Fundamental Of Petroleum Engineering

GEOLOGY AND EXPLORATION

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COURSE CONTENTS

- Rock Types
- Parameters Controlling Petroleum Occurrence
- Migration of Petroleum
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Rock Types: Igneous Rock

- Igneous rocks are crystalline solids which form directly from the cooling of magma. This is an exothermic process (it loses heat) and involves a phase change from the liquid to the solid state.
- Igneous rocks are given names based upon two things: composition (what they are made of) and texture (how big the crystals are).
- Texture relates to how large the individual mineral grains are in the final, solid rock. In most cases, the resulting grain size depends on how quickly the magma cooled. In general, the slower the cooling, the larger the crystals in the final rock.

- The other factor is composition: the elements in the magma directly affect which minerals are formed when the magma cools.
- Example of Igneous Rocks: Granite and Basalt.

Granite

Basalt

Rock Types: Sedimentary Rock

- Sedimentary rocks are called secondary, because they are often the result of the accumulation of small pieces broken off of pre-existing rocks. This accumulation get compacted and cemented together There are three main types of sedimentary rocks: clastic, chemical and organic sedimentary rocks.
- Clastic sedimentary rock:
  - Clastic sedimentary rocks are accumulations of clasts - little pieces of broken up rock which have compacted and cemented.
  - Example of clastic sedimentary rocks are sandstone, shale, siltstone and conglomerate.

Sandstone

Shale

Siltstone

Conglomerate

Rock Types: Sedimentary Rock

- Chemical sedimentary rock:
  - Many of these form when standing water evaporates, leaving dissolved minerals behind. Thick deposits of salt and gypsum can form due to repeated flooding and evaporation over long period of time .
  - Example of chemical sedimentary rocks are gypsum and dolomite.

Rock Types: Sedimentary Rock

- Organic sedimentary rock:
  - Any accumulation of sedimentary debris caused by organic processes. Many animals use calcium for shells, bones, and teeth. These bits of calcium can pile up on the seafloor and accumulate into a thick enough layer to form an "organic" sedimentary rock.
  - Example of organic sedimentary rocks are coal and coquina.

Gypsum

Dolomite

Coal

Coquina

Rock Types: Metamorphic Rock

- The metamorphics get their name from "meta" (change) and "morph" (form).
- Any rock can become a metamorphic rock. All that is required for the rock to be moved into an environment in which the minerals which make up the rock become unstable and out of equilibrium with the new environmental conditions.
- In most cases, this involves burial which leads to a rise in temperature and pressure. The metamorphic changes in the minerals always move in a direction designed to restore equilibrium.
- Common metamorphic rocks include slate, schist, gneiss, and marble.

Slate

Schist

Marble

Gneiss

Parameters Controlling Petroleum Occurrence

1. Source Rocks

- Fine grained sediment that in its natural setting has generated and released enough hydrocarbons to form a commercial accumulation of oil and gas.
- Source rocks are clay or carbonate organic rich muds deposited under low energy, reducing conditions.
- The most important factor in the generation of petroleum in source rock is temperature.
- The action of heat on the insoluble organic matter (kerogen) contained in source rocks leads to the formation of oil and gas.

