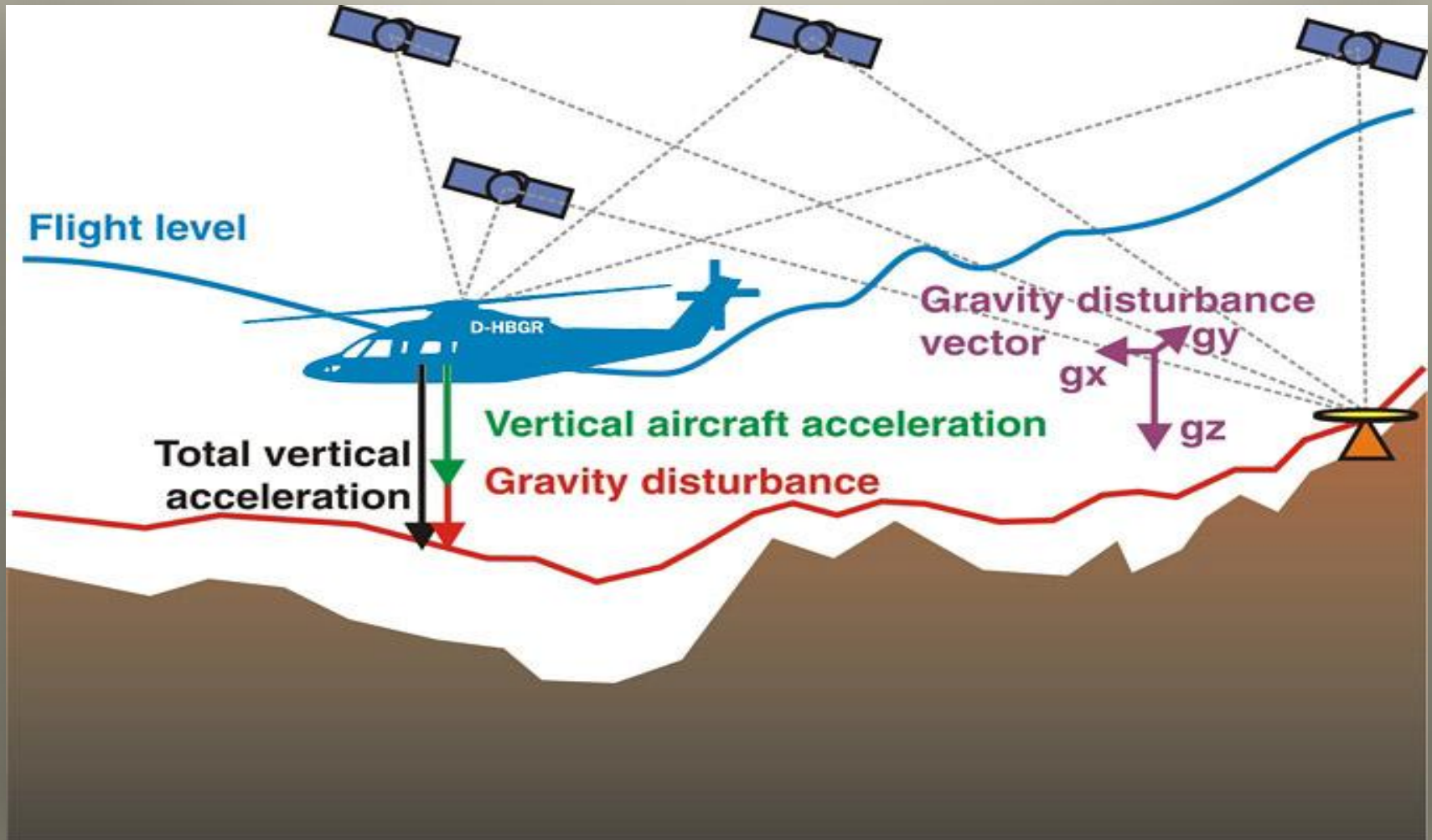
Gravity Methods

- Thus in a particular region, if surface bodies such as (ore deposits, coal seams and salt domes) whose densities are different from the surrounding rocks exist, the gravity field deviates from the normal value then expected from this deviations it is possible to locate the **inhomogeneous bodies** in the surface.

Gravity Investigations

- Gravity investigations are useful in
- Exploration of ore deposits
- In solving regional geological problem
- In exploration of oil and natural gas deposits
- In solving some engineering problems
- Gravity investigations are carried out always during oil and gas investigations because of their special success in that area.
- In case of engineering problems, mapping of dam sites, earthquake problems, tracing buried river channels gravity method are considerably useful.

Gravity Investigations



Magnetic Methods

- Like gravity methods, these investigations also take advantage of natural magnetic field associated with the earth and its relation to subsurface geology.

Controlling property

- The main controlling physical property in magnetic method is **magnetic susceptibility**.

Principle

- The magnetic methods are based on the fact that the magnetic bodies present in the earth's surface contribute to the magnetic field of the earth.
- In general, when the **magnetic field** of the earth or one of its components is measured on the surface, bodies possessing magnetic moments different from those of the surrounding rocks contribute to the deviations in the measured quantities. From the **magnetic anomalies**, it is possible to locate anomalous objects.

Magnetic Methods

- The different parameters measured during magnetic investigations are total **magnetic field** (intensity and direction) and **different space components**
- Magnetic surveys have a certain inherent limitations. Hence for unique and accurate solutions, magnetic prospecting is often carried out along with the **gravity or other methods**.



Magnetic Methods

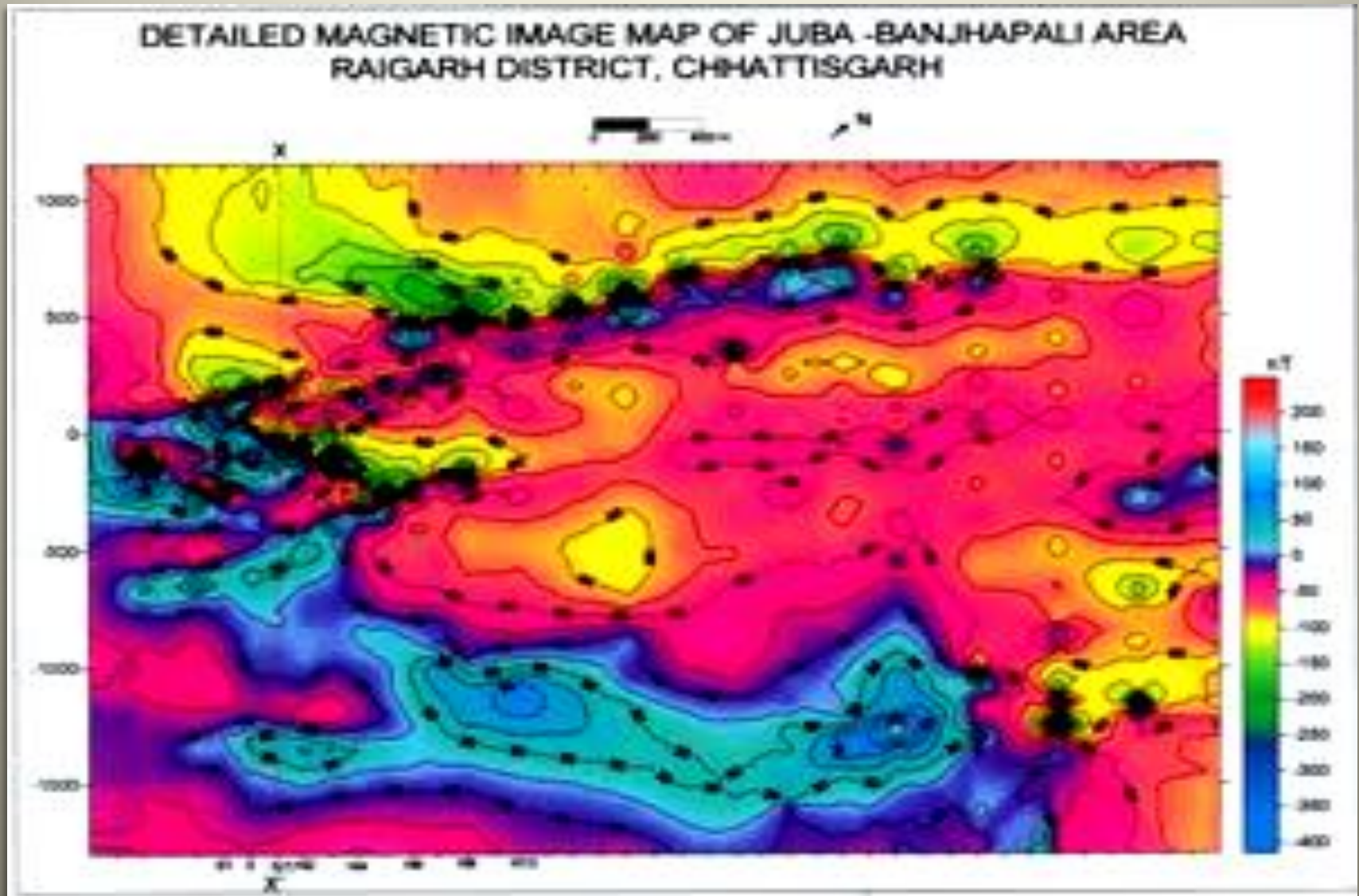


Magnetic Methods

Application of magnetic investigations

- For delineation of large structural forms favorable for the accumulation of oil and gases.
- For detection of and location of faults.
- For locating strongly magnetic iron ores.
- By virtue of their inexpensive nature and easy operation, magnetic methods are widely used for detection of ore deposits, geological structures.

Magnetic Methods



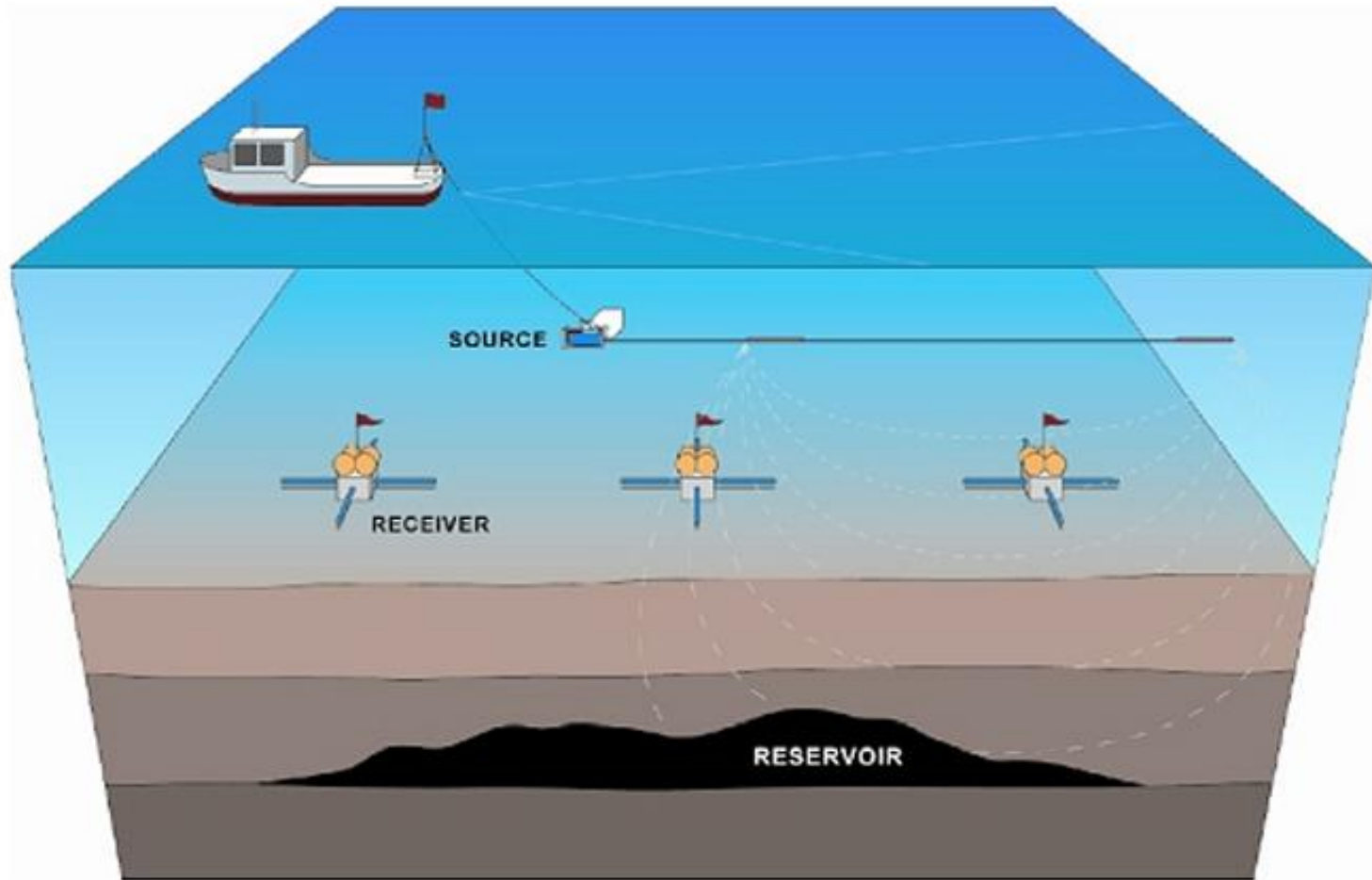
Electrical Methods

- Among the methods different geophysical
- Methods electrical method are numerous and more versatile, They are more popular because they are successful in dealing with a variety of problems like groundwater studies, subsurface structure, and many others.

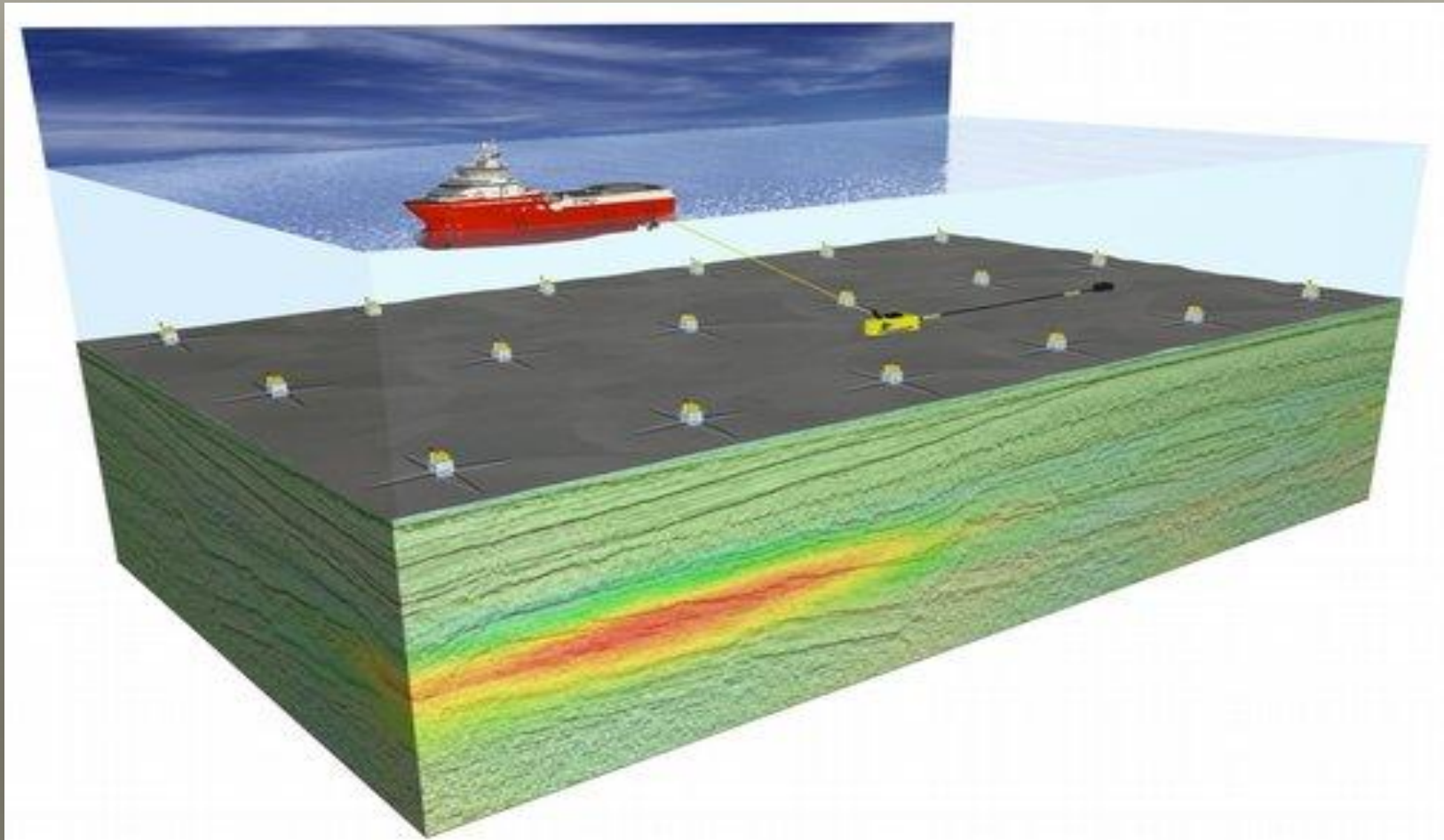
Controlling Properties

- In electromagnetic methods, electrical conductivity, magnetic permeability and dielectric constant of subsurface bodies are the relevant properties.

