GROUND WATER EXPLORATION- AN INTRODUCTION.

A PRESENTATION BY T.S. BADRINARAYANAN,
GEOSCIENTIST,
B SQUARE GEO TECH SERVICES, KOLLIDAM, SIRKALI TALUK,
NAGAI DISTRICT, TAMILNADU- 609 102.
MOB- 94430 46102, E-MAIL : tsbadri56@gmail.com

PRELUDE

- Water is one of the Mankind's most vital resources.
- An adequate supply of water is one of the pre-requisites for development and industrial growth.
- In areas where surface water is not available, Groundwater constitutes significant part of active fresh water resources of the world and is obviously dependable source for all the needs.
- The stress on water resources started due to exploding irrigation, domestic and industrial demands.
- The finite water resources are being explored to quench the thirst of millions of the populace.

WATER NEEDS AND CONSUMPTION

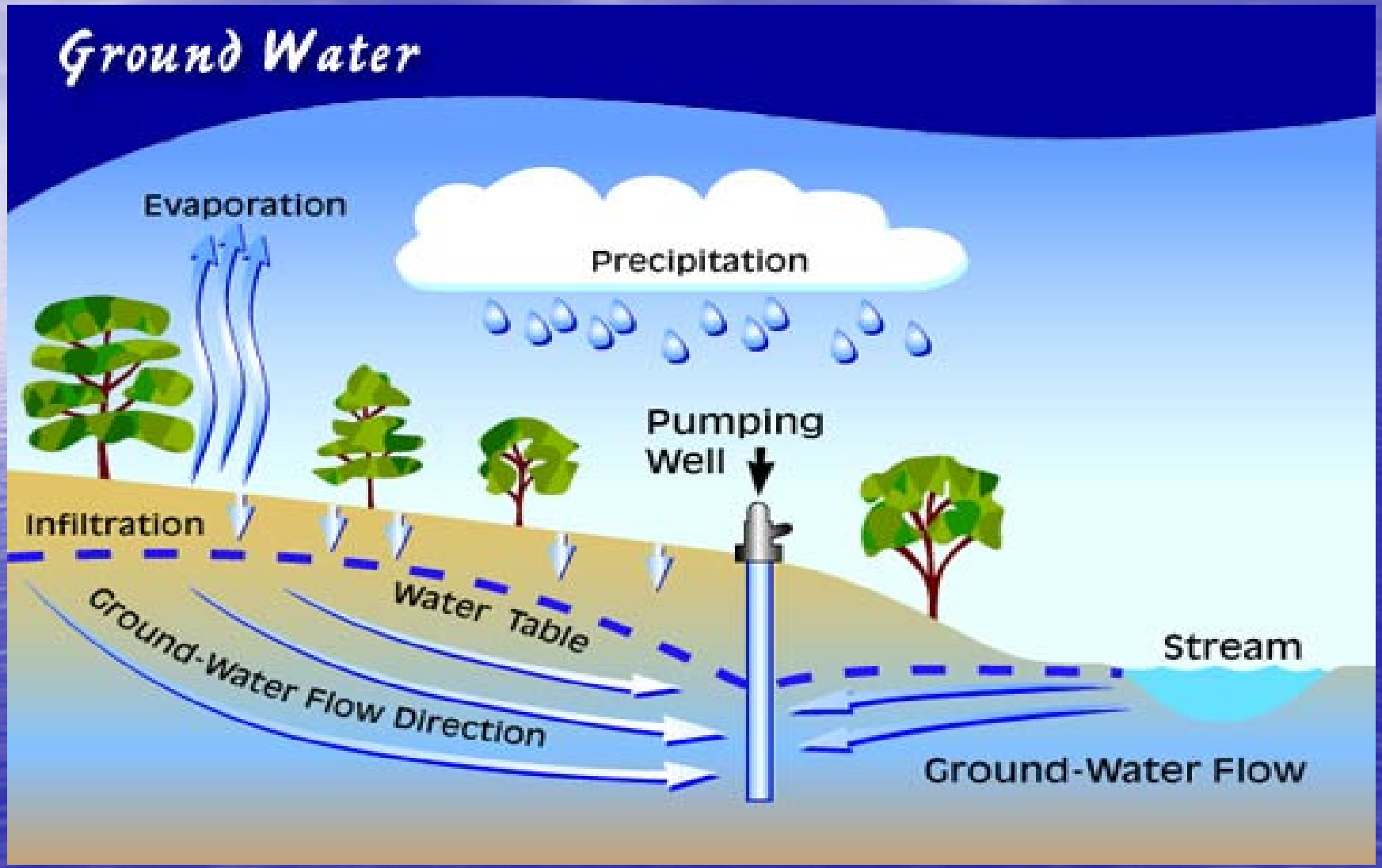
- In a developing country like India, the minimum daily requirement of a person is 200 litres for domestic use, while an equal or large amount will be needed for other purposes.
- It is estimated that out of the total of 1122 billion cubic meters of water utilized in India annually, 430 billion cubic meters is met from surface sources and the rest is met from ground water resources.

[Source, Hand Book for TWAD Hydrogeologists, 2002].

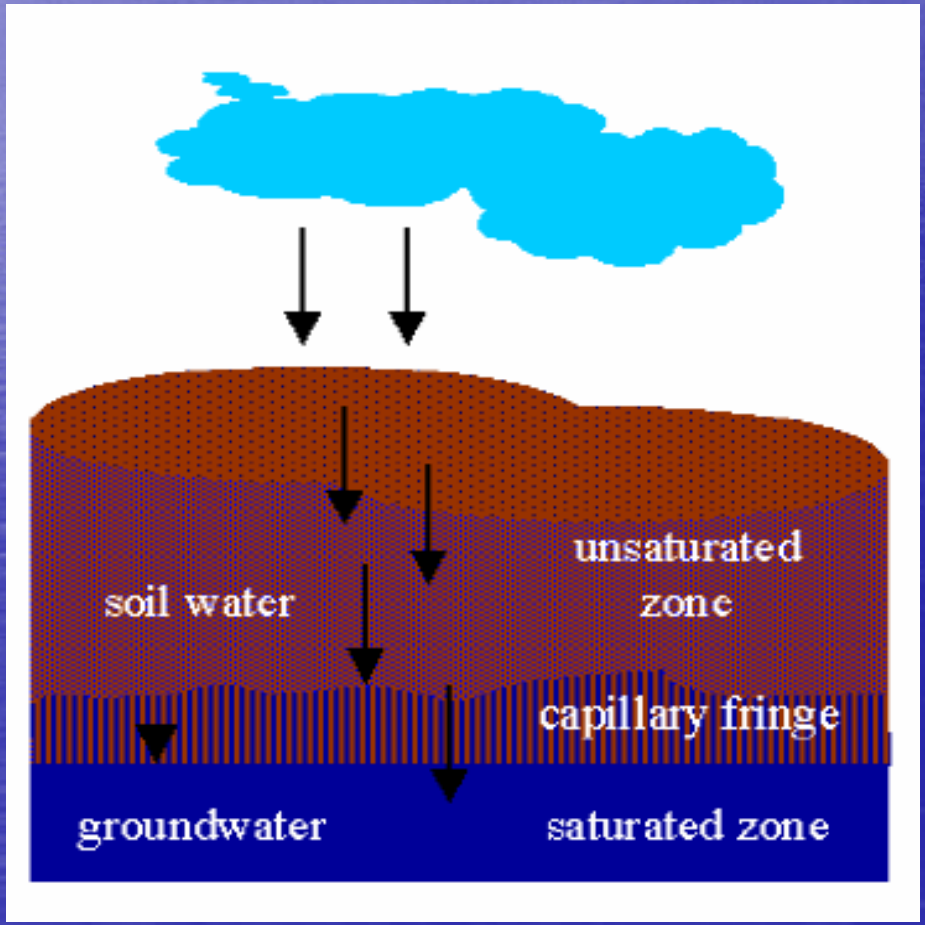
GROUND WATER

- Ground water is a mineral that occurs in the subsurface within sediments, rocks, desertic sand, ice & snow.
- It gets replenished from meteoric precipitation.
- Ground water is most widely distributed precious resource of the Earth.
- Among the natural water resources, ground water forms an invisible component of the system.

GROUND WATER



ORGIN OF GROUND WATER



PRECIPITATION.

INFILTRATION

RECHARGE

GROUND WATER EXPLORATION

- Though the ground water resources are widely distributed, Nature does not provide ground water at the places of our choice.
- The occurrence and distribution of ground water resources are confined to certain geological formations and structures.
- The ground water at all locations may not be directly used if the quality of water is poor.
- All these problems can be solved using proper exploration techniques.
- Explore is derived from Latin word *explorare* meaning- to learn or investigate.
- The proper exploration of ground water resources involves apart from source location, the well design and construction. These are all an integral part of the scheme of exploitation & management.

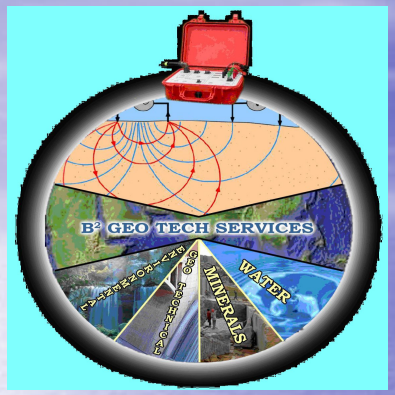
GROUND WATER EXPLORATION-HISTORY

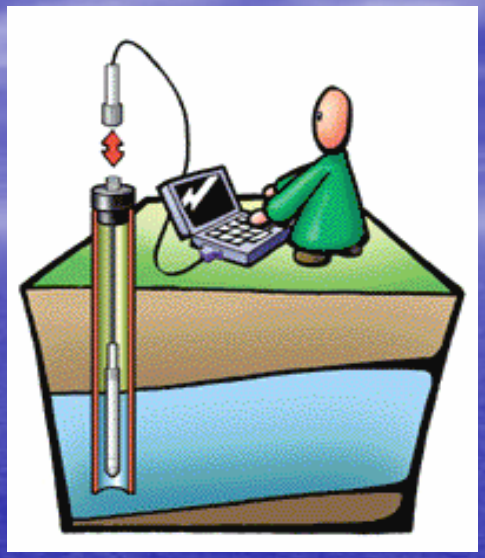
- The development of water resources seems to have started first in India & Egypt.
- Open wells for irrigation & drinking water were in common use in India as early as in the Mahabharata period about 6,000 years ago.
- Exploitation of ground water on modern lines can be said to have started at the turn of the century. The first tube well was sunk in 1935 in Uttar Pradesh.

OBJECTIVE OF GROUND WATER EXPLORATION

- Usually the ground water exploration projects pass through the phase of regional surveys, leading to detailed surveys and ultimately resulting in the exploitation of ground water by means of bore holes, wells.
- The main objective of these surveys is to study and understand the hydrological cycle of the region, to have an overall concept about the type, nature & number of aquifers, the quality of ground water.

METHODS AND TECHNIQUES OF GROUND WATER EXPLORATION





GROUND WATER EXPLORATION

- AERIAL
- SURFACE
- SUB-SURFACE
- ESOTERIC.

METHODS AND TECHNIQUES OF GROUND WATER EXPLRATION

AERIAL	SURFACE	SUB-SURFACE.	ESOTERIC.
1.Photogeologic Methods.	1.Geological Methods.	1. Geological.	1. Water divining.
2.Landsat/ IRS	2.Geomorphological methods.	2. Hydrogeological.	2. Astrological.
3.Infrared imagery.	3.Hydrogeological Methods.	3. Tracer techniques.	3. Biophysical.
4.Electro magnetic [EM] techniques.	4.Geophysical Methods.	4. Geophysical Logging techniques.	
	a). Electrical & EM. b). Seismic. c). Magnetic. d). Gravity.		
	5.Geobotanical Methods.		
	6.Geochemical Methods.		

