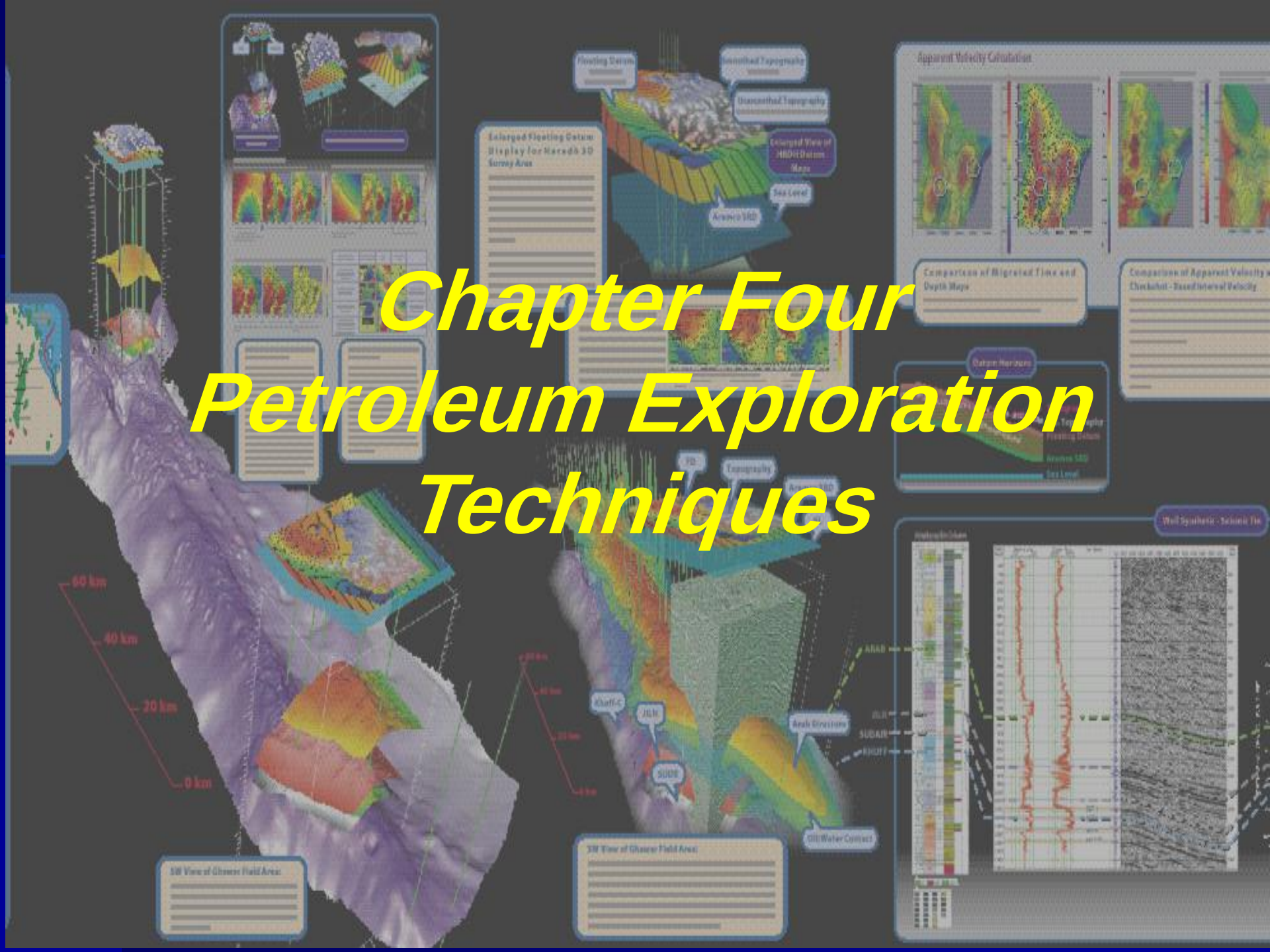
Chapter Four
Petroleum Exploration
Techniques

Chapter Four: Petroleum Exploration Techniques

Introduction

Exploration methods are the techniques employed in the search for petroleum.

The primary task in exploration is not directly to find oil but to provide physical evidence about the geological phenomena that identify a prospective hydrocarbon region and geological structures.

Geological interpretation of the data may eventually lead to drilling and the discovery of oil.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

Exploration methods can be divided it to two types :

- ✓ Surface Exploration Methods
  - Aerial Surveying
  - Satellite Surveying
  - Geological Exploration
  - Geochemical Exploration
  - Geophysical Exploration
- ✓ Subsurface Exploration Methods (Drilling Exploration)
  - Rock Cuttings
  - Core Samples
  - Reservoir Fluid Samples
  - Mud Logs
  - Well Logs

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

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Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

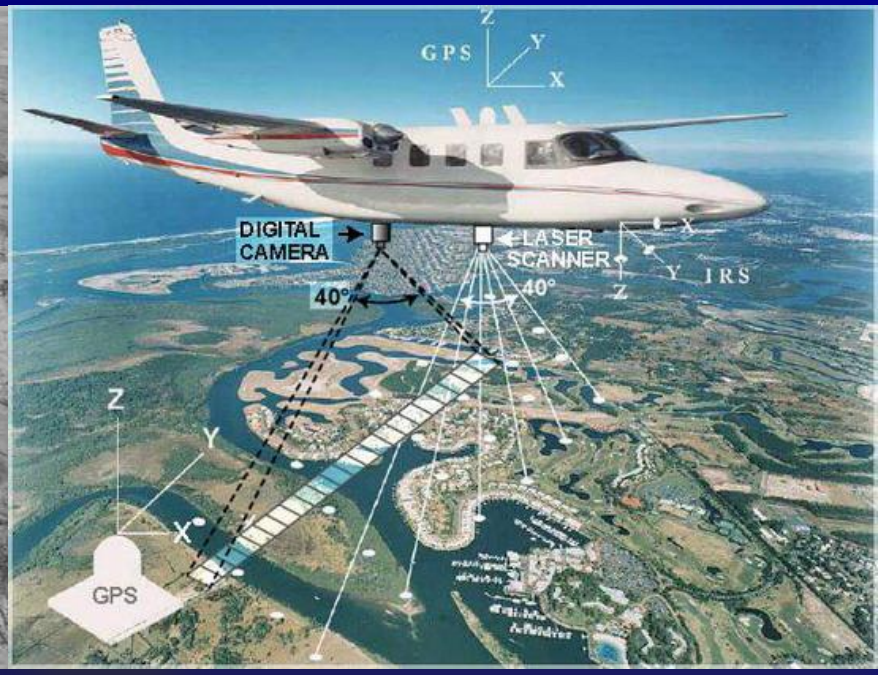
- Surface Exploration Methods
  - Aerial Surveying

An airplane fitted with a wide-angled camera flies strip wise over the area taking photographs each of which overlaps those adjoining.
By stereoscopic study of these photographs a fairly accurate topographical map and a geological map showing the geological surface features observable from the air are constructed.
These maps not only help in the planning of ground surveys but also enable geologists to go directly to the points of greatest interest.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- ✓ Surface Exploration Methods
  - ➢ Aerial Surveying



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Satellite Surveying

Growing use being made of satellites imaging techniques to detect potential subsurface deposits of hydrocarbons and other minerals.

The satellite system can be equipped with a coherent infrared imaging system which scans the area of observation for detecting the hydrocarbon gas cloud which appears above an oil or natural gas reservoir.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geological Exploration

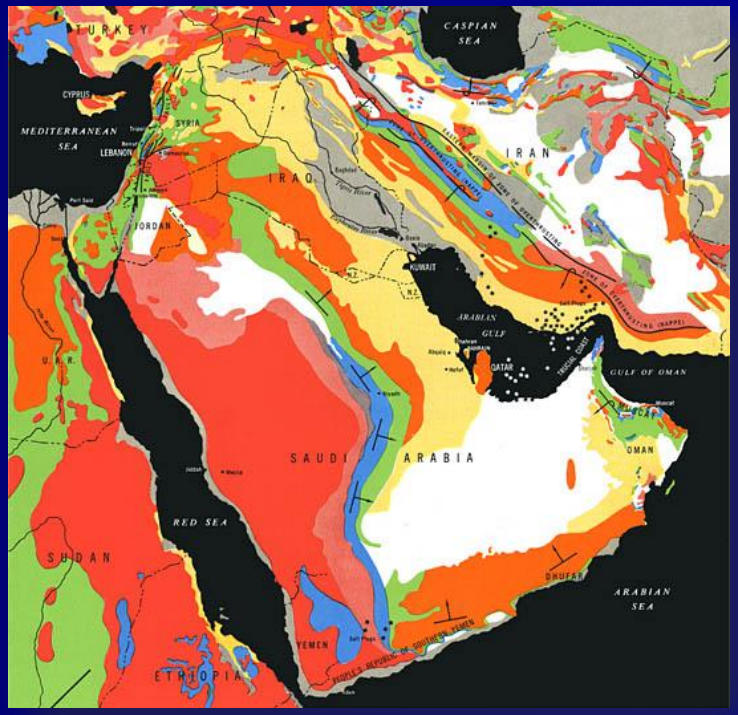
The outcrops of the rock layers in the potential oil reservoir area are mapped as accurately as possible as a result of geological observations on the ground.

Wherever possible, observations are made, in the banks of rivers, on mountain slopes and cliffs, of the inclination of the strata (the dip) and of the horizontal direction (the strike) in which they Extend.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geological Exploration



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geological Exploration

The physical characteristics (porosity and permeability) and the fossil contents of the rocks are recorded, and samples are taken, to correlate with beds exposed elsewhere, the final detailed geological map may be built up from hundreds or thousands of observations made by one or more geologists over many years.

In areas of good rock exposure, field work is comparatively straight forward.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geochemical Exploration

Little use has been made of geochemical exploration and its practical value is yet uncertain.
One method depends on the inference that in areas overlying accumulations of oil and natural gas at high pressure, small quantities of gas may be expected to permeate to the surface and be detectable by chemical analysis.
This is done by studying shallow cores and subsurface water for evidence of seepage or kerogens.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

    The geophysicist uses physical phenomenon such as magnetic attraction, the pull of gravity, the speed of sound waves through different types of rocks, and the behavior of electric currents to determine the subsurface structure.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

Geophysical surveys can generally be classified into two categories:
broad areas of interest that contain the thick sedimentary layers that have the potential to contain hydrocarbon traps; and
detailed surveys which are conducted to locate individual geologic structures which can then be drilled.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

Gravity and **magnetic** surveys would generally be classified as **broad** type surveys.

The most common geophysical technique for obtaining the **detailed** geologic structural information needed to pick well locations is, however, the **seismic** survey.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

(i) Magnetic:

Measurement of changes in the intensity and direction of the earth's magnetic field brought about by the presence of basement magnetic rocks (organic and metamorphic rocks) can give an indication of thickness of subsurface sediments overlaying the basement rocks.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

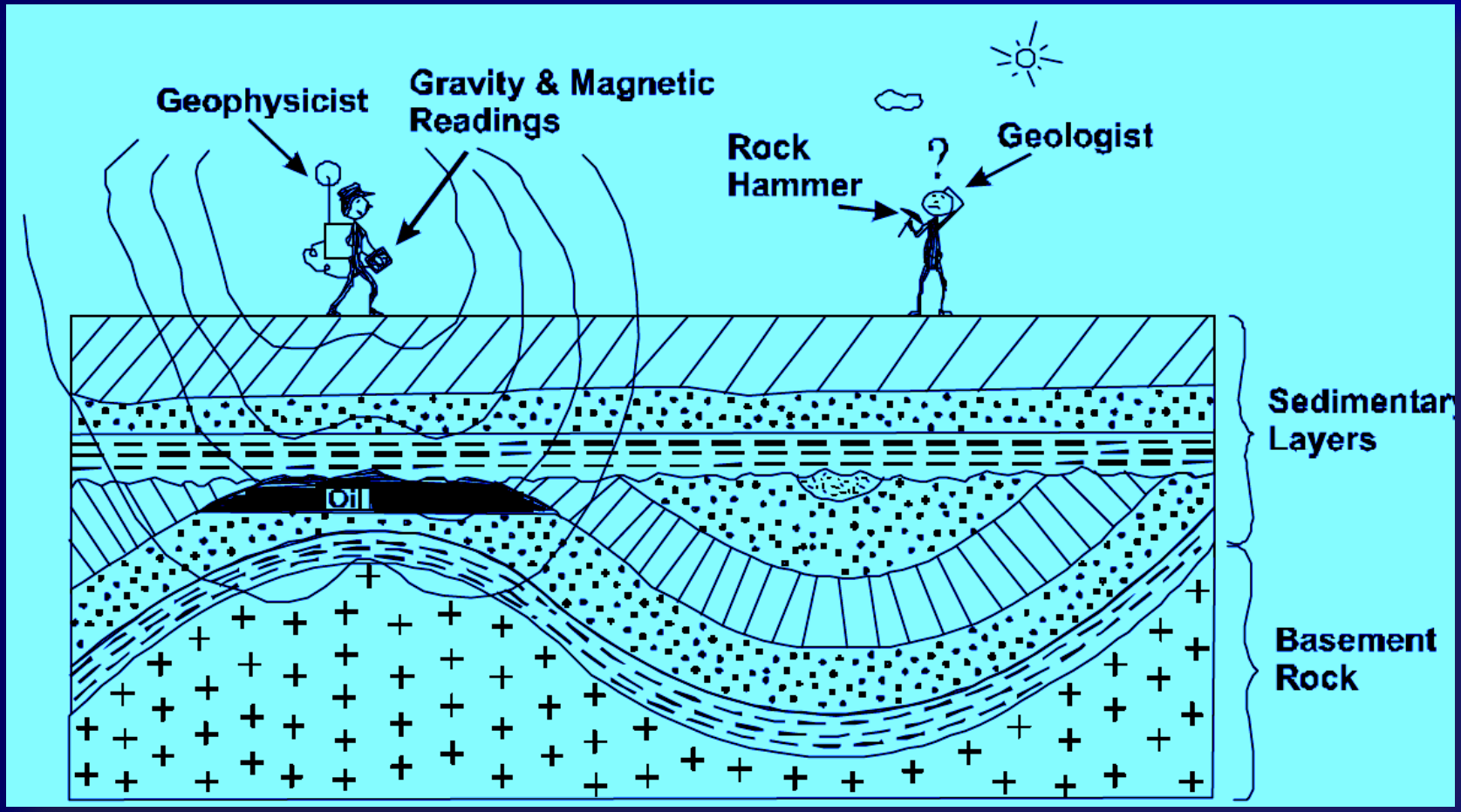
(ii) Gravimetric :

This method depends on the precise measurement of slight variations in gravity, or more correctly in "g" the acceleration due to gravity, on the surface caused by different densities of the rocks underlying the prospecting area.