2. Reservoir Rocks

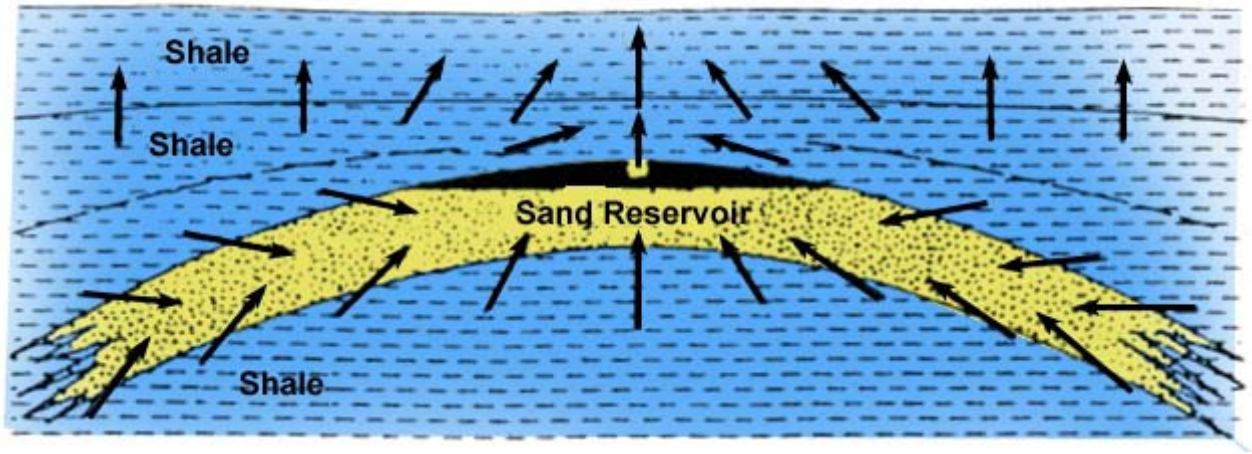
- A petroleum reservoir is a porous and permeable rock in communication with a mature source bed.
- Sandstones and carbonate rocks form the overwhelming majority of reservoirs world-wide.
- Under special circumstances, igneous and metamorphic rocks can also act as petroleum reservoirs.

3. Traps

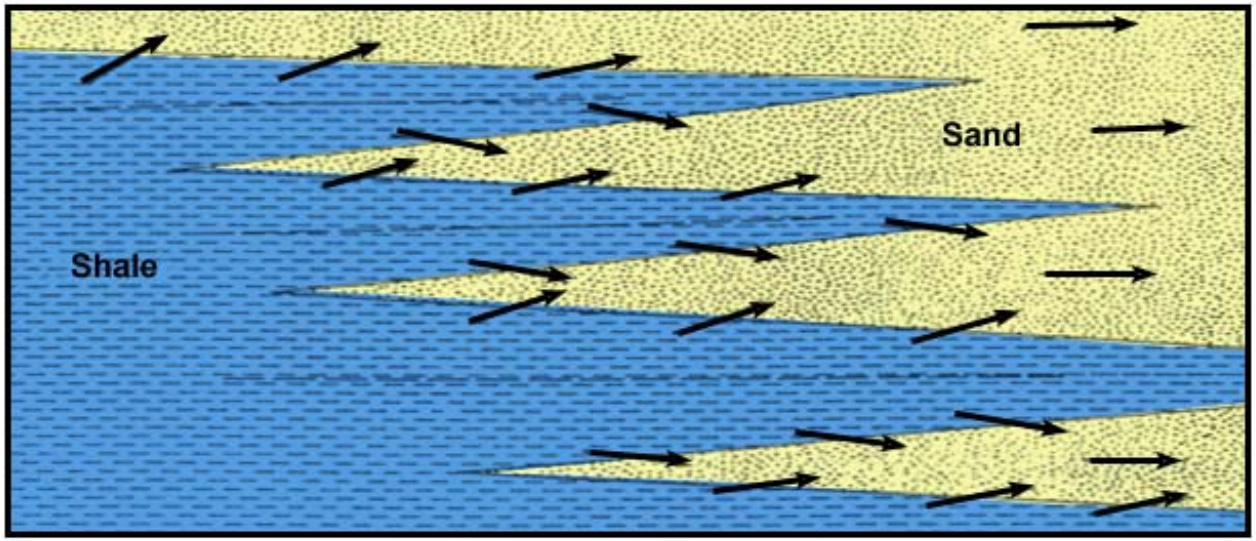
- A traps is a an arrangement of rock layers that contains an accumulation of hydrocarbons, yet prevents them from rising to the surface.
- The trap consists of an impermeable layer of rock above a porous, permeable layer containing the hydrocarbons.
- It can be structural traps or stratigraphic traps or combination of these factors. Structural traps occur when the reservoir formation deforms. Stratigraphic traps are those where porosity or permeability has changed within a formation.