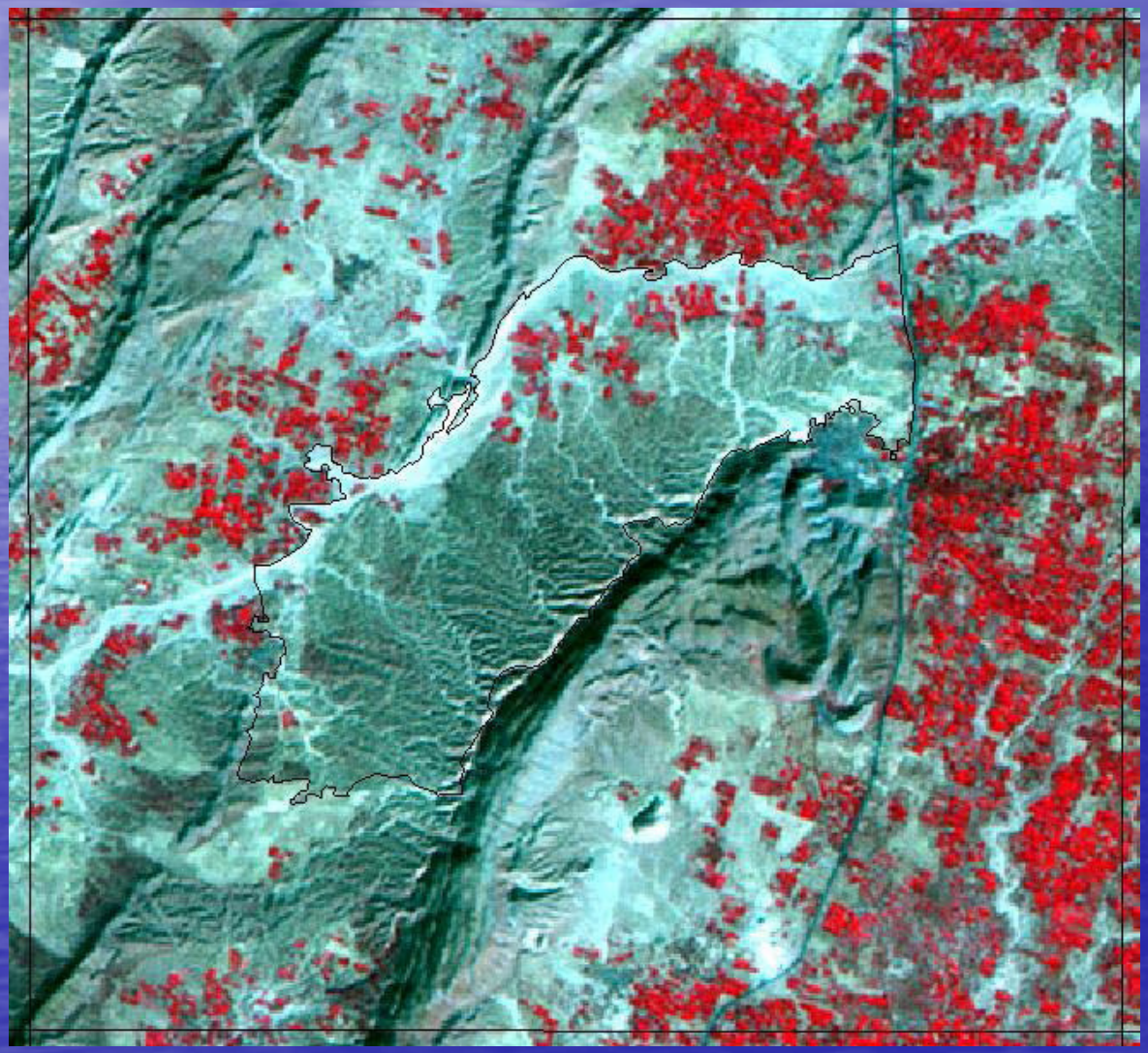
1. AERIAL METHOD

The most convenient methods for reconnaissance surveys of large areas aimed at identification of watershed characteristics of basins and locating prospective areas are the methods of aerial exploration.

1.1. REMOTE SENSING

- Remote sensing refers to obtaining reliable information about Earth's surface without physical contact, through the use of Electro magnetic radiation [EMR] as source energy and the sensors to record the images.
- The aerial photos are those taken from an aircraft mounted with the cameras, which shoot directly the terrain within the visible spectrum or in the near infrared region. The photos are taken in panchromatic [black & white], color & infrared.
- The RS data are found extremely useful in identifying the various geologic, geomorphic units, structures like faults, lineaments, joints, fractures, folds and drainage which are important since they control the movement and occurrence of ground water.

SATELLITE IMAGERY



AERIAL PHOTOGRAPHY

- Ground water investigation of an area requires the nature of lithological units, their structural dispositions, geomorphic set up, surface water conditions & climate of the area which can be studied through satellite images & aerial photographs that provide detailed information about a large part of the surface of the earth in a very short time.
- Remote sensing data do not directly detect deeper subsurface resources, but RS techniques have been effectively used in ground water exploration.

AERIAL PHOTO SURVEY

Aerial Photo Survey

Aerial photo survey is the study of the Earth surface by means of **remotely sensed** photographs (eg. aerial photographs).

The aerial photographs are studied as analogue images –based on the continuous variation in gray tone- or as digital images, converted from analogue images.

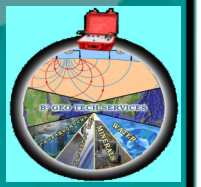
ADVANTAGES OF AERIAL PHOTO SURVEY

The advantages:

- Saving time,
- Observation of larger areas,
- More detailed ground surface information than topographic maps,
- Non-expensive than the studies carried out in the field,
- Study can be done anytime and at anywhere in 3D,
- Much more easy to carry out a study on the aerial photographs than studies in the field.

The disadvantage:

- Topographic contours and geographic names are absent on aerial photos.



PHOTOGEOLOGY

Photogeology

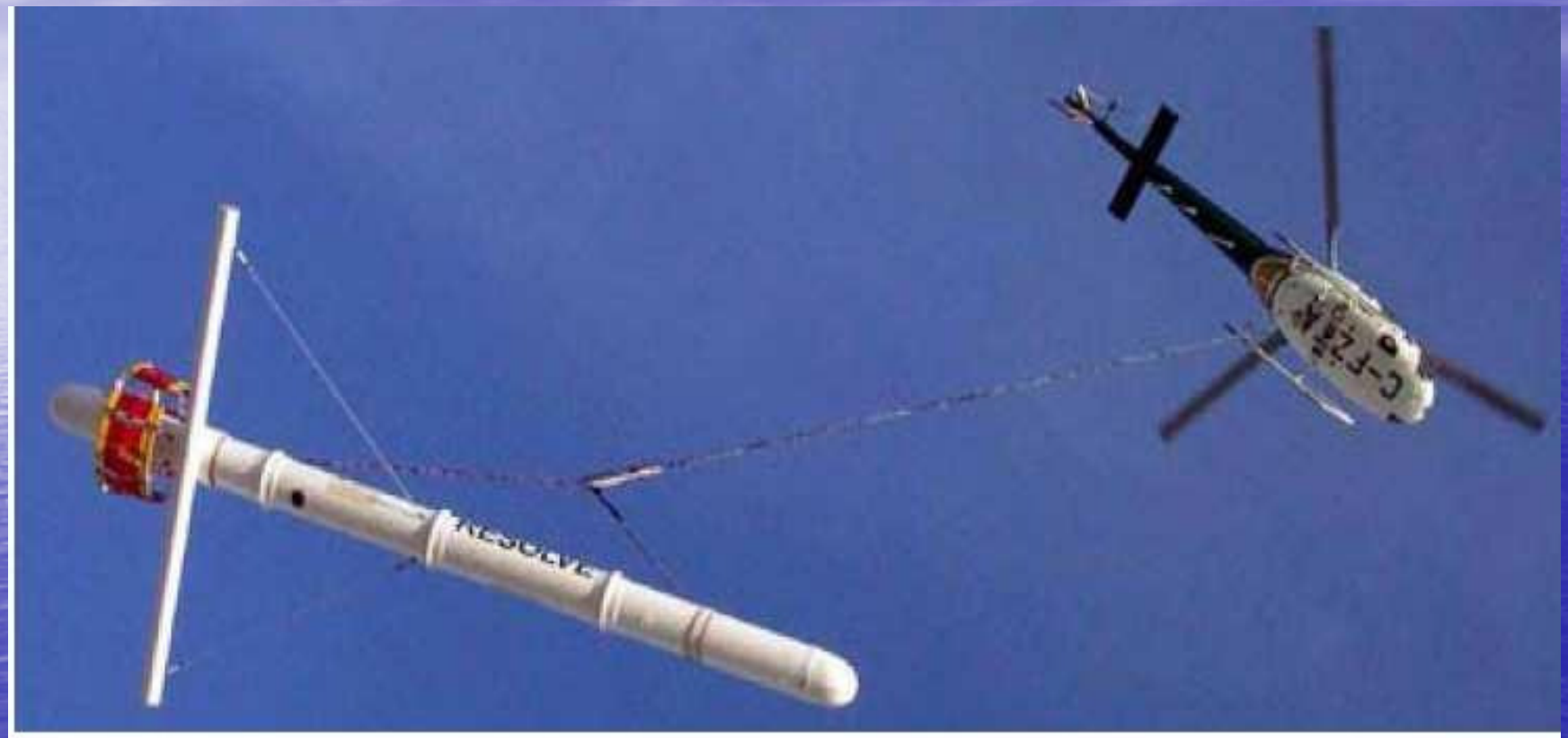
- **Photogeology** is the interpretation of the geological and geomorphological features by means of remotely sensed data.
- **A geological image interpretation** is defined as
  the study of imaged objects,
  extraction of geological features and
  study and analysis of the selected objects with the objective to come to the deduction of their geological meaning.
- The geological interpretation is based on the principal that the geological terrain conditions are more or less reflected in the morphology which is the **geomorphology.**

AERIAL PHOTO

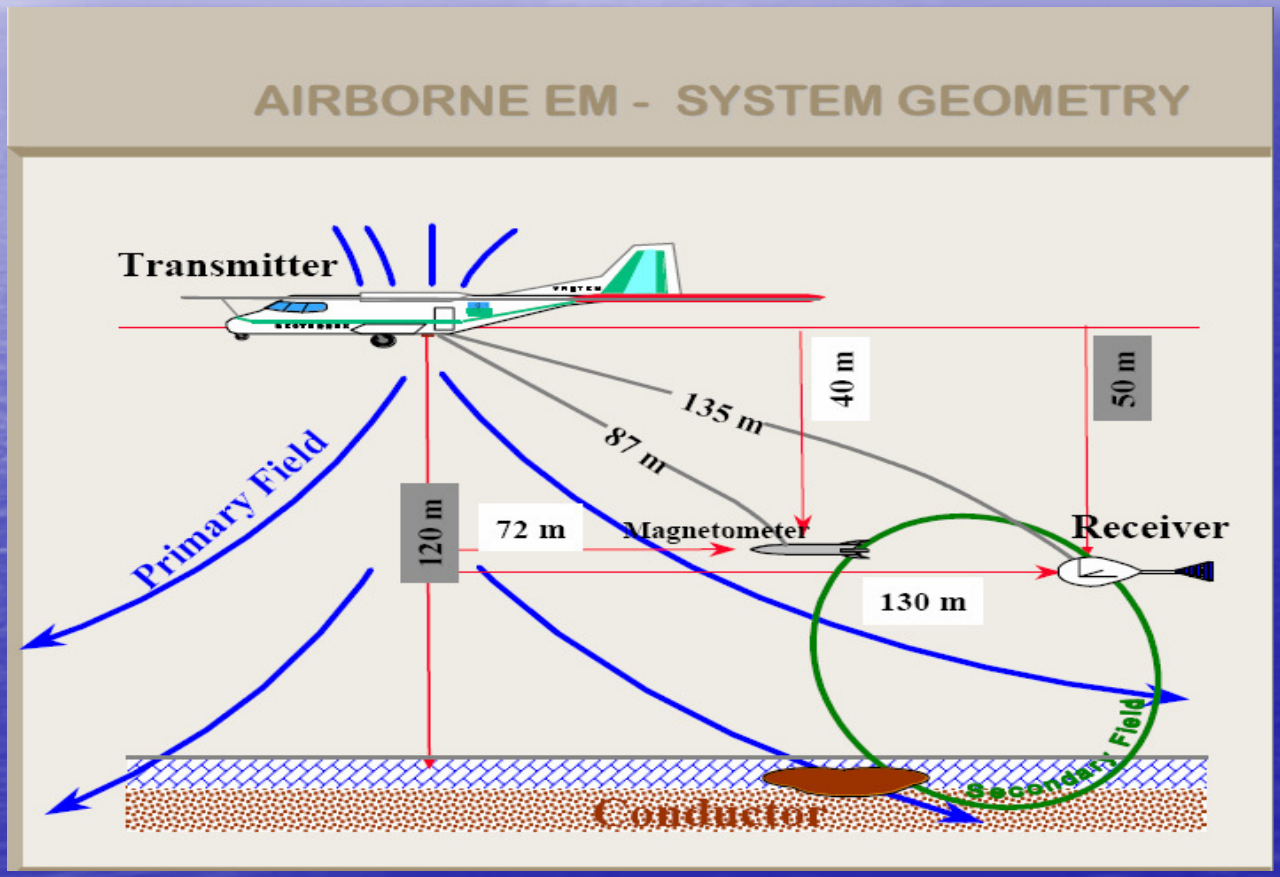
AIRBORNE ELECTROMAGNETIC SURVEY

- The advantage of airborne system is the rapid data acquisition over large areas & thus the technique is ideally suited to regional studies.
- Airborne electromagnetic survey [AEM] provides rapid assessment of the bulk resistivity of the subsurface of the large area.
- AEM survey is conducted from the aircraft @ height range of 60 to 120 meters.
- Generally in airborne electromagnetic survey [AEM] the primary magnetic field is generated through transmitter coil and the secondary magnetic field is picked up by the receiver coil.