As the density of the rocks varies, so does the gravitational attraction at the surface.

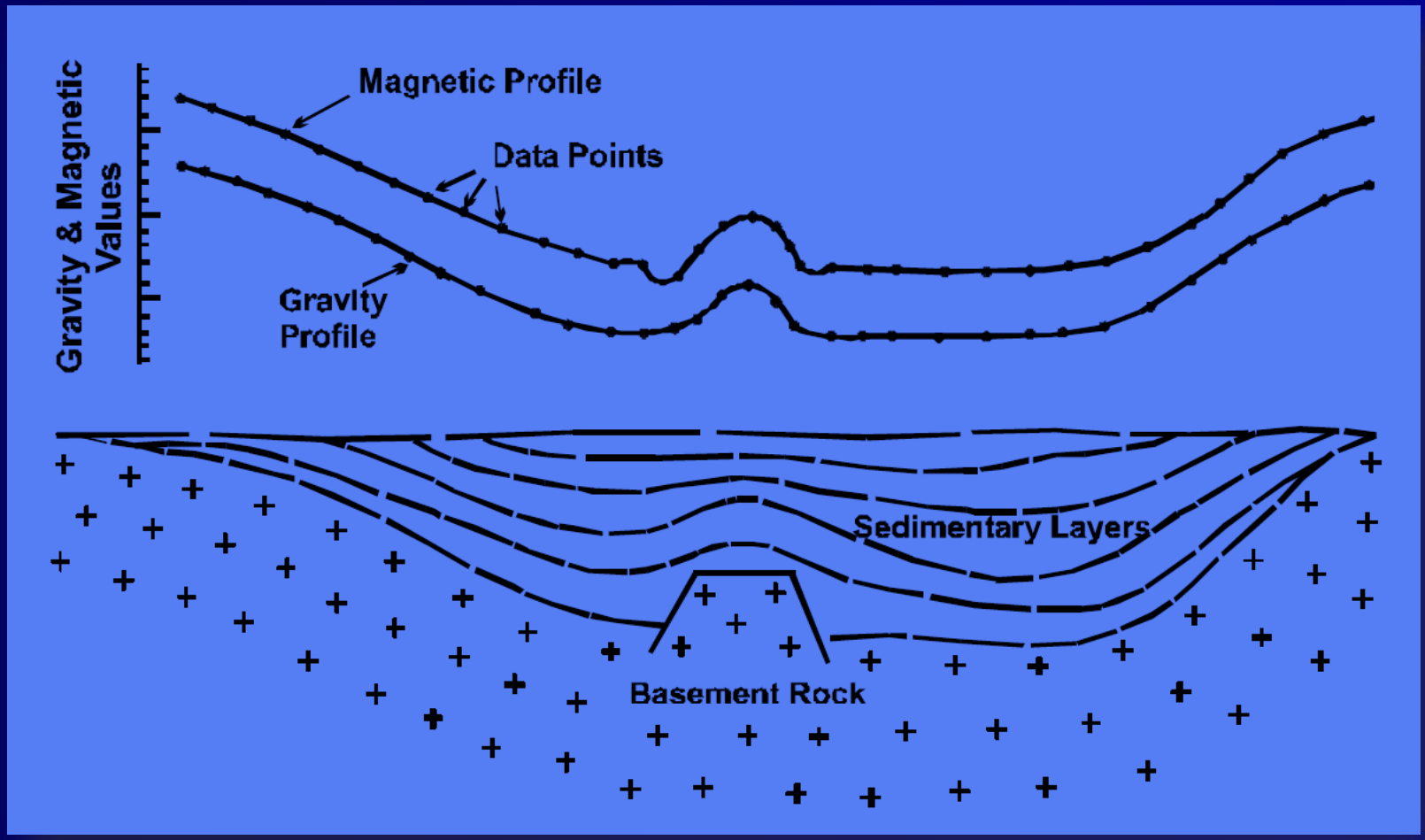
Chapter Four: Petroleum Exploration Techniques

Exploration Techniques



Chapter Four: Petroleum Exploration Techniques

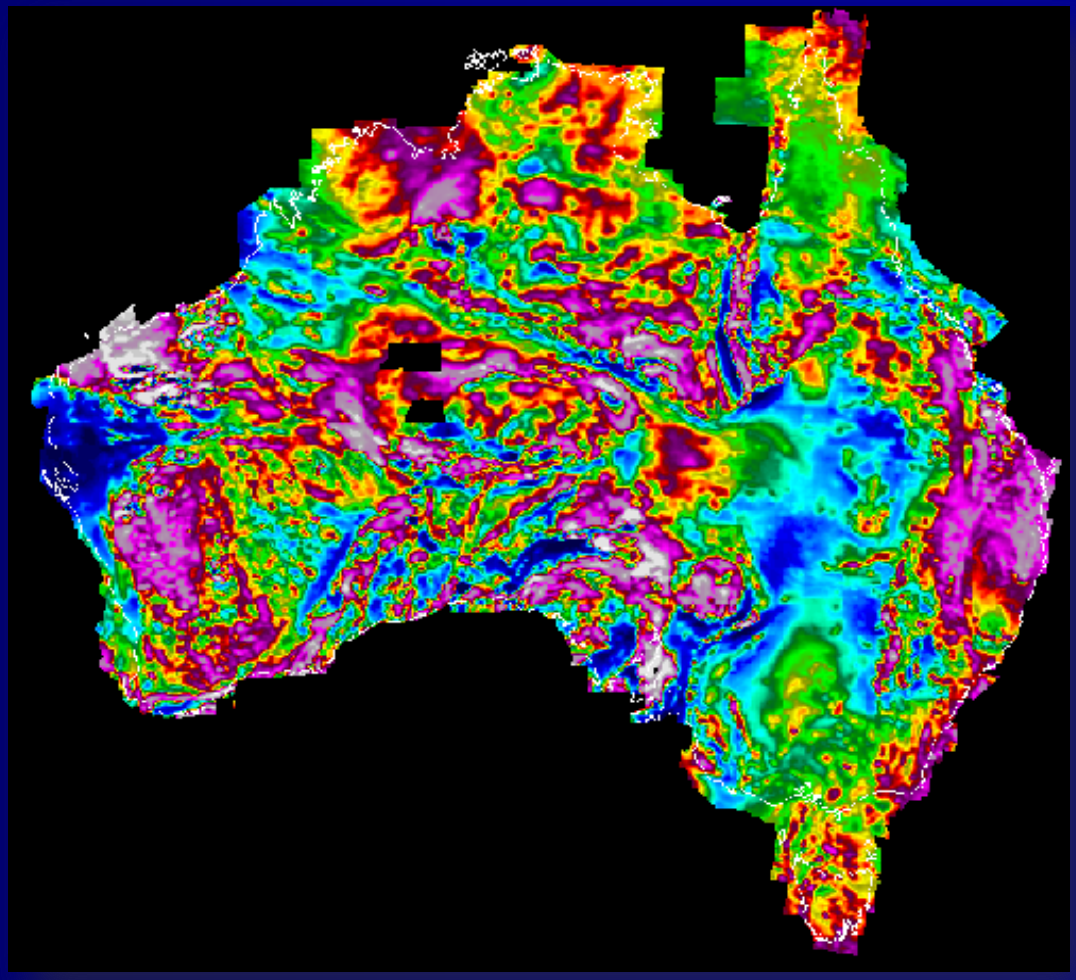
Exploration Techniques



Example of Broad Magnetic Survey (Australia)

Strong magnetic minerals tend to be igneous rocks (red area)

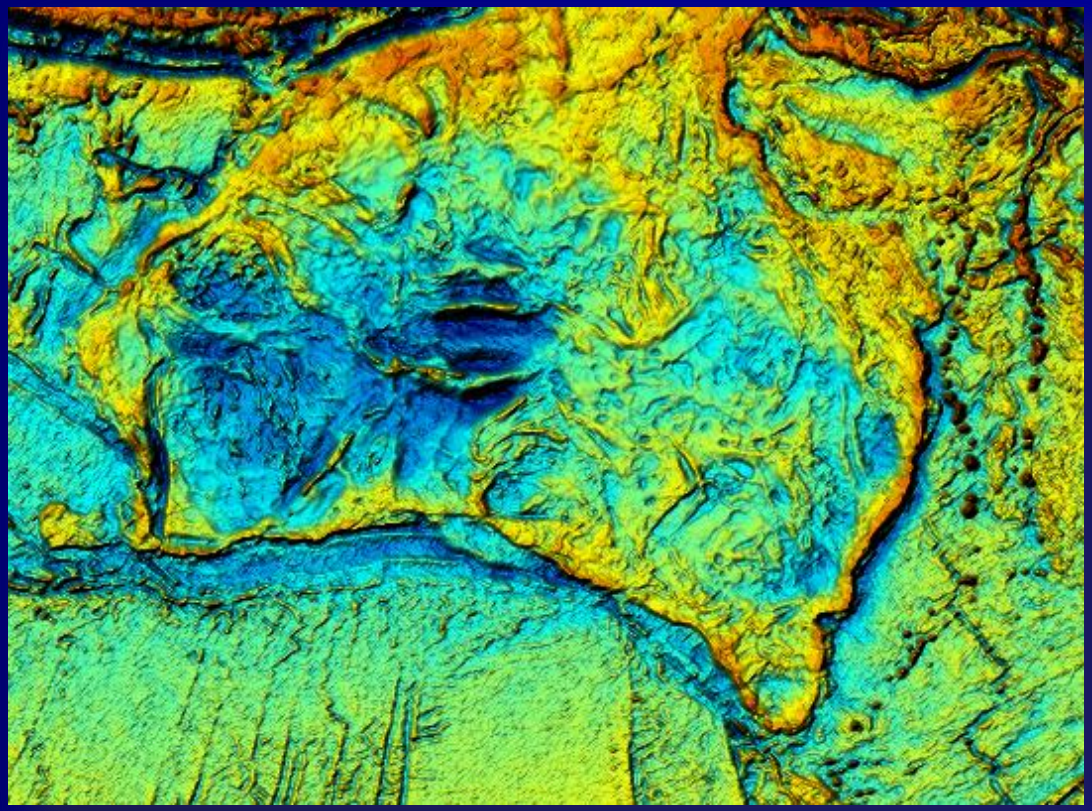
Weakest Magnetic Presence (blue area)



Example of Broad Gravity Survey (Australia)

Low Density (Blue)

Reservoir Type Rocks



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

(iii) Seismic :

is the most effective method for examining the earth's structure by use of geophysics, is based upon recording artificially generated shock waves that are reflected due to elastic discontinuities between different rocks.

Two main methods are used: reflection and refraction. In both, an explosive charge or shock by means of a special truck is performed near the earth's surface.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Surface Exploration Methods
  - Geophysical Exploration

(iii) Seismic :

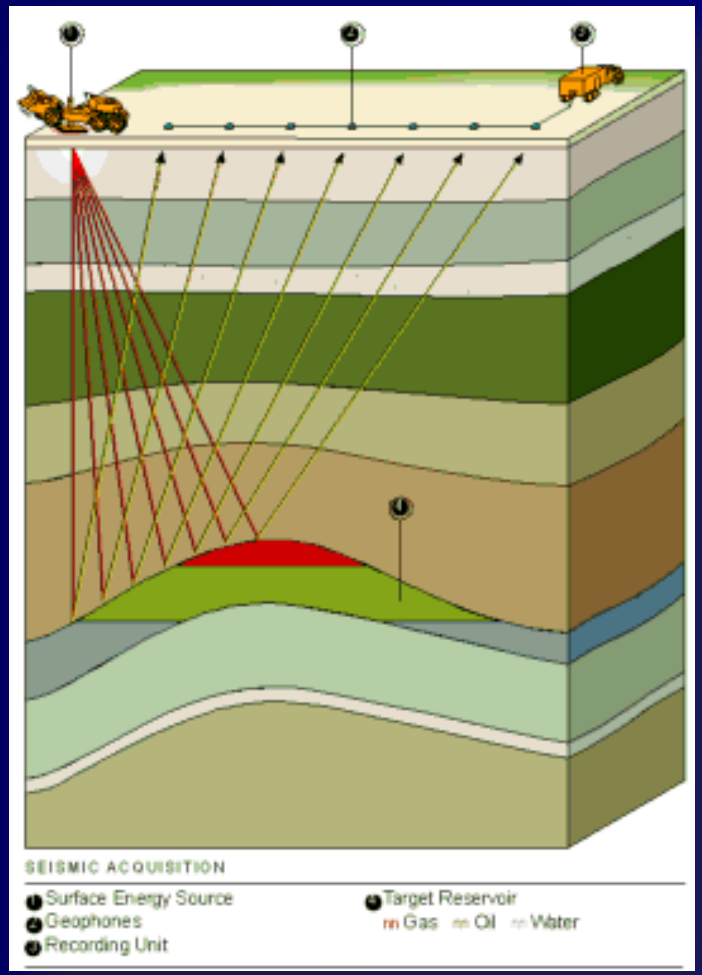
The shock waves travel down through rocks, and are then reflected or refracted upward.

Two definite measurements are recorded , the travel time for the waves and their velocities.