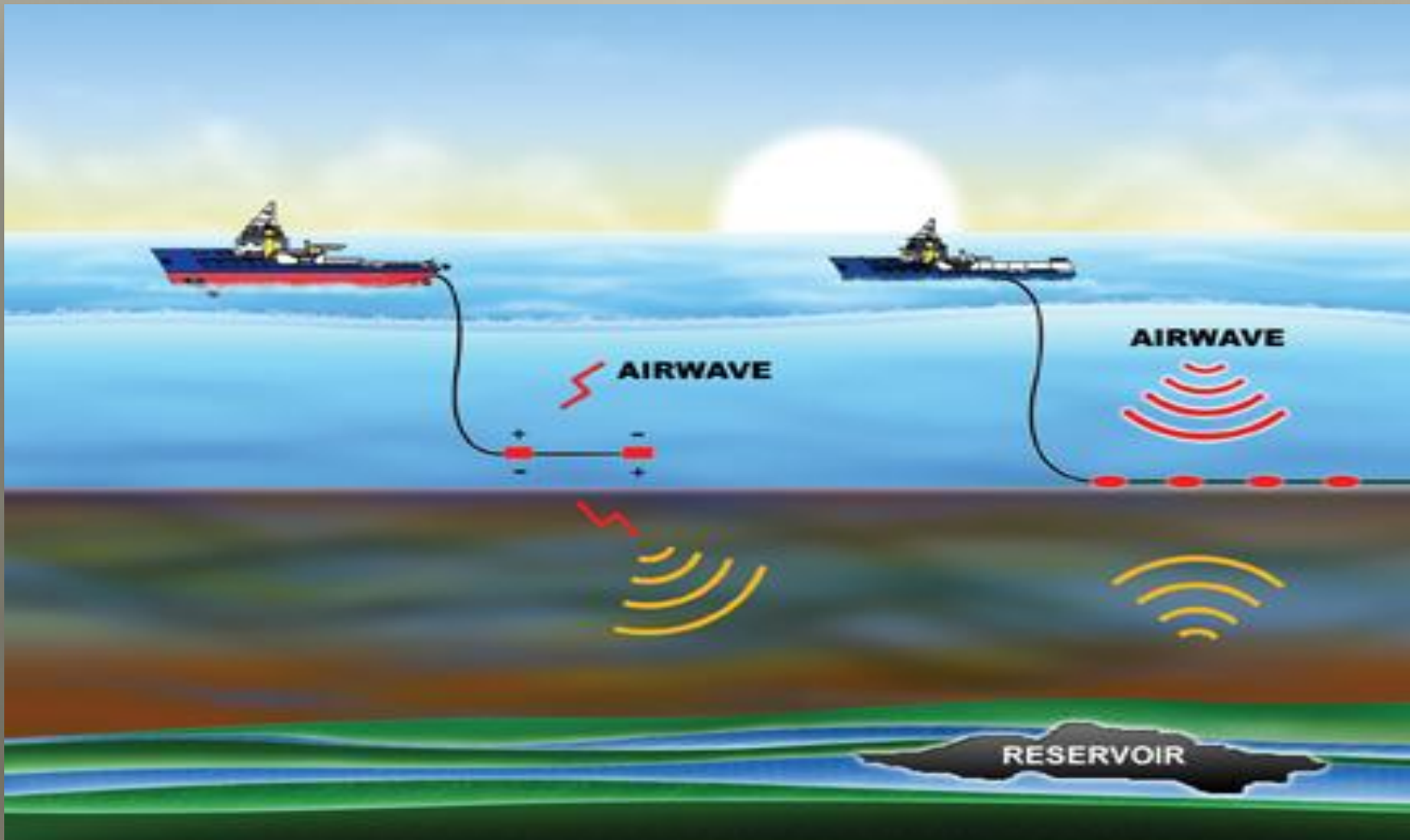
Electrical Methods



Electrical Methods



Electrical Methods



Electrical Methods

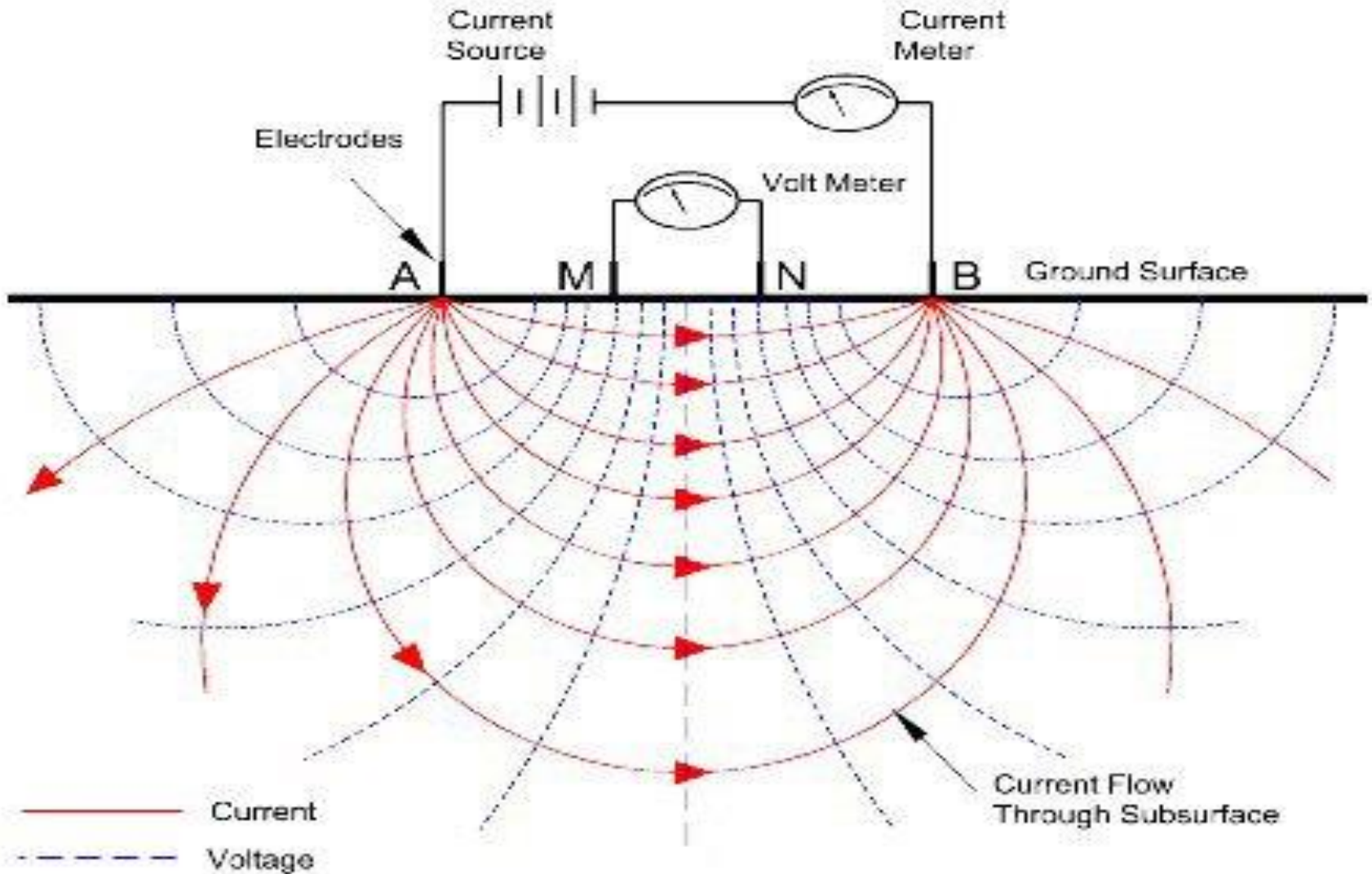
Principle

- Electric methods are based on the fact that the subsurface formation, structures, ore deposits, etc. possess different electrical properties. These differences are investigated suitably and exploited to draw the necessary conclusion.

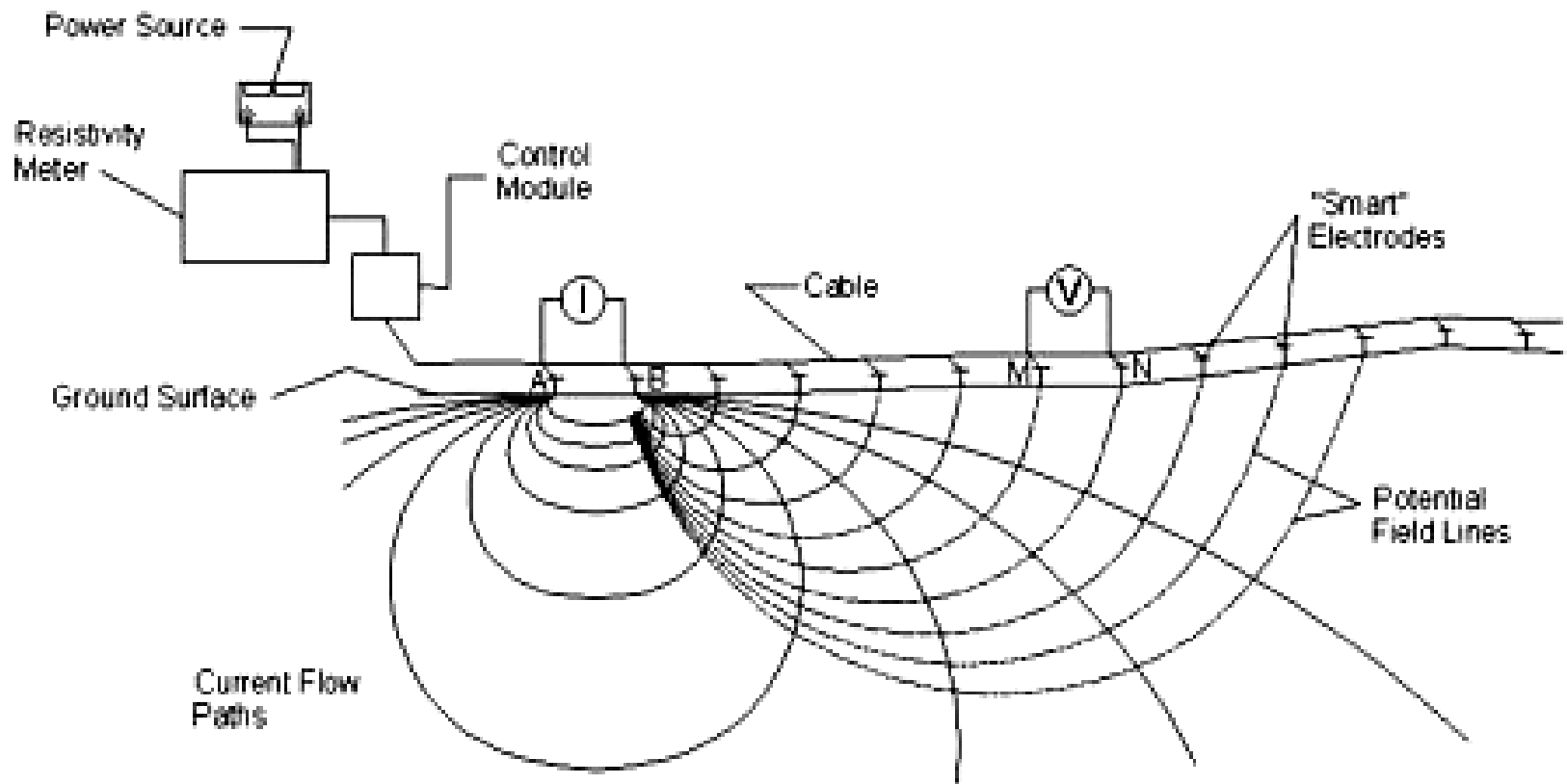
Electrical methods

- Electrical resistivity methods, electromagnetic methods, self-potential methods and induced polarization methods are the very important categories of electrical methods.

Electrical Methods

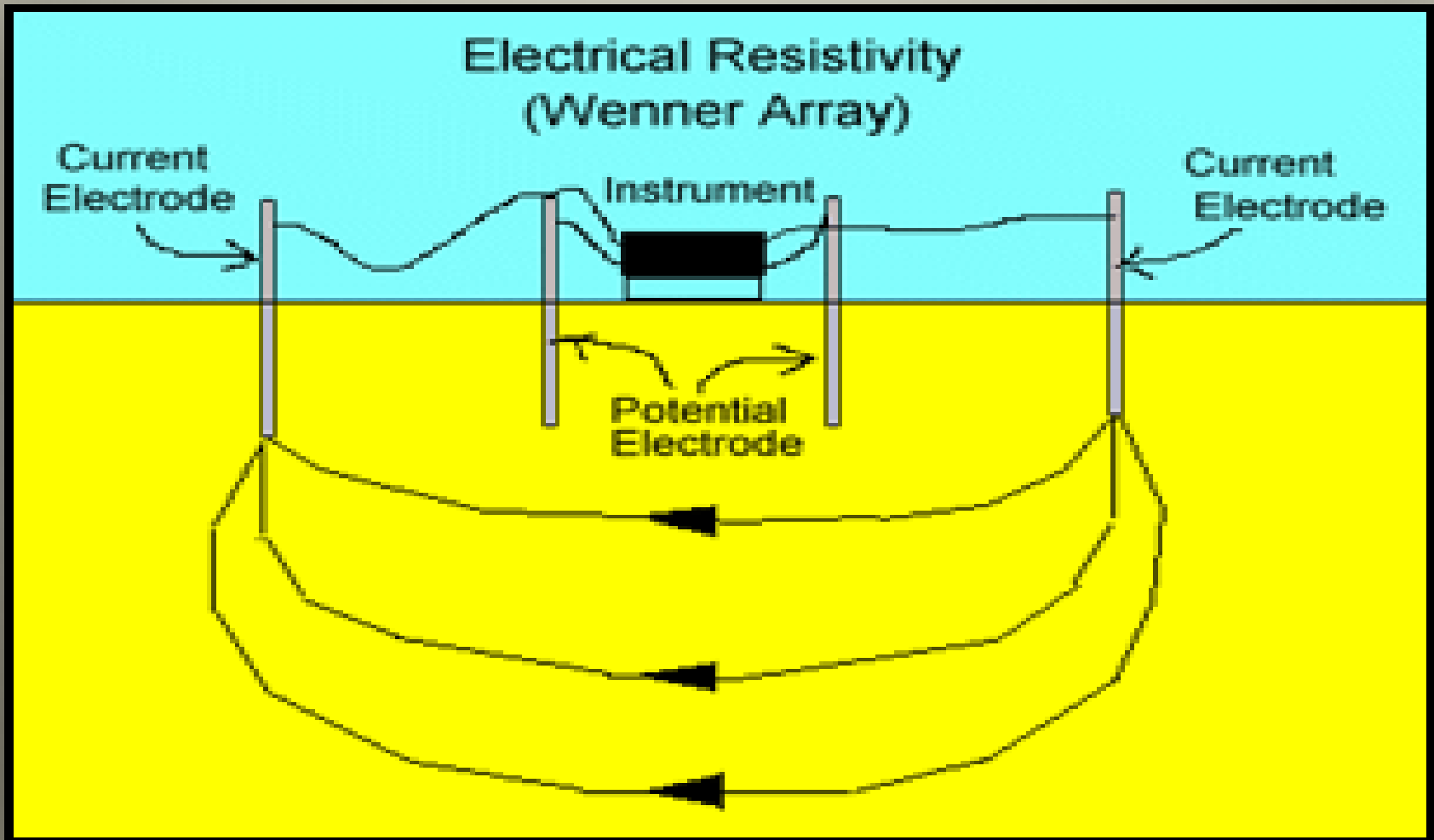


Electrical Methods



"DIPOLE-DIPOLE" ARRAY

Electrical Methods



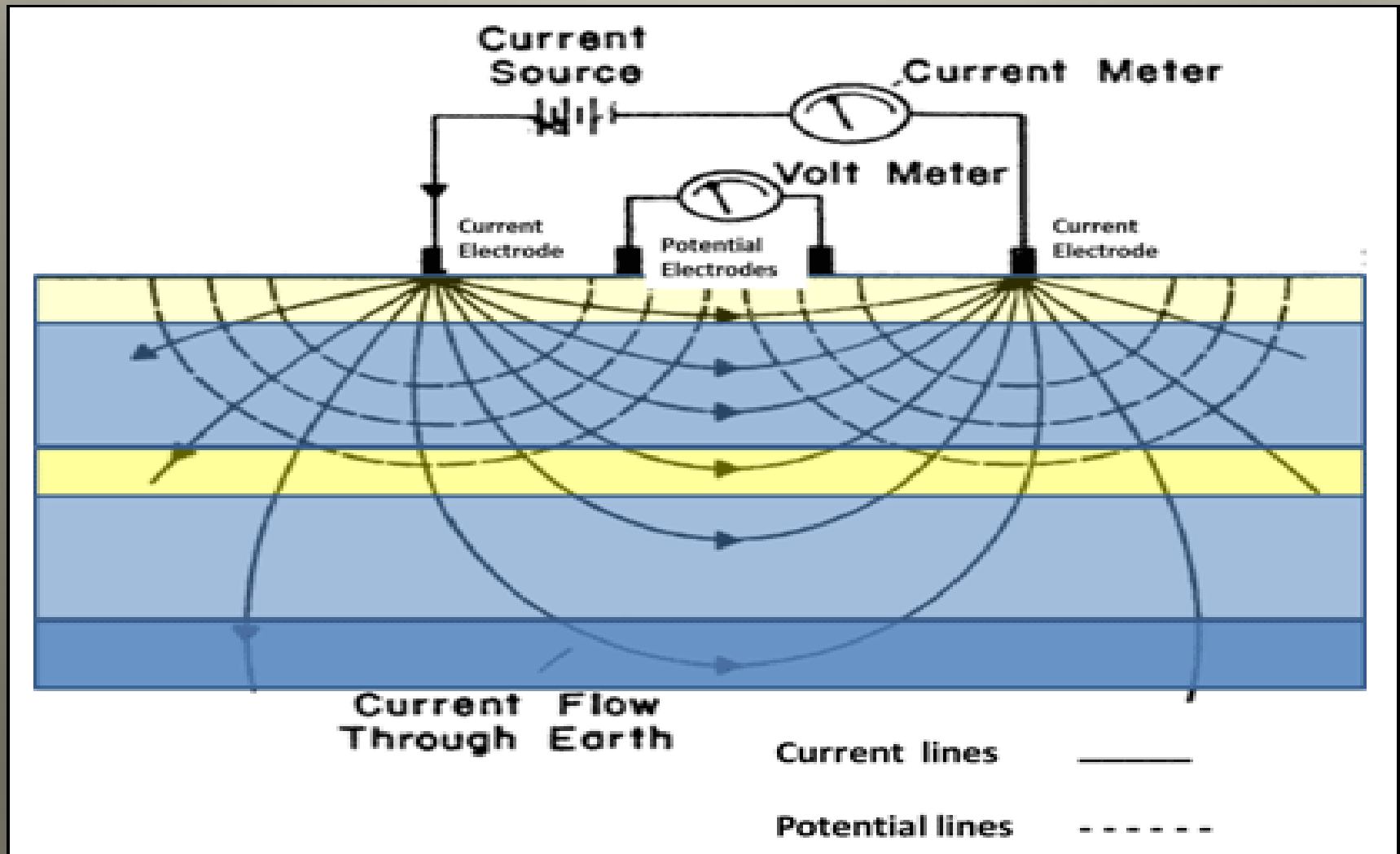
Electrical Methods

- **Electrical Resistivity Method**
- **Principle**
- The electrical resistivity's of subsurface formation vary from one another if they are inhomogeneous and are studied with the help of resistivity method. In the case of a **resistive subsurface body**, current lines move away from it and in the case of a **conductive subsurface body**, the current lines move towards it.

Electrical Resistivity method

- **Profiling and Sounding** are two types of resistivity investigations. **Profiling is done to detect lateral changes in resistivity.** This throws light on the change in the **subsurface lithology** or structure from place to place.
- Sounding is done to determine the **vertical changes in resistivity.** In other words, this study reveals changes in lithology, etc. at a particular place with increasing depth.

Electrical Resistivity method



Seismic Methods

- **Controlling Properties**
- **Elastic property differences** in rocks is the controlling property.
- **Principle**
- Seismic method of study is based on the principle that subsurface rock formations bear **different elastic properties**. Because of this, the velocities of propagation of seismic waves through the subsurface layers of earth, suffer reflection or critical reflection arrive at the surface of the earth where they are detected by geophones. From the time taken by the waves to travel through the subsurface formation and from the seismic wave velocities of the media. **It is possible to determine the depth of various elastic boundaries.**

Seismic Methods

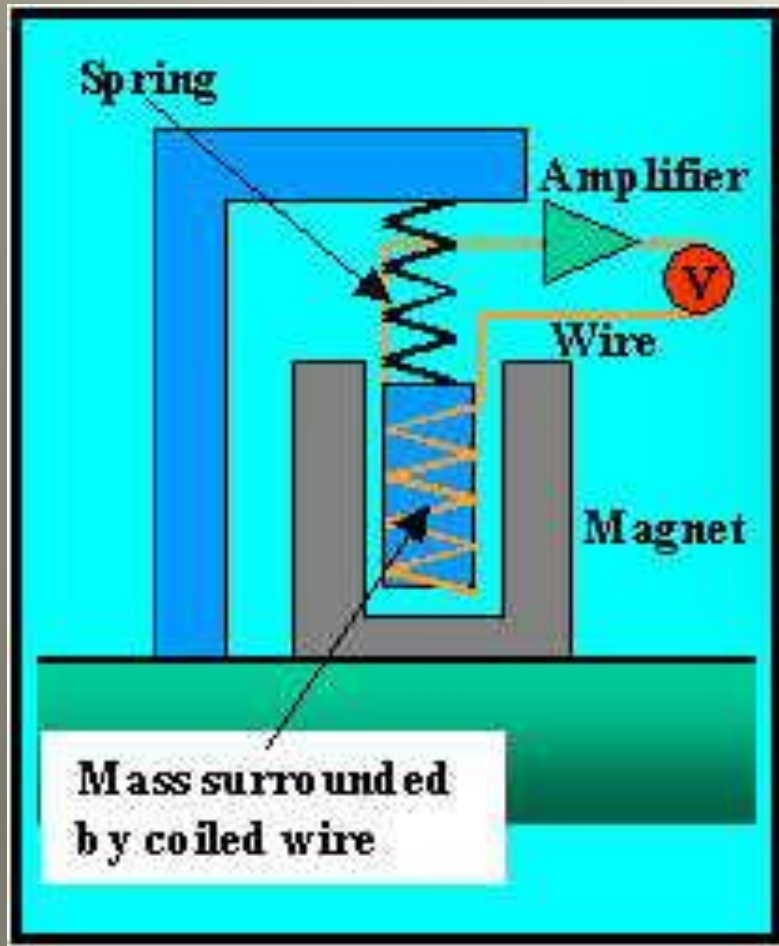
- With the help of **geophones** fixed at suitable intervals on the ground, the different seismic waves reaching the surface are recorded and from the times of their arrival, time –distance curves are constructed. **The direct waves are the first to reach the geophones** placed between point and the distance beyond the point is called the **critical distance**.

