Reservoir Geology

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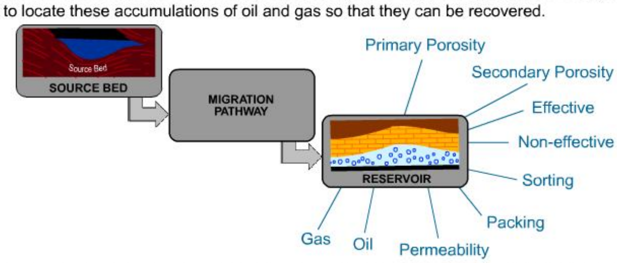
After hydrocarbons are generated within their source bed they are expelled and migrate through porous and permeable rock until their flow is eventually impeded by some impermeable barrier. The geologist's objective is to locate these accumulations of oil and gas so that they can be recovered.



Some hydrocarbons accumulate under conditions where their recovery is limited, while other conditions provide for more significant recoveries. Determining whether or not oil and gas can be recovered depends on a detailed knowledge of the reservoir.

Navigate through the Explore section using the Next and Back buttons above. When you see text in red, roll your mouse over the text to see the definition.

Reservoir Geology

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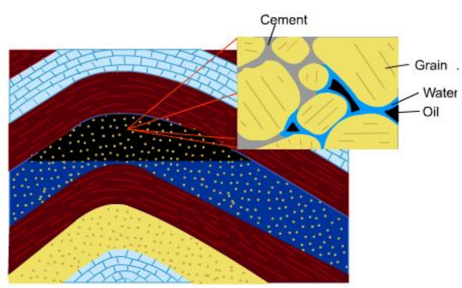
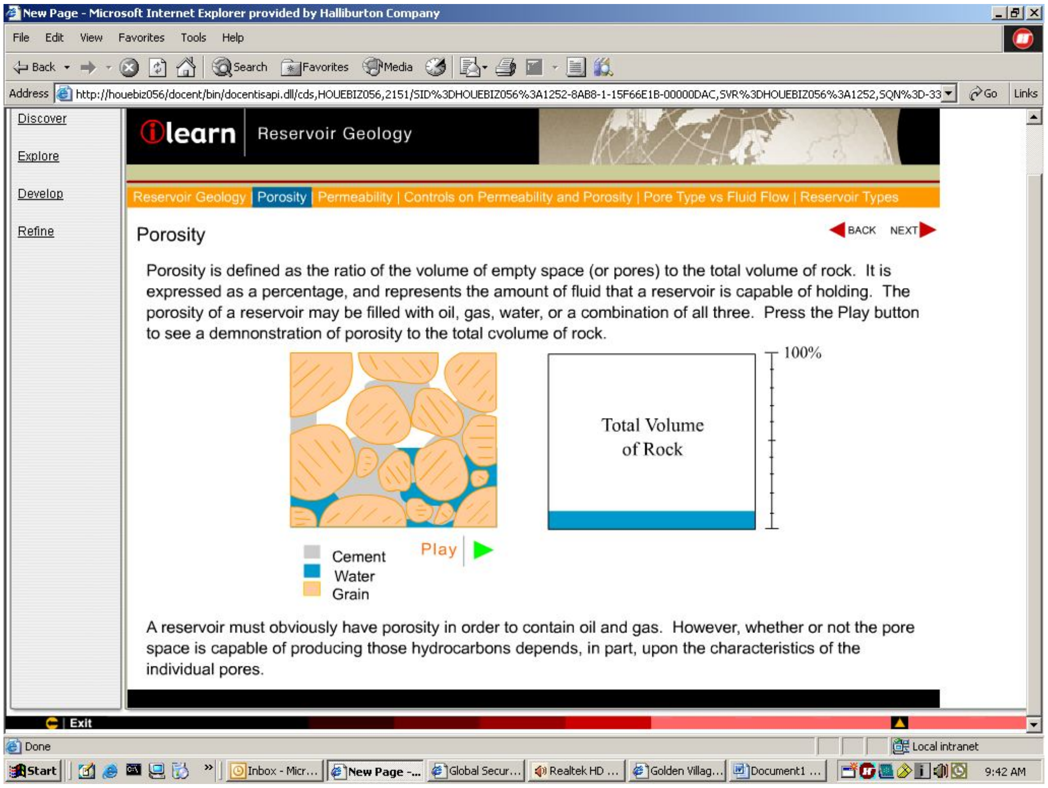
To this point, it has been implied that any porous and permeable rock is capable of containing hydrocarbons so long as an impermeable barrier, or seal, is present. While these three factors are required for oil and gas to accumulate, the ability to recover them depends upon a greater number of factors. The reservoir diagram shows water, oil, and cement occupying pore spaces between grains.