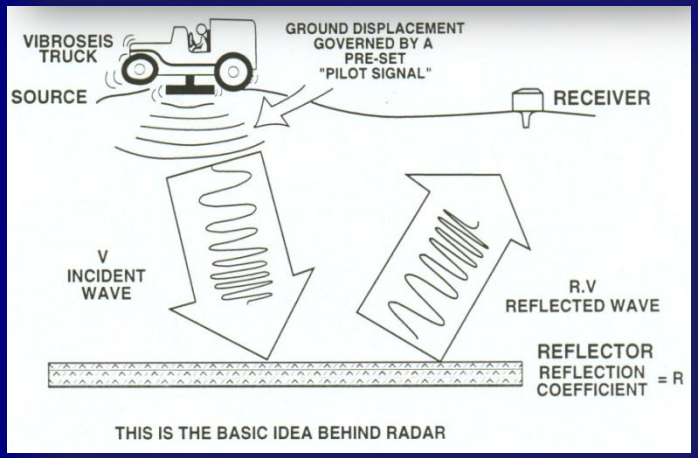
From these measurements distances and depths can be calculated.

Chapter Four: Petroleum Exploration Techniques

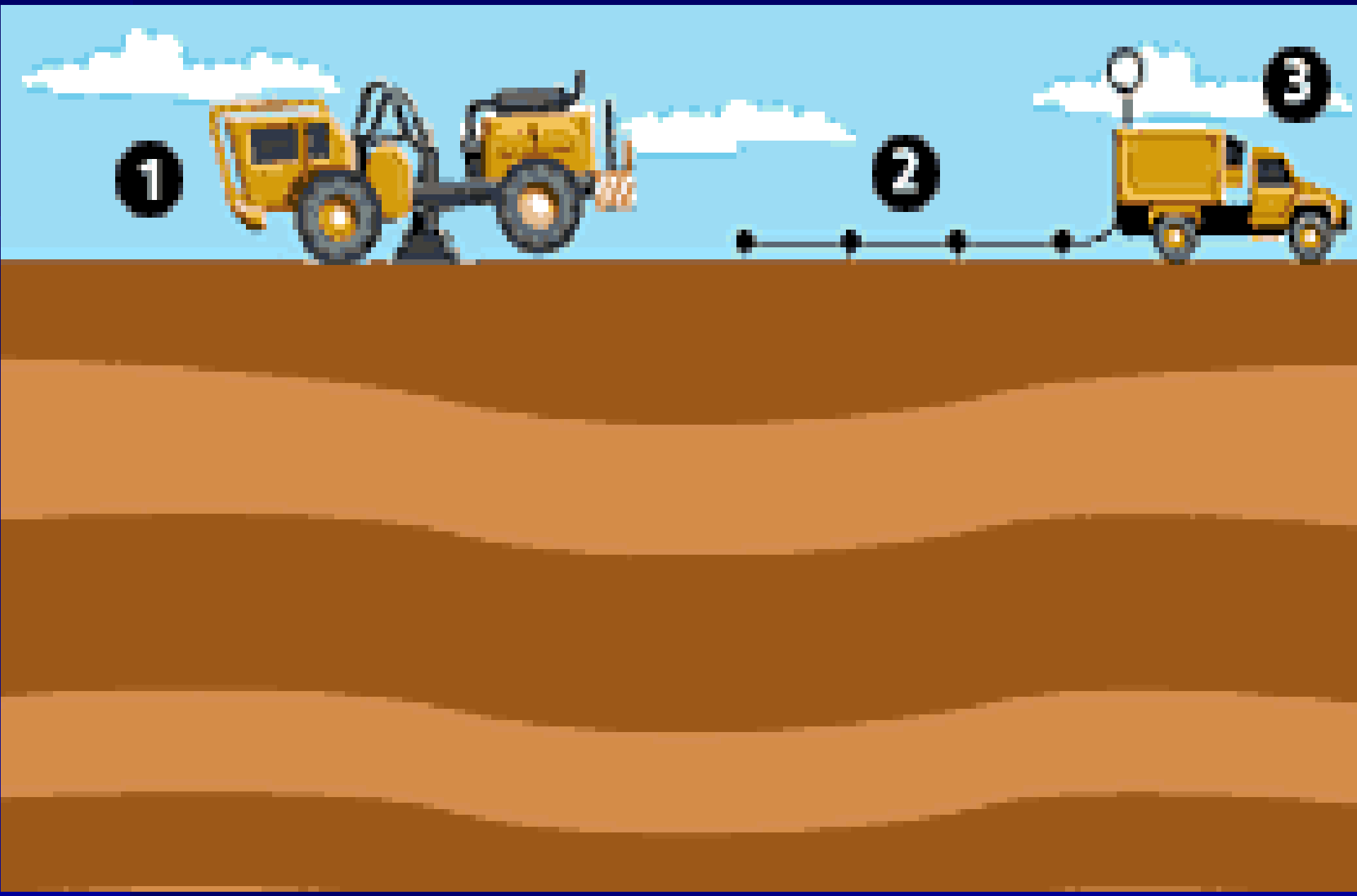
Exploration Techniques



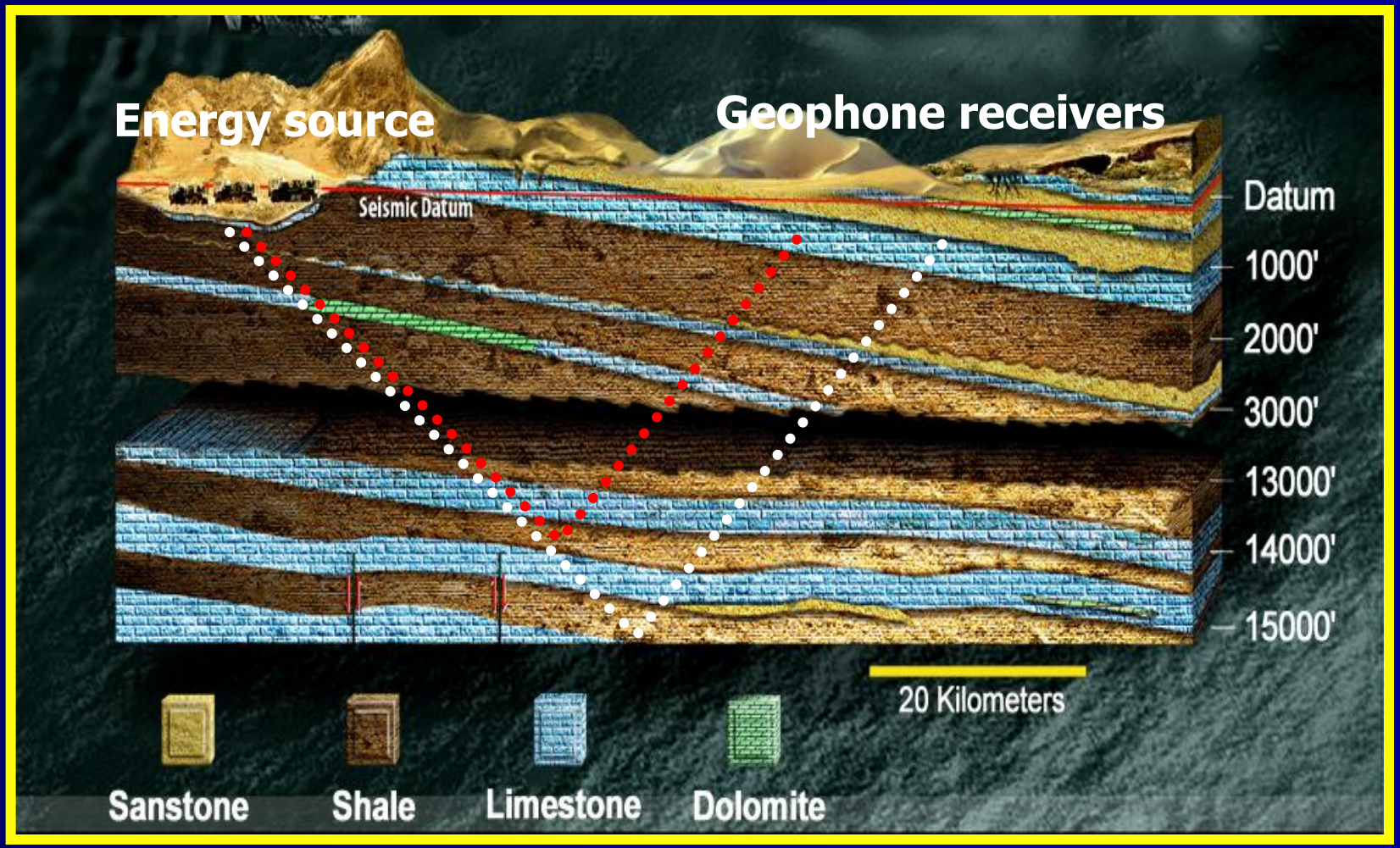
Vibroseis



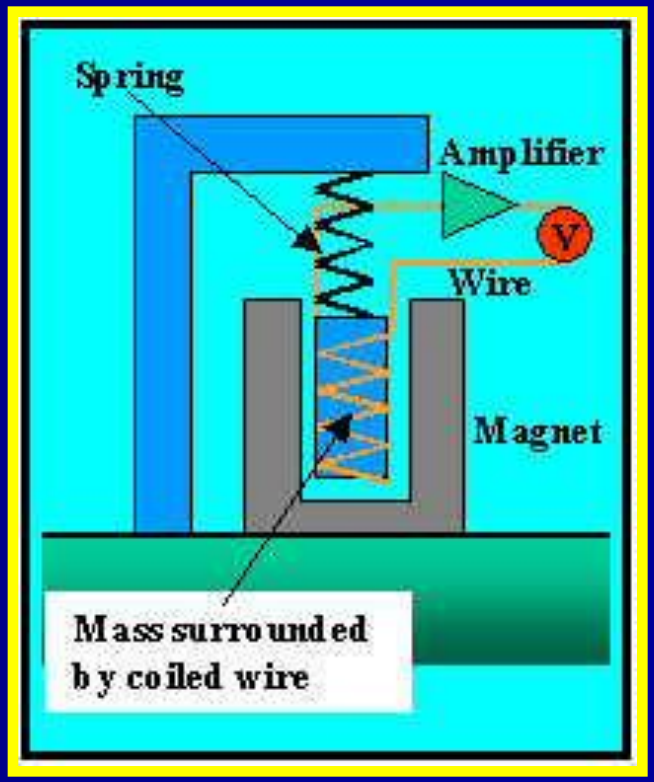
Exploration Techniques

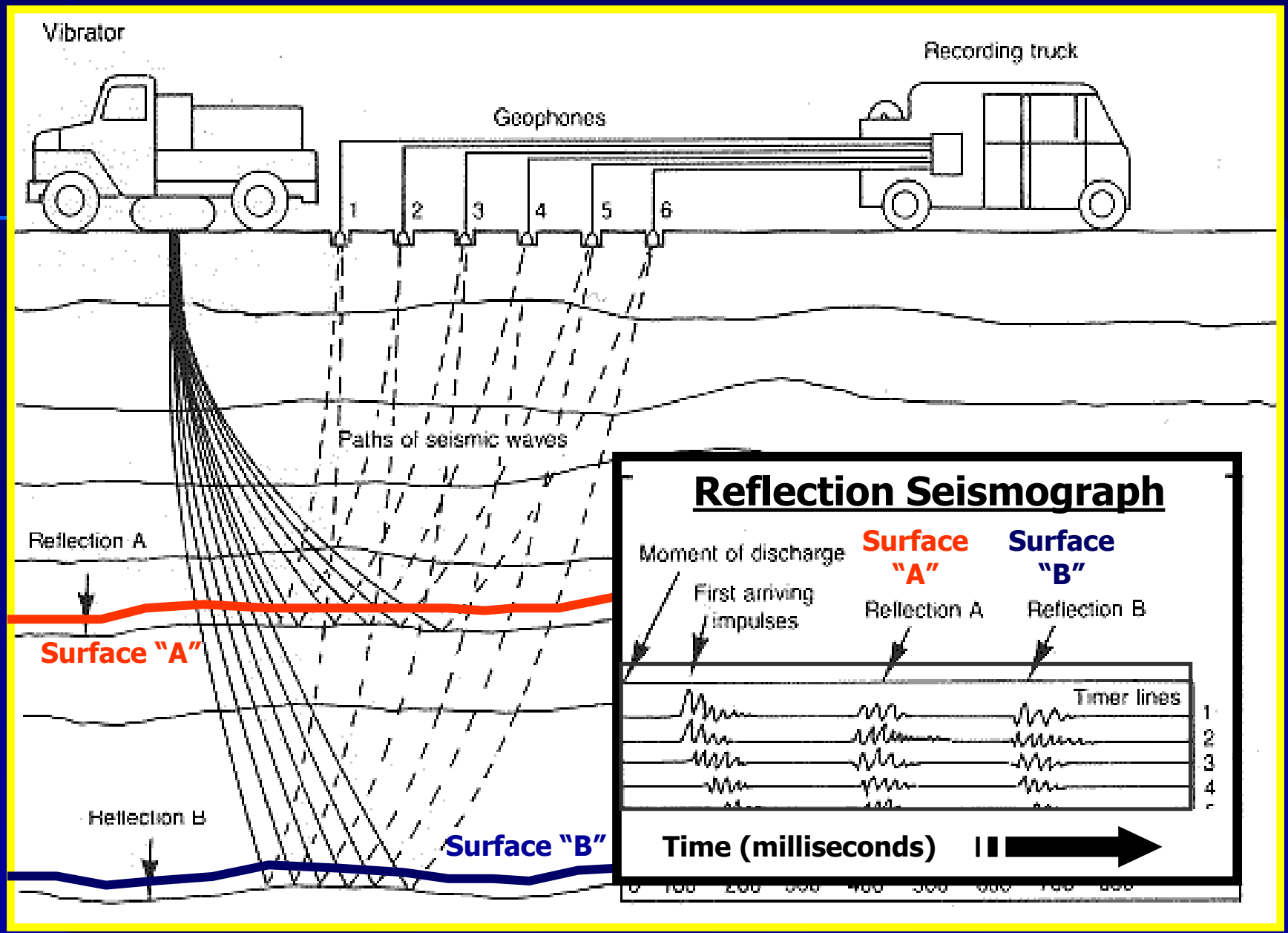

1
2
3

Seismic Reflections