Seismic Methods

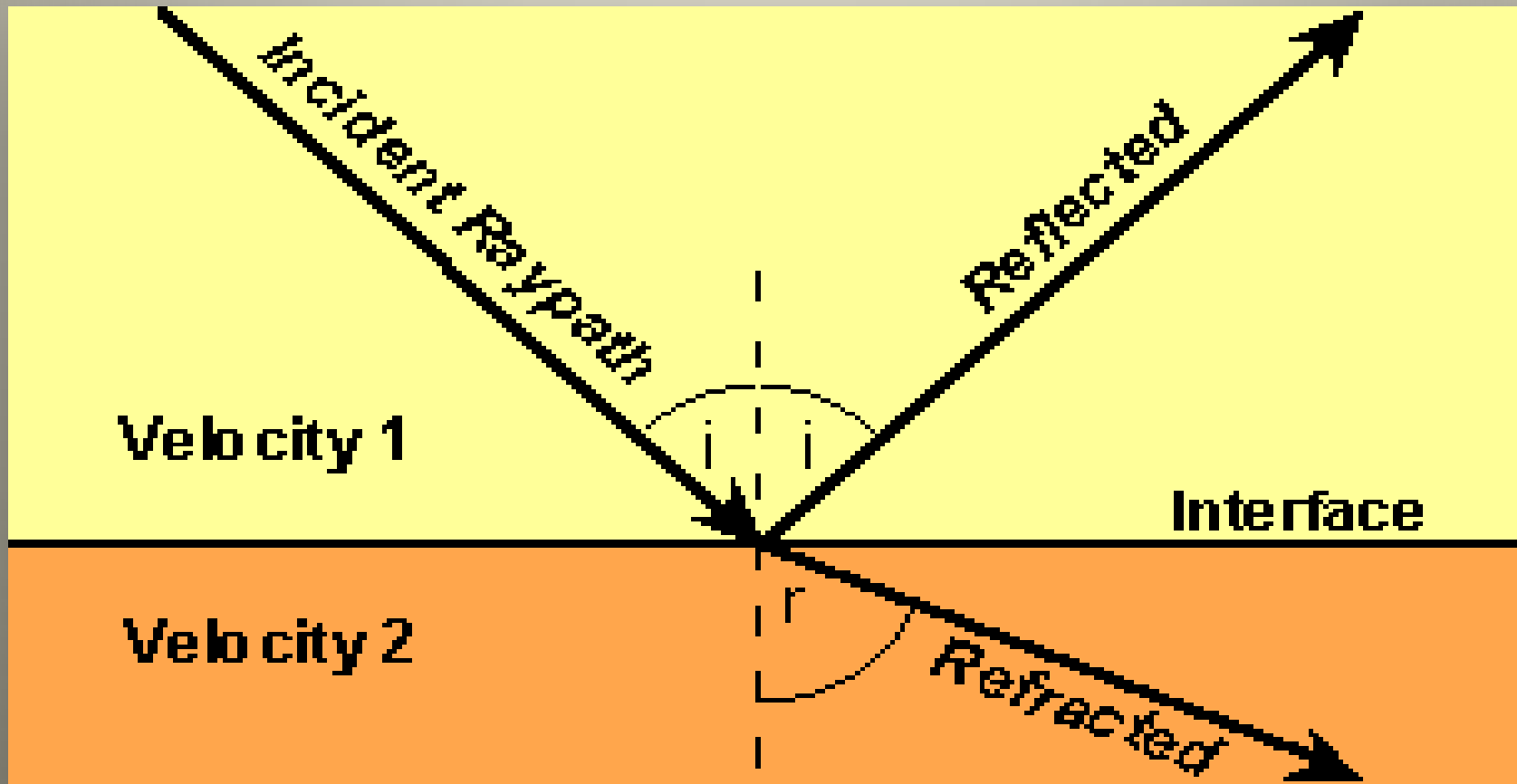
- Depending upon whether **reflected waves** or **refracted waves** are used in the investigation, there are two types of methods, namely, **seismic reflection method** and **seismic refraction method**.
- A geophone an amplifier and a galvanometer are the basic units required for reflected or refracted wave registrations.

Seismic Methods

- **Seismic refraction studies** are effective for depths more than 100m but are **not suitable for shallow exploration**
- Refraction methods are employed for investigating depths from close to the surface to several kilometer deep. These methods are also followed for the investigation of deeper crust under seismic studies.
- Shallow seismic refraction have found effective application in investigating the suitability of foundation sites for civil engineering structures.

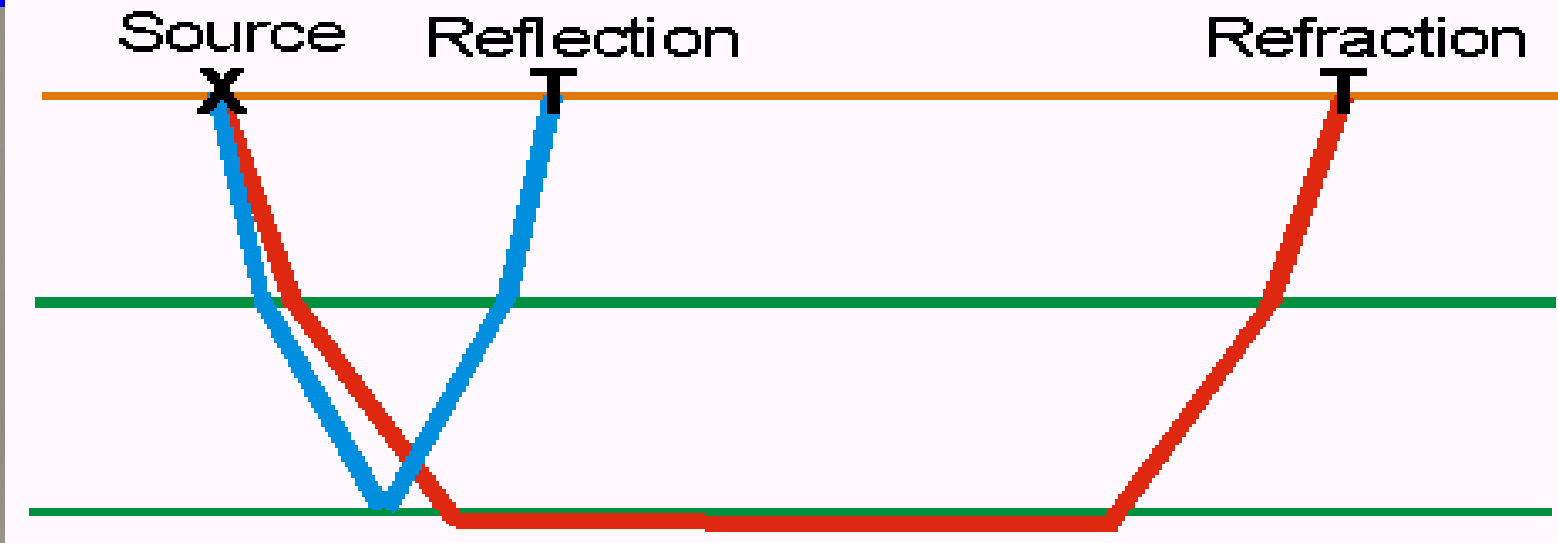


Geophone



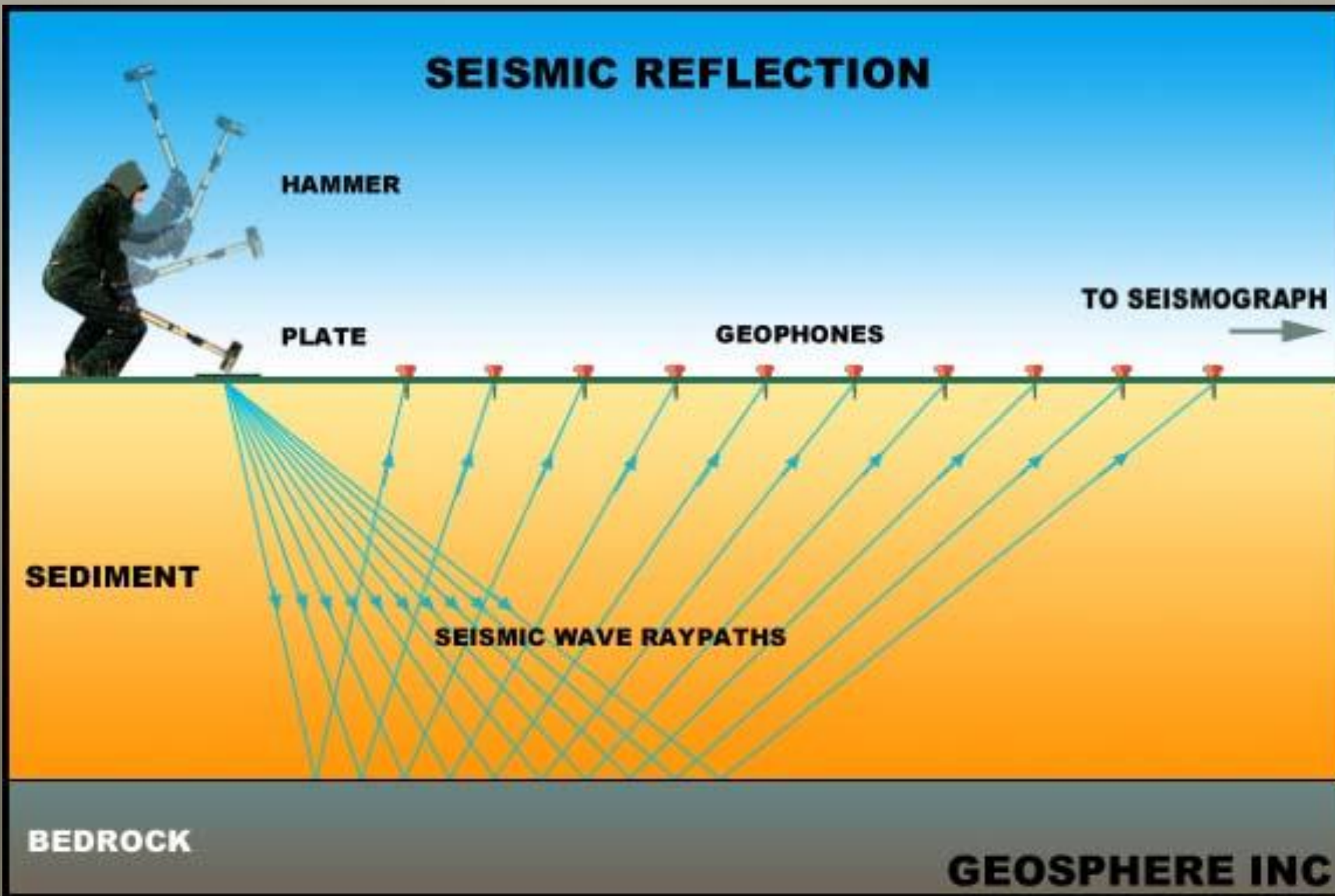
Reflection and refraction of P or S ray paths (and associated wavefronts which are perpendicular to ray paths)

Refraction Vs. Reflection



- **Seismic Refraction:** the signal returns to the surface by refraction at subsurface interfaces, and is recorded at distances much greater than depth of investigation
- **Seismic Reflection:** the seismic signal is reflected back to the surface at layer interfaces, and is recorded at distances less than depth of investigation