The type of porosity and its effect on permeability, and the types of fluids and their abilities to flow through the pore network must be considered. The effects of pressure also play an important role in the recovery of hydrocarbons. Porosity and permeability alone do not guarantee that a reservoir will produce oil and/or gas.



Focusing On The Reservoir



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Porosity

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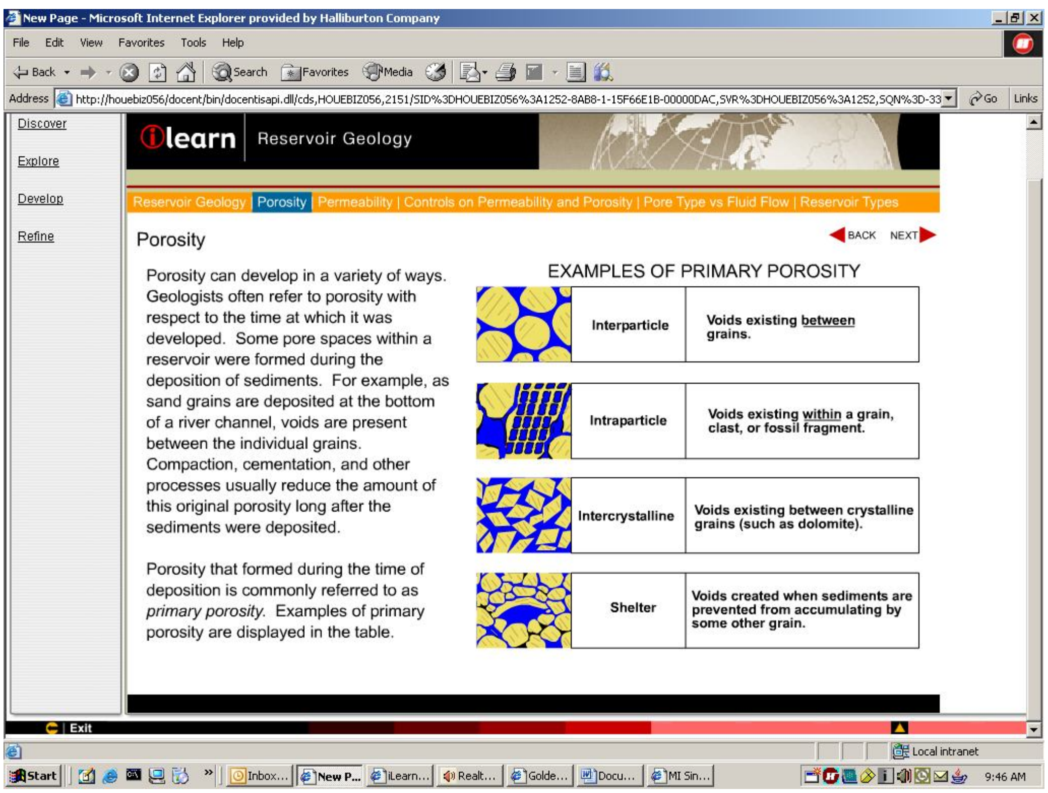
Porosity is defined as the ratio of the volume of empty space (or pores) to the total volume of rock. It is expressed as a percentage, and represents the amount of fluid that a reservoir is capable of holding. The porosity of a reservoir may be filled with oil, gas, water, or a combination of all three. Press the Play button to see a demnonstration of porosity to the total cvolume of rock.

A reservoir must obviously have porosity in order to contain oil and gas. However, whether or not the pore space is capable of producing those hydrocarbons depends, in part, upon the characteristics of the individual pores.