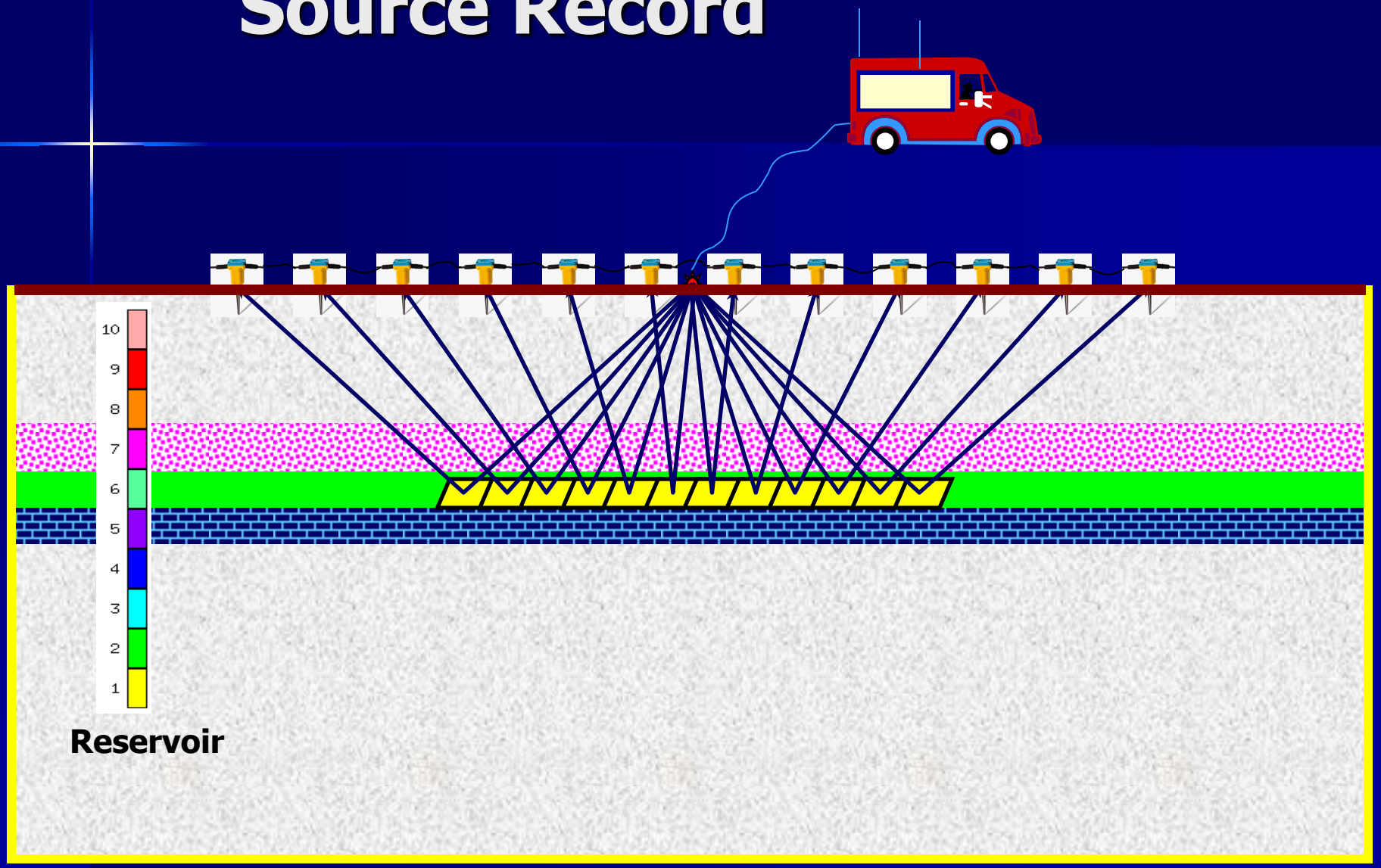


Geophones

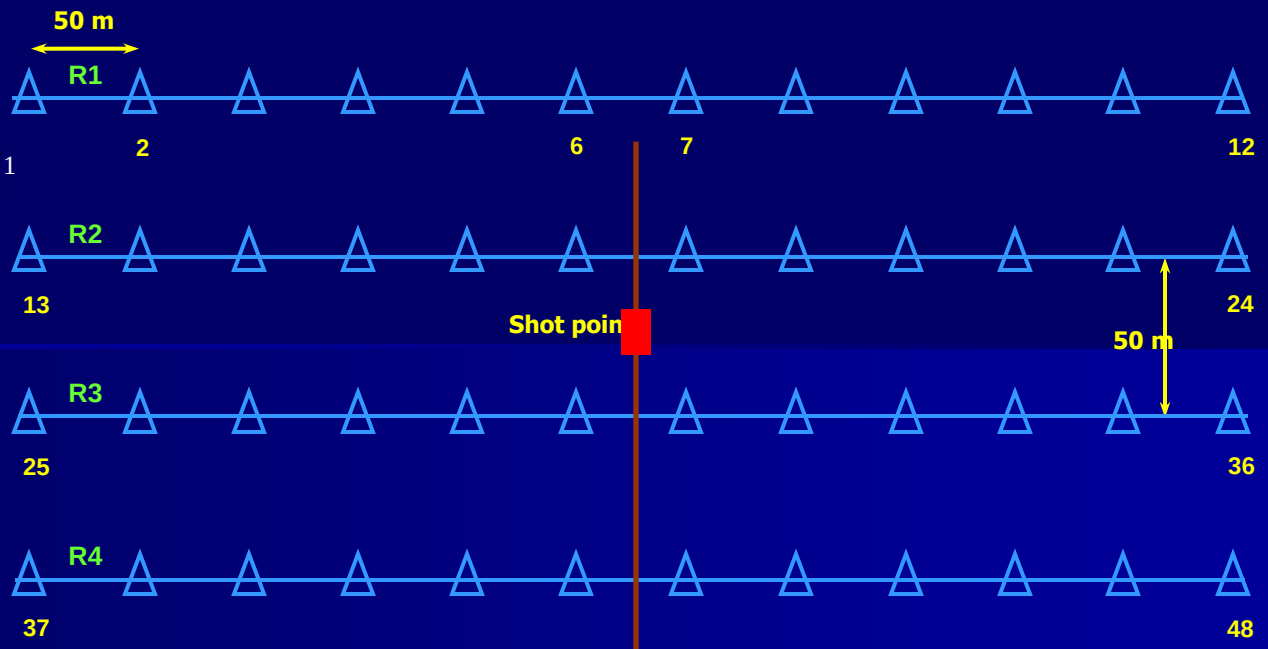

Spring
Amplifier
V
Wire
Magnet
Mass surrounded
by coiled wire


Vibrator
Recording truck
Geophones
1
2
3
4
5
6
Paths of seismic waves
Reflection A
Surface "A"
Reflection B
Surface "B"
Reflection Seismograph
Moment of discharge
First arriving impulses
Surface "A"
Reflection A
Surface "B"
Reflection B
Timer lines
1
2
3
4
Time (milliseconds)