1.2. AIRBORNE SURVEY



AIR BORNE EM SURVEY PRINCIPLE



2. SURFACE METHODS

- The most common and time tested methods are the surface variants of different techniques from geology, geomorphology, hydrogeology, geophysics etc.
- These methods are applied where the purpose is the detailed study of the distribution of potential water bearing zones in lateral and vertical directions.

2.1. GEOLOGICAL METHODS

- The ground water occurrence and movement mainly depend on the geology of the area. Geological studies are very much essential.
- The type of terrain, rock formations, lithological units, geological structures like lineament, fold, fault, joints and fracture system have to be studied in depth.
- Only after the geological investigations, the type of geophysical method to be conducted may be decided.

2.2. GEOMORPHOLOGICAL METHODS

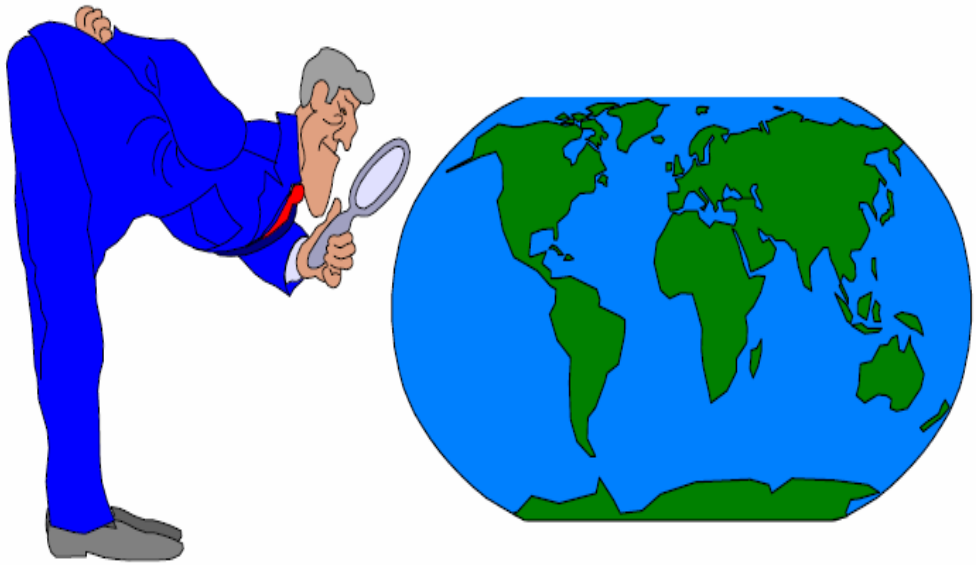
- After a thorough study of the satellite imagery and geomorphology map, a field check is highly necessary to know the geomorphological features to assess the ground water potential.
- The geomorphic units like pediments, flood plains, drainage pattern, soil types, lineaments which primarily control the occurrence, movement and potential of ground water have to be investigated in detail.

2.3. HYDROGEOLOGICAL METHODS

- The ground water potential of an area mainly depends upon the hydrogeological set up, for which a detailed & systematic hydrogeological survey is a prerequisite.
- Well inventory study is very important in any ground water exploration programme.
- Especially in hard rock terrain ground water confines to the weathered mantle, joints and fractures. The weathering thickness, joint & fracture system of the area ought to be studied in depth.
- Water level measurements, water level fluctuation studies are the important factors in the assessment of ground water potential.
- Only by a systematic hydrogeological study, the ground water abstracting structures like open well, bore well, tube well have to be finalized.
- The recharge and discharge areas ought to be identified.
- The fluvial hydrological studies like the river & stream flows, whether it is perennial etc details are important in quantifying the potential.

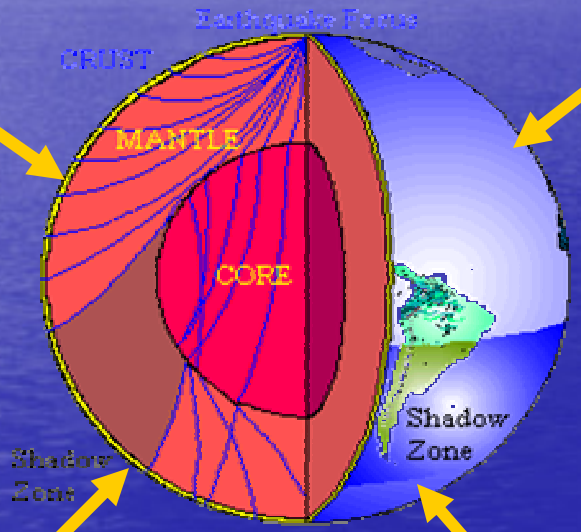
2.4. GEOPHYSICAL METHODS.

Exploring the Earth with Geophysics!

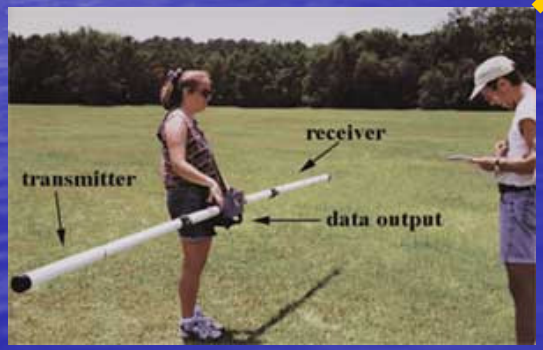


2.4. GEOPHYSICAL METHODS.

Resistivity.



Electromagnetic.



WHAT IS GEOPHYSICS ?

- The study of the earth using quantitative physical methods, remote insight into the earth.
- We designate the study of the earth using physical measurements at the surface as geophysics.
- In a broader sense, geophysics provides the tools for studying the structure and composition of the earth's interior

GEOPHYSICAL INVESTIGATION

- Geophysical methods comprise of measurement of signals from natural or induced phenomena of physical properties of sub surface formation.
- Various physical properties that are made use of in different geophysical techniques are electrical conductivity, magnetic susceptibility, density, elasticity & radioactivity.

GROUND WATER GEOPHYSICS OR HYDROGEOPHYSICS

- **All ground water investigation requires the service of Geophysical method as it aids in determining the subsurface structure.**

- **Exploring the ground water by geophysical method is termed Ground water geophysics.**

GEOPHYSICAL METHODS USED IN GROUND WATER EXPLORATION

- A]. Electrical method.
- B]. Electro magnetic method.
- C]. Seismic method.
- D]. Magnetic method.
- E]. Gravity method.

2. 4A- ELECTRICAL PROSPECTING METHODS

- Electrical methods of prospecting include a large group of geophysical techniques employed for investigating the electrical fields of the earth.
- Such fields are generated in the earth naturally or artificially by generators or batteries.
- The distribution & intensity of electrical fields depend on the source of excitation as well as upon the electrical properties & geological structures in the region.
- The different electrical properties that influence electrical fields are primarily the resistivity ρ, the dielectric permeability μ & magnetic permeability ε.
- Electrical parameters vary depending upon the lithology & more influenced by the presence, content & quality of water.

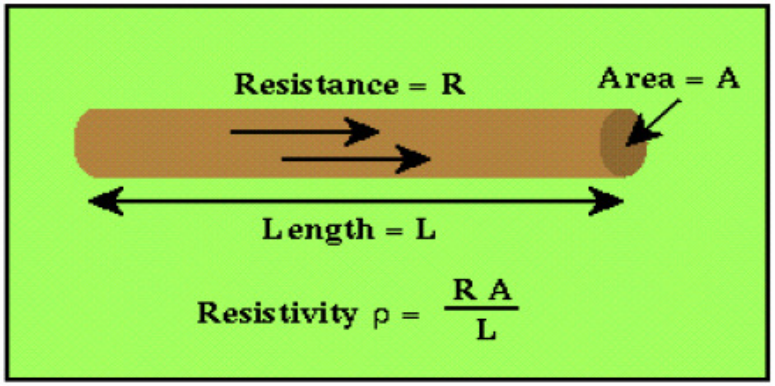
WHAT IS RESISTIVITY?

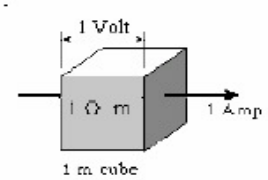
- Resistivity is the resistance in ohm meter of a unit cube of material.
- According to Ohm's law resistance r = v / i, where v- is the potential difference in volts & i is the current in amperes.
- Resistivity: measures apparent resistance of ground to direct current (dc) flow.
- Resistance is the inverse of conductance.