SEISMIC REFLECTION



SEDIMENT

BEDROCK

GEOSPHERE INC

SEISMIC REFRACTION



HAMMER

PLATE

GEPHONES

TO SEISMOGRAPH



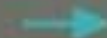
SEDIMENT

SEISMIC WAVE RAYPATHS

BEDROCK



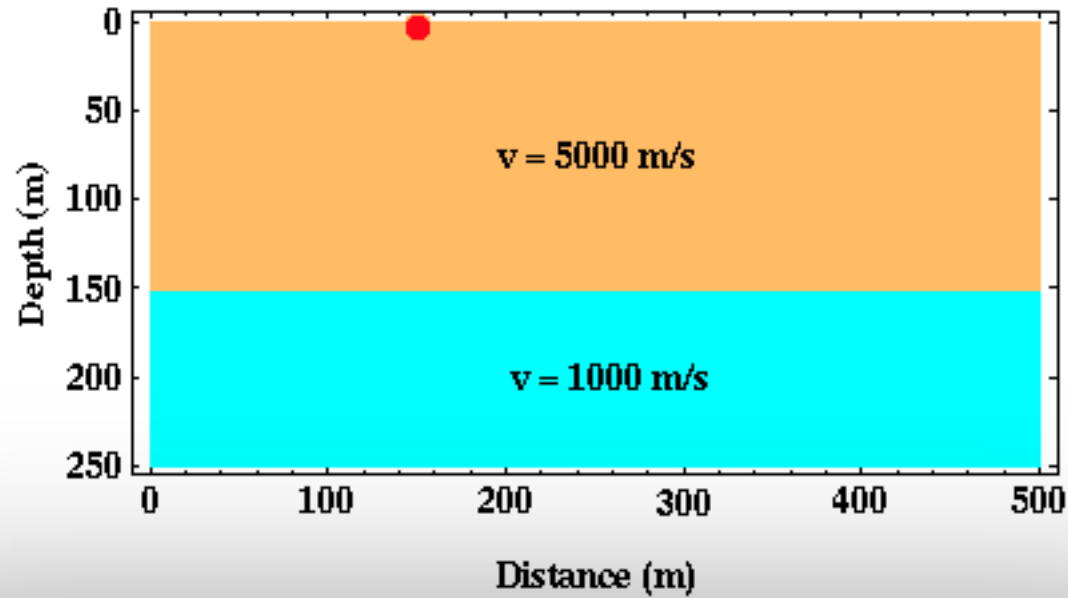
DIRECT WAVE



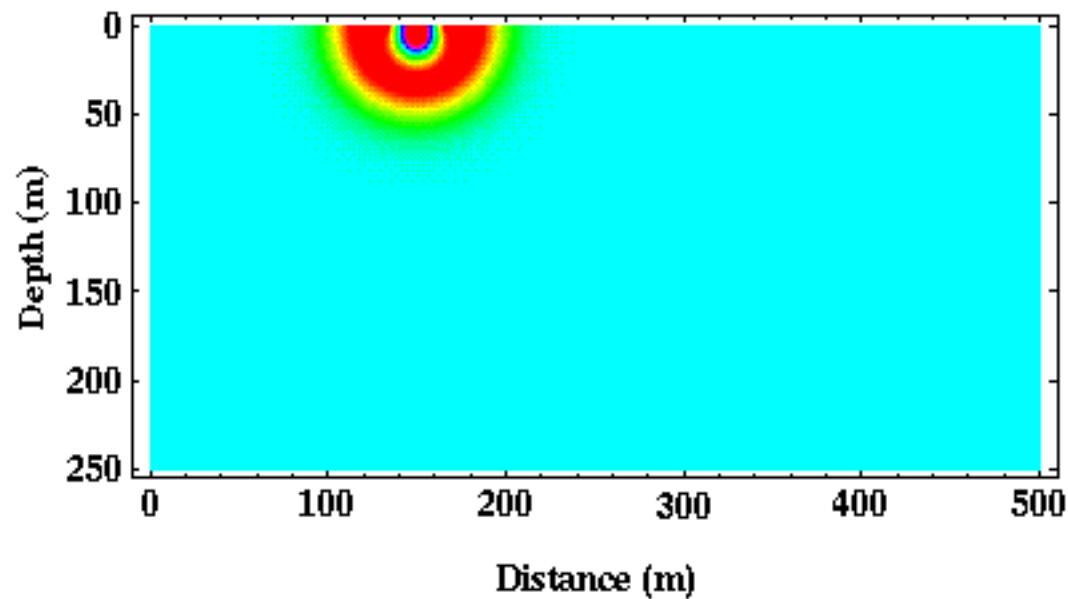
REFRACTED WAVE

GEOSPHERE INC

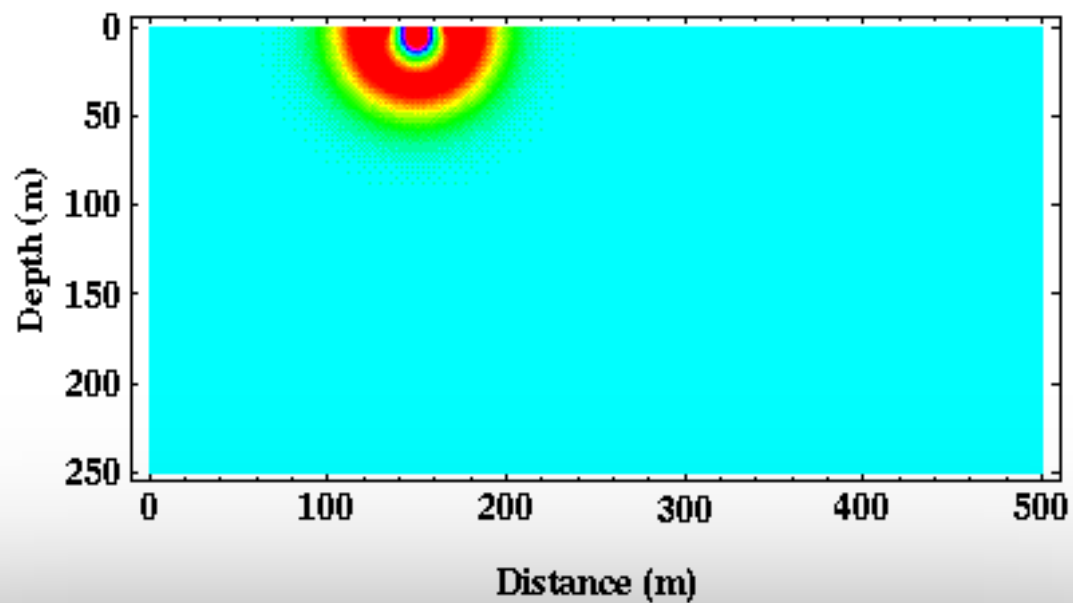
Velocity Model



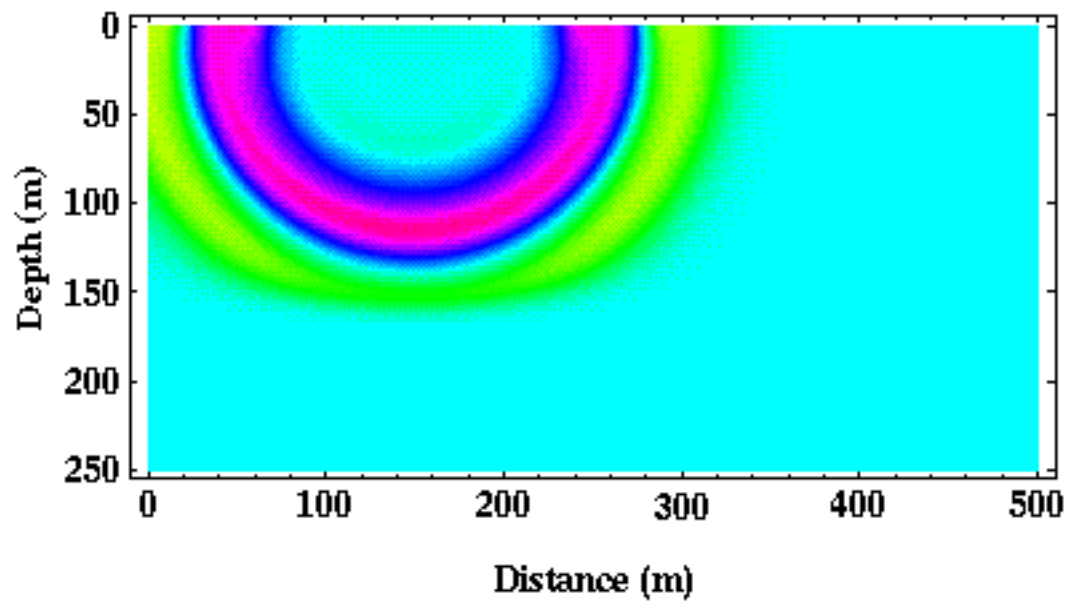
Time = 25 ms



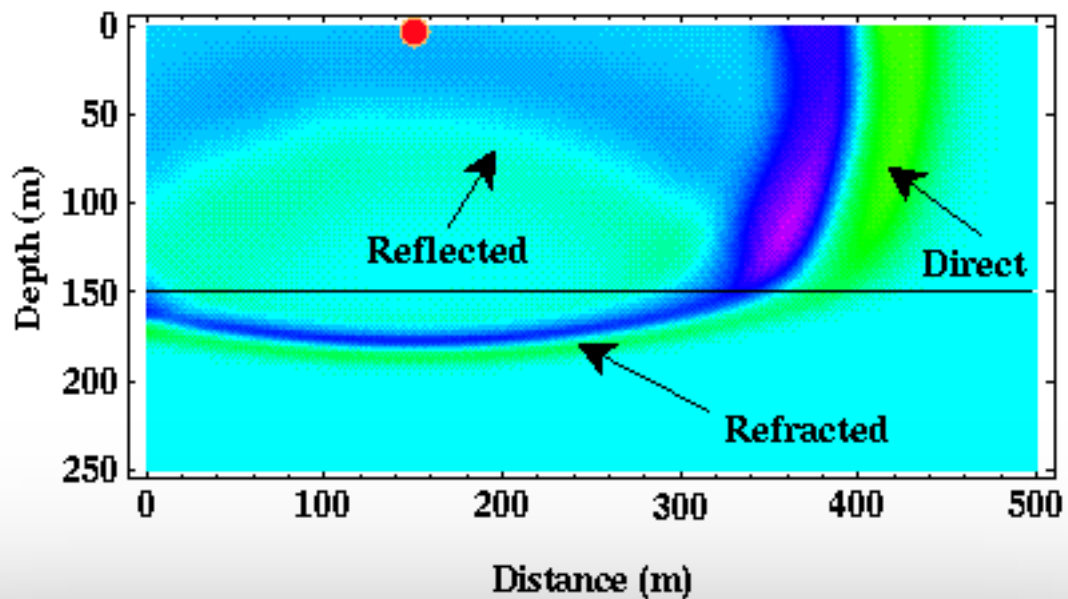
Time = 25 ms



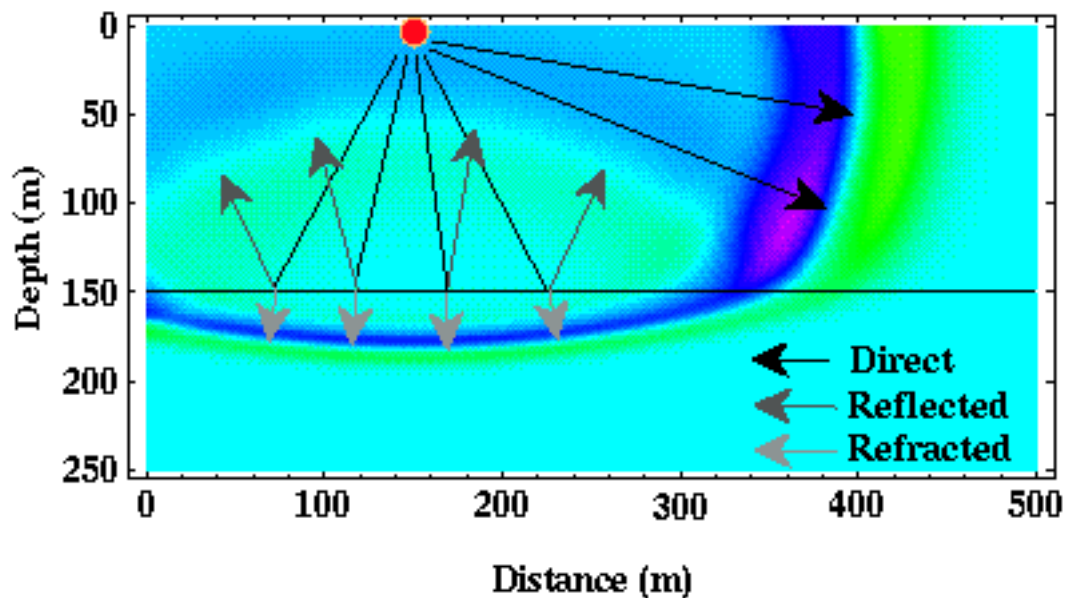
Time = 50 ms



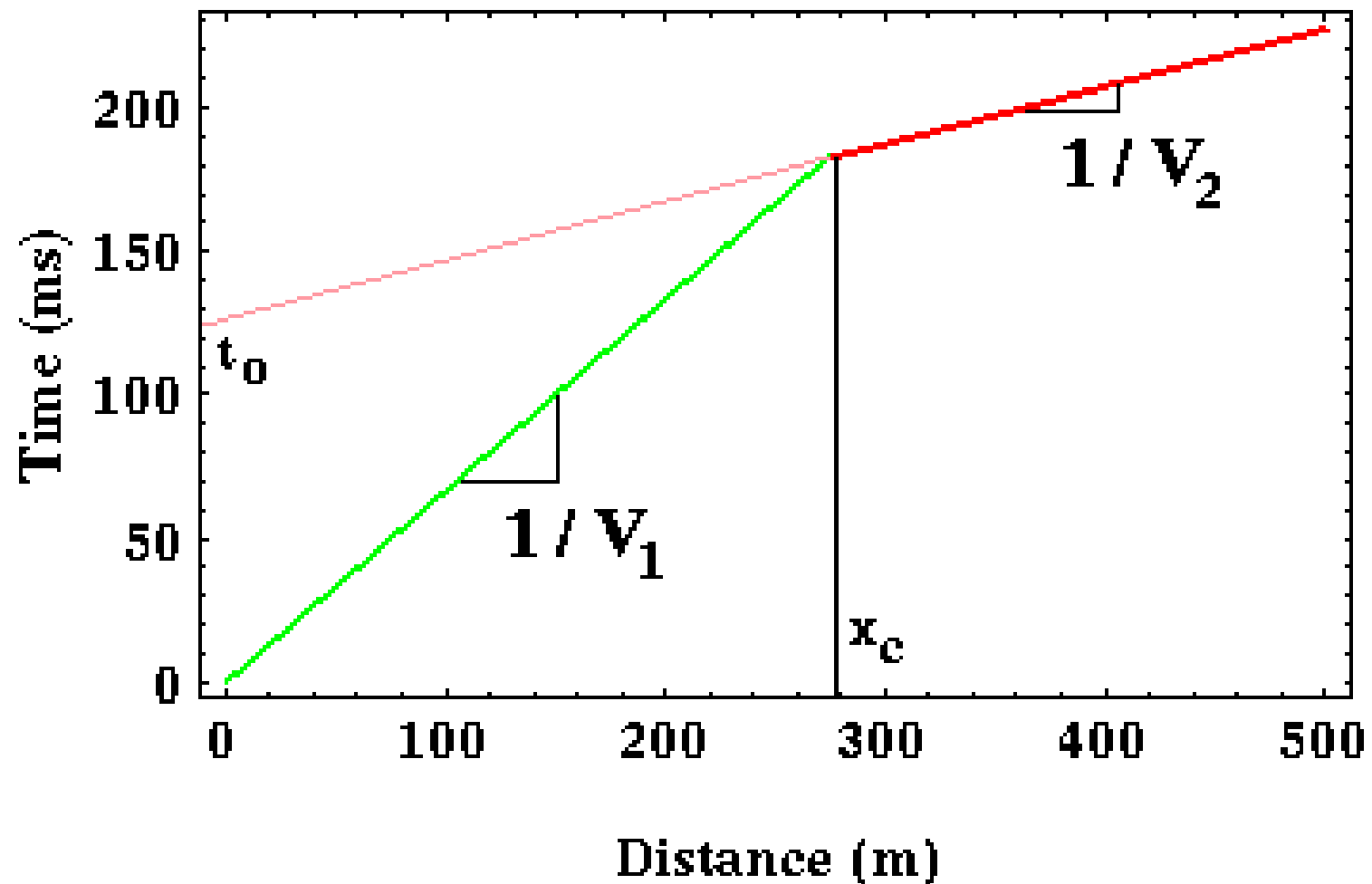
Time = 75 ms



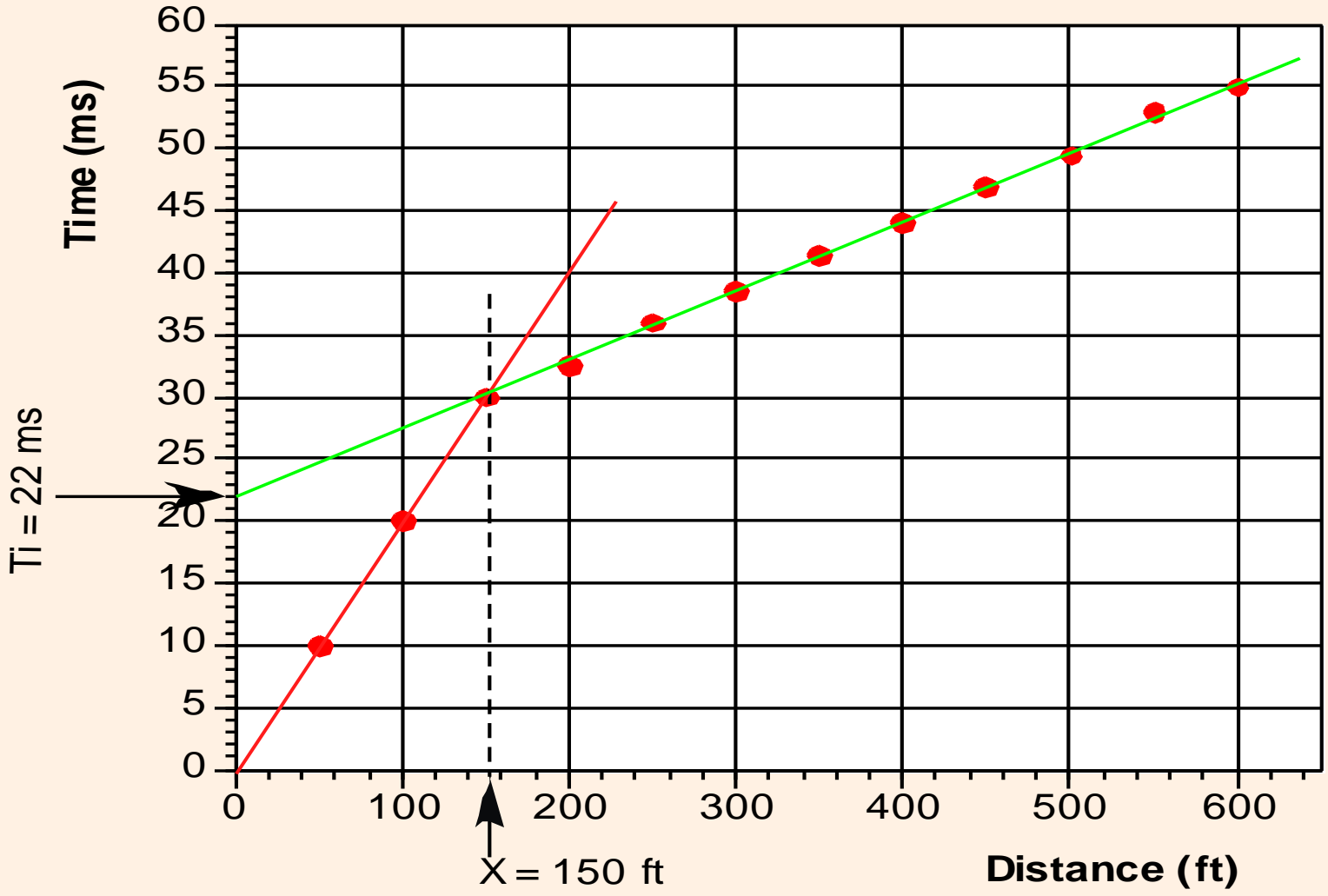
Time = 75 ms



Relationship Between Curve and Parameters



Seismic Refraction



Radiometric Methods

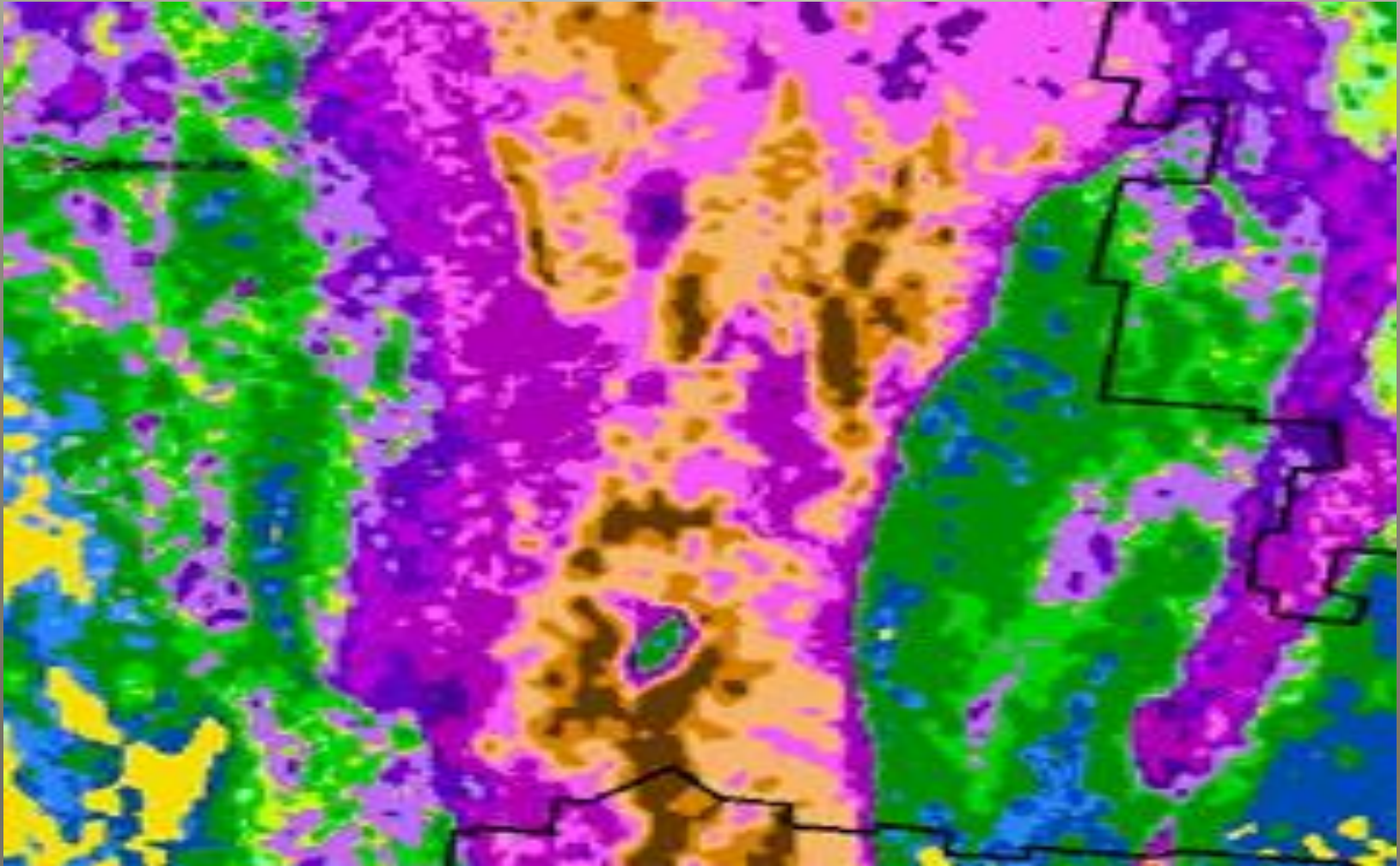
- Controlling property
- Natural radioactivity of rocks and ores
- Principle
- The normal radioactivity is different in different types of rocks. In igneous rocks, it decreases with decreasing acidity. If rock contains radioactivity ore bodies, such areas will exhibit very high radioactivity, giving rise to anomalies during surveys. Thus based on the study of radioactivity. It is not only possible to distinguish different rock types but also to detect radioactive ore bodies. The profile drawn clearly brings out the subsurface lithology, structure and ore body.

Radiometric Methods



4-Channel Gamma ray Spectrometer

Radiometric Methods



Radiometric Methods

- Instruments used in radiometric prospecting are called radiometer. A radiometer consist of three basic components
- (I) a detector
- (ii) an amplifier or recording unit.
- (iii) a power supply unit.
- Radiometric methods of investigation are useful in many ways
- Exploration of radioactive substances such as uranium and thorium
- Location of some rare minerals
- Geological mapping
- Exploration of oil & gas
- Ground water studies

Geothermal Methods

- These methods are latest addition to the group of geophysical method.

Controlling Property

- Thermal conductivity

Principle

- Temperature distribution on the surface of the earth is due to three different sources.
- They are
 - (I) heat received from the sun;
 - (ii) Heat conveyed from the hot interior of the earth due to conduction and convection processes.
 - (iii) heat due to decay of radioactive minerals in the crust of the earth.
- By applying the necessary corrections, it is possible to eliminate the solar heat component and also the heat contribution of radioactive mineral decay. When this is done, the residual values of temperature distribution on the earth's surface can be interpreted in terms of subsurface structures, rock formation and ore bodies. This forms the principle and basis for geothermal method of investigation.

Geothermal Methods

Conduction **VS** Convection

Vaporizers generally fall into two categories based on their primary heating method.

con-duc-tion

n. The transfer of thermal energy through a substance or solid.

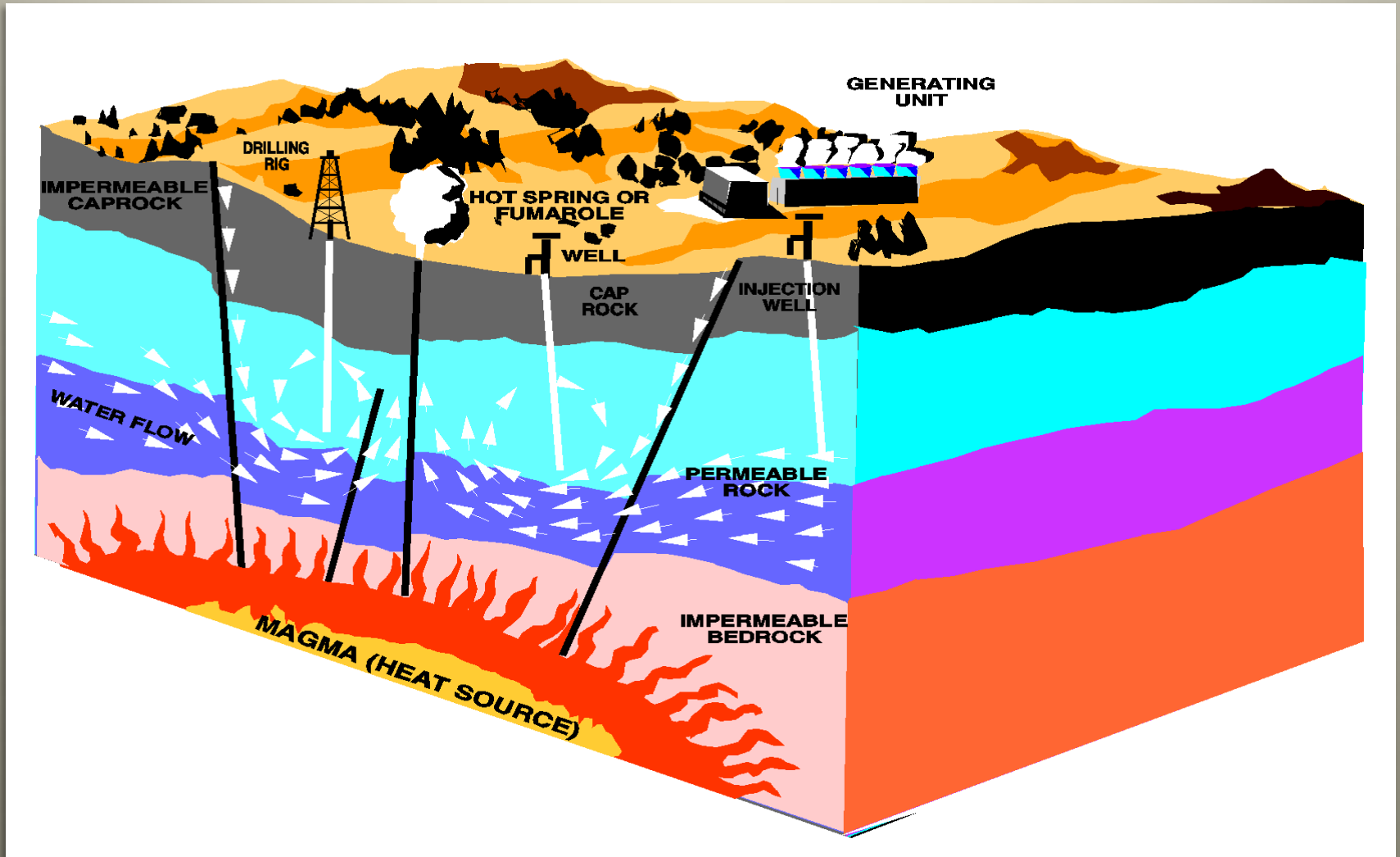
con-vec-tion

n. The transfer of thermal energy through a liquid or gas.