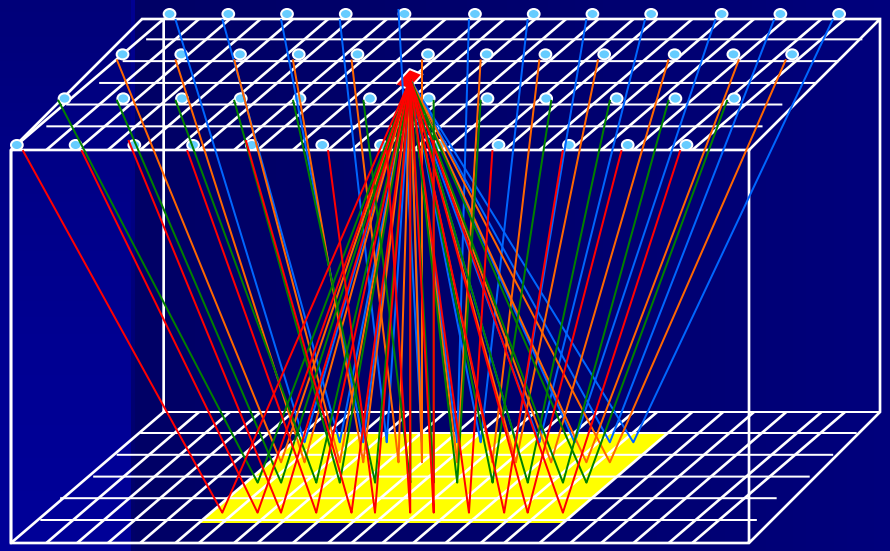
2-D Recording Common Source Record

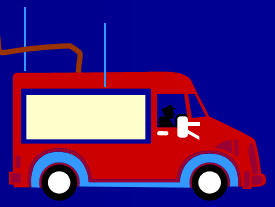


3-D Seismic Layout



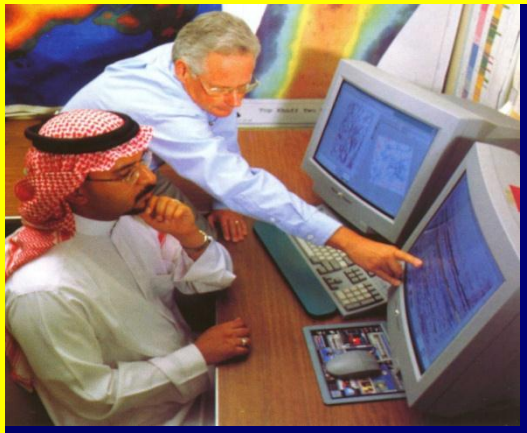
3-D View of Ray Path



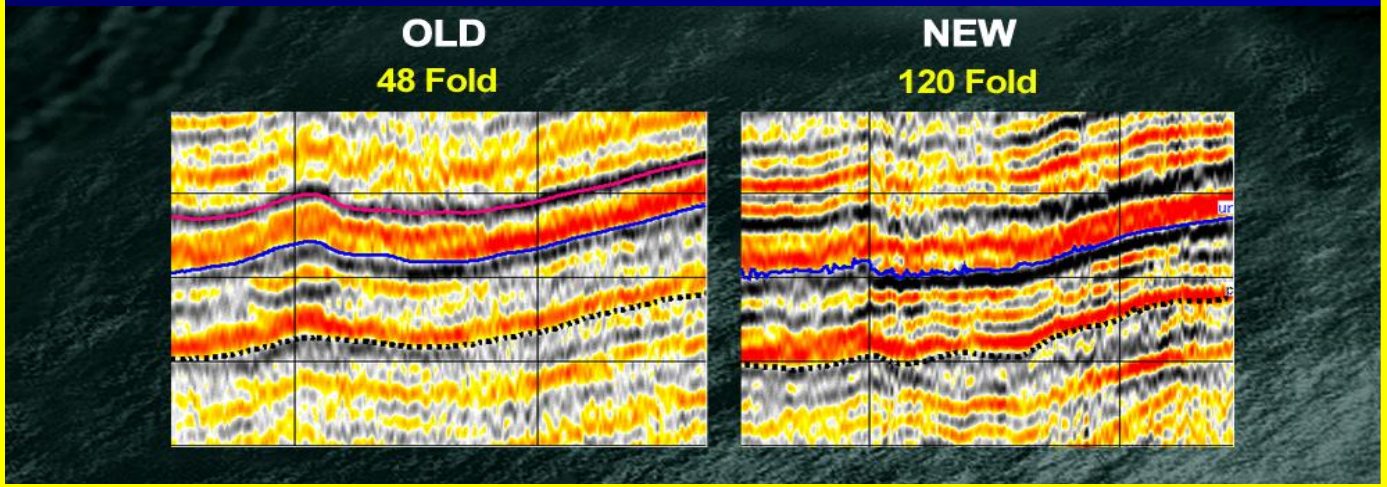


Receiver Station

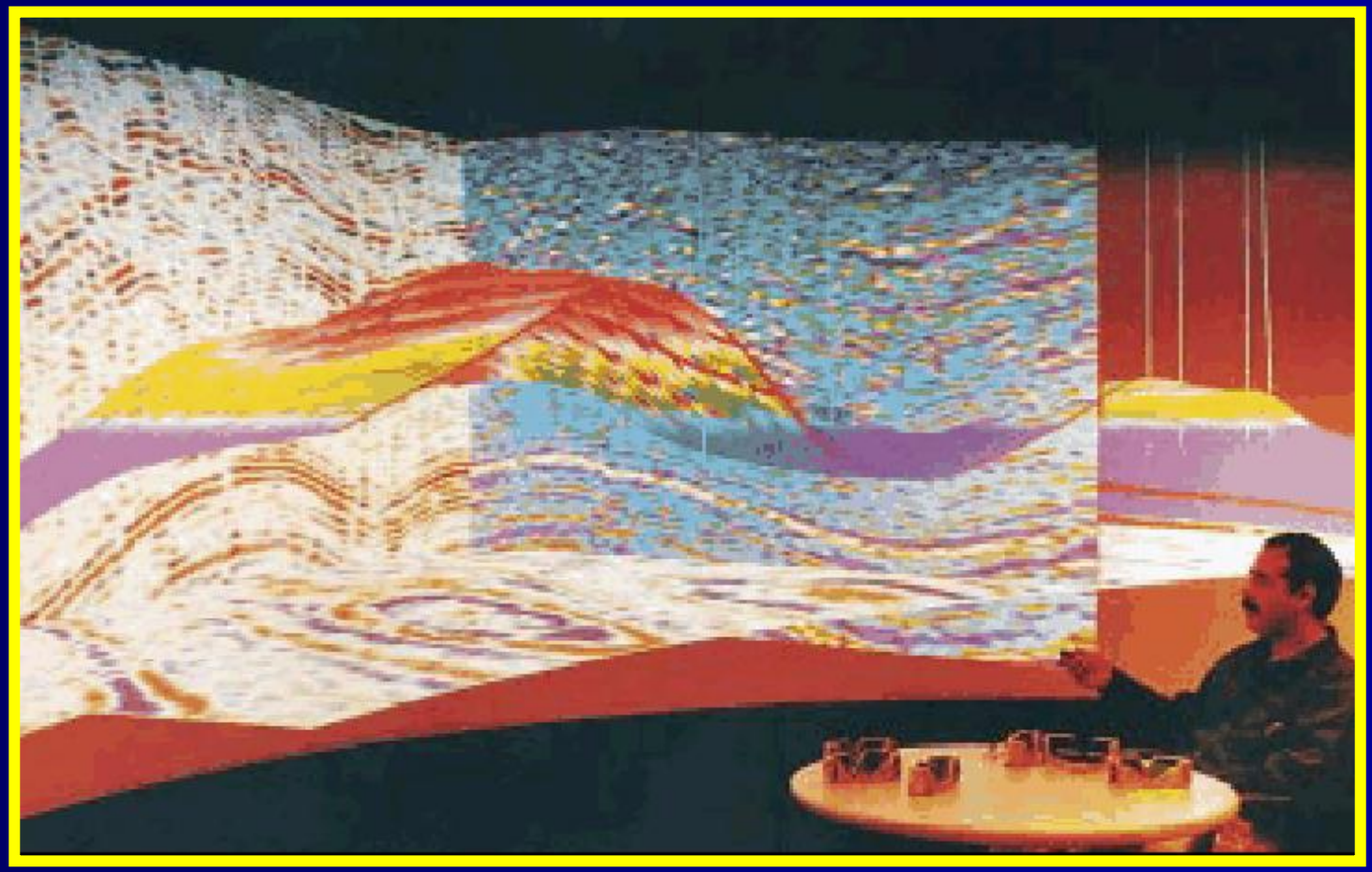
Processing of Seismic Data



Better Resolution

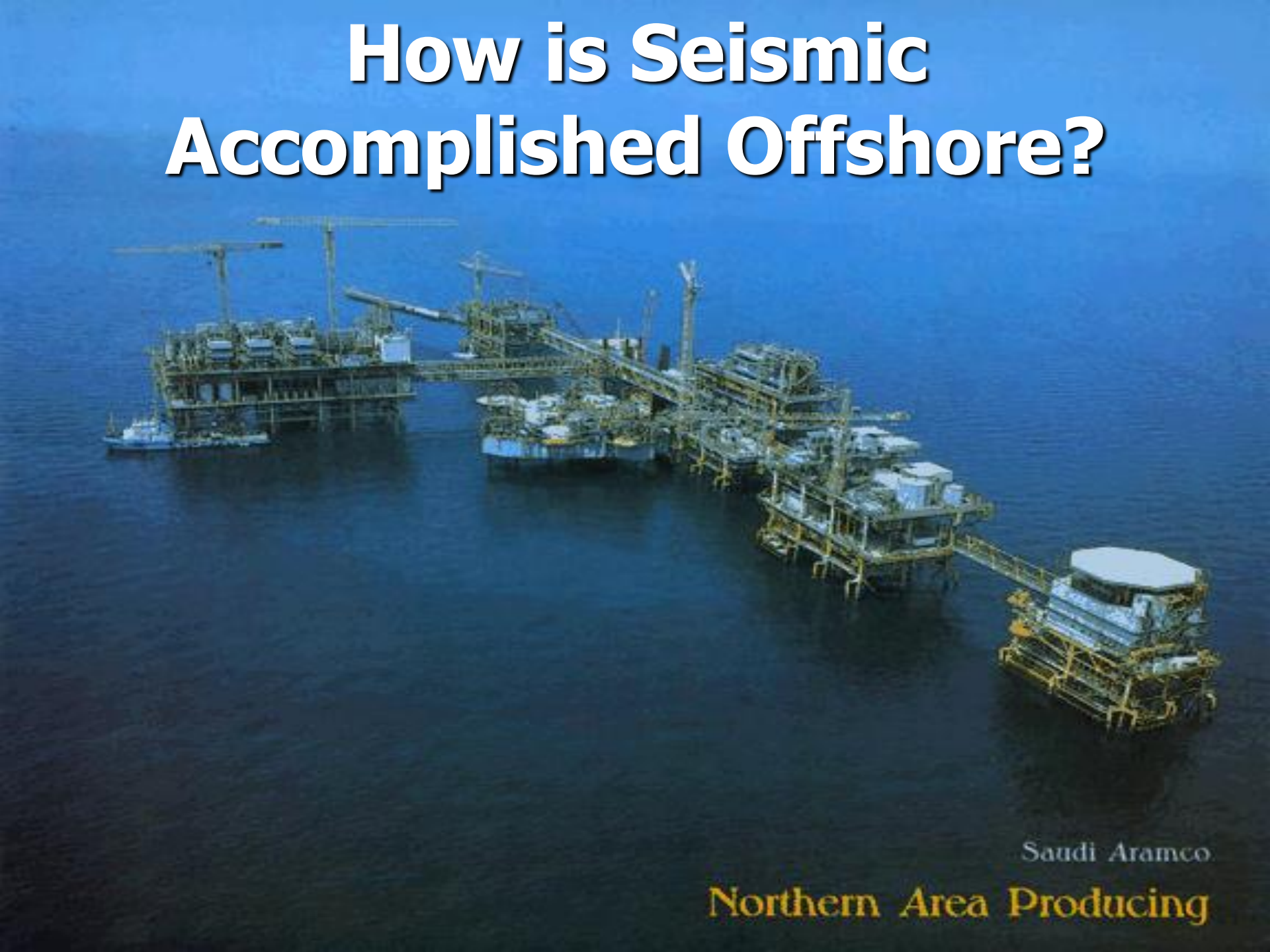


3-D Visualization Center for Geoscientists & Petroleum Engineers

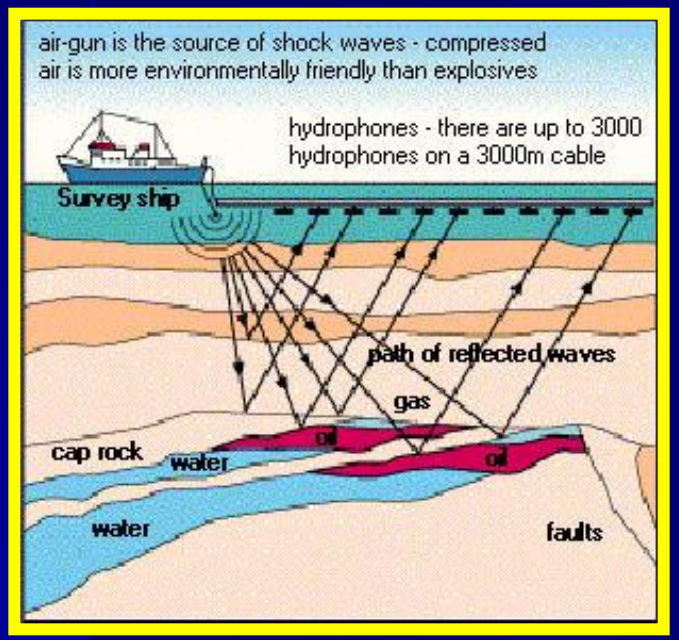


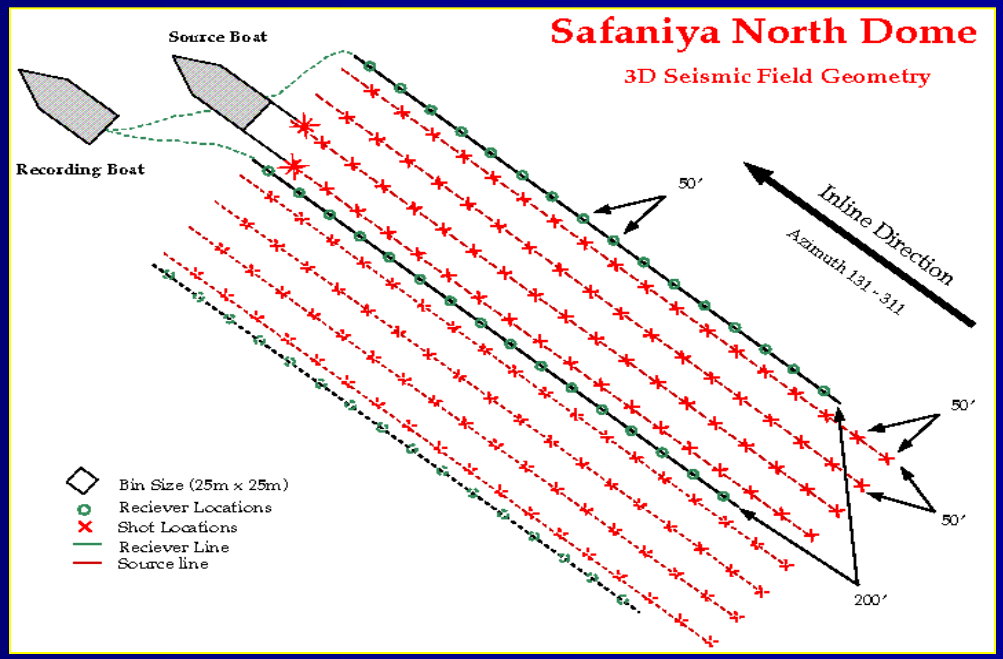
Create multicolored representations of petroleum reservoirs

How is Seismic Accomplished Offshore?



Seismic Vessel with Hydrophone Streamer & Disturbance Source





Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

Exploration methods can be divided it to two types :

- ✓ Surface Exploration Methods
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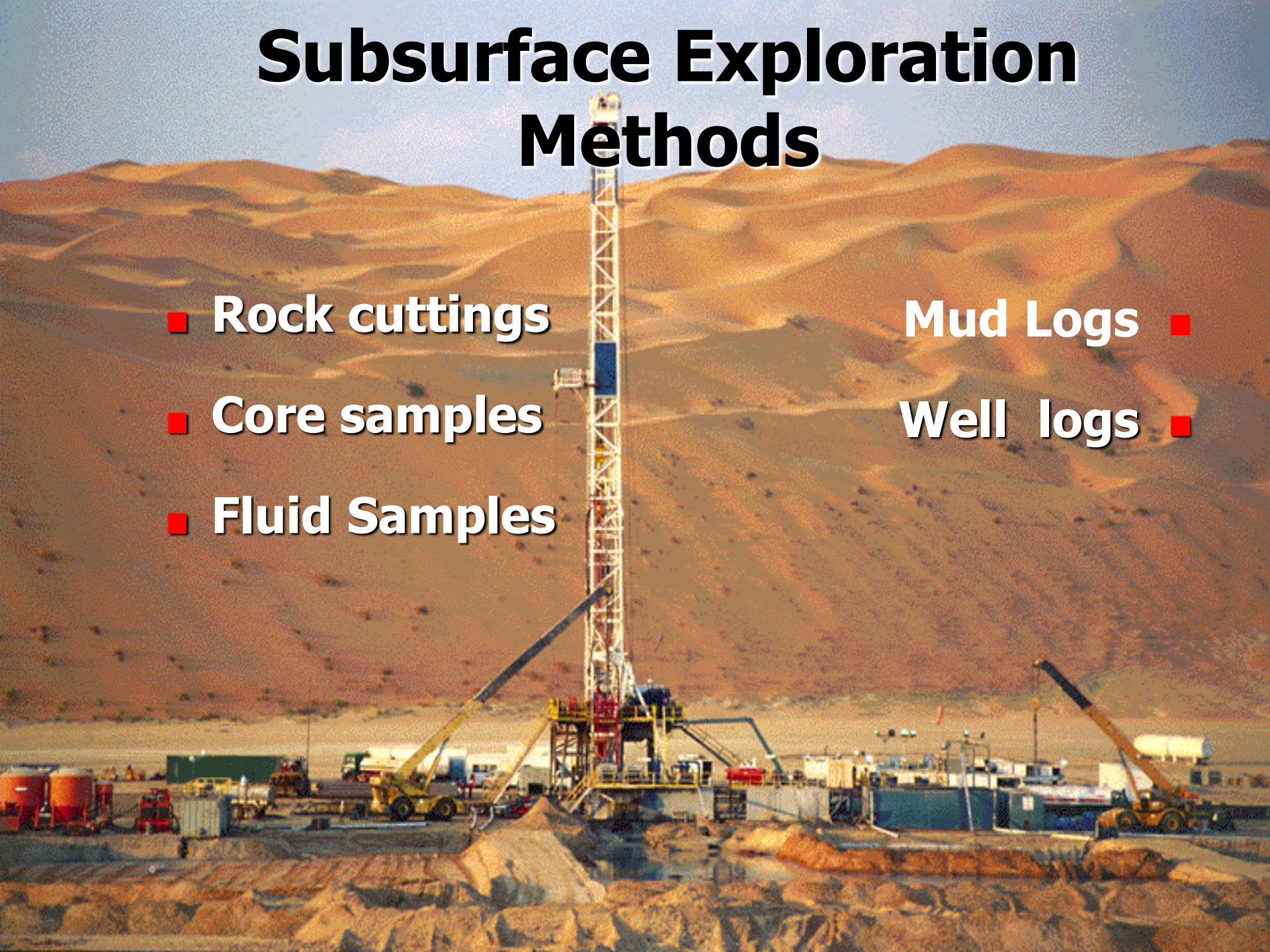
  - Geochemical Exploration
  - Geophysical Exploration
- ✓ Subsurface Exploration Methods (Drilling Exploration)
  - Rock Cuttings
  - Core Samples
  - Reservoir Fluid Samples
  - Mud Logs
  - Well Logs