Migration of Petroleum

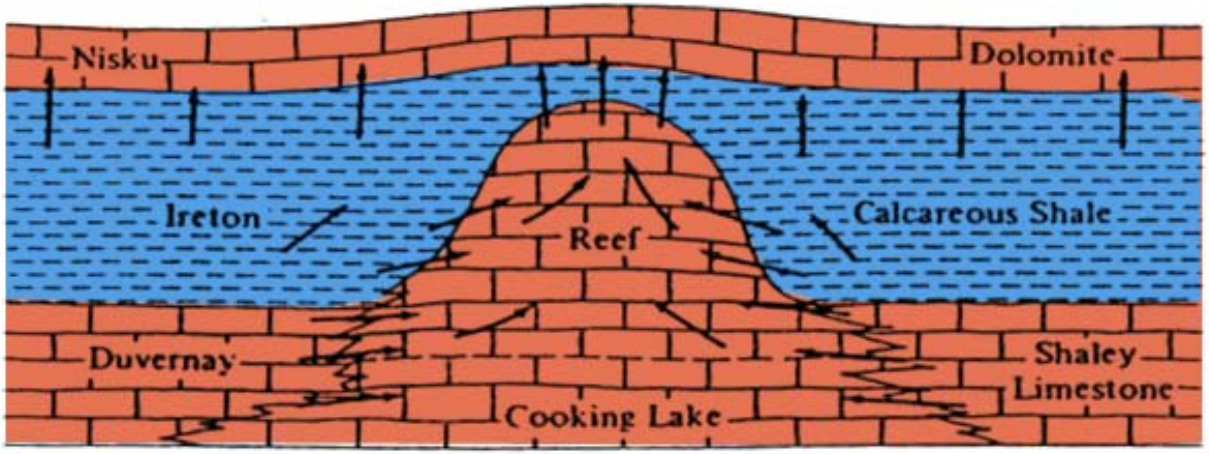
- Oil and gas move out of the source beds and accumulate in the reservoir rocks.
- The transfer from source rocks to reservoir rocks is called primary migration.
- Movement of petroleum within the porous and permeable reservoirs beds is known as secondary migration.
- The primary cause of movement of fluids is compaction.
- The more permeable silt and sand bodies within compacting muds are the main channels of fluid migration.



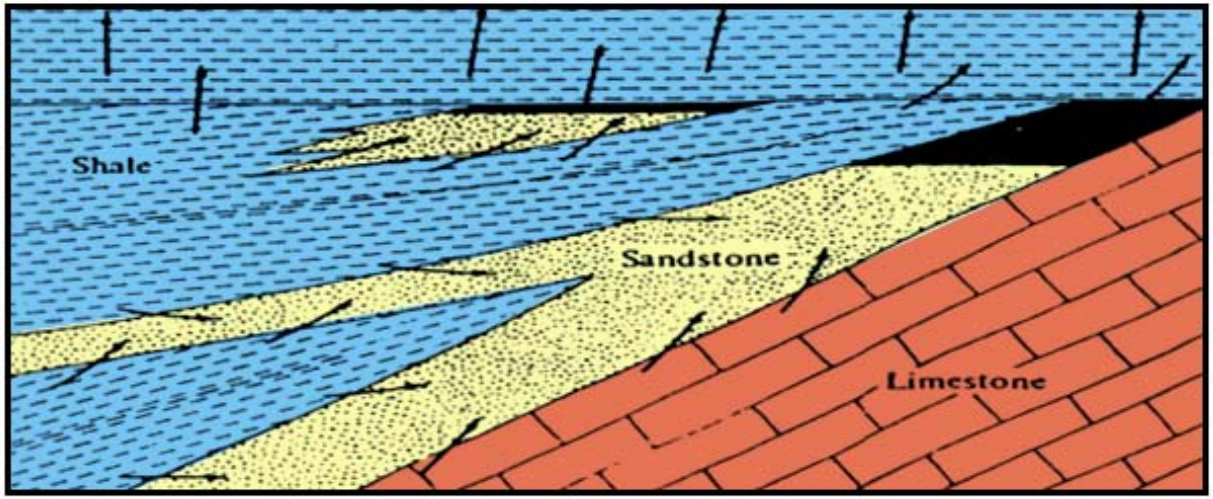
Direction of fluid migration into anticline