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Porosity

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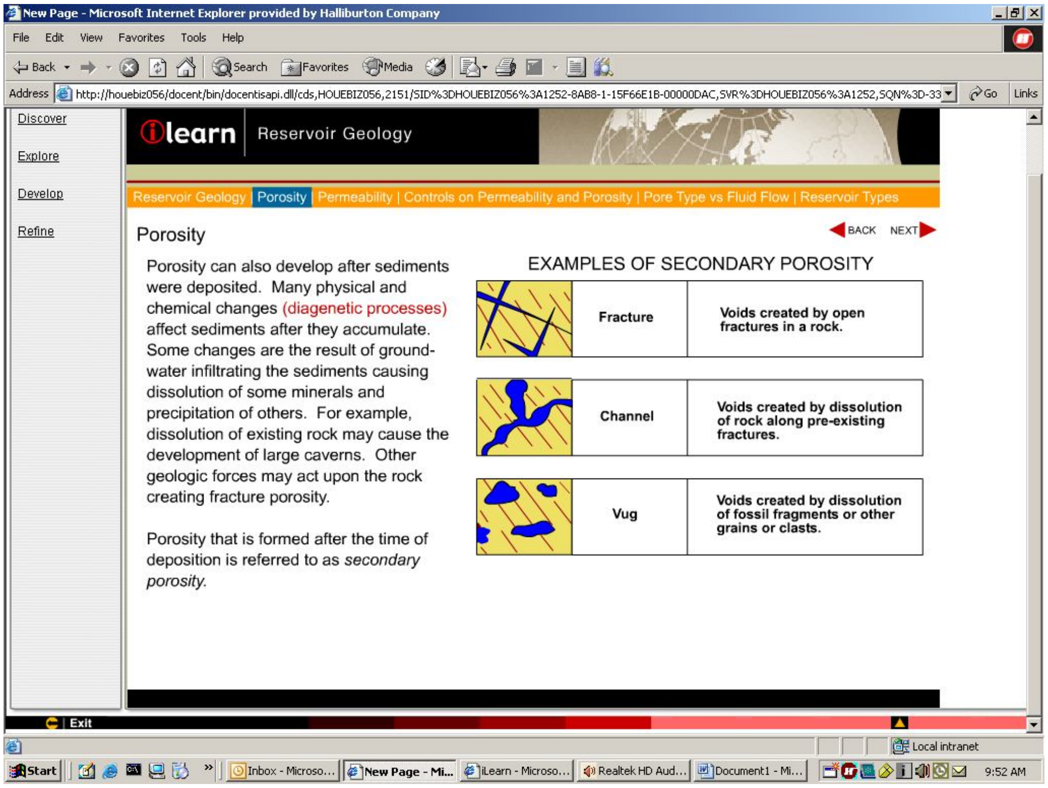
Porosity can develop in a variety of ways. Geologists often refer to porosity with respect to the time at which it was developed. Some pore spaces within a reservoir were formed during the deposition of sediments. For example, as sand grains are deposited at the bottom of a river channel, voids are present between the individual grains. Compaction, cementation, and other processes usually reduce the amount of this original porosity long after the sediments were deposited.

Porosity that formed during the time of deposition is commonly referred to as *primary porosity*. Examples of primary porosity are displayed in the table.