Subsurface Exploration Methods



- Rock cuttings
- Core samples
- Fluid Samples
- Mud Logs
- Well logs

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

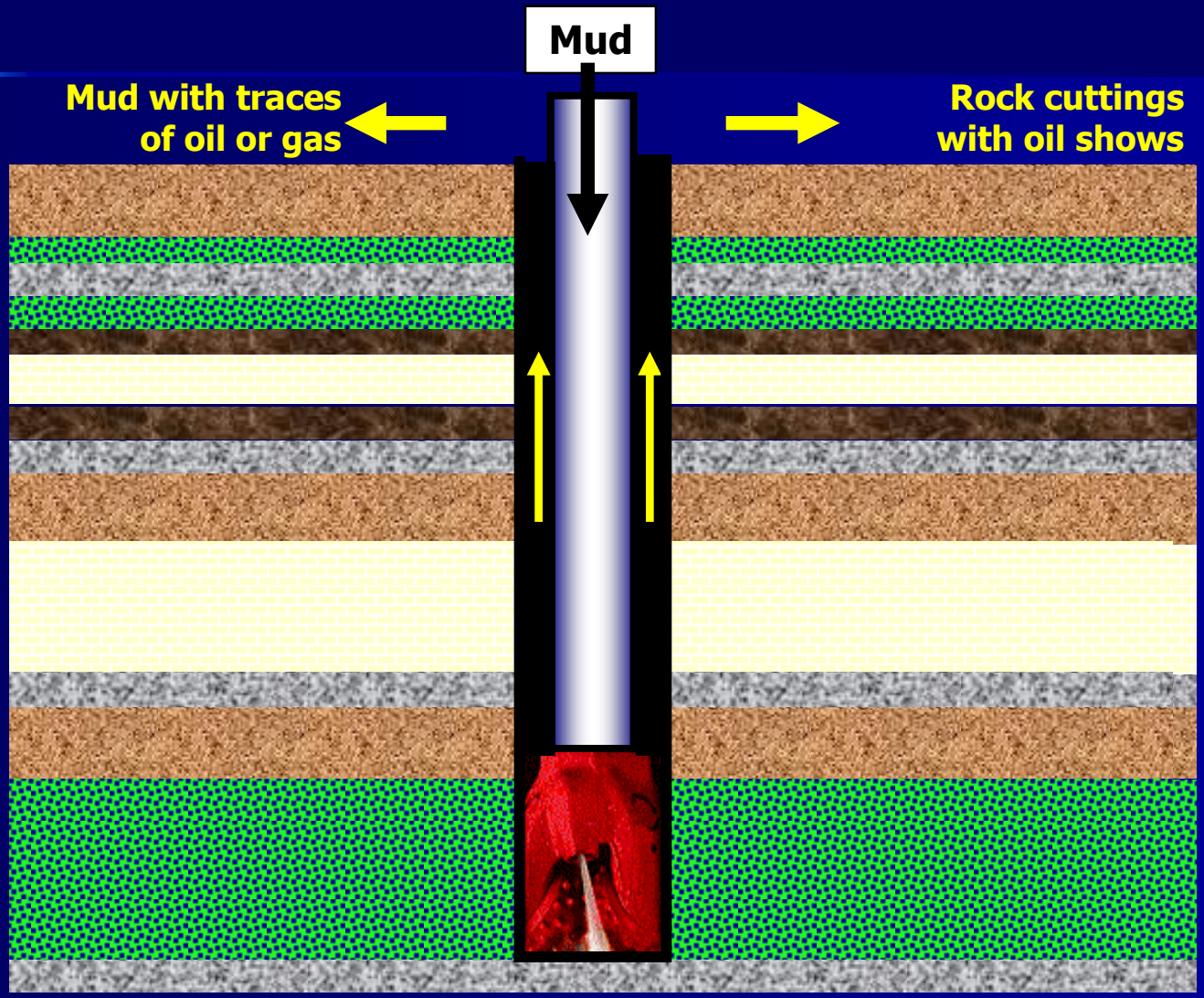
- Subsurface Exploration Methods
  - Rock Cuttings

    During the drilling operation, rock removed from the subsurface formations by the drill bit, are being returned to the surface on a continuous basis.

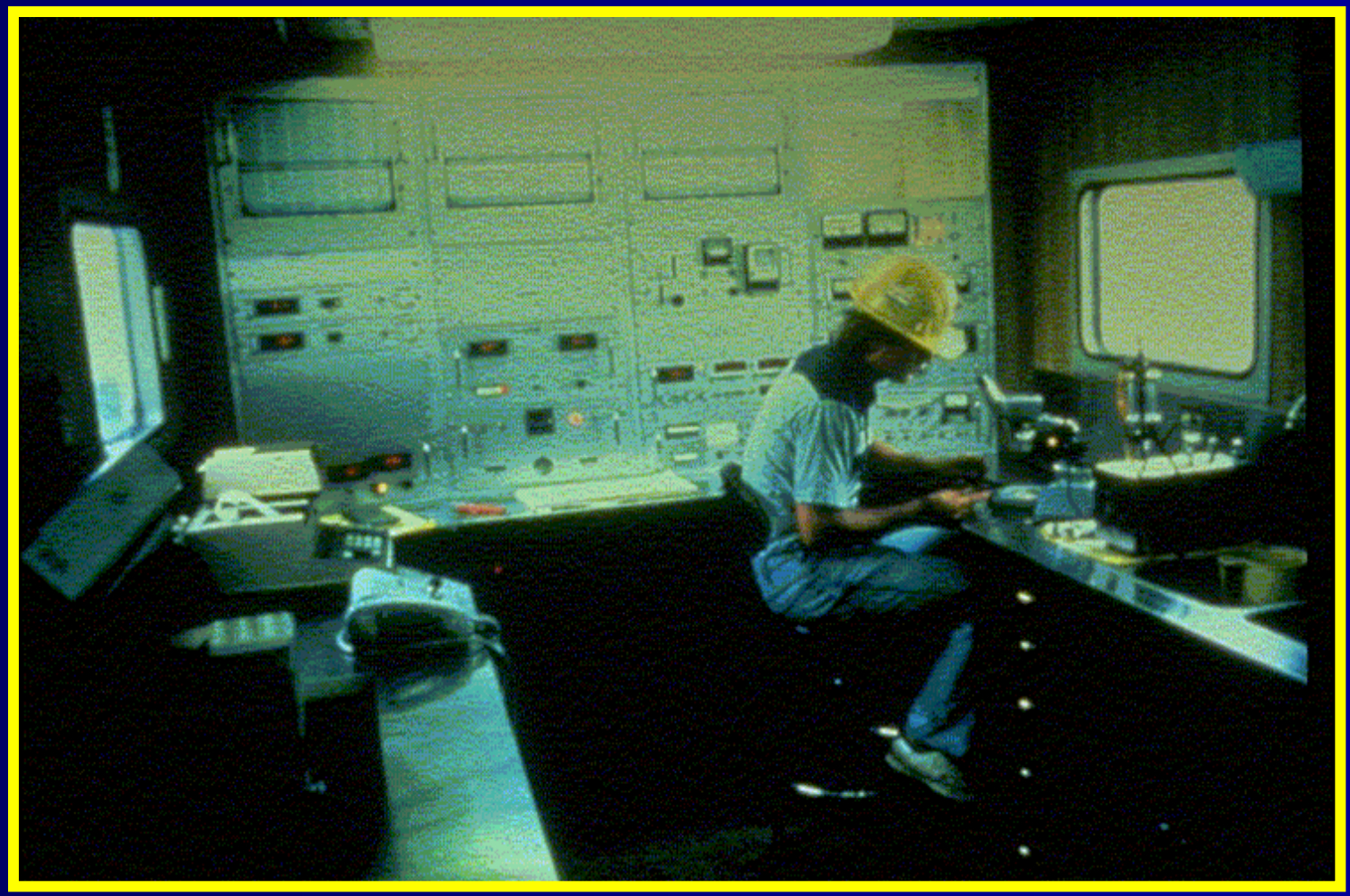
    These samples are analyzed in order to describe the subsurface geology and for indications of hydrocarbon presence within the cuttings.

    A cuttings analysis with well depth is used to complete a stratigraphic column as a summary of subsurface geology.

Exploration Information from the Drilling Process



Exploration Technician Collecting Data at Well Site



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Core Samples

    When a formation of interest is encountered while drilling, one of the most important sources of downhole information is the core of the reservoir rock.

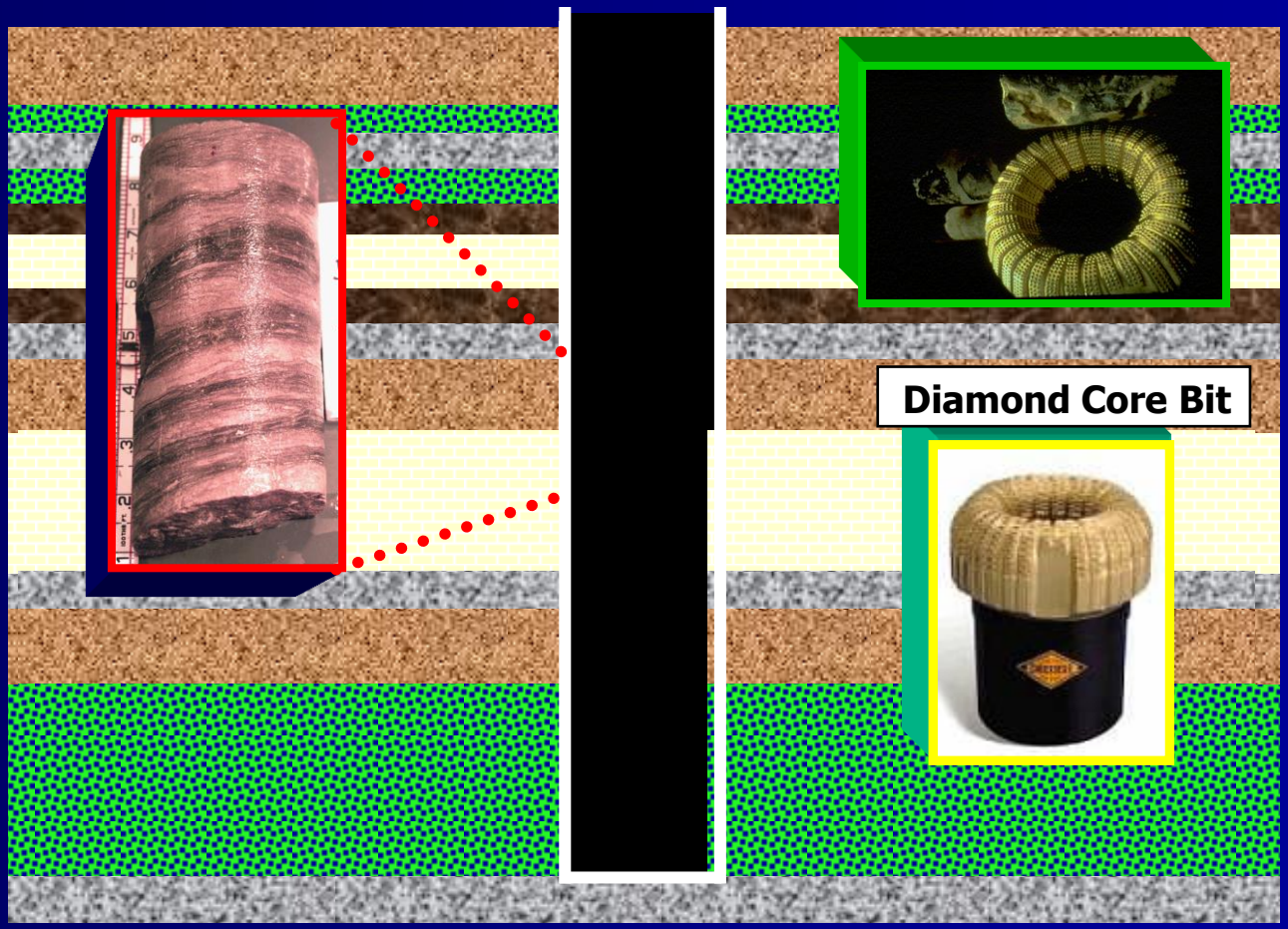
    A typical core is a rock cylinder, normally 4" to 6" in diameter, of the reservoir rock retrieved from the wellbore to the surface in a core barrel.

    The core is sent to the laboratory for analysis. Potential information obtained includes rock type, rock characteristics, source of the sediments, depositional environments, porosity, permeability, radioactive properties and estimates of fluid saturations in the rock.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- ✓ Subsurface Exploration Methods



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

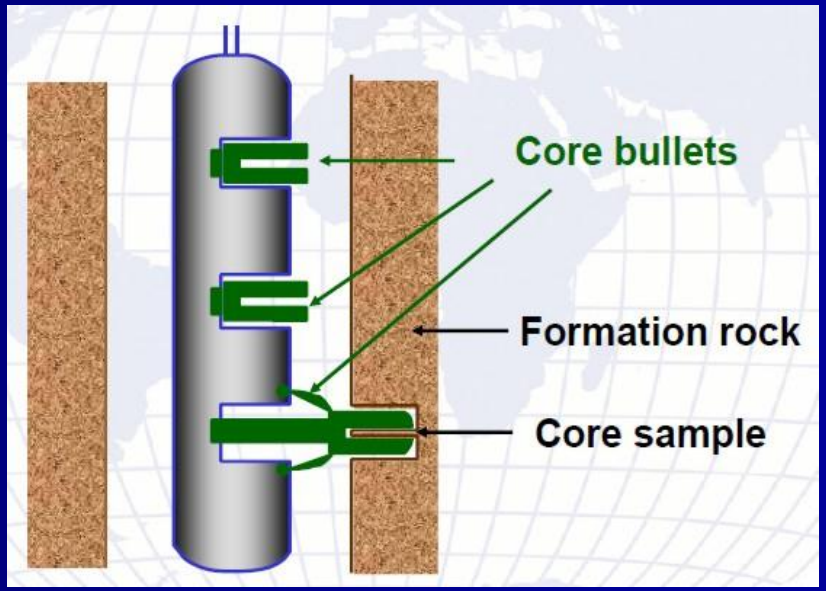
- Subsurface Exploration Methods
  - Core Samples