Migration from an interbedded shale-sand sequence



Migration into a pinnacle reef



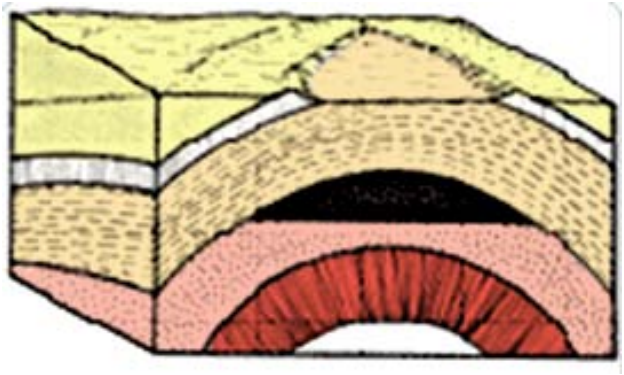
Migration into stratigraphic traps

Entrapment of Petroleum

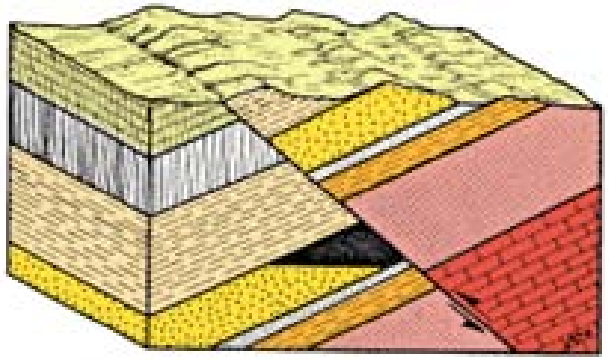
- Oil, gas and water slowly migrate through permeable rocks, driven by natural forces of gravity (buoyancy) and pressure gradients.
- When they meet an impermeable barrier, they can go no further, so oil and gas accumulate. This barrier is generally referred to as a trap.
- Varying densities make the gas phase rise, while the water settles to the lowest point, and the oil remains in the middle.
- Traps may be classified according to the manner in which they are formed, and categorized as structural trap, stratigraphic trap and combination trap.

Structural Traps

- By far the greatest number of fields discovered world-wide and the largest proportion of total proven reserves are associated with structural traps.
- Structural traps result from a local deformation such as folding and/or faulting of the rock layers.
- Faulting can also produce traps by juxtaposing a reservoir against an impervious stratum.

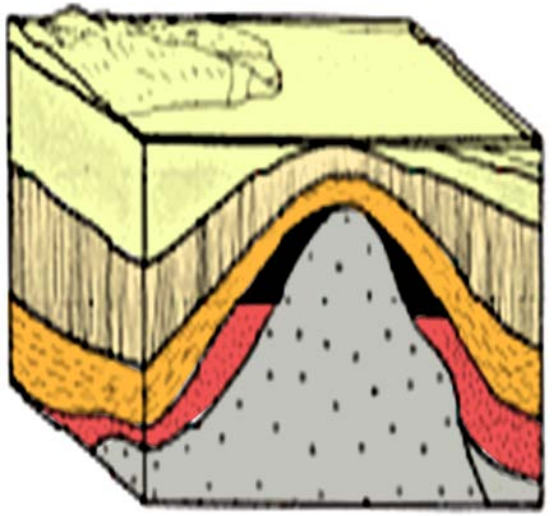


Anticlinal oil traps



Structural oil trap caused by faulting

- Draping or compaction over a buried hill, carbonate reef also produces traps on a smaller scale.