EXAMPLES OF PRIMARY POROSITY

	Interparticle	**Voids existing between grains.**
	Intraparticle	**Voids existing within a grain, clast, or fossil fragment.**
	Intercrystalline	**Voids existing between crystalline grains (such as dolomite).**
	Shelter	**Voids created when sediments are prevented from accumulating by some other grain.**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Porosity can also develop after sediments were deposited. Many physical and chemical changes (diagenetic processes) affect sediments after they accumulate. Some changes are the result of ground-water infiltrating the sediments causing dissolution of some minerals and precipitation of others. For example, dissolution of existing rock may cause the development of large caverns. Other geologic forces may act upon the rock creating fracture porosity.
Porosity that is formed after the time of deposition is referred to as *secondary porosity.*
EXAMPLES OF SECONDARY POROSITY
Fracture
Voids created by open fractures in a rock.
Channel
Voids created by dissolution of rock along pre-existing fractures.
Vug
Voids created by dissolution of fossil fragments or other grains or clasts.
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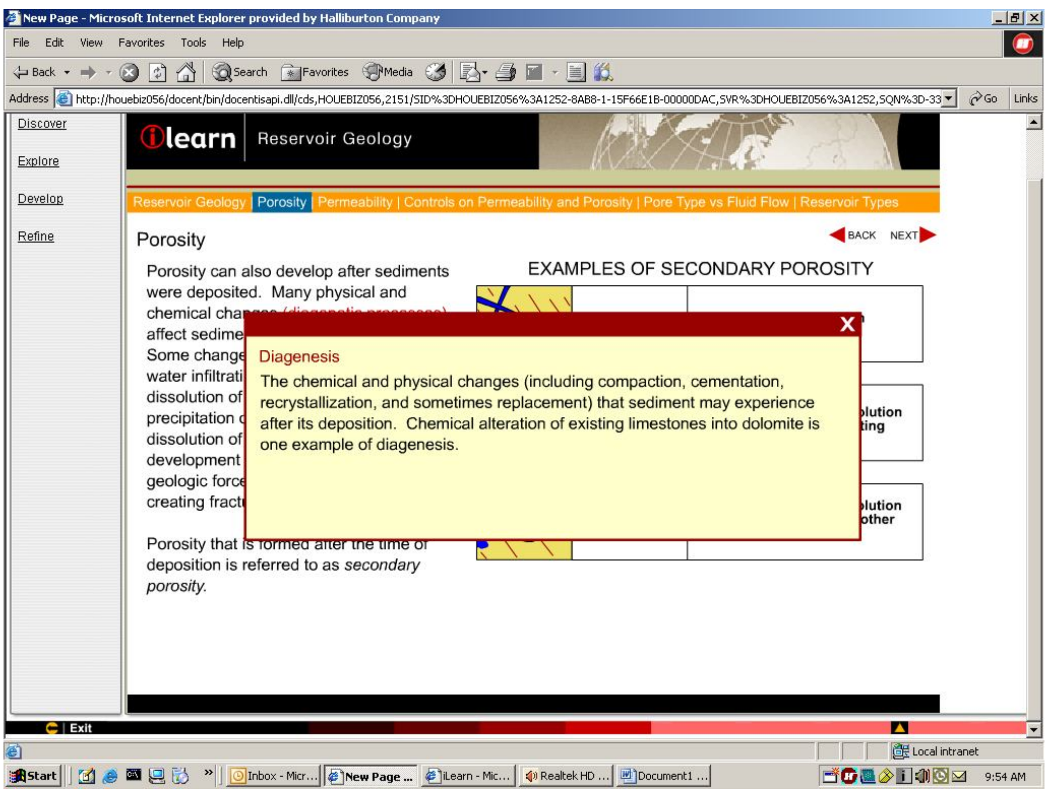
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EXAMPLES OF SECONDARY POROSITY
X
Diagenesis
The chemical and physical changes (including compaction, cementation, recrystallization, and sometimes replacement) that sediment may experience after its deposition. Chemical alteration of existing limestones into dolomite is one example of diagenesis.
deposition is referred to as *secondary porosity.*
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Permeability

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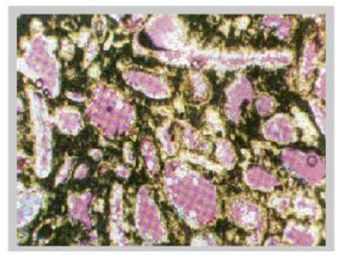
Permeability, simply stated, is a measure of the ease with which fluid can flow through a reservoir. A reservoir must have interconnected pore space for fluids to flow. The photographs show a sandstone with interconnected pores and a carbonate sample with isolated pores.

Some reservoirs have permeability while others do not. A coarse grained sandstone with large amounts of interconnected pore space may have relatively high permeability. On the other hand, a limestone may have the same amount of porosity as this sandstone, but lack permeability if all of its pore space is isolated.