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Core Samples

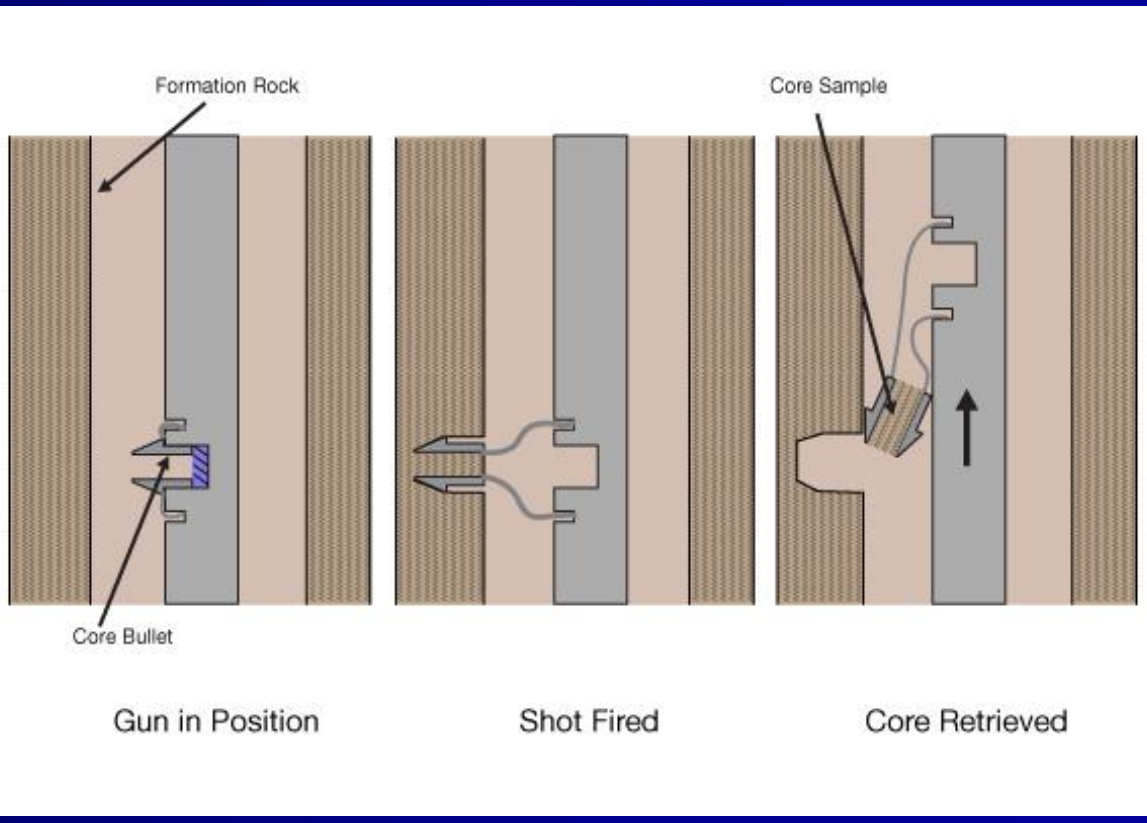
    Sidewall cores, which are less than 1" in diameter and less than 3" in length, can be taken instead of the full hole cores which can be 30 – 60 feet in length.



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods



Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Reservoir Fluid Samples

    Reservoir fluid samples are collected from any reservoir rocks that are of potential interest.
    These fluid samples are sent to the laboratory for a PVT analysis.
    This provides important reservoir fluid data such as chemical composition, fluid formation volume factors, bubble point pressure, solution gas oil ratio, viscosity and density.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Reservoir Fluid Samples

    The drilling fluid, pumped through the inside of the drill string and exiting the drill bit while drilling, carries rock samples back to the surface in the drilling mud.

    When drilling into a rock formation containing hydrocarbons, traces of reservoir fluids encountered will be returned to the surface in the drilling mud.

    Surface samples of the mud are collected and analyzed for hydrocarbon presence. This is known as a mud log.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Mud Logs

    The mud log contains description of the rock type based on inspection under a microscope, plot of penetration rate, gas composition based on gas chromatography, oil cut based on washing the cuttings in toluene and ultraviolet fluorescence to determine presence of oil.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

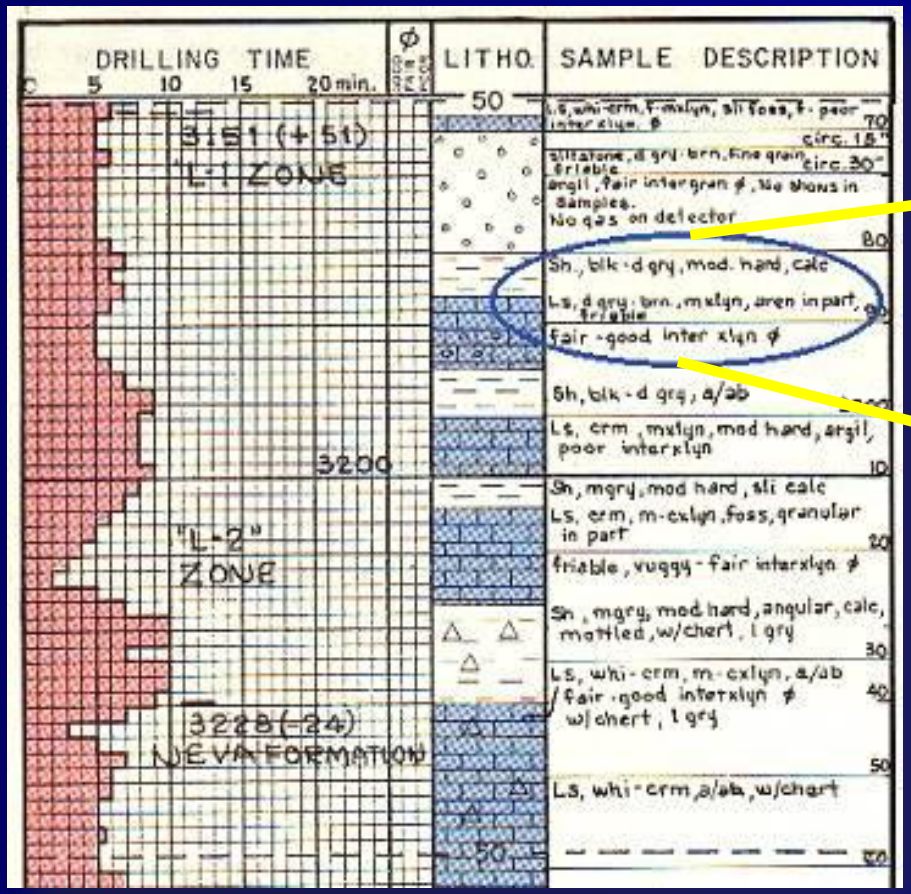
- Subsurface Exploration Methods
  - Mud Logs

    The mud log contains:
    - description of the rock type based on inspection under a microscope,
    - plot of penetration rate,
    - gas composition based on gas chromatography,
    - oil cut based on washing the cuttings in toluene, and
    - ultraviolet fluorescence to determine presence of oil.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- ✓ Subsurface Exploration Methods



Shale black to dark gray, medium hardness

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

- Subsurface Exploration Methods
  - Well Logs

    A log of a well is a determination of downhole properties relative to depth.

    Many types of logs are run in a borehole, depending upon the information desired and equipment available.

    Typical logs run are electric logs, magnetic logs, sonic logs, radioactive logs and physical logs of various types.

    Properties measured by these logs may include pressure, temperature, rock density, porosity, permeability, fluid saturations, magnetic properties, radioactive properties and sonic velocity.

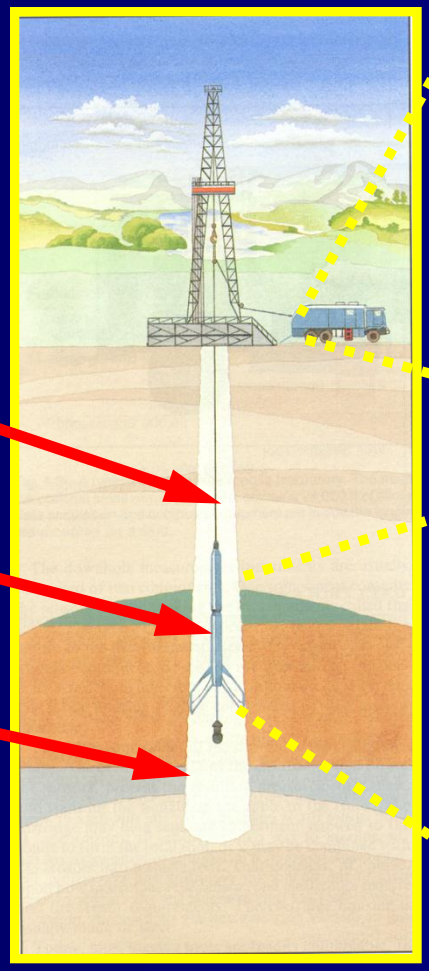
Chapter Four: Petroleum Exploration Techniques

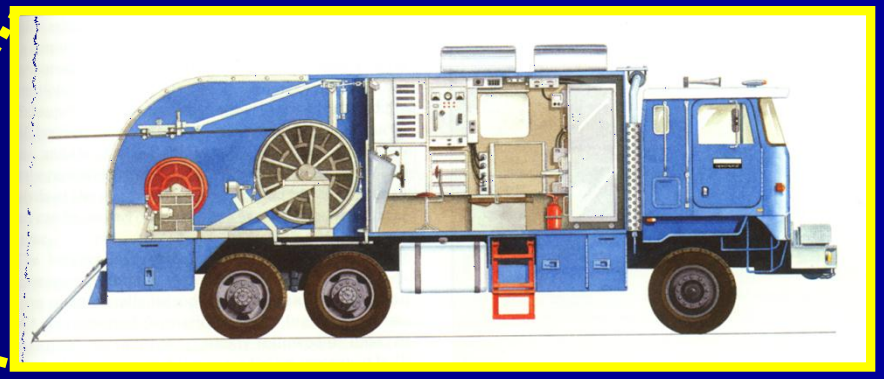
Exploration Techniques

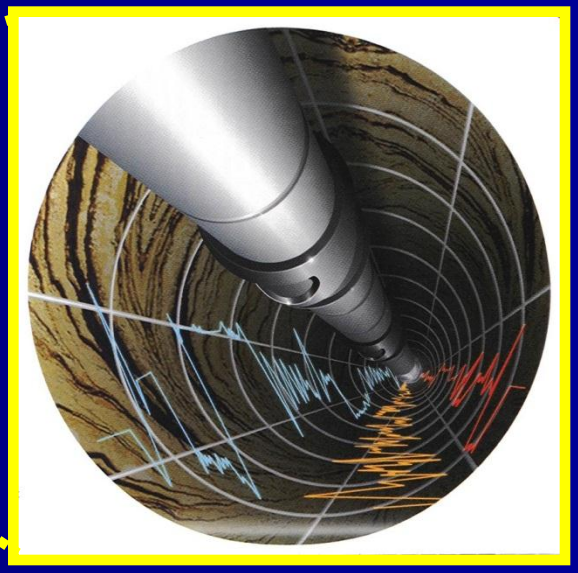
- Subsurface Exploration Methods
  - Well Logs

    In most instances more than one log are run simultaneously during a logging run.

Logging a Well







Logging a Well

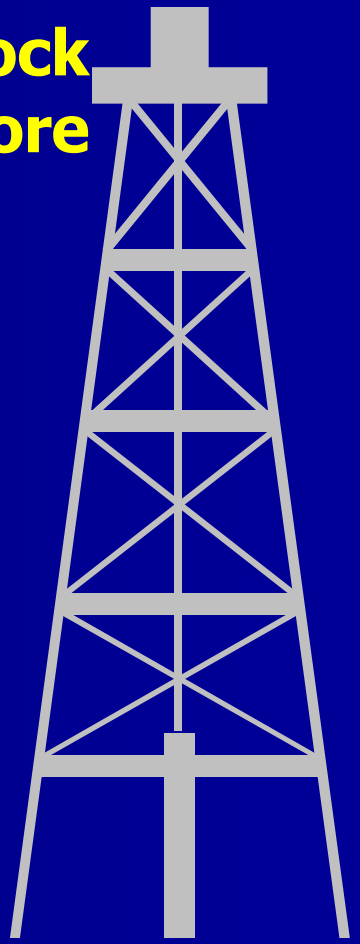
Logging Tools Detect Lithology, Porosity, etc.

Open Hole Logs

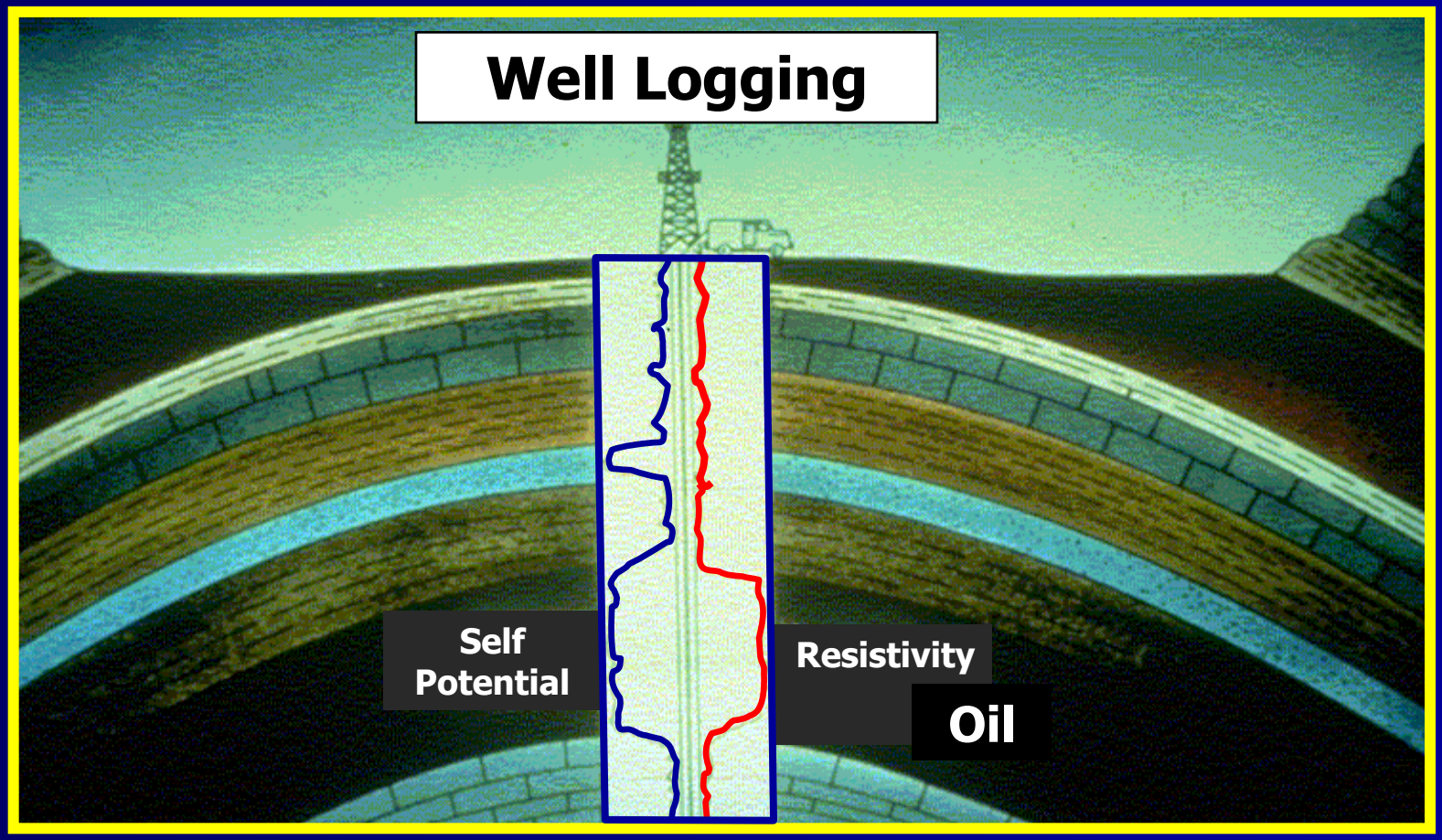
Used to evaluate the fluid & rock properties around the wellbore