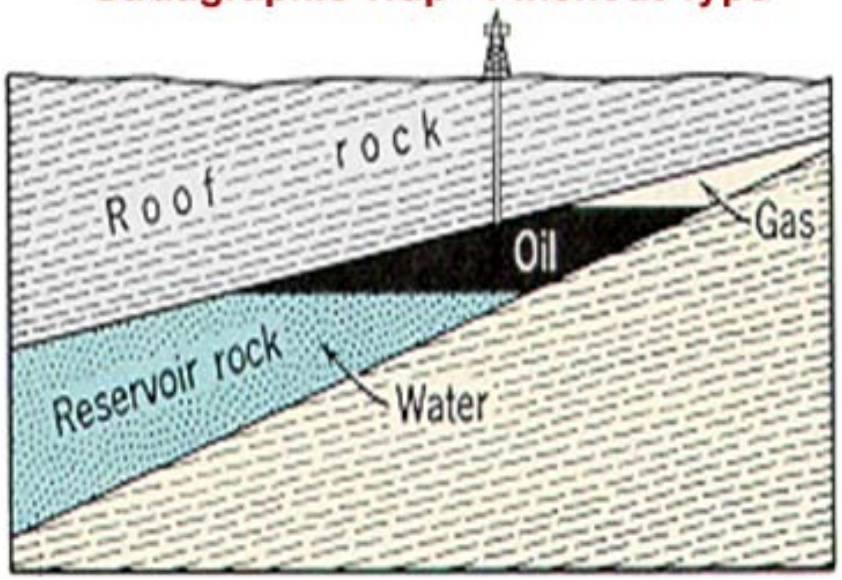


Sediment draping

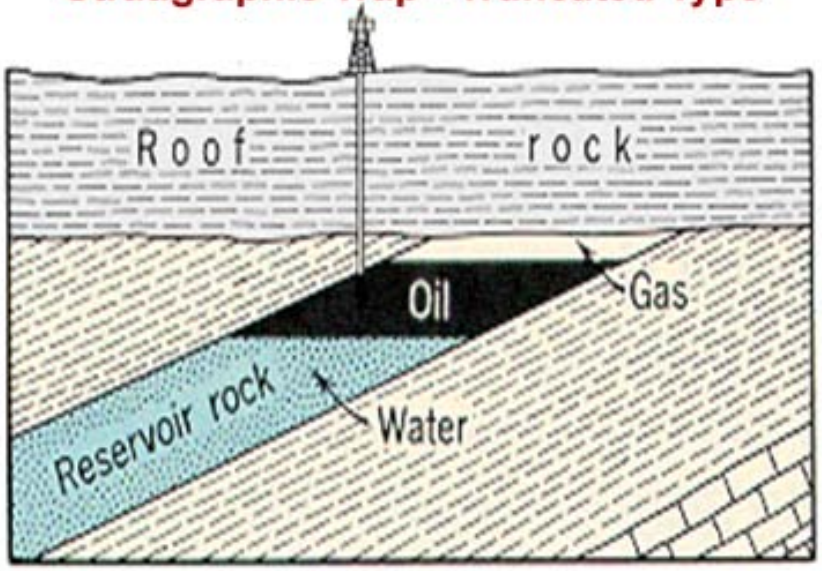
Stratigraphic Traps

- Most basins contain facies changes, unconformities with resulting truncated beds, and buried erosional or constructive surfaces such as reefs, hills, barrier sand bars, channels, and other related geologic phenomena which form the basic requirements for the creation of stratigraphic traps.
- Stratigraphic trap is a general term for traps that are chiefly the result of a lateral variation in the lithology of the reservoir rock, or a break in its continuity. A permeable reservoir rock changes to a less permeable or to an impermeable rock.
- Two common types of stratigrapic traps are Pinchout Type and Truncated Type.