ELECTRICAL RESISTIVITY VS RESISTANCE

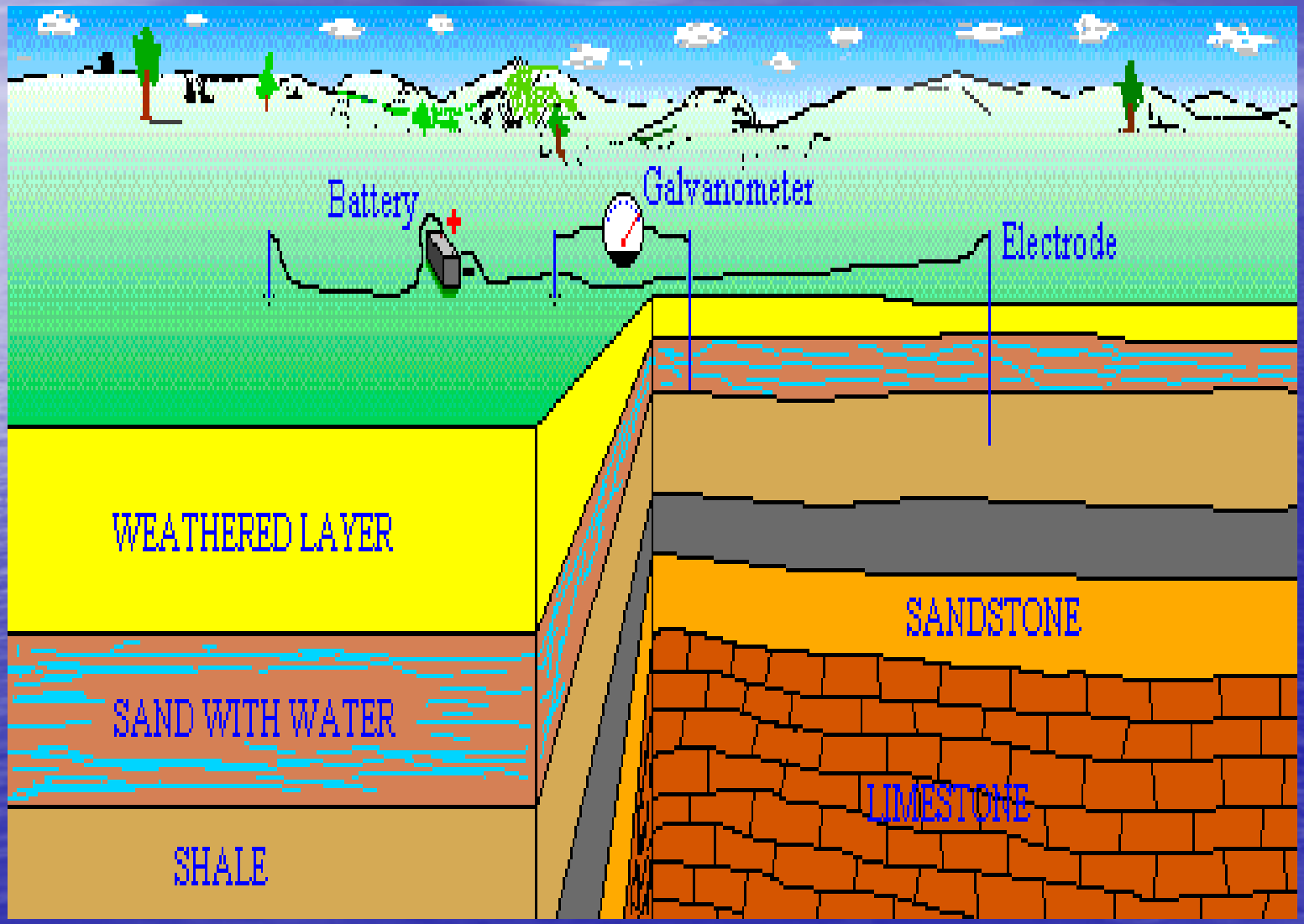
DC resistivity basics

Resistivity vs. Resistance



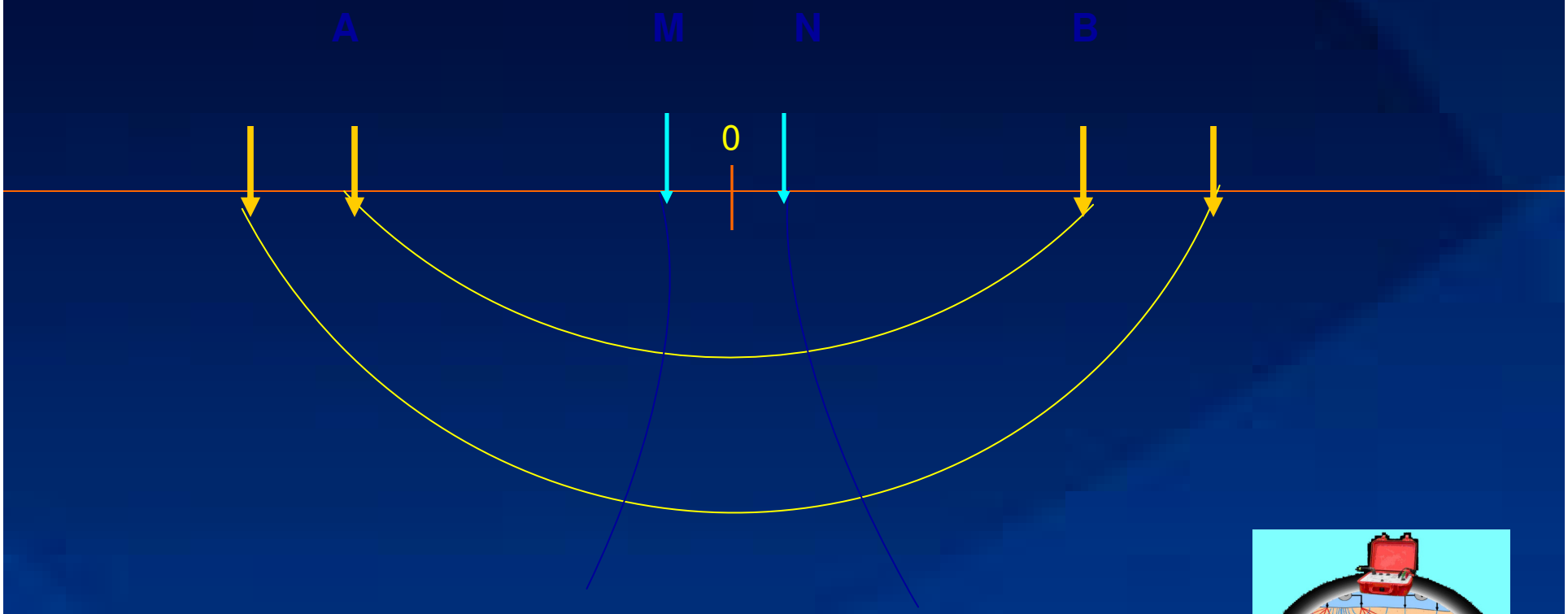


RESISTIVITY SURVEY

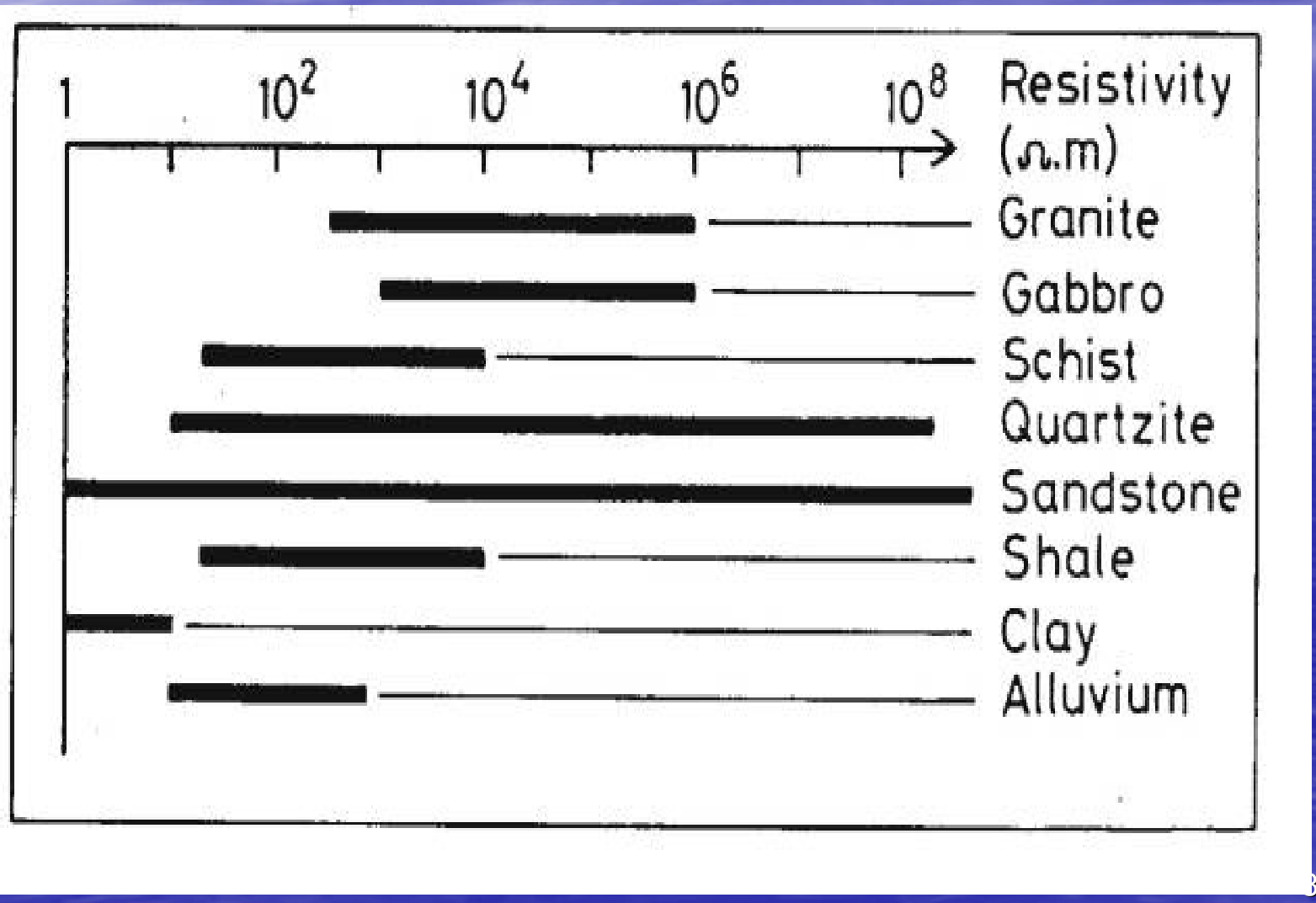


SCHEMATIC DIAGRAM OF CURRENT FLOW IN EARTH

SCHLUMBERGER CONFIGURATION



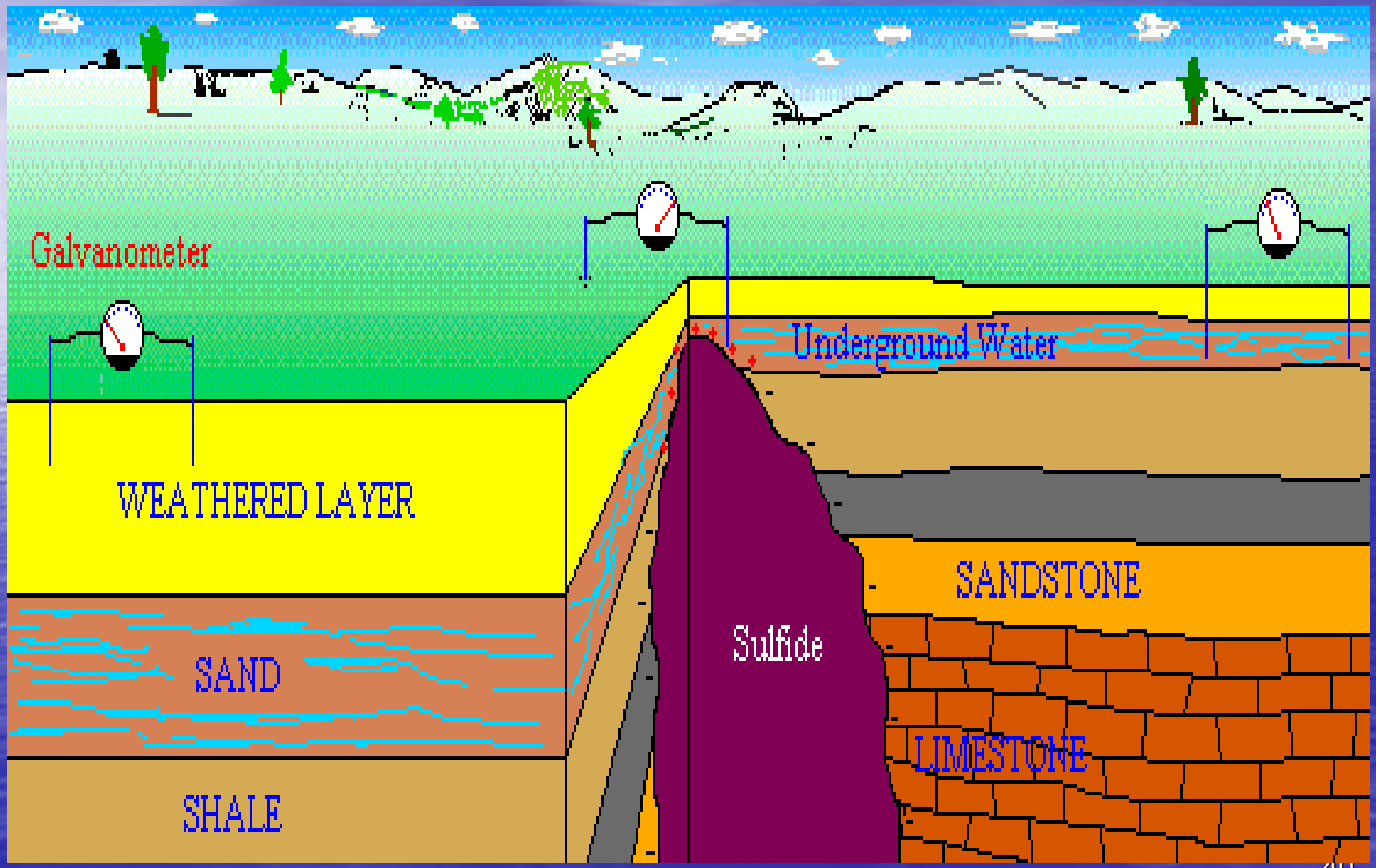
RESISTIVITY VALUES FOR GEOLOGICAL FORMATIONS



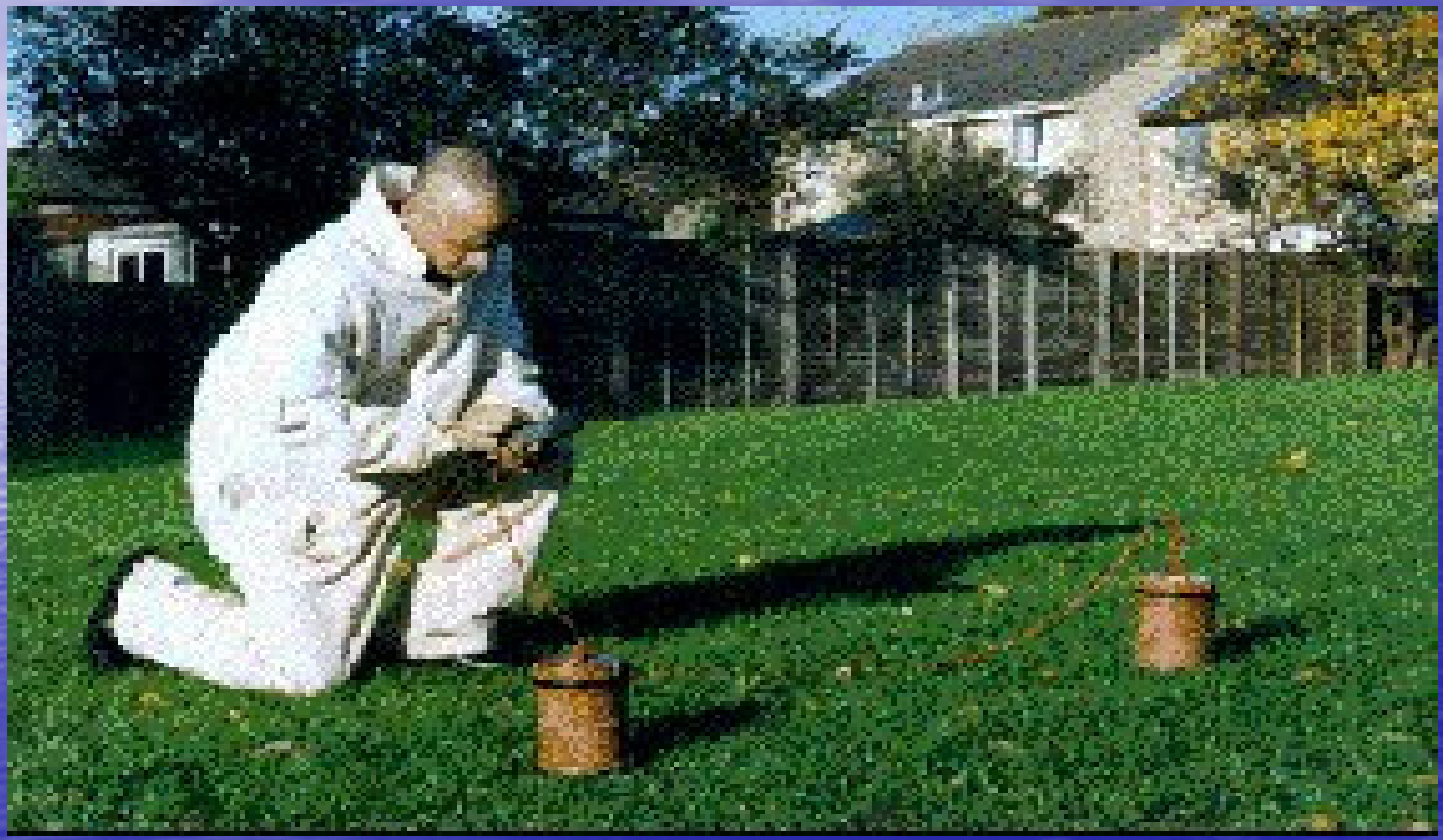
SELF OR SPONTANEOUS POTENTIAL- SP

- Self potential is naturally occurring electric potential in the ground due to several origin.
- Self potential is of 3 kinds-
- Diffusion potential.
- Membrane potential.
- Electro-kinetic potential.
- SP measurements- 2 non-polarizable electrodes & a high impedance milli-volt meter are sufficient to make sp measurements.
- Two field methods- gradient & total field methods.

SELF POTENTIAL- SP



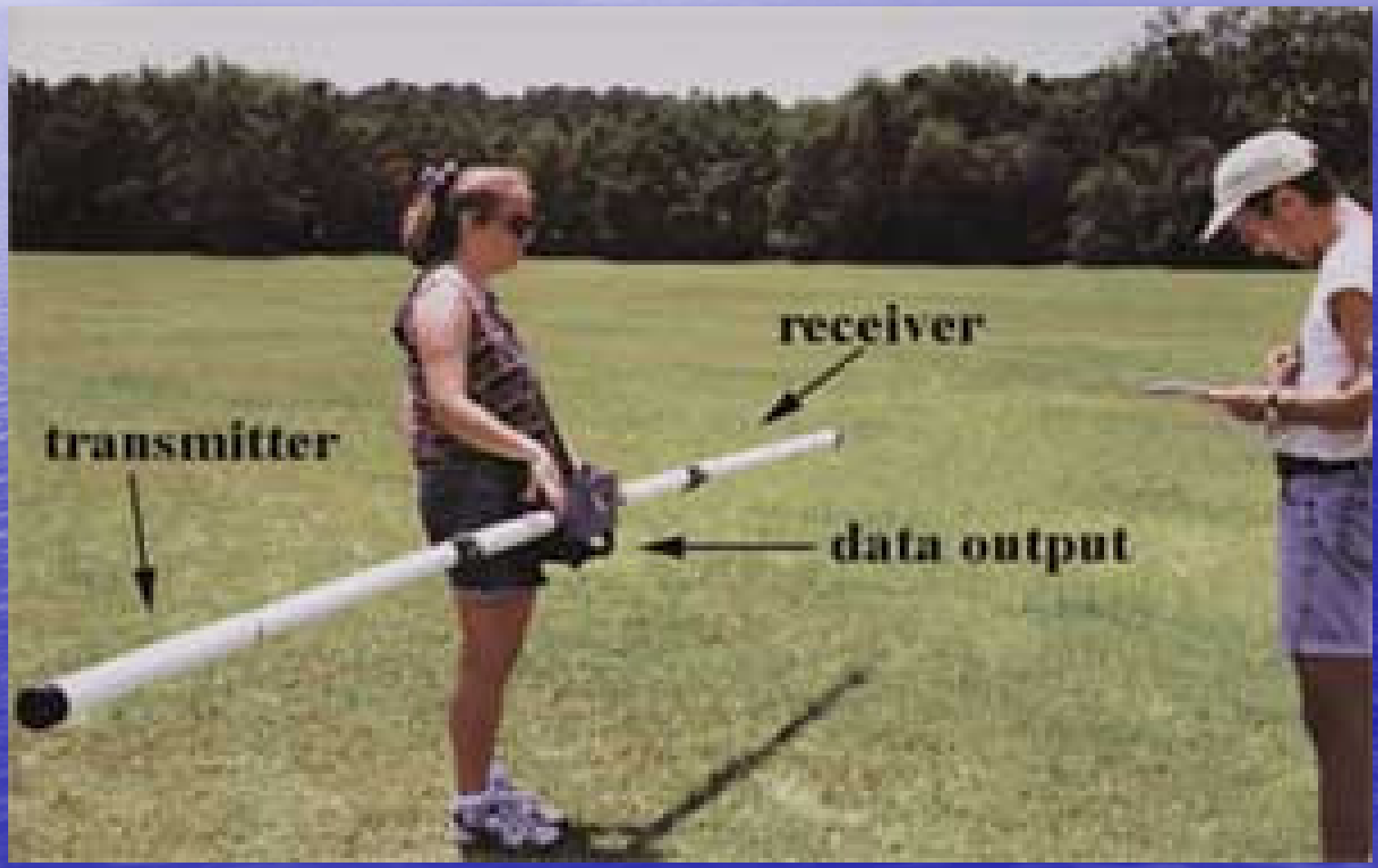
SELF POTENTIAL MEASUREMENT



2. 4B- ELECTROMAGNETIC METHODS

- Electromagnetic methods based on the measurement of conductivity of subsurface minerals & formations – useful for exploring minerals & ground water.
- The flow of electrical current in conductor is always accompanied by the presence of magnetic fields.
- The interaction of electrical & magnetic fields is governed by Maxwell's equation & well known laws of ampere & faraday.
- Geophysical methods make use of the interaction of electrical & magnetic fields with each other & their mutual interaction with matter to determine the properties of electrical conductivity or magnetic permeability of the earth.