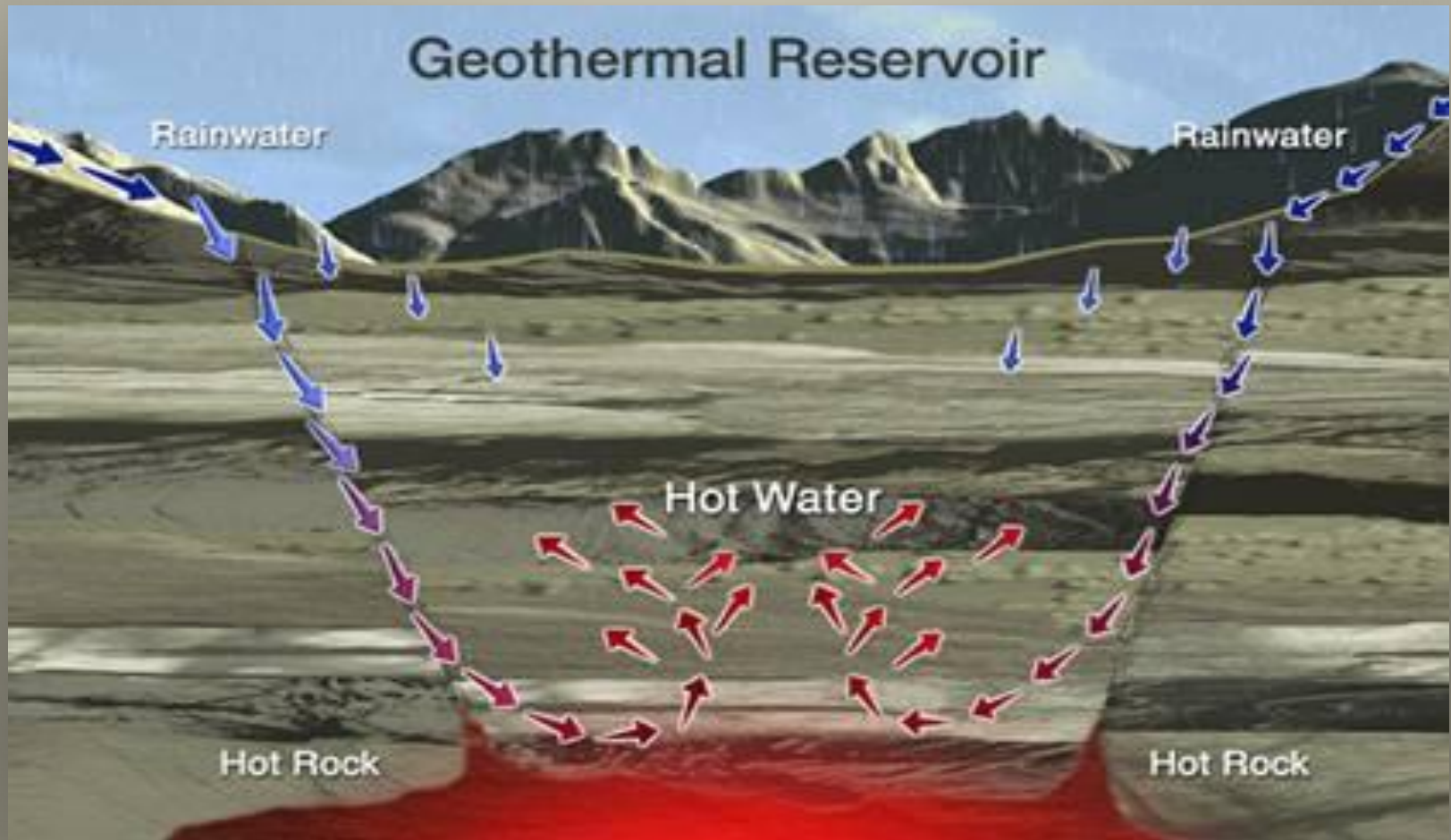
Geothermal Methods

- For the measurement of the temperature on the surface of the earth, in shallow holes or in deep bore holes, thermistors thermometers are used. Other instruments such as crystal detectors and radiometers are used.
- The geothermal methods find application in deep structural studies, ore deposits, groundwater studies, for delineation of salt-water fresh water interfaces. Etc.

Geothermal Methods



Geothermal Methods



Electrical Resistivity Method

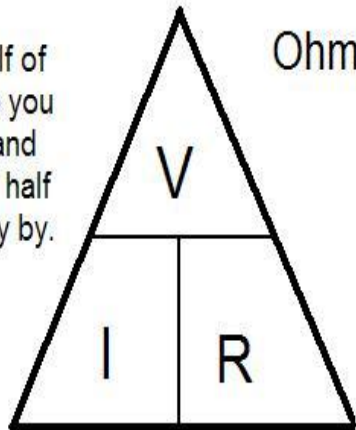


Electrical Resistivity Method

- All geological formations have a property called electrical resistivity which determines the ease with which electric current flows through them. This resistivity is expressed in the units of ' Ωm ohms meter and is indicated by the symbol ρ

Electrical Resistivity Method

The top half of the triangle you divide by, and the bottom half you multiply by.



Ohms Triangle

V = Volts

I = Amps

R = Ohms

$$V = I \times R, I = V / R, R = V / I$$



V, voltage

Measured in volts V

Is energy per unit of charge

1V = 1 joule/coulomb

I, current

Measured in amps A

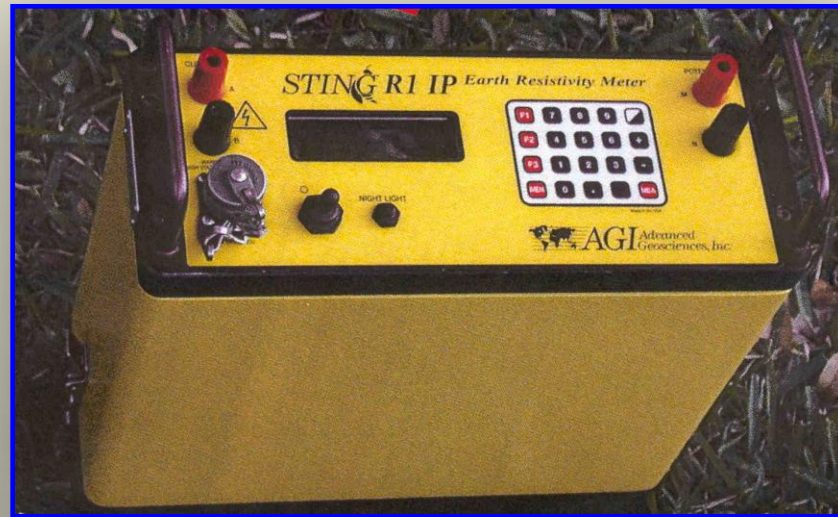
Is rate of flow of charge

1A = 1 coulomb/second

R, resistance

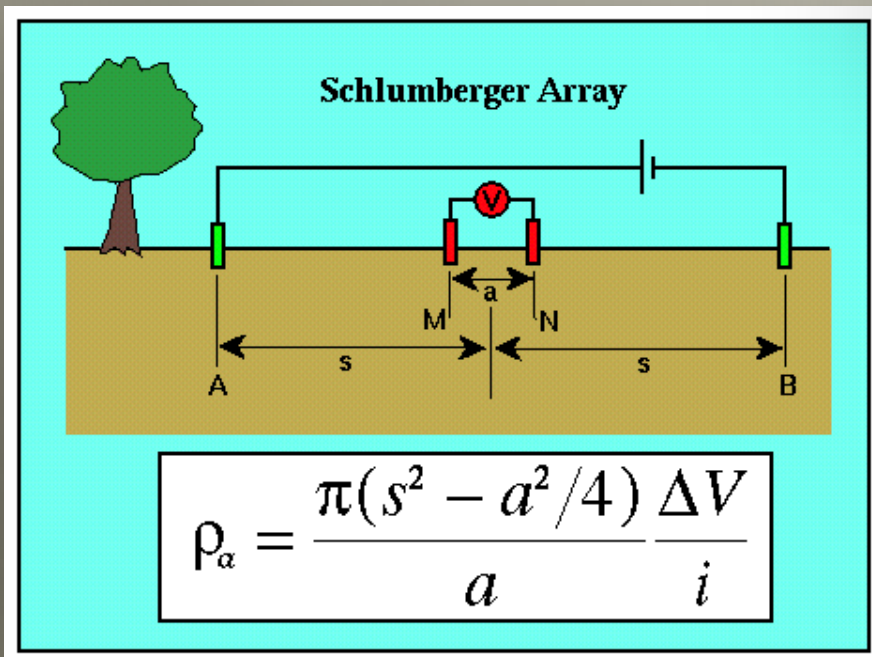
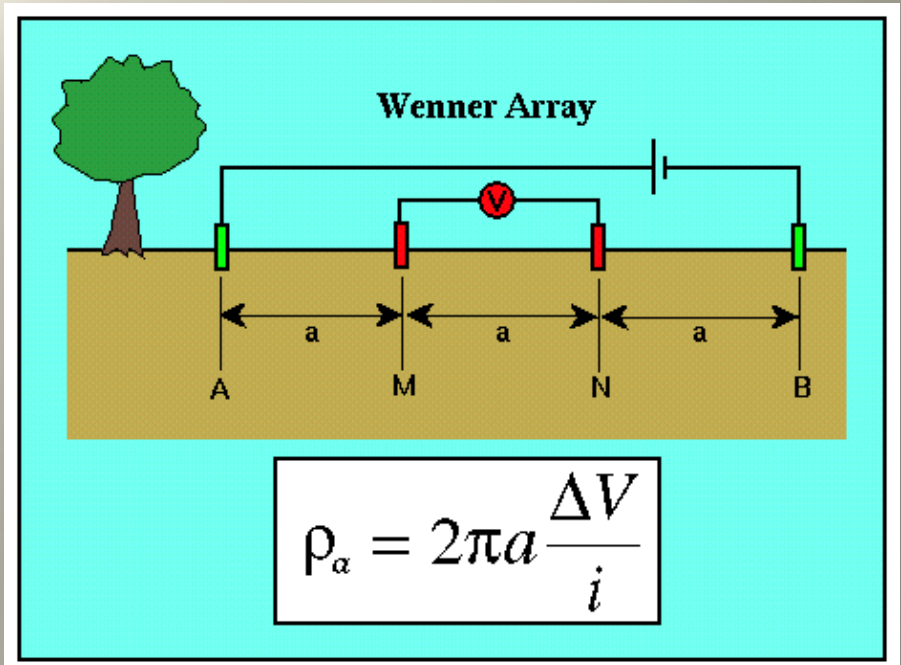
Measured in ohms Ω

Electrical Resistivity Measurements



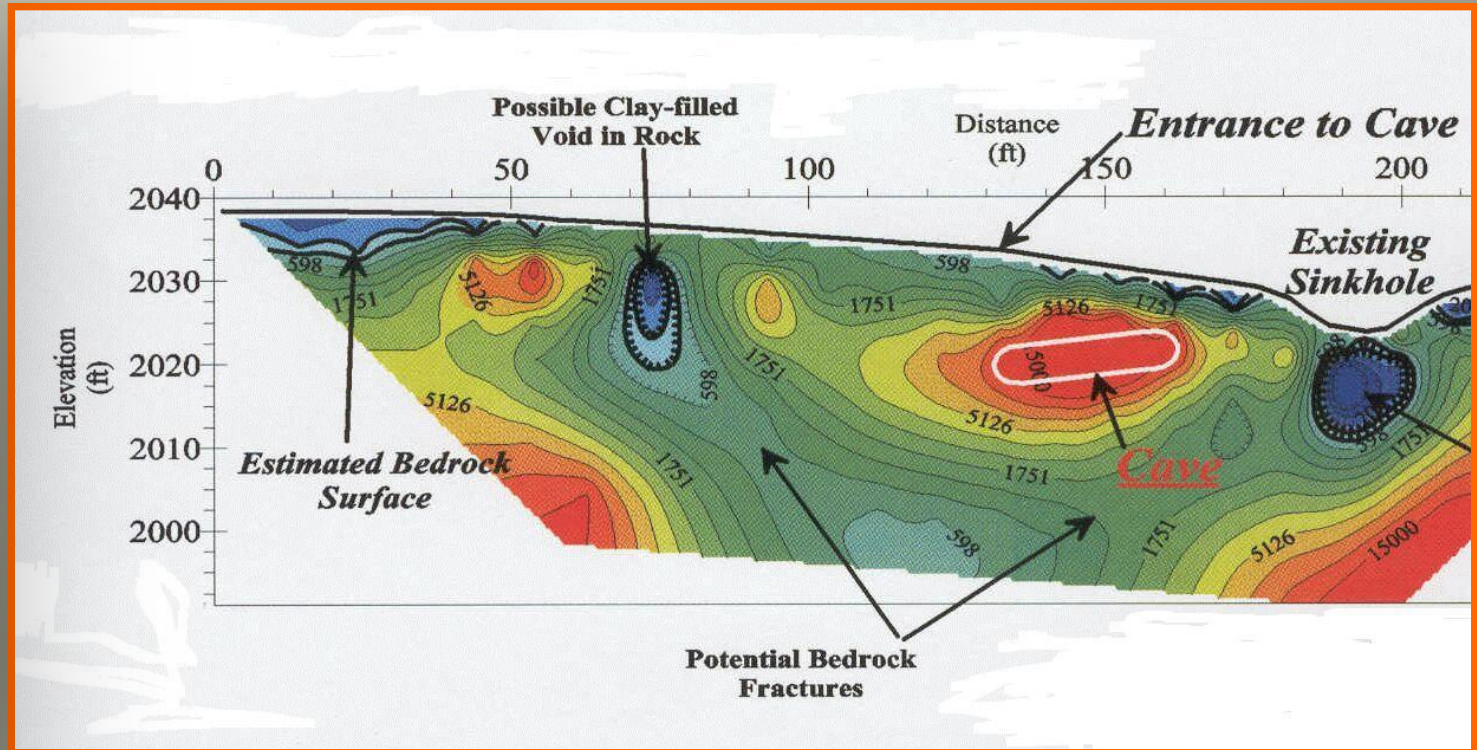
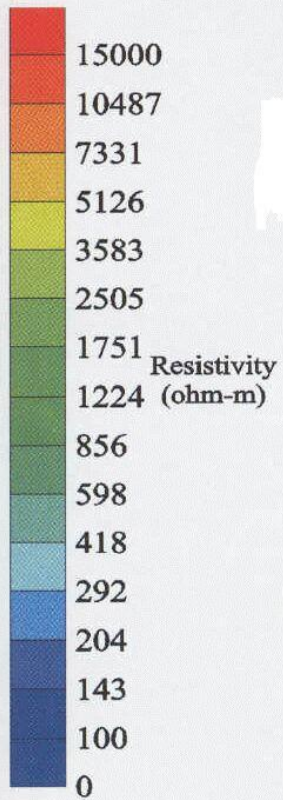
OYO McOHM 21 RESISTIVITY SYSTEM

