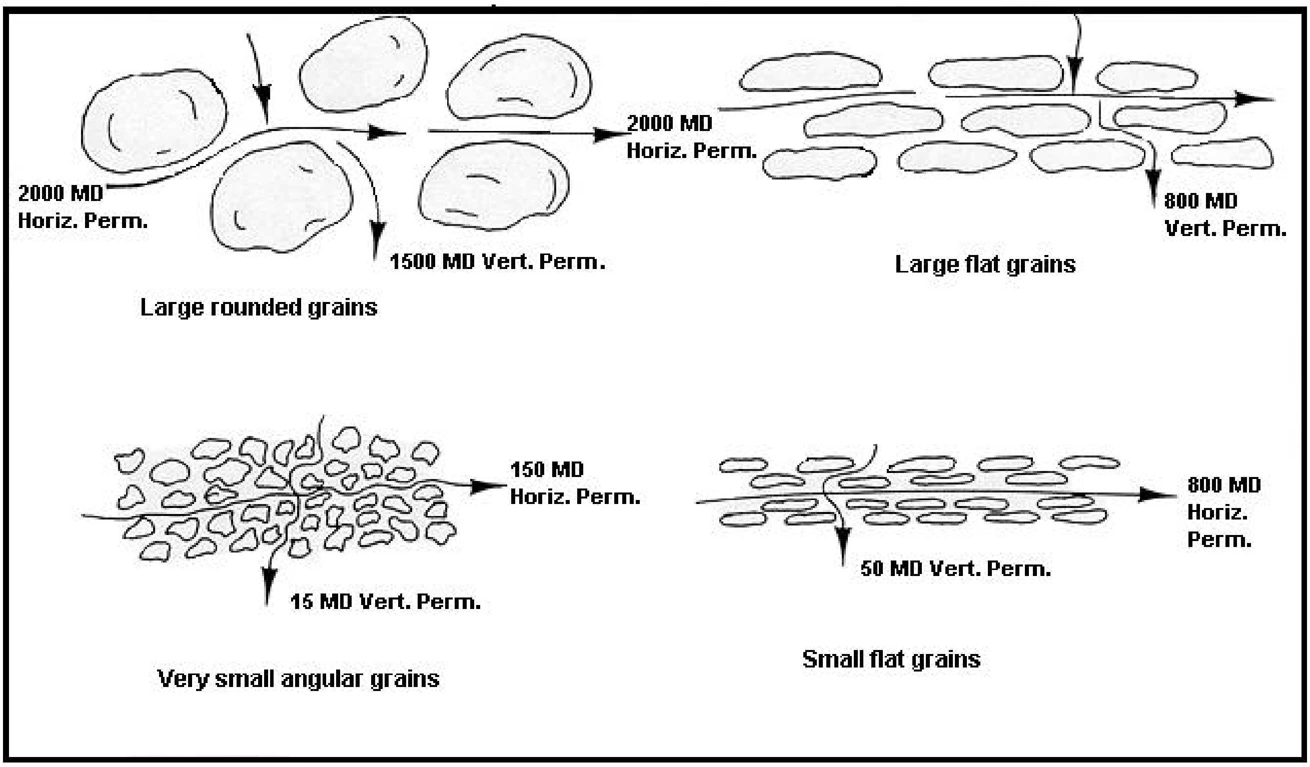
Permeability

Recovery of hydrocarbons from the reservoir is an important process in petroleum engineering and estimating permeability can aid in determining how much hydrocarbons can be produced from a reservoir. Permeability is a measure of the ease with which a formation permits a fluid to flow through it. To be permeable, a formation must have interconnected porosity (intergranular or intercrystalline porosity, interconnected vugs, or fractures).

To determine the permeability of a formation, several factors must be known: the size and shape of the formation, its fluid properties, the pressure exerted on the fluids, and the amount of fluid flow. The more pressure exerted on a fluid, the higher the flow rate. The more viscous the fluid, the more difficult it is to push through the rock. **Viscosity** refers to a fluid's internal resistance to flow, or it's internal friction.

Permeability is measured in darcies. Few rocks have a permeability of 1 darcy, therefore permeability is usually expressed in millidarcies or 1/1000 of a darcy.

Permeability is usually measured parallel to the bedding planes of the reservoir rock and is commonly referred to as horizontal permeability. This is generally the main path of the flowing fluids into the borehole. Vertical permeability is measured across the bedding planes and is usually less than horizontal permeability. The reason why horizontal permeability is generally higher than vertical permeability lies largely in the arrangement and packing of the rock grains during deposition and subsequent compaction. For example, flat grains may align and overlap parallel to the depositional surface, thereby increasing the horizontal permeability, see Figure below. High vertical permeability is generally the result of fractures and of solution along the fractures that cut across the bedding planes. They are commonly found in carbonate rocks or other rock types with a brittle fabric and also in clastic rocks with a high content of soluble material.