- Telluric method makes use of the electric field due to naturally flowing earth currents by activities in the ionosphere.
- Magnetic – telluric [MT] method makes use of the electromagnetic fields due to telluric earth currents & measures time variations for the deep subsurface structures.

ELECTRO MAGNETIC INDUCTION



2. 4C- SEISMIC METHODS

- Seismic prospecting developed from seismology, the science of earth quake- also called applied / exploration seismology.
- It has its basics in utilizing the propagational time of elastic waves excited @ the surface.
- The energy generated @ the source travels as waves & these elastic waves have different transmission times.
- Most widely used artificial sources of generating elastic waves are explosions – non explosive sources such as mechanical vibrations are also used.

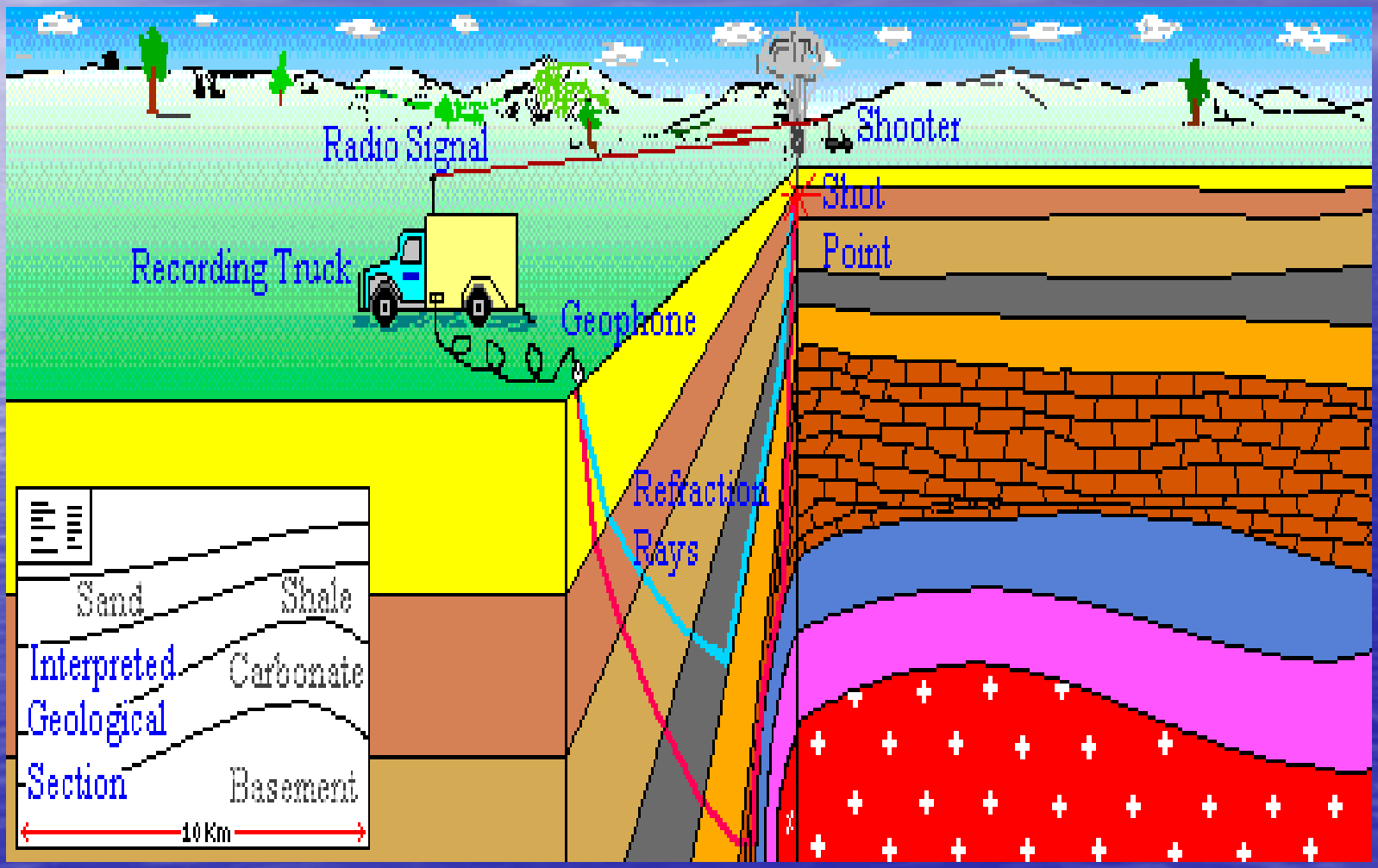
METHODS OF SEISMIC PROSPECTING

SEISMIC SURVEY

REFLECTION SEISMIC

REFRACTION SEISMIC.

SEISMIC LAYOUT



2. 4D- MAGNETIC METHODS

- Magnetic method based on the measurement of susceptibilty contrast between the anomalous body & the rock around it.
- Ferromagnetic minerals particularly magnetite are the main source of local magnetic anomalies.
- Instruments measuring magnetic susceptibility are called magnetometers- different types – Schmidst & torsion magnetometers, the flux gate magnetometer, the proton precision & rubidium vapour magnetometers.