Electrical Resistivity Measurements



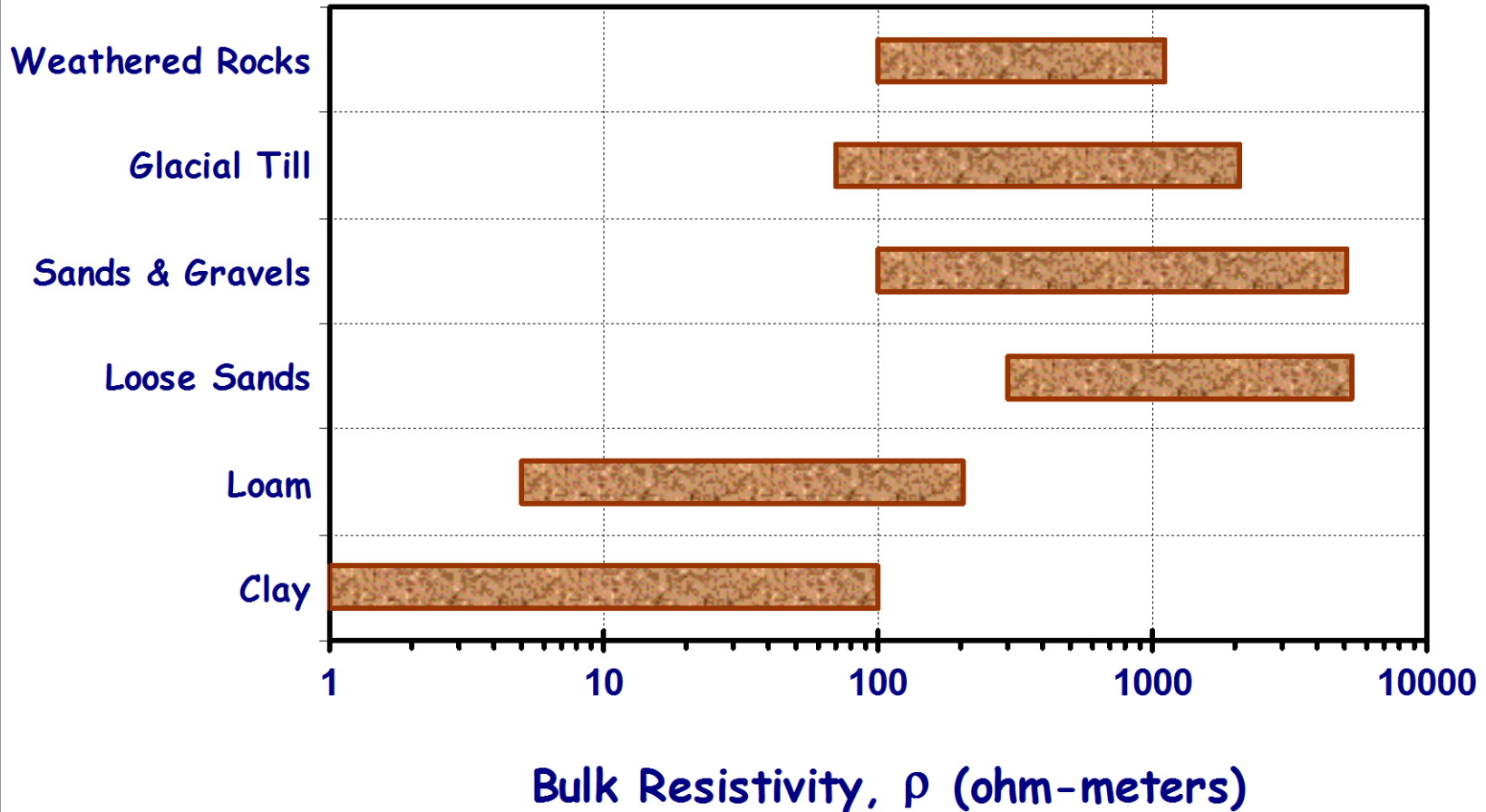
Electrical Resistivity Measurements

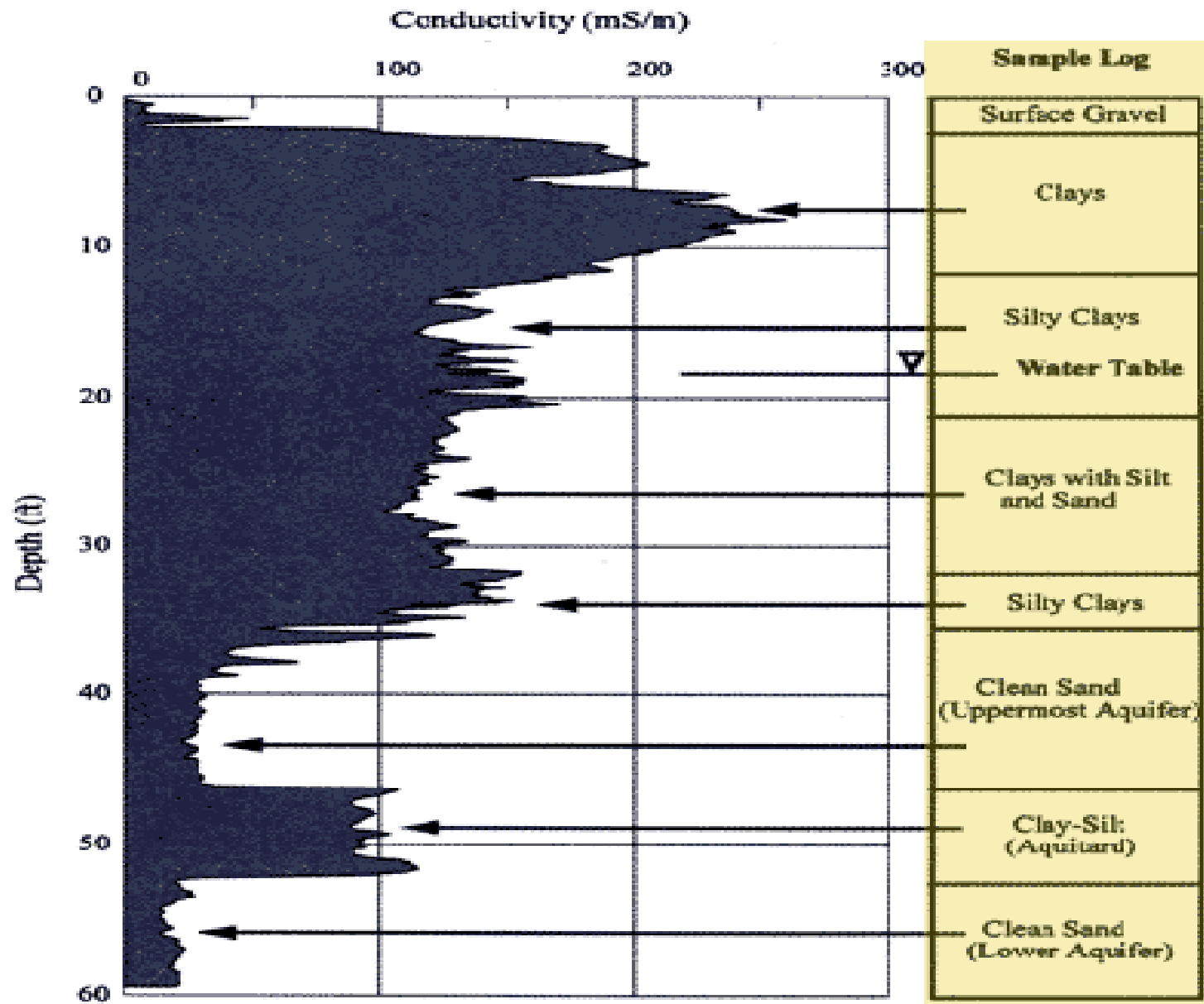
Legend



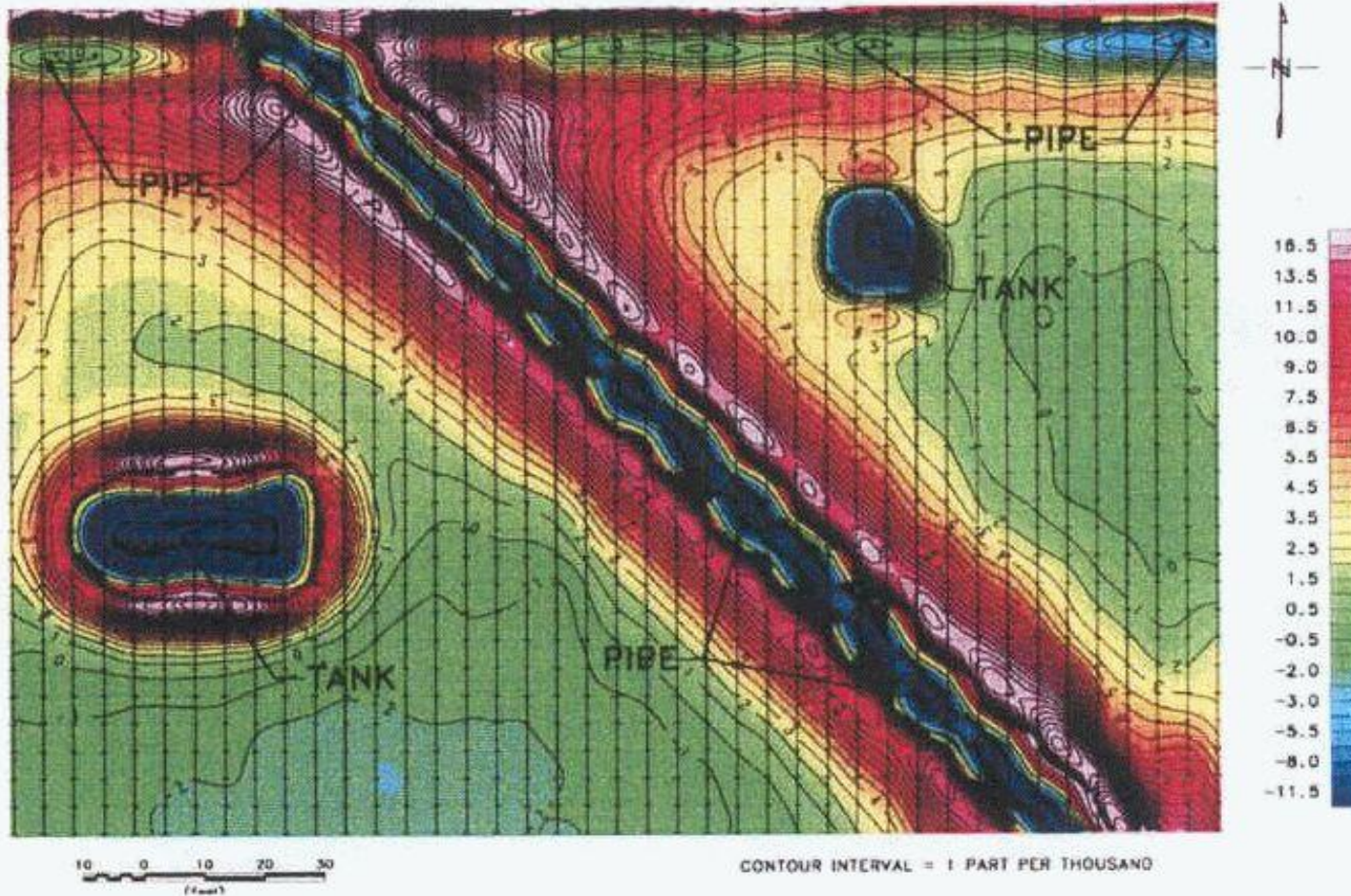
Electrical Resistivity Measurements

Resistivity Values (ConeTec & GeoProbe, 1997)





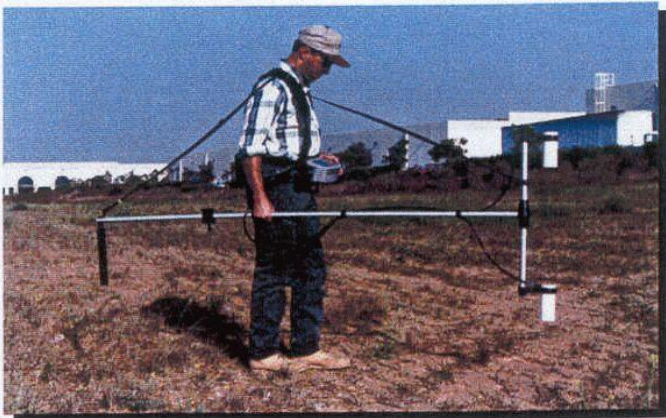
Electromagnetic Conductivity (EM)



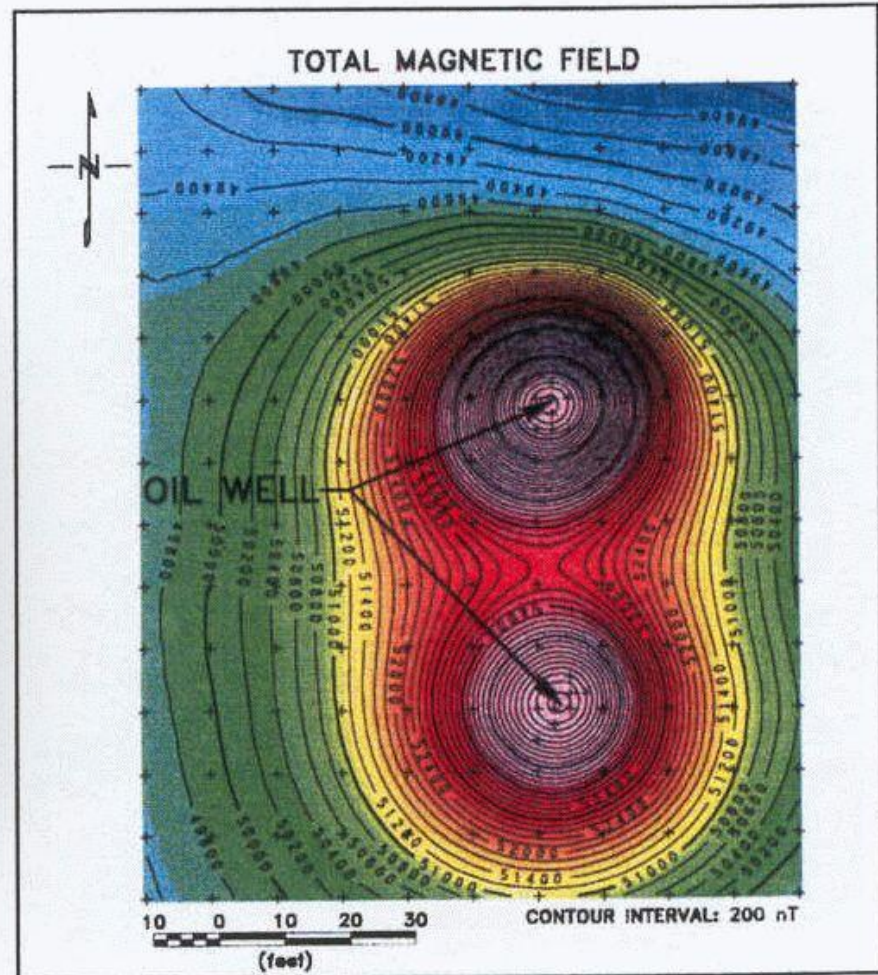
Geonics EM-31 Survey to Locate Underground Storage Tanks

Magnetometer Surveys (MS)

Measure relative changes in the earth's magnetic field across a site.

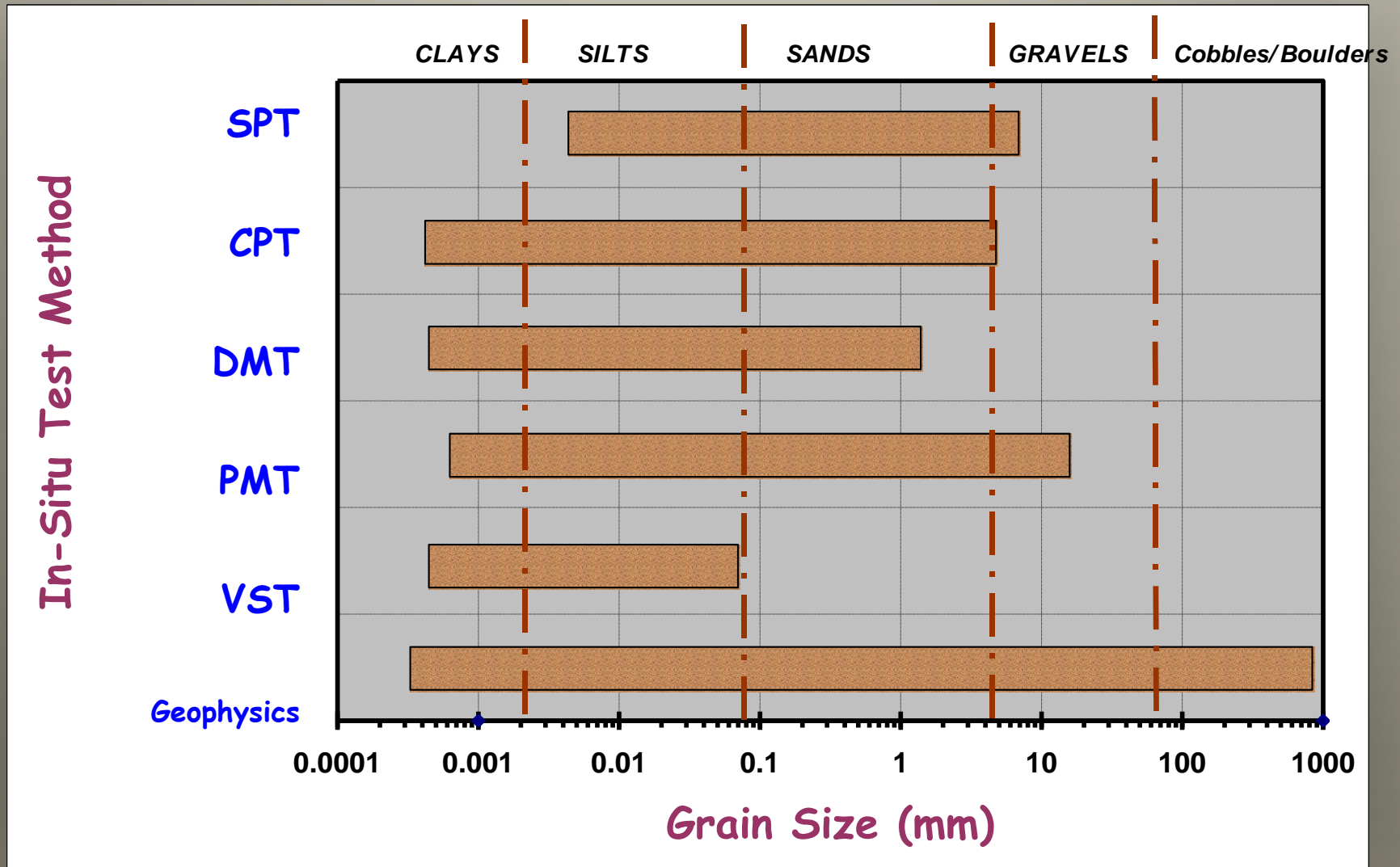


Geometrics G-858 Magnetometer



Magnetic Survey to Locate Abandoned Oil Wells

Applicability of In-Situ Tests

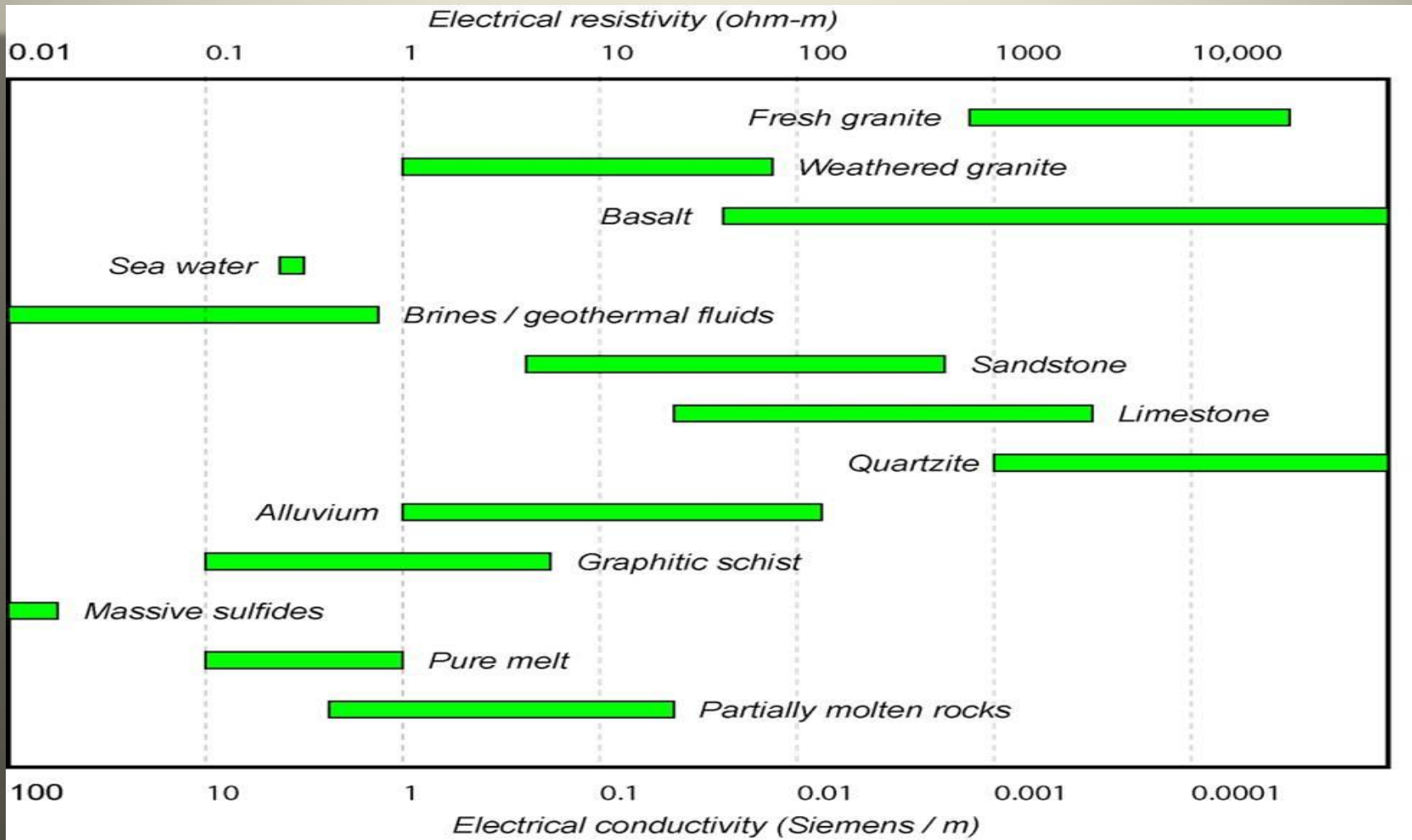


Electrical Resistivity Method

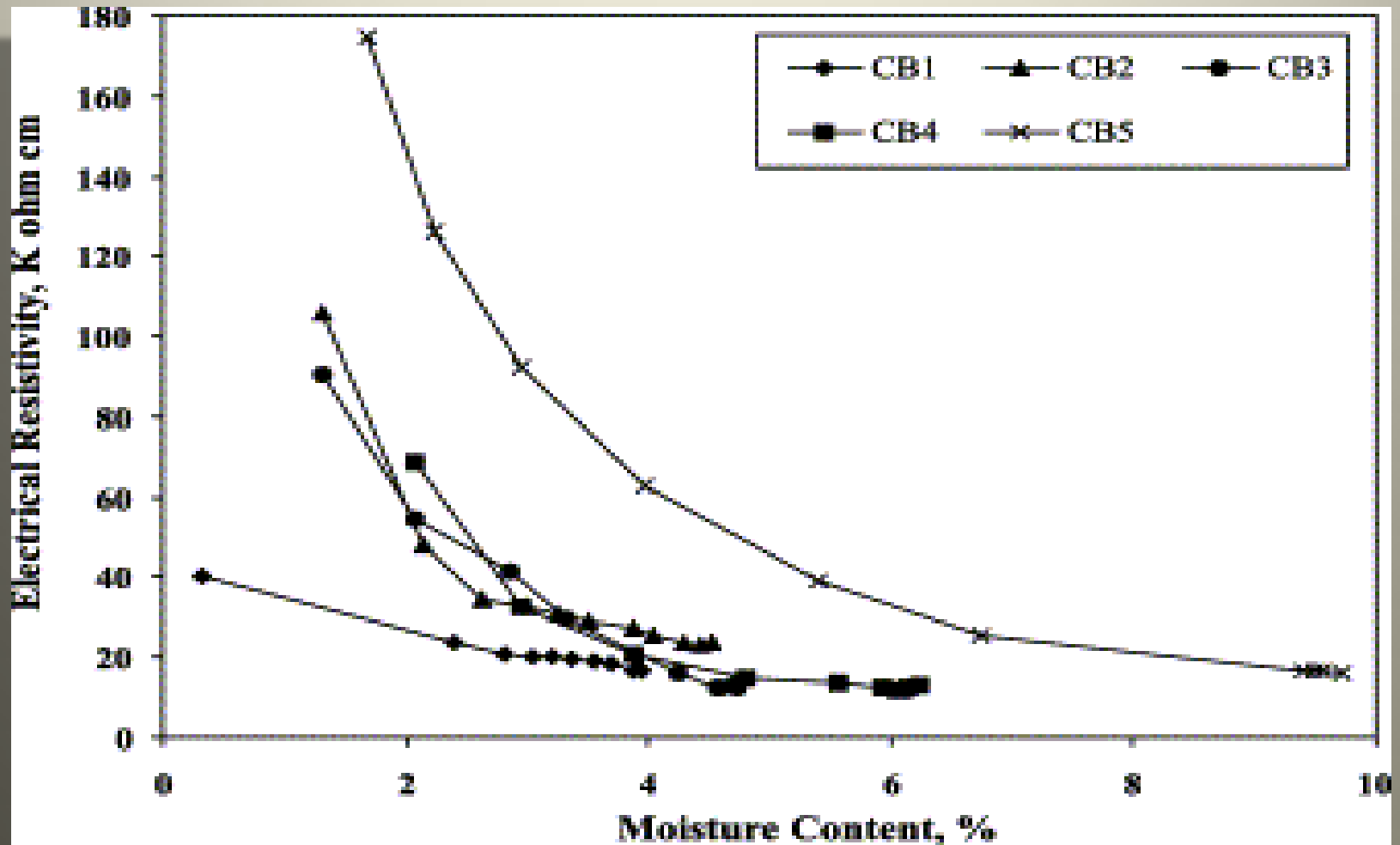
Factors Influencing Electrical Resistivity

- The various geological factors which influence the electrical resistivity are ; **mineral content, compactness, moisture content, salinity of moisture and texture of rocks.**
- **Mineral Content**
- Most of the rock forming minerals have high resistivity, whereas sulphide mineral possess a high conductivity.
- **Moisture content**
- Moisture may occur in the rock either as ground water or mere moisture in the pore spaces. Then the resistivity decreases considerably. But this change is not of the same order in all formation.
- Further the resistivity of water is dependent on its salt content and temperature.

Electrical Resistivity Method



Electrical Resistivity Method



Electrical Resistivity Method

Resistivity method and measurement of Resistivity

- For the principle of the electrical resistivity method of exploration and for measurement of resistivity. A high resistive overburden is a disadvantage for resistivity studies. This is so because very little current penetrates the ground which means that the investigation of deeper layer is not possible.