Types of open hole logs:

- **Porosity logs**
- **Resistivity logs**



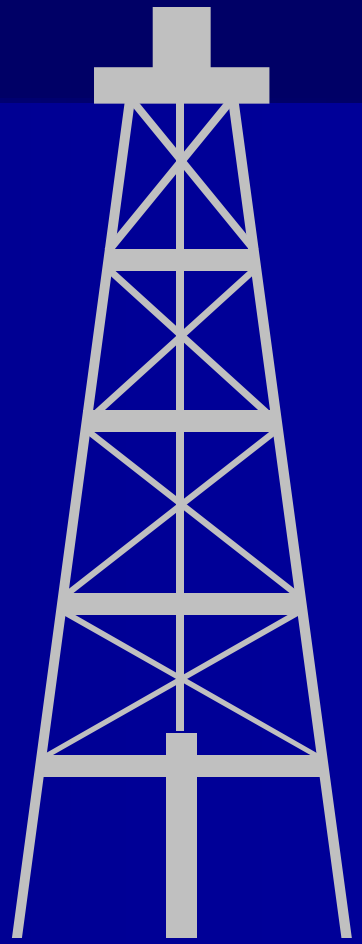
Typical Logs Represented by SP (Self Potential) & Resistivity Logs



High resistance = oil, low resistance = water

Cased Hole Logs

Used to evaluate the existence or movement of fluid behind the casing or inside the wellbore



Types of cased hole logs:

- **Porosity logs (pulsed neutron)**
- **Flowmeter log**

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

Well Types:

The first exploratory well may reveal a commercial reservoir, giving geological information or sufficient shows of oil or gas to justify further drilling before a final judgment is passed on the value of the area.

1. **Exploratory well (wild Cat)**

   All wells drilled to discover accumulations of oil are "exploration wells", commonly known,as 'wildcats' a designation emphasizing the hazards and the speculative nature of drilling in a new area.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

Well Types:

1. **Exploratory well (wild Cat) cont.**

   A successful **wildcat** is called a "**discovery well**", an unsuccessful one is called a "**dry hole**".

2. **Appraisal wells**

   are the next few wells drilled to confirm the size and quality of the discovered field.

Chapter Four: Petroleum Exploration Techniques

Exploration Techniques

Well Types:

3. **Development wells**

   All subsequent wells being "exploitation" wells or "development" wells.

   The development plans are revised when further information are obtained.

   At this stage, a new field will then have been added to the world's oil and natural gas map.

Chapter Four: Petroleum Exploration Techniques

Contour Maps

Contour maps are one of the most effective means of displaying exploration data for a specific area.

A contour line connects points of equal value. If a contour line represents an elevation on the surface of the earth ground, it is called a topographical contour.

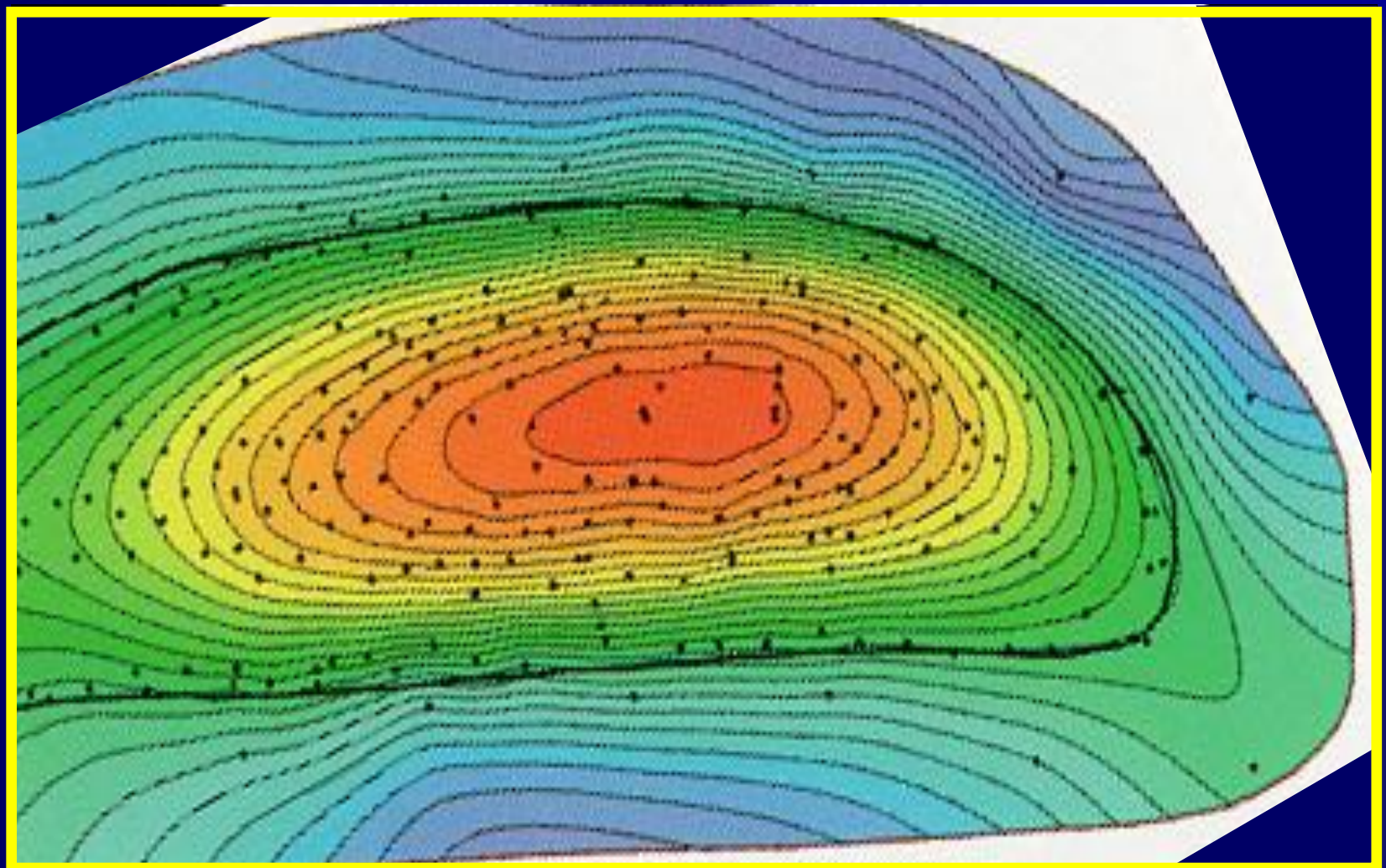
A map showing topographical contours for an area is called topographical map.

If such a contour line represents an elevation of a rock layer below ground surface, then it is called structural contour .

Structural maps are very important way for identification of geological structures (traps) below earth surface.

Chapter Four: Petroleum Exploration Techniques

Contour Maps



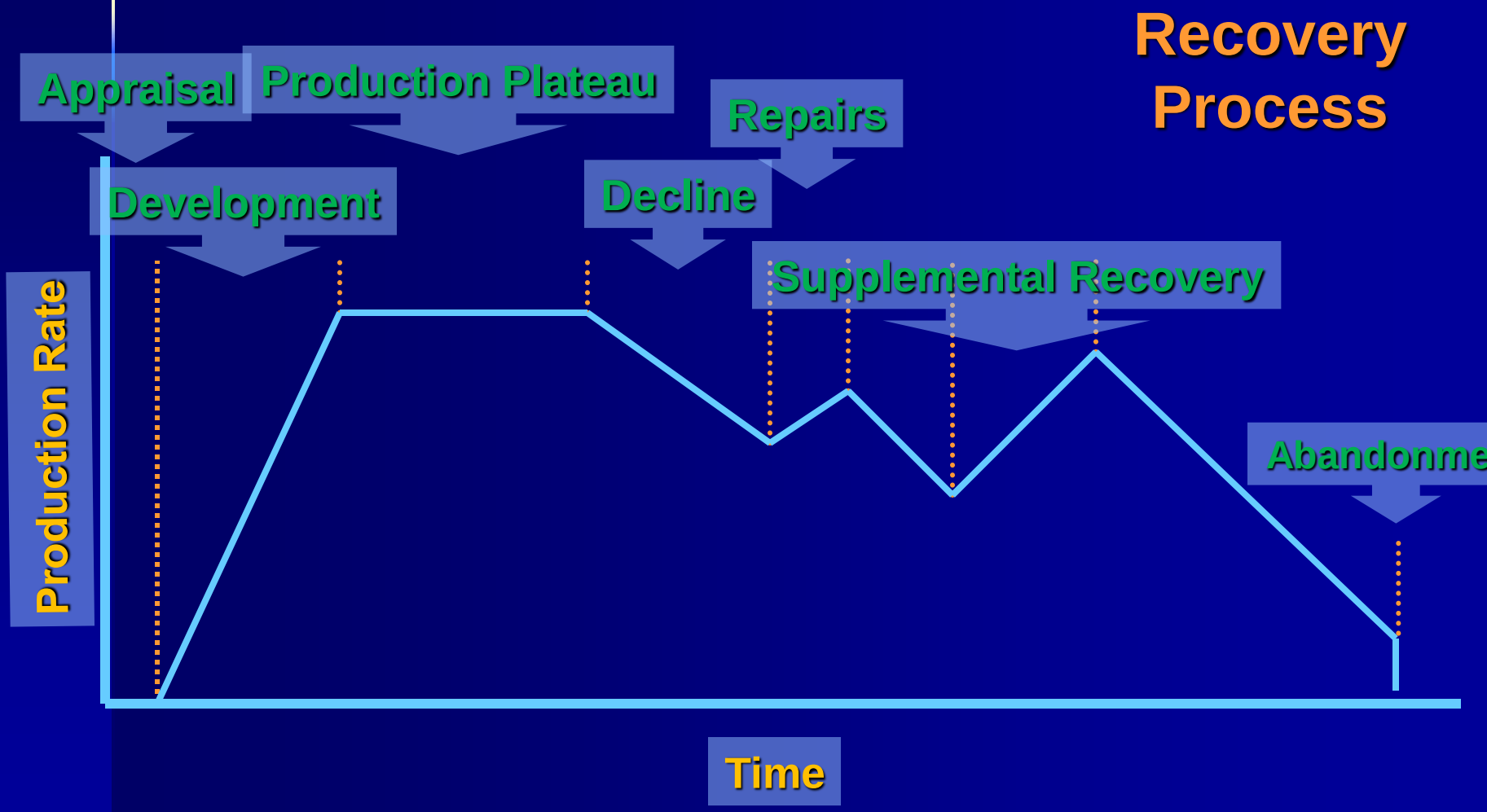
Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

The development of petroleum fields from initial exploration through evaluation and into subsequent development can vary in length depending upon the size of the field, its complexity, and the environment in which the field is located.

Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development



Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

The development of petroleum fields from initial exploration through evaluation and into subsequent development can vary in length depending upon the size of the field, its complexity, and the environment in which the field is located.

The various phases of the development of an oil or natural gas field are as follows:

1. **Exploration:**

   In this stage, several exploration techniques are conducted searching for potential geological structures (traps).

   Surface and subsurface structural maps are produced at this stage.

Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

The development of petroleum fields from initial exploration through evaluation and into subsequent development can vary in length depending upon the size of the field, its complexity, and the environment in which the field is located.

The various phases of the development of an oil or natural gas field are as follows:

2. Discovery, Evaluation and Development :

After completing the exploration stage of an oil or gas field, exploration, discovery and appraisal wells are drilled. Reserve, lithology, petrophysical properties (porosity, permeability, etc.), saturations, productivity, etc. are estimated at this stage by the utilization of data obtained from core testing, logging and well testing.

Chapter Four: Petroleum Exploration Techniques

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2. Discovery, Evaluation and Development :

If the reservoir is found commercially feasible, numerous other wells are drilled for production, injection and monitoring. The total number of these wells depends on the size and geology of the field. After sometime, infill wells are drilled to enhance recovery from this field if necessary.

Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

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The various phases of the development of an oil or natural gas field are as follows:

3. Production and Utilization:

The main goal in this stage is to achieve maximum rate for maximum period possible at maximum safety for personnel, reservoir, and the environment.

Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

The development of petroleum fields from initial exploration through evaluation and into subsequent development can vary in length depending upon the size of the field, its complexity, and the environment in which the field is located.

The various phases of the development of an oil or natural gas field are as follows:

3. Production and Utilization:

After the drilling program is completed, the gathering pipelines network is constructed and production is directed to the gas-oil separation plant (GOSP) to remove water, gas, salts, and solids from the produced hydrocarbons. Development , production and workover processes continue until the economic limit is reached.

Chapter Four: Petroleum Exploration Techniques

Basis of Petroleum Field Development

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The various phases of the development of an oil or natural gas field are as follows:

4. Abandonment:

The reservoir abandonment process starts by closing wells that can no longer produce oil or gas economically, i.e., the cost of well maintenance and its production will exceed the revenue coming from hydrocarbon production. When the last well in the field is closed, the field is known as "depleted field".