Stratigraphic Trap - Pinchout Type

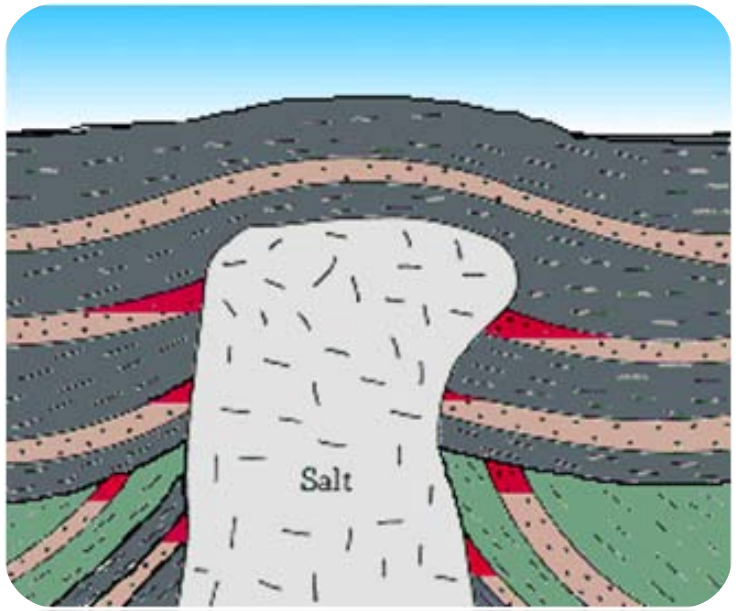


Stratigraphic Trap - Truncated Type



Combination Trap

- The geometry of this type of trap is the result of a combination of tectonic processes and changes in lithology.
- A common trap that would be an example of a Combination Trap is a salt dome.



Salt dome

Oil Exploration Method

- In the early days of petroleum, most oil finds were the result of digging or drilling near known oil and gas seeps or of accidental finds while drilling for water.
- A good definition of a seep is *''the surface expression of a migration pathway, along which petroleum is currently flowing, driven by buoyancy from a sub-surface origin''.*
- At the most basic level, this demonstrates that the basin contains a generating source rock and hence a viable petroleum system

Surface Geology

Remote Sensing Method

- The selection of effective exploration targets is an important step to achieve success in oil exploration.
- Remote sensing refers to using infrared or other means to map an area.
- This method is used to study the basic of petroleum geological conditions.
- The remote sensing images have characteristics of realty and provide accurate visual data for directly determining geometric shapes of sedimentary basins.

- The remote sensing techniques are more effective and useful for understanding and studying those basins in the out-of-the-way mountains and remote deserts.
- Remote sensing equipments can be carried by airplanes or by satellites.
- Companies using remote sensing data, however, still need traditional exploration information to pinpoint the location of commercial deposits.

Geophysical Exploration

1. Magnetic Methods

- Sedimentary rocks generally have a very small magnetic susceptibility compared with igneous or metamorphic rocks, which tend to have a much higher magnetite (a common magnetic mineral) content.
- By conducting a magnetic survey over a given area, a prospector can determine where oil-bearing sedimentary rock is more likely to be found.
- The *magnetometer* is used to measure the magnitude of the earth's total magnetic field over a large area.

- A magnetometer can be towed behind a ship or an airplane to cover large areas. It transmits data to a device on board which records the information onto paper or magnetic tape.
- A development of airborne magnetics is the micromagnetic technique for oil exploration. An airplane tows a micromagnetometer from a low altitude, normally about 300 ft above the ground. It detects micromagnetic anomalies, or deviations from the norm.
- Geologist use these data to predict the characteristics of the overlying sediments.