Electrical Resistivity Method

Classification of Resistivity Methods

- The resistivity methods are classified as **profiling type, sounding type, and potential type** of methods.
- **Profiling method** is used for measurement of resistivity in **lateral direction**. **Sounding type** in which measurements are made in **vertical direction**. **Potential methods** are used in ore prospecting and are of **not of engineering relevance**.

Types of Electrode Configurations

- In profiling or in sounding, there is scope for electrode arrangements to be made in different ways in the field, and such arrangements are called "Configurations".
- The different electrode configurations are.
- Number of electrodes
- Mutual interval of electrodes
- Mode of arrangement of electrodes
- Whether the electrode are arranged symmetrical or not with reference to the point of investigations.

Types of Electrode Configurations

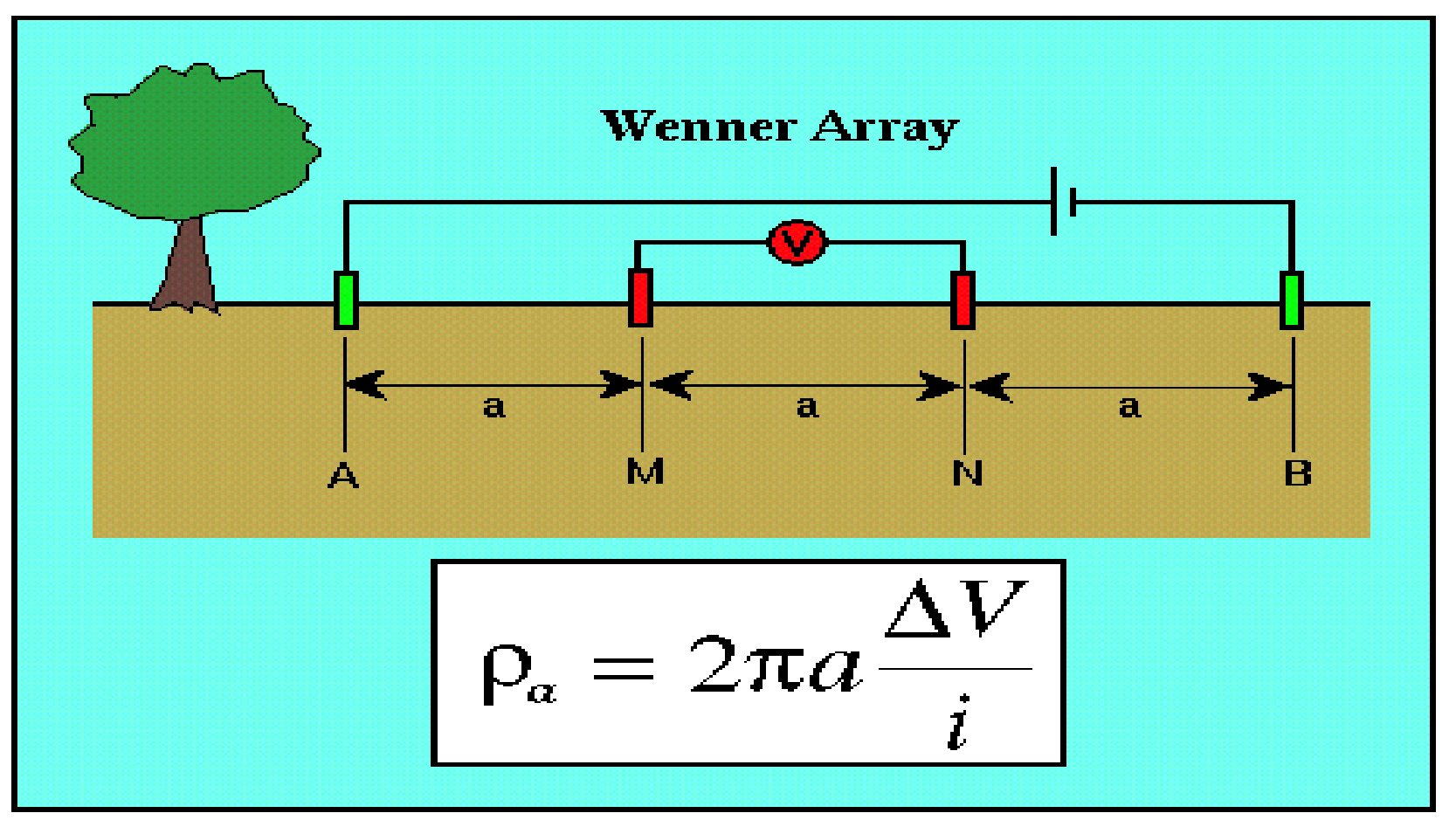
(a) Symmetrical Electrode Configurations

- In this set-up, four electrodes are placed in line (i.e., collinear) on the surface, two for energizing the earth and the other two for measuring the resultant voltage (potential difference). These are arranged symmetrically on either side of the point of investigation. The Wenner and Schlumberger configurations belong to this category.

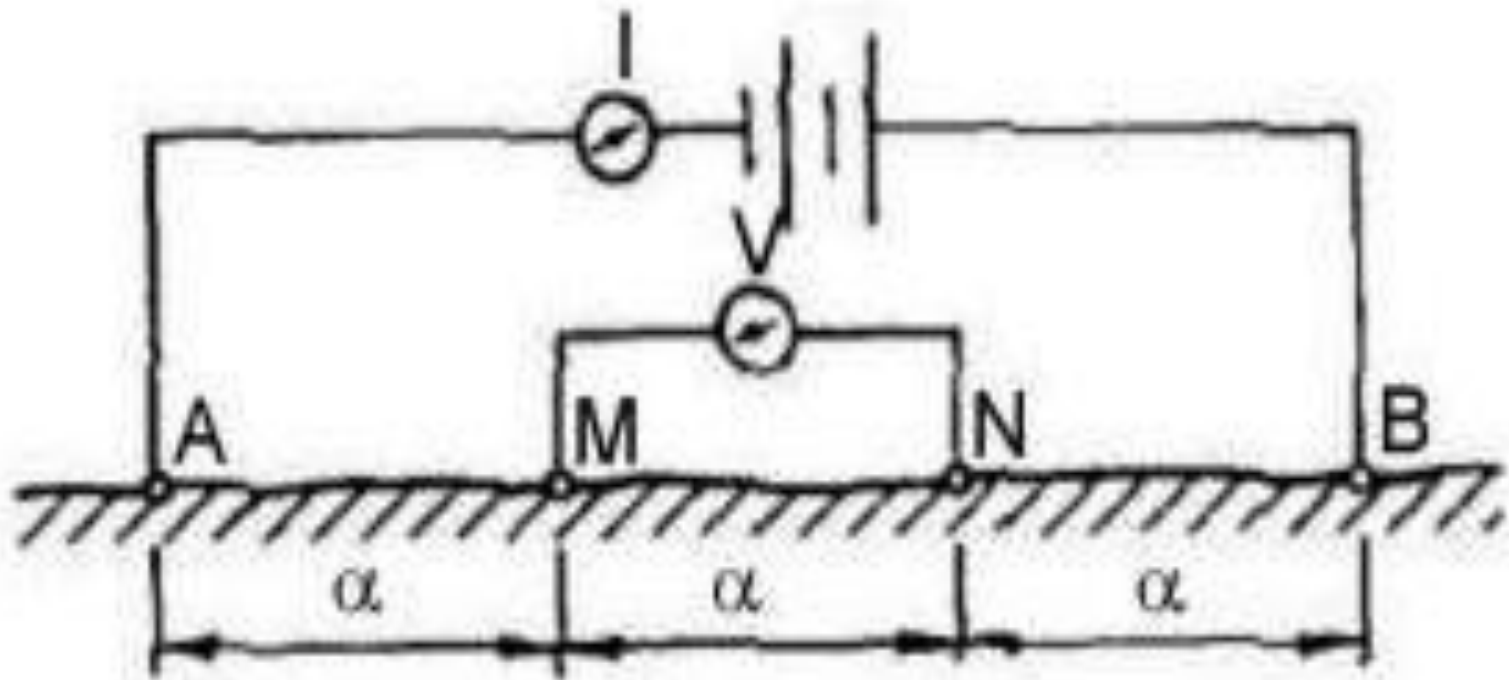
The Wenner Configuration

- This was developed by Wenner in 1915. In this configuration, the outer electrode C_1 and C_2 , are used to send current into the ground and the inner electrode P_1 and P_2 are used to measure the potential. The important feature of this set-up is that the distance between any two successive electrodes is equal. The apparent resistivity measured with the wenner array is given by $\rho_a = 2 \pi a [\Delta v] / I$,
- where a = electrode separation,
- v = potential difference measured and
- I = current sent into the ground

The Wenner Configuration



The Wenner Configuration

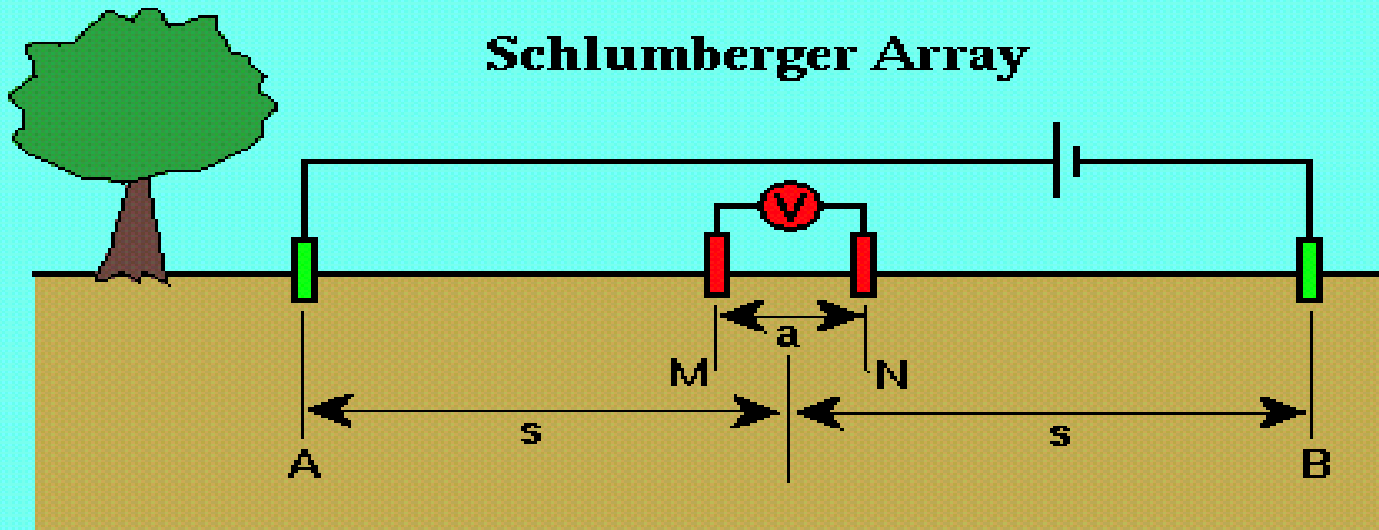


b. Wenner Array

The Schlumberger configuration

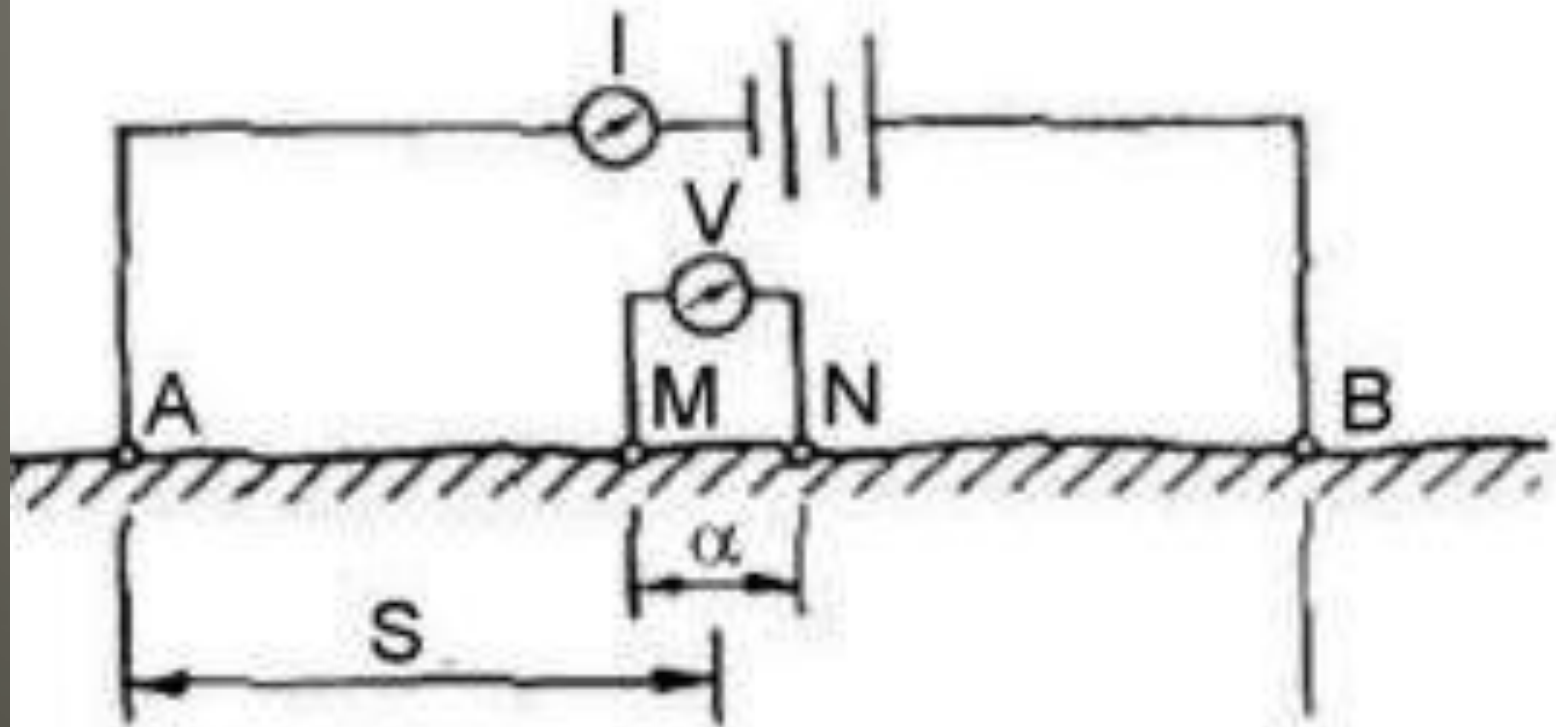
- This was developed by Schlumberger in 1916. This method measures the potential gradient rather than the potential difference. For this purpose, potential electrodes are kept at smaller separation compared to the current electrodes. Here A and B are the current electrodes and M and N are the potential electrodes. In general $MN \leq 1/5 AB$ relation is maintained in this investigation

The Schlumberger configuration



$$\rho_a = \frac{\pi(s^2 - a^2/4) \Delta V}{a i}$$

The Schlumberger configuration



a. Schlumberger Array

Advantages and Disadvantages of Wenner and Schlumberger Arrays

The following table lists some of the strengths and weaknesses of Schlumberger and Wenner sounding methods.

Schlumberger		Wenner	
Advantage	Disadvantage	Advantage	Disadvantage
Need to move the two potential electrodes only for most readings. This can significantly decrease the time required to acquire a sounding.			All four electrodes, two current and two potential must be moved to acquire each reading.
	Because the potential electrode spacing is small compared to the current electrode spacing, for large current electrode spacing's very sensitive voltmeters are required.	Potential electrode spacing increases as current electrode spacing increases. Less sensitive voltmeters are required.	
Because the potential electrodes remain in fixed location, the effects of near-surface lateral variations in resistivity are reduced.			Because all electrodes are moved for each reading, this method can be more susceptible to near-surface, lateral, variations in resistivity. These near-surface lateral variations could potentially be misinterpreted in terms of depth variations in resistivity.
	In general, interpretations based on DC soundings will be limited to simple		In general, interpretations based on DC soundings will be limited to

Types of Electrode Configurations

- In the Wenner method, all electrodes are shifted to new positions whenever the readings are taken. But in the Schlumberger method, only current electrodes are shifted to new positions, while potential electrodes are kept undisturbed for 3 to 4 readings. In the Schlumberger method, since potential electrodes remain in the same place, the local inhomogeneities will have less bearing and this factor is desirable.

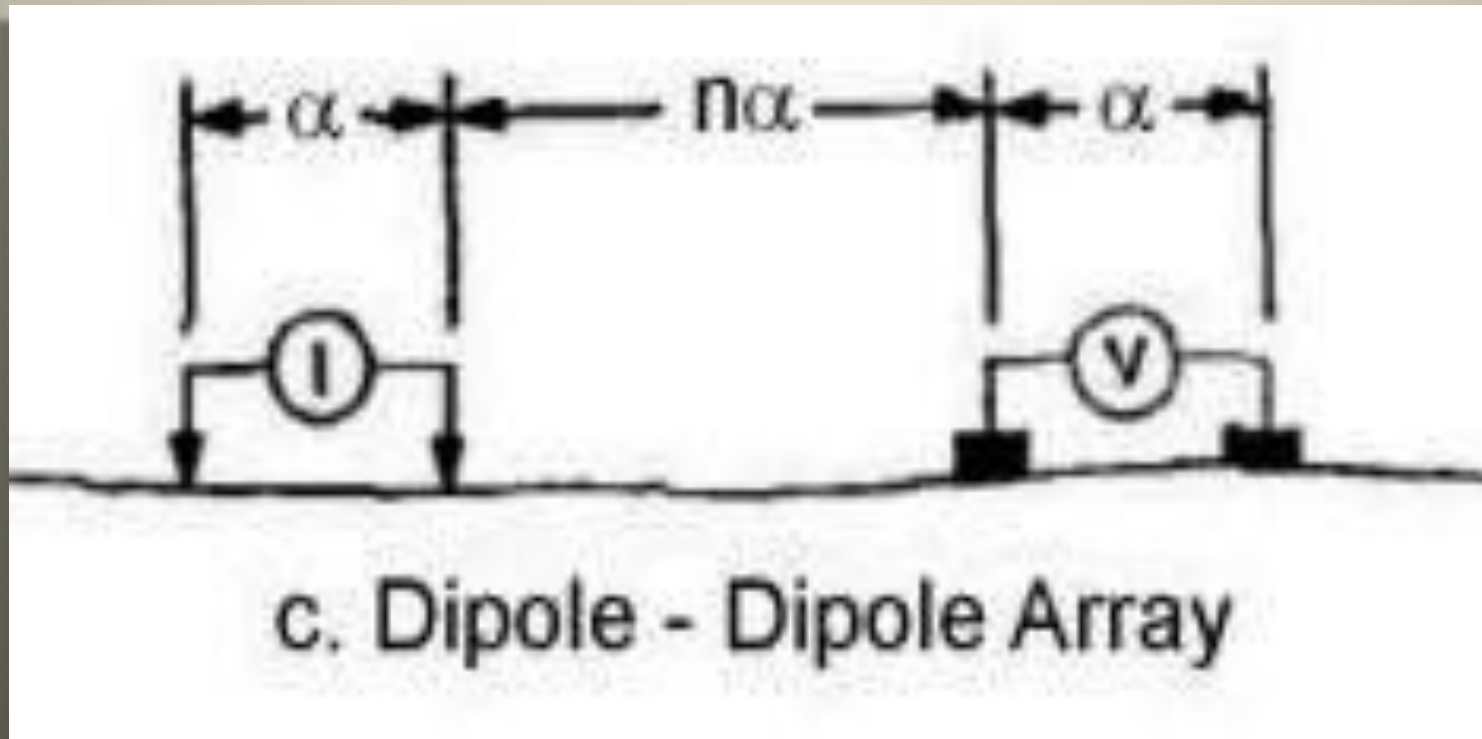
Double Distance Symmetrical Electrode Configuration

- This is similar to the preceding one, but differ in that it utilizes two more current electrode (A' and B'). The distance A'O is greater than AO. By using first the AB pair of current electrode ρ_a is known. next by using A' B' current electrode ρ'_a is known. In both the operations, the potential electrode are kept at the same place. The configuration is more useful because it indicates the subsurface structure in a clearer manner. This technique is also called "multiseperation resistivity profiling"

Asymmetrical Electrode Configurations (Used in profiling)

- The dipole-dipole, three electrode and central gradient configuration belong to this group.
- **Dipole-dipole type:** In this, two dipoles are used, each consisting of two similar electrodes. One pair is used for energizing and the other pair for measuring potential difference. In this set-up the distance between electrodes of a pair should be less than 5 to 6 times the distance between the centres of two dipoles.
- **Three electrode type:** In this system, either one current or one potential electrode is kept at infinity and the other three electrode remain in their positions as in the symmetrical set-up. In profiling, this set-up of three electrode is moved and pa reading are obtained.
- **Central Gradient type:** In this system, the current electrodes remain fixed, a large distance apart, and the potential electrodes are moved in the central regions.