MAGNETIC ANOMALY

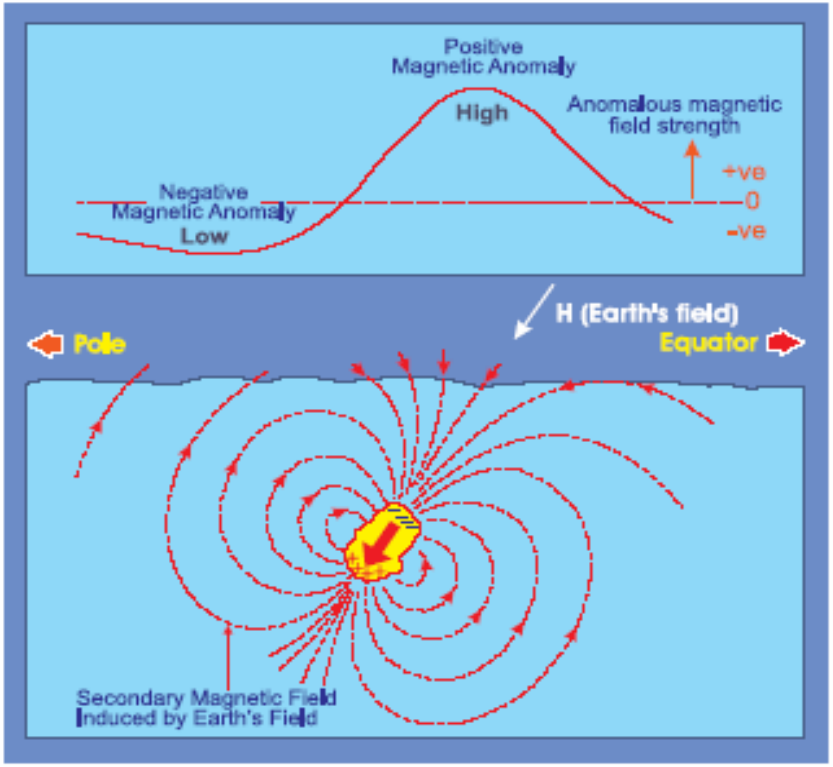


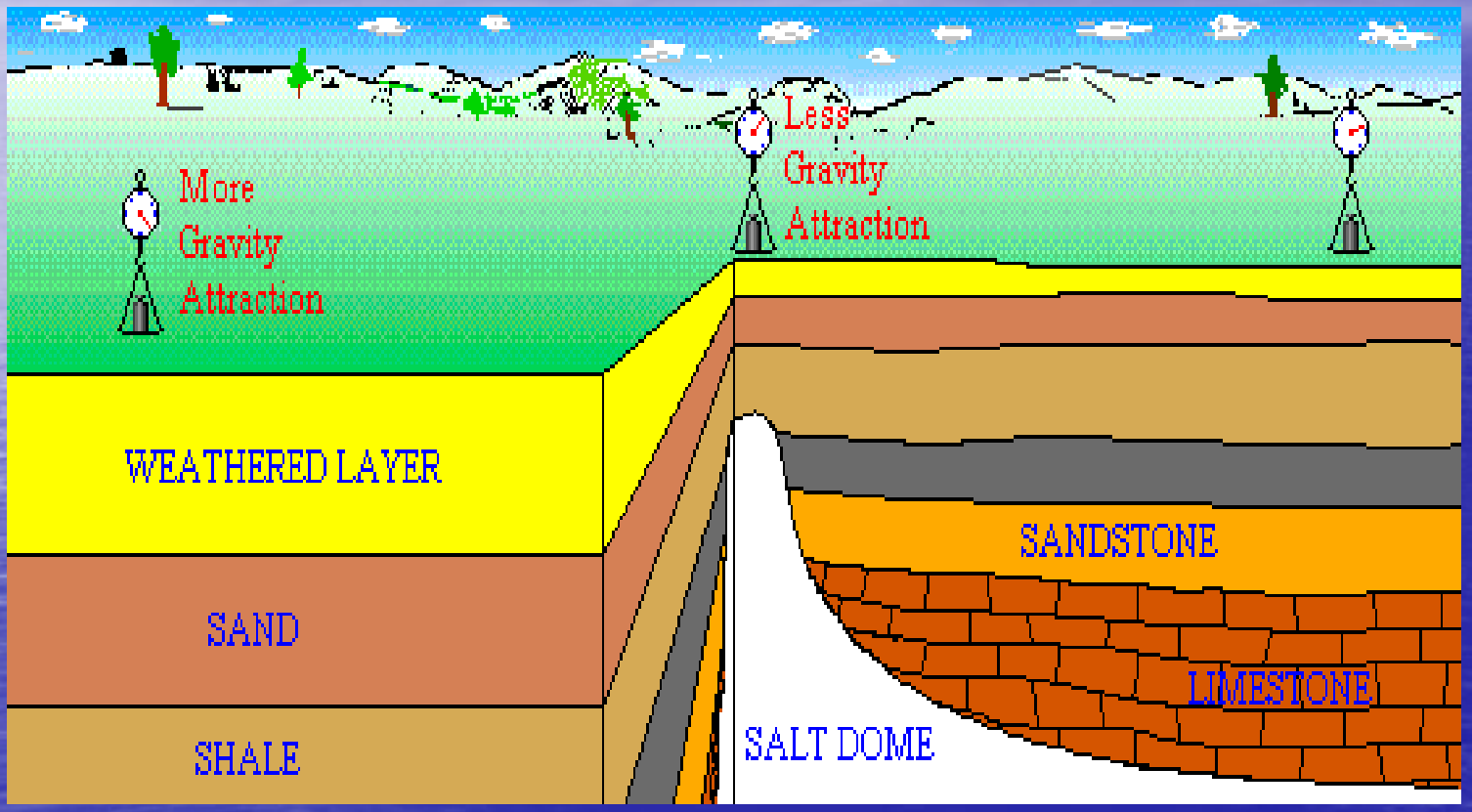
Fig. 3: Induced magnetization in geological body produces local magnetic anomaly.

4

2. 4E- GRAVITY METHOD

- Measurements of the gravitational field at a series of different locations over an area of interest. the objective in exploration work is to associate variations with differences in the distribution of densities and hence rock types.
- Based on the measurement of density contrast between the anomaly causing body & the surrounding rocks.
- This method may be used for the exploration of minerals, ground water, oil & gas.
- In mineral exploration this method is useful particularly for heavy minerals- barite & chromite.

GRAVITY SURVEY



GRAVIMETER

3. SUB-SURFACE METHODS

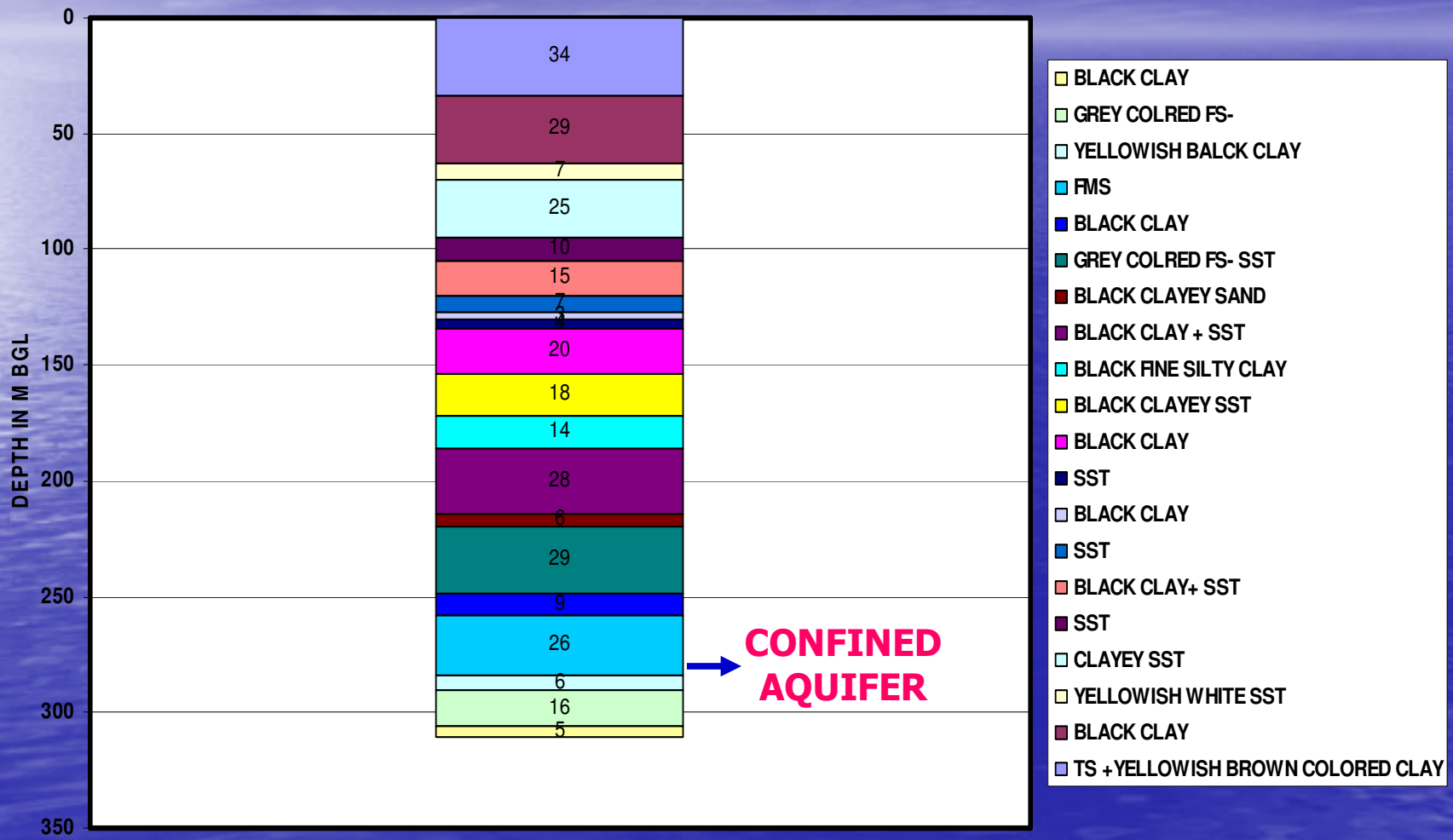
- The subsurface methods are useful only where a borehole is available or can be drilled for the purpose of verifying the results of surface investigations.
- Quantitative data on aquifers is obtained to determine the suitability of aquifers for exploitation.

3.1- GEOLOGICAL

- Under subsurface geological methods, the bore hole soil & rock samples collection is highly essential to study the lithological units, to prepare liholog, to identify granular zones to locate the aquifers.
- Litholog of a pilot bore hole is highly useful to correlate with geophysical logs to ascertain the quality, well design & construction.

3.1. LITHOLOG.

JEYARAMAN, KO.PAVALANGUDI, LITHO LOG.



3.2- HYDROGEOLOGICAL

- Under sub surface hydrogeological methods, the water level studies, the aquifer system studies & pumping tests are important.
- Pumping test is a controlled field experiment to find out the hydraulic characteristics of an aquifer or the yield characteristics of a well.

3.4- GEOPHYSICAL LOGGING

GROUND WATER GEOPHYSICS.

SURFACE GEOPHYSICS.

SUBSURFACE OR BORE HOLE GEOPHYSICS.