Geophysical Exploration

2. Gravity Methods

- The Earth's gravitational attraction varies slightly from one place to another on the Earth's surface. Some of this variation occurs because the Earth is not a perfect sphere, and some is related to differences in elevation on the Earth's surface.
- For example, in north-central Kansas, there is an anomaly known as the Midcontinent Gravity High where the Earth's gravity is about 0.006% greater than normal.
- In gravity prospecting, geophysicists measure variations in the force of gravity from rocks up to a few miles beneath the earth's surface.

- Different types of rocks have different densities, and the denser rocks have the greater gravitational attraction.
- If the higher-density rock formations are arched upward in a structural high, such as an anticline, the Earth's gravitational field will be greater over the axis of the structure than along its flanks.
- A salt dome, on the other hand, which is generally less dense than the rocks into which it is intruded, can be detected from the low value of gravity recorded compared with that measured on either side.

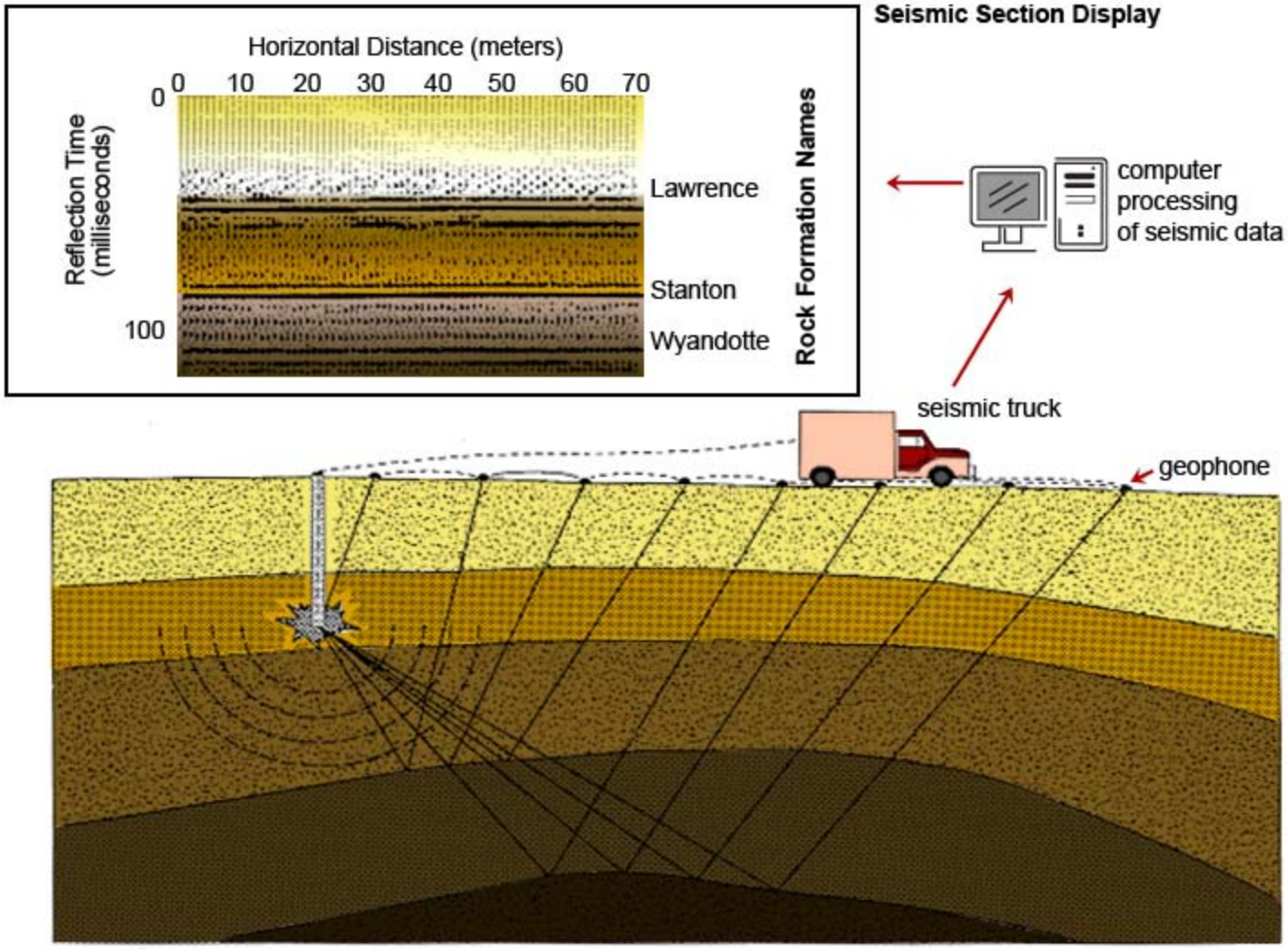
Geophysical Exploration

3. Seismic Methods

- Seismic reflection, a powerful technique for underground exploration, has been used for over 60 years. It will give more precise details on the formations beneath the surface.
- Seismic waves are essentially sound waves that travel underground at velocities of 2 to 4 miles per second (3 to 6 km per second), depending upon the type of rock through which they pass.