Dipole-dipole type



Circular or Radial Method

- When dykes, veins or joints set are present below the surface, they cause differences in p_a value when measured in different directions. In such cases, profiling is done along different directions. In such cases, profiling is done along different directions over the same point by using any one configuration. When the corresponding values are plotted along the different directions, the asymmetry of the figure obtained gives the detail of the strike and dip directions of the subsurface inhomogeneity.

Profiling

- This is also known as electrical profiling or lateral electrical investigation. In this process, the electrode array as a whole is moved from place to place along the chosen traverse and the ρ_a value at each of these stations is determined. The changes in ρ_a indicates lateral variations in the subsurface corresponding to a certain depth. If the current-electrode separation is more

Profiling

- Profiling technique will be useful in detecting only vertical or steeply inclined structures (such as vertical beds, faults and dykes) because, only then the measured value ρ_a differ from place to place. On the other hand, if the bed are horizontal, the ρ_a value will remain more or less unchanged. This means the depth-wise variation cannot be known.

Profiling

- Profiling may be carried out in one or a few traverses with the intention of obtaining an outline of the geology or structure of an area or in a grid pattern. In order to produce a resistivity map of the area for proper profiling the following points should be kept in mind.
- Normally the interval between stations on a profile has to be chosen depending on the minimum dimensions of the body to be demarcated.
- The distance between profiles shall be two to five times the station interval.
- The choice of configuration is also important factor. Asymmetrical configuration are well suited to demark thin beds or dykes or vein, which are vertical or steeply inclined. But in dealing with geological mapping or thick beds, symmetrical configurations are preferable.
- The electrode spacing should be chosen such that the distance between the current electrodes and potential electrodes permits the investigation of targets at a desired depth.

Profiling

- The presentation of profiling data is done in two ways, i.e... as profiling graphs and a contour maps. In the first case, the ρ_a is plotted as a function of the position of the centre of electrode configuration of the ground. The midpoint of the two potential electrode is designated as the station.
- In the second case, the ρ_a value for a particular electrode separation (i.e.. electrode interval) are noted against the positions where they are measured. The map is then contoured with the line along which ρ_a value are the same. Such map are called “ isoresistivity contour map”. The contour interval can be fixed suitably.
- The interpretation of the profiling data is mainly of qualitative importance.

Sounding

- This method is popularly known as vertical electrical sounding. It is also described as 'depth probing', 'electrical coring', etc. In this method, a number of ρ_a values are measured at the same place by increasing the distance between the current electrodes each time after taking reading. This kind of successive increasing in distance makes the current penetrate more and more deeply. Hence the change in ρ_a value measured indicates the vertical variations in the subsurface at the investigated point. Thus the sounding technique is useful in investigating only horizontal or gently inclined structures. This is so because, under such conditions only ρ_a value shows variation when the successive

Planning of Sounding Studies

- As in the case of profiling, sounding also can be done either along a selected traverse or in a grid pattern.
- The depth at which the bedrock occur will be known on interpretation at each point of investigation.
- This also measures the thickness of loose overburden at the place of study. However it is important to have proper planning, before taking up sounding surveys to suit the aim of investigation.
- If the purpose is to obtain the bedrock profile along a selected area such as along the axis of a proposed dam, sounding should be done at close intervals along the direction. The bedrock depths at these points are plotted on a graph to get the required bed rock profile.
- In the case of ground water studies, however, to avoid undesirable mutual interferences of the well or borewells, they should be located mutually at considerable distances. This means sounding studies should not be made at closed distances. If the sounding is carried out in the grid pattern, the bedrock contour can be drawn which will give more information relevant to ground water conditions.

Application of Electrical Resistivity Studies

- From the civil engineering point of view the 'resistivity' investigations are useful in solving a number of geological problems. They are aimed at
 - (i) foundation studies
 - (ii) location of suitable building material
 - (iii) ground water studies

Application of Electrical Resistivity Studies

- Some of the specific problems are listed below
- To determine the thickness of loose overburden or the depth of the bed at the site.
- To detect fractures.
- To ascertain the subsurface rock type and their compactness.
- To locate dykes or vein in foundation rocks.
- To know the strike and dip of rocks
- To detect structural defects like foundation rock
- To detect the structural defects like faults at the foundation site
- To locate suitable building material if required near the project site

Seismic Refraction Method

- In seismic method of prospecting, artificial exploration are made and elastic deformation are induced in rock present in the ground. The propagation of such seismic(elastic) waves through the geological formation is studied. Seismic waves are similar to light waves, since prospecting can be done by making use of direct wave, reflected waves or refracted waves. The two chief types of seismic exploration are by seismic refraction methods and seismic reflection methods. Compared to the light waves, the seismic waves are extremely slow in their velocities. The light have a velocity of 300,000 km/sec. whereas the seismic wave velocity is only 0.31 km/s to 0.36 km/sec in air.

Factors Influencing Seismic Wave Velocities

- The geological factor which influence the seismic wave velocities are mainly the composition of rocks, compaction of rocks, and saturation of rocks with ground water.
- Composition
- The seismic wave velocities depend on the composition of rocks. This may be inferred from the following example

Rock type	Seismic Wave Velocity
• Granite	4-6 km /sec
• Basalt	5-6.5 km/sec
• Sandstone	1.5 to 4 km /sec
• Limestone	2.5 to 6 km/sec

Factors Influencing Seismic Wave Velocities

Compaction

- This refers to the porosity or fracturing or degree of consolidation of rock. The velocity of seismic waves in rocks is influenced considerably by this factor, the wave velocity is more in denser/ compact formations. This may be observed from the following data:

Formation	Seismic Wave Velocity
• Loose sand and soil	0.1 to 0.5 km /sec
• Moist Clay	1.5 to 2.5 km/sec
• Sandstone	1.5 to 4 km /sec
• Shale	2.1 to 4 km/sec

Factors Influencing Seismic Wave Velocities

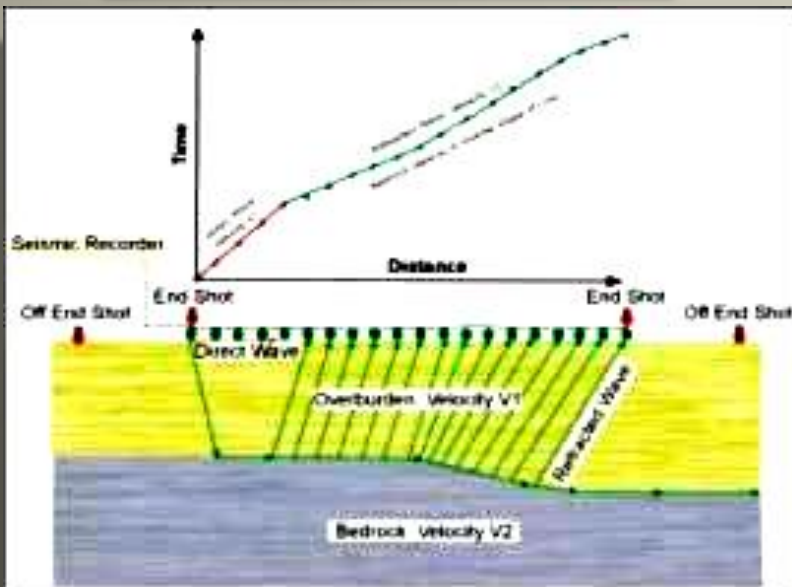
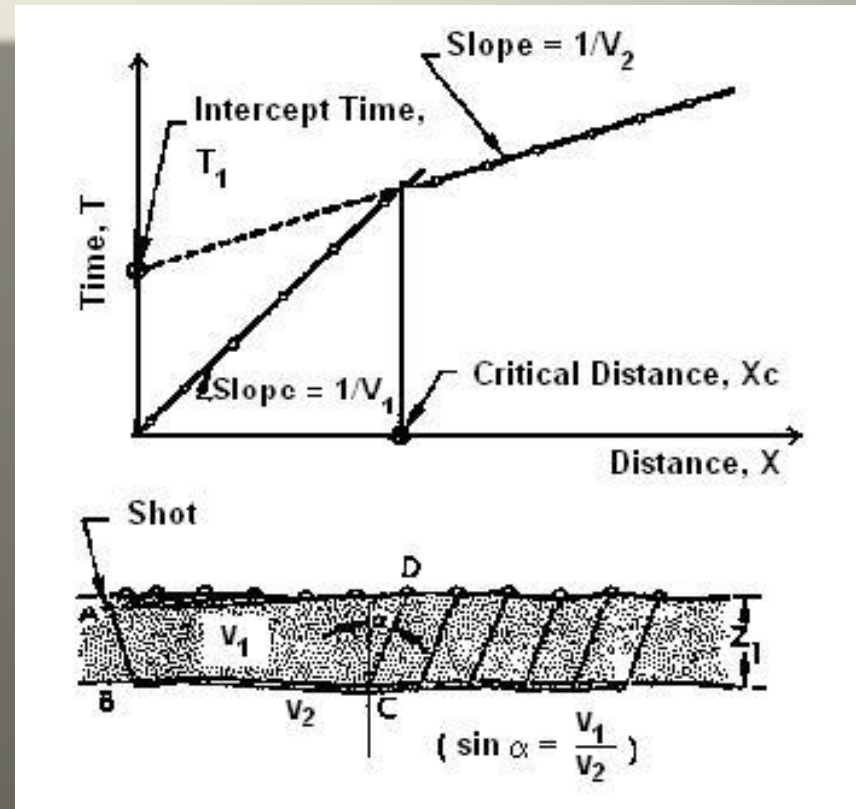
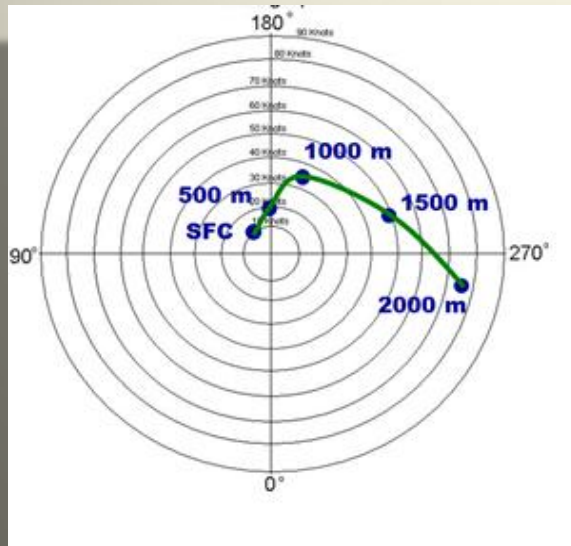
Saturation

- The Seismic wave velocity increases with the increase of moisture content in the formation. For ex
- (I) Loose soil has a velocity of 0.1 to 0.5 km/sec, while moist clay has a velocity of 1.5 to 2.5 km/sec
- (ii) Dry sand has a velocity of 0.15 to 0.4 km/sec, while wet sand has a velocity of 0.6 to 1.8 km/sec.

Travel-Time Curves

- The Seismic studies are carried out by means of “Travel Time Curves”. These are also known as “Travel Distance Curves” or “Hodographs” These curves are obtained as follows In the field, by using a number of detectors at regular intervals, the timings required for the seismic waves to reach the different detectors from the shot point are noted and plotted. Such points when joined gives hodographs. These indicate the degree of fracturing or weathering and the geological boundaries in the subsurface.

Travel-Time Curves



1a) Instrument layout, refracted waves, and time-distance plot

Nature of Seismic Refraction Studies

- The two common methods of seismic exploration are known as “reflection Shooting” and “refraction Shooting”. Refraction methods and others are better suited to study lesser depths. Since exploration of civil engineering interest are of the shallow type, only the refraction and other methods are chosen for description.
- The seismic refraction methods are based on the phenomenon of total internal refraction of seismic energy which, consequently is directed to travel along the boundary. The refracted head wave then sends out waves towards the surface which enables the deciphering of the refraction boundaries. This is possible only when the overlying layer are less dense and underlying layer are more dense.

Types of Refraction Studies

- There are three types of refraction shooting namely, fan shooting, arc shooting and profile shooting. The difference between these methods lies in the manner in which the geophones are laid with respect to the location of the shot point. While the first two methods are followed for reconnaissance investigations, the profile shooting is the most common method followed for reconnaissance or detailed studies

Instruments Used in Seismic Studies

- The basic components of seismic instruments are meant to take into account the chief functions involved in prospecting. These chief functions are (i) detection of signal, (ii) differentiation of signal followed by its amplification, (iii) recording of that signal. These functions are performed by the geophones, amplifier and galvanometer.

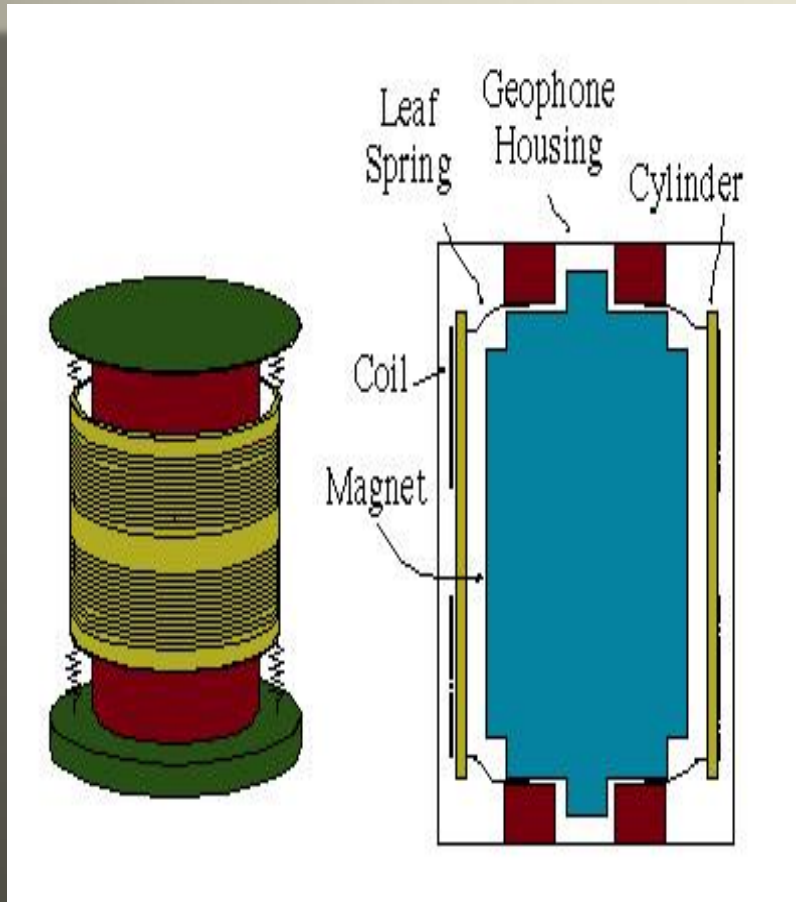
Instruments Used in Seismic Studies

- The geophone (detector), which is planted in the ground, picks up the signal and, depending on the consequent ground displacement velocity (i.e. the intensity of disturbances suffered by the geophones), gives out a proportional voltage.
- This Voltage, after undergoing unwanted frequency filtration, is amplified in electrical circuit (i.e.. signal). The entire job is done by amplifier.
- The voltage is fed to the seismic galvanometer which has the mechanism to give out a trace of the signal on photographic paper. This photograph is the seismic record which is used for interpretation.

Geophone

- The geophone consist of a casing, magnet, a coil and its spring, of these either the magnet or the coil is fixed permanently to the casing. The other one, i.e.. either coil or magnet hangs suspended by a spring.
- At the time of disturbance a relative movement occurs proportional to the disturbances and voltage is induced in the coil.

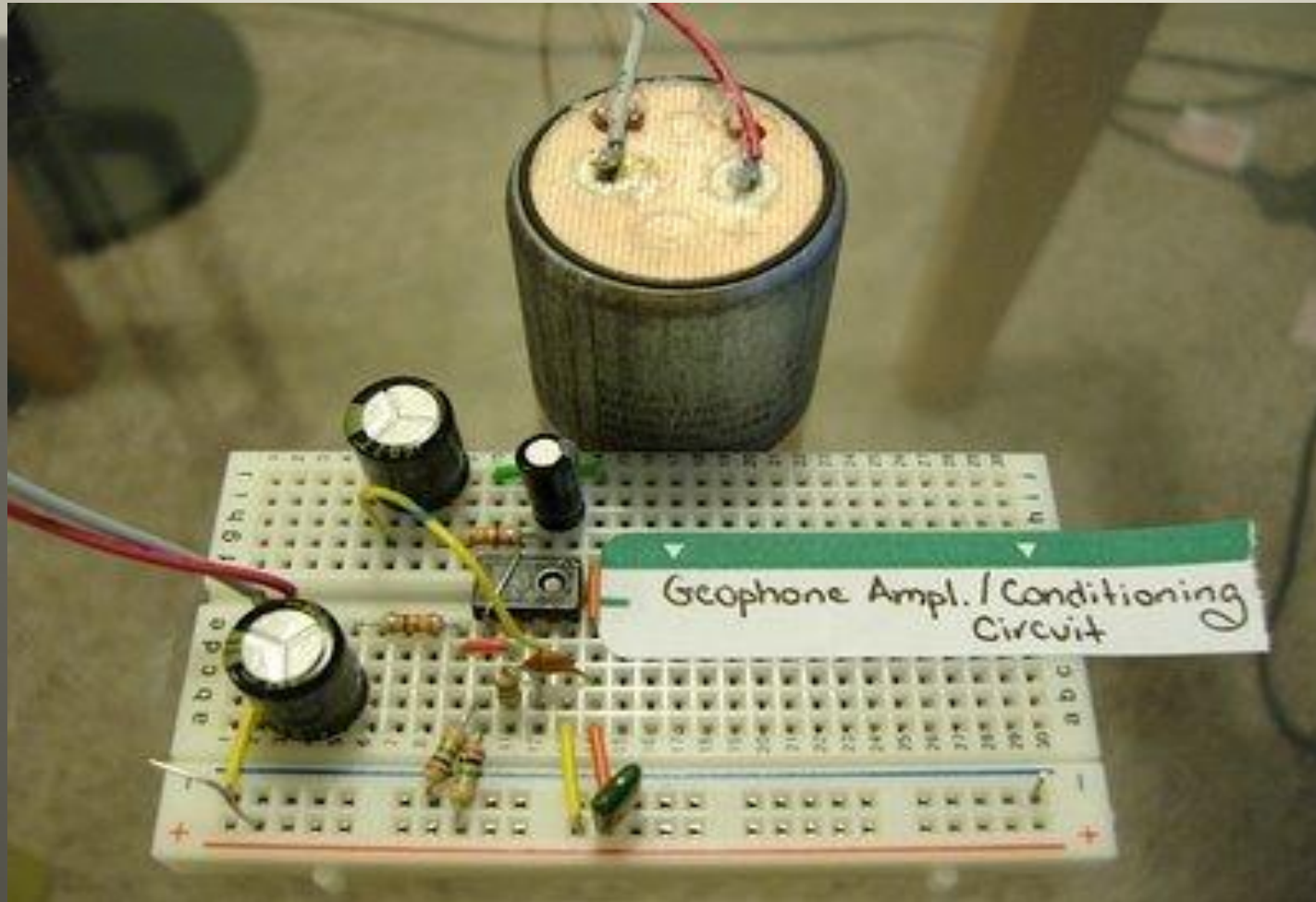
Geophone



Amplifier

- Actual ground movements caused by signals in seismic prospecting are only of the order of a few microns, therefore, the voltage obtained from the geophone will be very small. The purpose of amplifier is to magnify this voltage millionfold if necessary. Simultaneously, the amplifier also filters and suppresses the unwanted or spurious signals.

Amplifier



Galvanometer

- The seismic galvanometer represents a very complex system mainly comprising of the source of light, mirror, magnet, galvanometer, oscillograph and recording system.
- The galvanometer acts in conjunction with the oscillograph (for marking time) and the recording system. A light beam which is horizontal is focused against the photograph. This paper moves vertically downward and the light beam, as controlled by the voltage, makes the mark on the photopaper. Thus seismic record is produced.

Applications of Seismic Refraction

- Refraction methods are useful in many respects such as oil exploration, prospecting for some economic minerals, geological mapping, ground water studies and bed-rock studies at foundation sites of civil engineering projects
- In ground water studies, this method helps in detecting fractured zones which have the potential for ground water occurrence