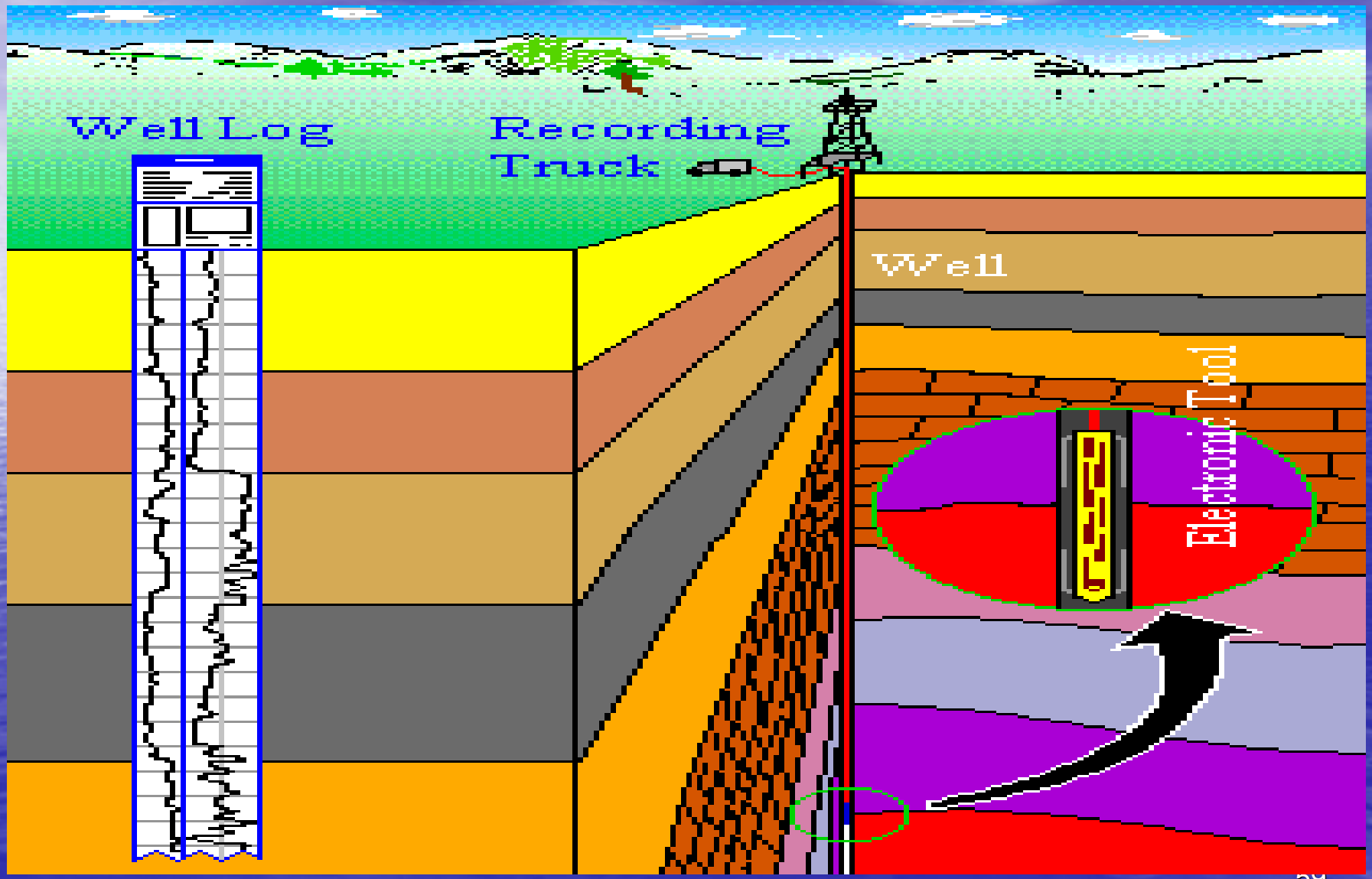
3.4- GEOPHYSICAL LOGGING TECHNIQUES OR BORE HOLE GEOPHYSICS- AN OUTLINE

- Geophysical logging of boreholes came a long way since 1927, when Schlumberger brothers ran the firs electric log.
- In India the geophysical logging of water well was carried out for the first time in 1953 by GSI, in Bihar.
- Basically there are two types of logging techniques- first utilizing the natural source & second utilizing stimulated controlled source.
- Geophysical logging technique utilizes the measurement of certain physical Parameters across different subsurface formations with the help of sensing probe inside the bore hole providing a continuous record of these parameters versus depth.
- These parameters are interpreted in terms of lithology, porosity, moisture content & quality of formation fluids.
- Different physical properties like electrical conductivity, magnetic susceptibility, radioactivity & velocity etc are utilized.

PURPOSE OF WELL LOGGING

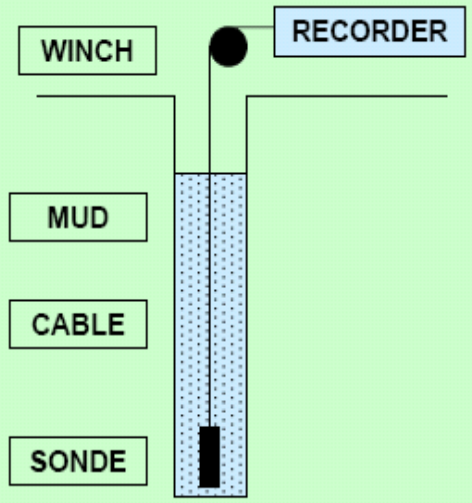
- It is a subsurface geophysical method of exploration, to get a clear picture about the under ground.
- The primary purpose of well logging is the identification of formations traversed by a bore hole & salinity of fluids.
- Used for stratigraphic correlation, detection of bed boundaries, porous & permeable zones.
- Used for the water well design & construction.
- Used for sea water intrusion studies of coastal aquifers.
- In hard rock bore wells the fracture systems can be studied for rejuvenation.
- Normally logging is carried out in pilot bore holes recommended, after thorough geological & surface geophysical surveys.

WELL LOGGING



LOGGING CONFIGURATION

Logging Configuration



Logging Components

- mud column
- sonde (tool)
- cable (wireline)
- winch
- recorder

Tool records as it is raised from the bottom of the hole.

DIFFERENT TYPES OF LOGGING METHODS

- Electric logging – electrical resistivity & sp.
- Radioactive logging – gamma ray & neutron logs.
- Induction logging.
- Sonic logging.
- Fluid logging – temperature, fluid resistivity, flow meter & tracer logging.
- Caliper logging.

2.4.1- ELECTRIC WELL LOGGING

- The continuous recording of electrical resistance / resistivity & sp of the formations by a drill bore hole is electric logging.
- Point resistance & resistivity logs-the response of formations in form of resistance offered to the electric conduction is measured in 2 modes- resistance & resistivity.
- Sp log- the potential drop between bore hole electrode & a reference electrode @ the surface is recorded.
- Sp logs are highly useful in deciphering saline water & clay predominant zones.
- Resistivity logs- normal resitivity logs are 4 electrode system- used for ground water & mineral explorations.

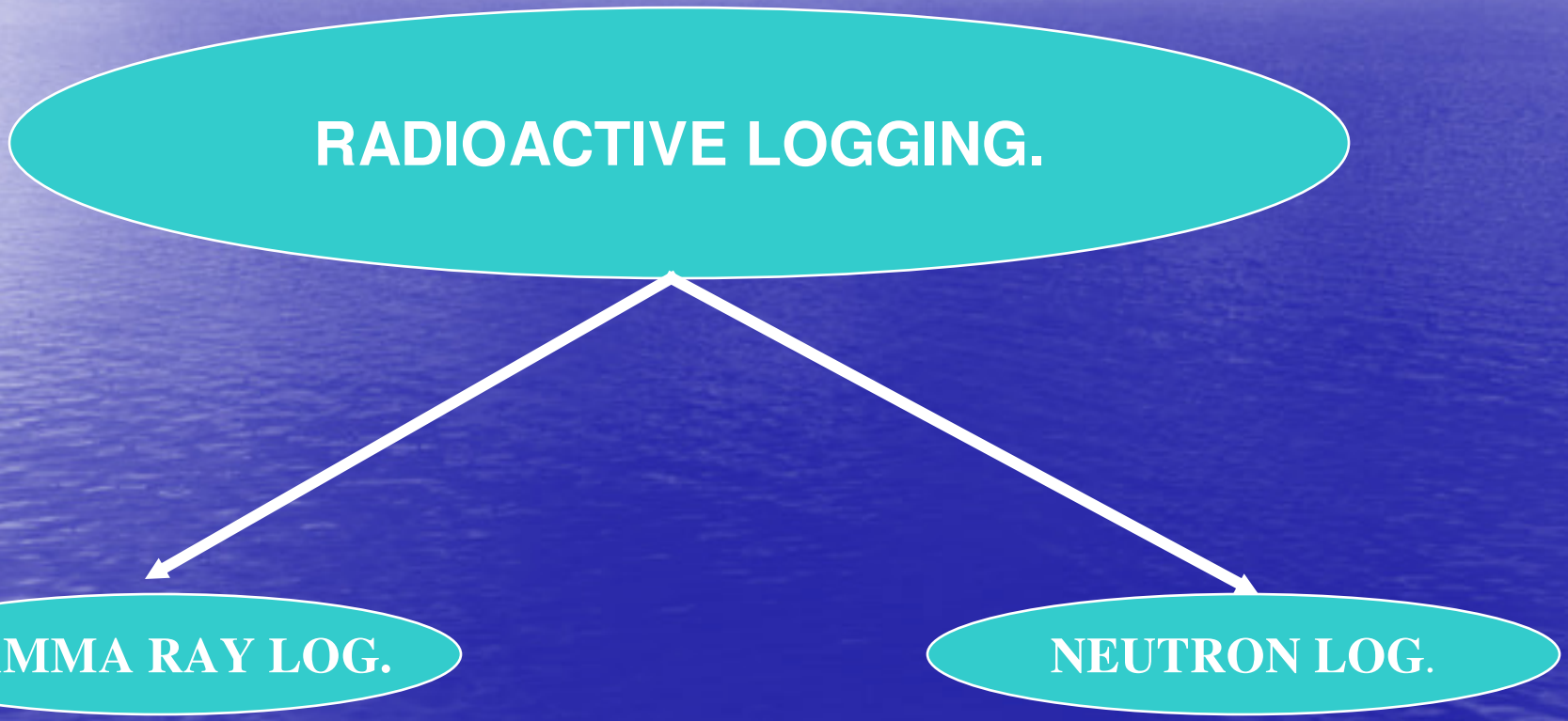
2.4.2- RADIOACTIVE LOGGING

- The principle is that the atoms of a few naturally occurring elements spontaneously disintegrate accompanied by radiations of alpha, beta & gamma rays.

Principal uses –

- Best suited to for lithology identification & stratigraphic correlations.
- Can be used in both in open holes & cased wells.
- Depths & thickness of clay & non clay beds can be obtained.
- Gamma ray data are valuable as a supplement to the electric log, in particular to help identify thin clay layers & porous zones in dense rocks.
- Neutron logs are useful in determining the porosity of formations.
- Radioactive mineral resources in the subsurface can be identified.