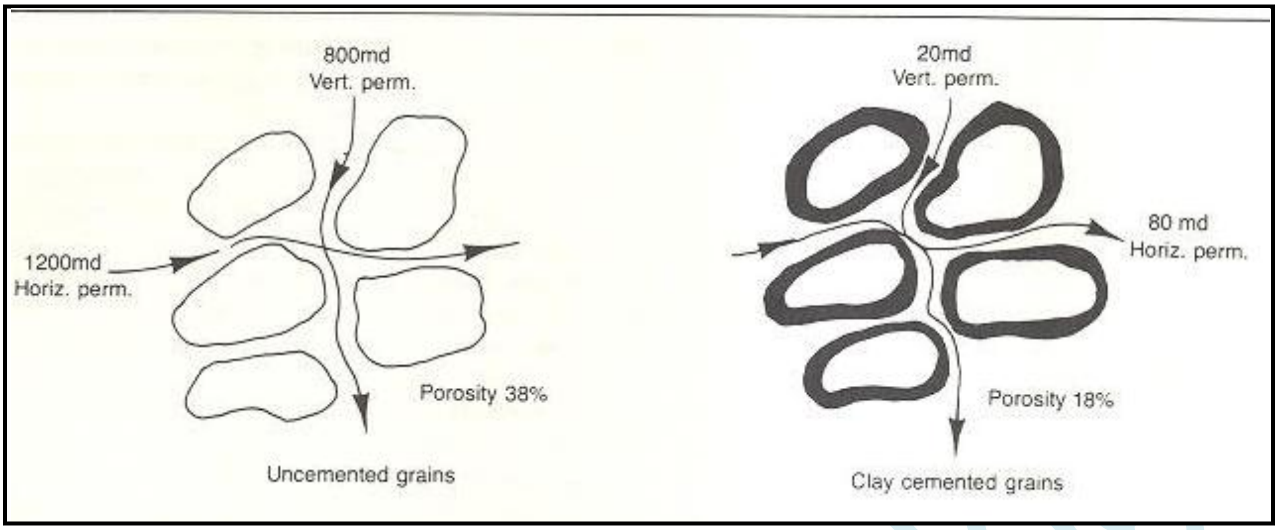
Examples of variations in permeability and porosity

• Some fine-grained sandstones can have large amounts of interconnected porosity; however, the individual pores may be quite small. As a result, the pore connecting individual pores may be quite restricted and tortuous; therefore, the permeabilities of such fine-grained formations may be quite low.

• Shale and clays— which contain very fine-grained particles— often exhibit very high porosities. However, because the pores within these formations are so small, most shale and clays exhibit virtually no permeability.

• Some limestone may contain very little porosity, or isolated vuggy porosity that is not interconnected. These types of formations will exhibit very little permeability. However, if the formation is naturally fractured (or even hydraulically fractured), permeability will be higher because the isolated pores are interconnected by the fractures.

Note: Intergranular material in a rock, such as clay minerals or cement, can reduce permeability and diminish its reservoir potential. It is evident, however,that mineral grains must be cemented to some degree to form coherent rock and that permeability will reduce to some extent in the process.



Exploration and Mapping Techniques

Exploration for oil and gas has long been considered an art as well as a science. It encompasses a number of older methods in addition to new techniques. The explorationist must combine scientific analysis and an imagination to successfully solve the problem of finding hydrocarbons.

Subsurface Mapping

Geologic maps are a representation of the distribution of rocks and other geologic materials of different lithologies and ages over the Earth's surface or below it. The geologist measures and describes the rock sections and plots the different formations on a map, which shows their distribution. **subsurface mapping** is a valuable tool for locating underground features that may form traps or outline the boundaries of a possible reservoir.

Subsurface mapping is used to work out the geology of petroleum deposits. Three dimensional subsurface mapping is made possible by the use of well data and helps to decipher the underground geology of a large area where there are no outcrops at the surface.

Geophysical Surveys

Geophysics is the study of the earth by quantitative physical methods. Geophysical techniques such as seismic surveys, gravity surveys, and magnetic surveys provide a way of measuring the physical properties of a subsurface formation. These measurements are translated into geologic data such as structure, stratigraphy, depth, and position. The practical value in geophysical surveys is in their ability to measure the physical properties of rocks that are related to potential traps in reservoir rocks as well as documenting regional structural trends and overall basin geometry.

Seismic Surveys

The geophysical method that provides the most detailed picture of subsurface geology is the seismic survey. This involves the natural or artificial generation and propagation of seismic (elastic) waves down into Earth until they encounter a discontinuity (any interruption in sedimentation) and are reflected back to the surface.

Magnetic Surveys

Magnetic surveys are methods that provide the quickest and least expensive way to study subsurface geology over a broad area. A magnetometer is used to measure local variations in the strength of the earth's magnetic field and, indirectly, the thickness of sedimentary rock layers where oil and gas might be found. Igneous and metamorphic rocks usually contain some amount of magnetically susceptible iron-bearing minerals and are frequently found as basement rock that lies beneath sedimentary rock layers. Basement rock seldom contains hydrocarbons, but it sometimes intrudes into the overlying sedimentary rock, creating structures such as folds and arches or anticlines that could serve as hydrocarbon traps. Geophysicists can get a fairly good picture of the configuration of the geological formations by studying the anomalies, or irregularities, in the structures.

Gravity Surveys

The gravity survey method makes use of the earth's gravitational field to determine the presence of gravity anomalies (abnormally high or low gravity values) which can be related to the presence of dense igneous or metamorphic rock or light sedimentary rock in the subsurface. Dense igneous or metamorphic basement rocks close to the surface will read much higher on a gravimeter because the gravitational force they exert is more powerful than the lighter sedimentary rocks. The difference in mass for equal volumes of rock is due to variations in specific gravity.

Geophysicists applied this knowledge, particularly in the early days of prospecting off the Gulf of Mexico. Often, they could locate salt domes using data from a gravity survey because anticline structures are associated with maximum gravity, whereas salt domes are usually associated with minimum gravity.