- The reflections are recorded by detecting instruments responsive to ground motion (geophones). They are laid along the ground at distances from the shot point which are generally small compared with the depth of the reflector.

- Variations in the reflection times from place to place on the surface usually indicate structural features in the strata below.
- From the geophones, the wave will be send through cables to a recorder.
- The recorder, a seismograph, amplifies and records the wave characteristics to produce a seismogram.
- Seismograms generate a seismic section, which is a two-dimensional slice from the surface of the earth downward.
- The information from a seismic survey indicates the types of rock, their elative depth, and whether a trap is present.

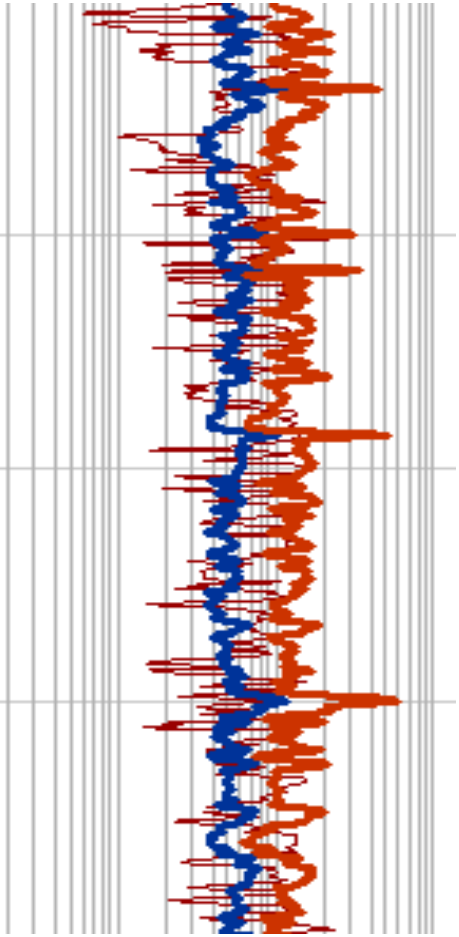
Onshore seismic operation



Sub-Surface Geophysical Exploration

Well Correlation

- Consists of establishing correlations by matching strata, rock hardness or softness, and electrical and radioactivity data to determine the origin, composition and distribution of rock strata.
- Electrical logs, radioactivity logs, and acoustic logs help geologists predict where oil bearing strata occur.
- Sample logs, compiled from well cuttings and cores, are used to identify key beds and lithologic sequences..



Well Correlation

- Core samples are taken from the top to the bottom of a well and shows rock in sequential order as it appears in the ground.
- Core samples also provide information on porosity, permeability, and saturation of rock in the well.
- Cuttings are not a continuous record like core samples, but provide a means for identifying sections within larger thick layers through fossil and mineral deposits.