RADIOACTIVE LOGGING



NATURAL GAMMA LOGGING

5. Natural Gamma Logging

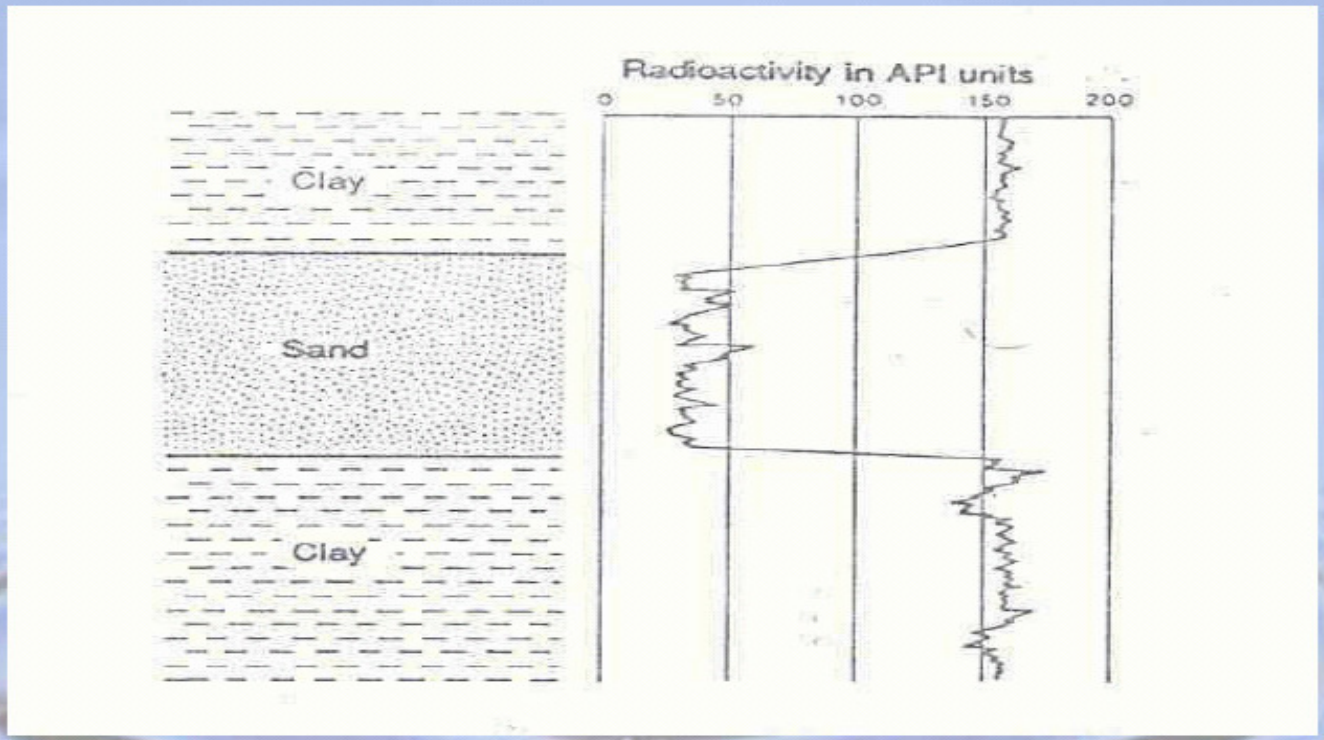
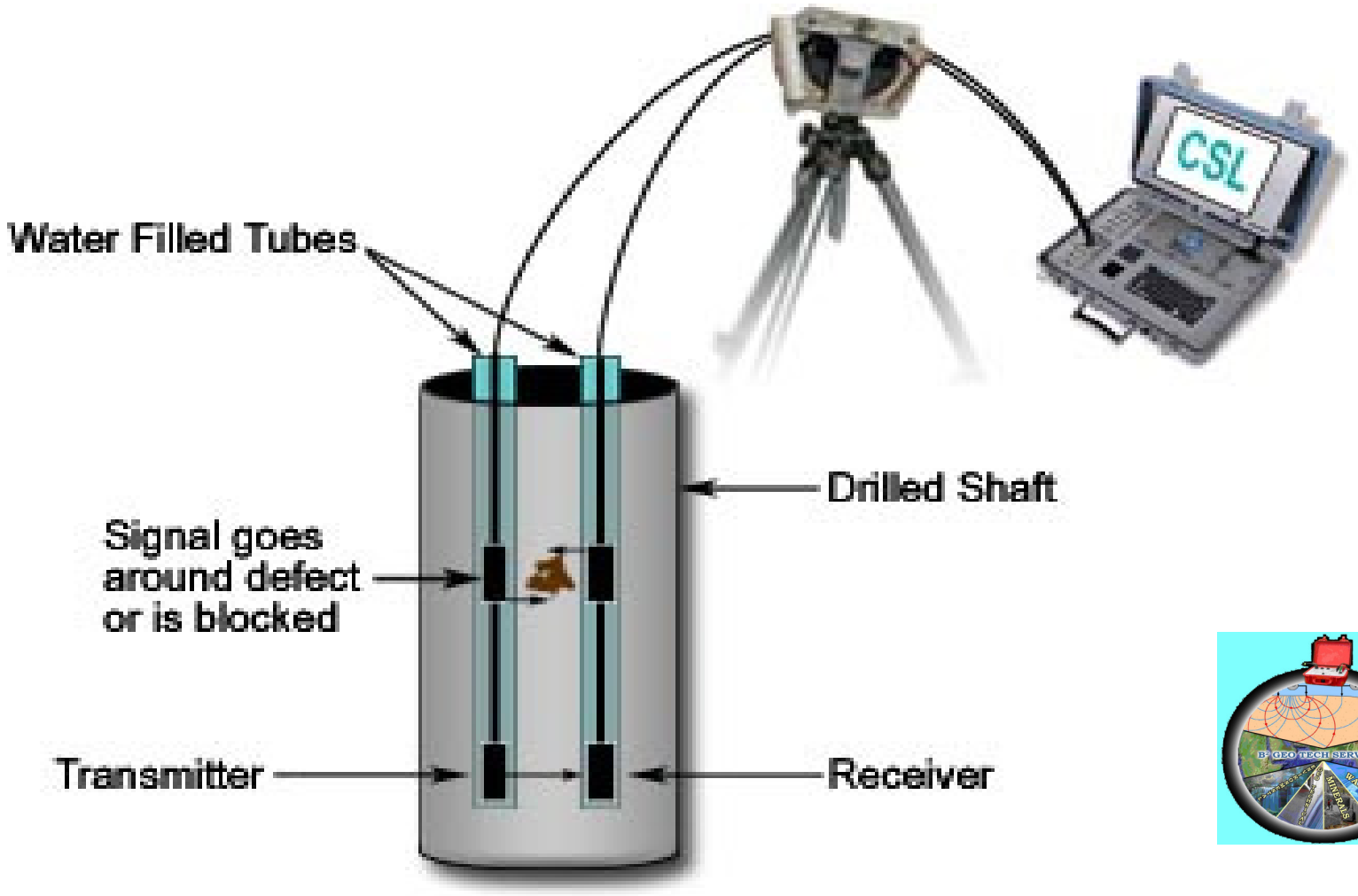


Figure 5.2: Natural radioactivity of clays

CROSS HOLE SONIC LOGGING



2.6. GEOCHEMICAL METHODS

- Water quality is as important as quantity in hydrogeological studies.
- The science dealing with the chemical quality of water is called Hydrogeochemistry.
- Ground water comes into contact with various minerals which are soluble in water. The dissolved minerals determine the usefulness of the water for various purposes.
- The presence of some minerals beyond certain limits may make it unsuitable for irrigation, drinking or industrial purposes.
- The quality of water depends upon the total quantity of dissolved solids depicted by parts per million.
- In any ground water development, it is essential to conduct chemical analysis of representative samples of water.
- Chemical analysis of water samples is done based on the purpose of usage. For drinking purpose physio chemical analysis of water sample is conducted to know the potability.
- For each purpose there are water quality standards to be followed.

2. 6- GEOCHEMICAL METHOD….

- The simplest classification of water is based on the TDS. The four main types of water are fresh, brackish, saline & brine.
- The water quality should satisfy the requirements or standards set for the specific use, namely domestic, livestock, agricultural and industrial purposes.

2.6- GEOCHEMICAL METHOD....

- There are some critical parameters like total dissolved solids [TDS], hardness, alkalinity, fluoride, nitrate and iron to decide the chemical quality & potability of drinking water.
- The quality of ground water depends upon geology, hydrogeology, soils, exploitation, rain fall and so on.
- Sea water intrusion and pollution are the other factors in quality degradation.
- Pollution of ground water may be defined as the artificially induced degradation. Pollution contaminates the water making it unfit for usage creating hazards to public health.
- The major contaminant sources are septic tank systems, sanitary land fills, chemical land fills & waste water disposal ponds.
- The main cause of pollution in coastal aquifers is the sea water intrusion which occurs when permeable formations outcrop into a body of sea water and when there is a landward hydraulic gradient.

2. 5- GEOBOTANICAL METHOD

- Under surface method of ground water exploration, geobotanical method is the very oldest since the ancient Rig, Adharvana Vedhas and Varahamihira, a versatile astronomer, hydrologist in 6th century in his magnum opus "BRAHAT SAMHITA" described termite mounds associated with palm and neem trees as good hydrologic indicators.

4. ESOTERIC METHOD

- Even from early ages, ground water prospecting was carried out by water diviners, dowsers by following certain traditions and beliefs.
- Water divining and dowsing methods are still in practice, using Y shaped twigs, copper rods, key chain & wrist watch.
- These attempts were not always successful as they were not based upon sound scientific reasoning.

GEOGRAPHIC INFORMATION SYSTEM [GIS]

- A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location.
- GIS is a computer based information system used to digitally represent & analyze the geographic features present on the earth's surface.
- Geographic information system (GIS) technology can be used for scientific investigations, resource management, and development planning.

COMPONENTS OF GIS

1. Hardware: GIS relies on a computer for storage & processing of data.
2. Software: The core of GIS system lies the GIS software itself providing the functionality to store, manage, link, query & analyze geographic data.
3. Data: Data for GIS comes in two forms- geographic or spatial data & attribute or spatial data.
4. Methods: GIS systems are designed & developed to aid the data management & decision support processes.
5. People: The system users- those who will use the GIS to solve spatial problems.

GIS COMPONENTS

GIS FUNCTIONS

1. Capturing data: GIS must provide methods for inputting geographic & tabular data. The more input methods available, the more versatile the GIS.
2. There are two basic models for geographic data storage- Vector & Raster. A GIS should be able to store geographic data in both models.
3. Querying data: GIS must provide utilities for finding specific features based on location or attribute value.
4. Analyzing data: GIS must be able to answer questions regarding the interaction of spatial relationship between multiple data sets.
5. Displaying data: GIS must have tools for visualizing geographic features using a variety of symbology.
6. Output: GIS must be able to display results in a variety of formats such as maps, reports & graphs.

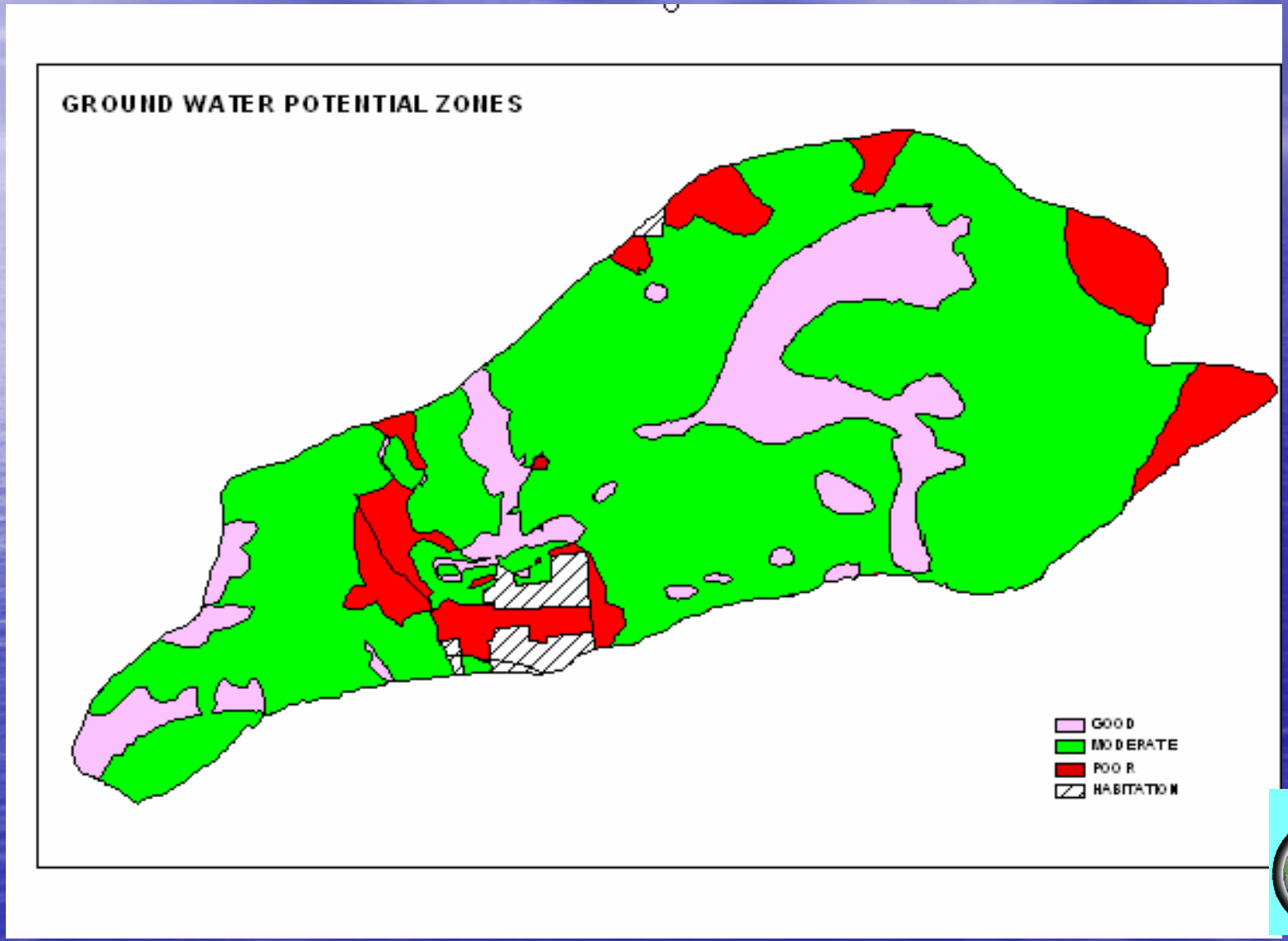
GIS LAYERS


Land Use
Streets
Districts
Parcels
Parks
River
Discharge Point
Sand and Gravel
Sandstone Aquifer
Water Table
Shale

GIS APPLICATION IN GROUND WATER EXPLORATION

- The parameters such as geology landform, soil, slope, lineament, weathered zone which controls the ground water occurrence and movement can be integrated through geographical information system for locating ground water potential zones.
- GIS has been found to be one of the most powerful techniques in assessing the suitability analysis.
- GIS is a good tool to delineate ground water potential zones by integrating different thematic layers, which have direct control on ground water occurrence.

GROUND WATER POTENTIAL ZONES- VALAVANTHI MICRO WATERSHED, KARAIPOTTANAR WATERSHED, TAMILNADU.



SOURCE- TWAD BOARD

CONCLUSION

- Thus there are several methods and techniques to explore the ground water potential.
- The success of ground water exploration depends upon the methodology adapted based on the geology & field conditions.
- Exploration is the first stage, followed by drilling, development and finally well completion.
- The explored water should be exploited correctly and managed properly.
- Water is precious. Let us conserve.

THANK YOU. HAVE A NICE DAY

T.S. BADRINARAYANAN, GEOSCIENTIST,
B SQUARE GEO TECH SERVICES,
97- AGRAHARAM STREET, KOLLIDAM, SIRKALI TALUK,
NAGAI DISTRICT, TAMILNADU- 609 102.
MOB- 94430 46102, E-MAIL : tsbadri56@gmail.com