Sandstone with interconnected Pores
Width of sample = .20 mm.



Carbonate with Isolated Pores
Width of sample = .38 mm.

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Permeability

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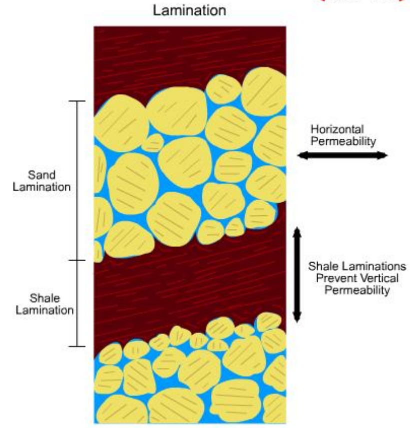
Unlike porosity, permeability--because it deals with the flow of fluids--may be directional in nature. A reservoir consisting of very thin layers, or laminations, of sandstone and shale may exhibit a great deal of horizontal permeability, but no vertical permeability.

Lamination



Controls on Porosity and Permeability

Many factors control the amount of porosity and permeability in a reservoir. In some reservoirs, porosity and permeability may be closely related. For example, you may find reservoirs with large amounts of pore space and high permeabilities. However, in other reservoirs there may be no relationship between the two properties. It is possible for a reservoir with large amounts of pore space to be completely impermeable.

A look at the characteristics of sedimentary rocks that control porosity and permeability is helpful for understanding why oil and gas can be recovered from some rocks and not from others.

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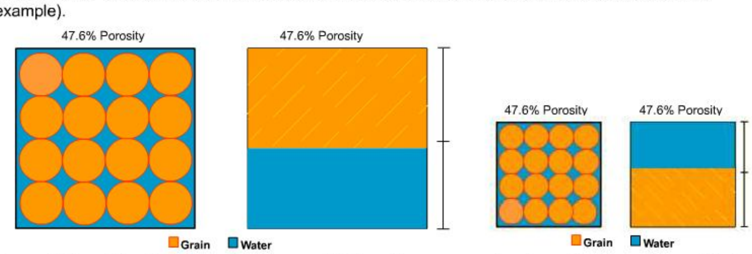
Controls on Porosity and Permeability > Grain Size

Grain size has little impact on porosity but may greatly affect permeability. At first glance, it appears that a coarse grained sandstone contains more porosity than a fine grained sandstone. In both of the illustrated examples, the ratio of pore volume to total rock volume is identical; therefore, the porosities of both rocks are the same. This similarity in porosity is only true if all grains are of the same shape (spheres, for example).



Permeabilities of the illustrated examples would differ. The coarse grained sandstone would permit better flow of fluids because of the larger passageways between individual pores (pore throats). Even though the two rocks contain the same amount of pore space, the coarse grained sandstone would present a higher permeability.

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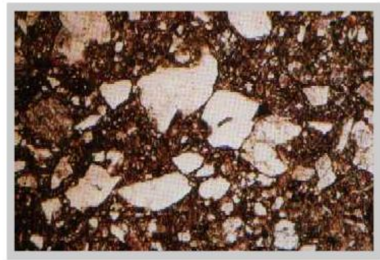
Controls on Porosity and Permeability > Sorting

The distribution of grain sizes within a reservoir--referred to as sorting--plays a role in the porosity and permeability of a reservoir. Reservoirs containing grains that are all approximately the same size (well sorted) contain larger amounts of pore space than those with a wide distribution of grain sizes (poorly sorted). The photograph shows a rock formation with poor;ly sorted grains.

As porosity varies with sorting, so will permeability. Poorly sorted sediments often have extremely small pore throat diameters, resulting in lower permeabilities than well sorted sediments.



Poorly Sorted Grains
Width of sample = .28 mm.

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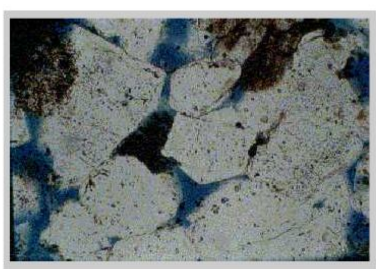
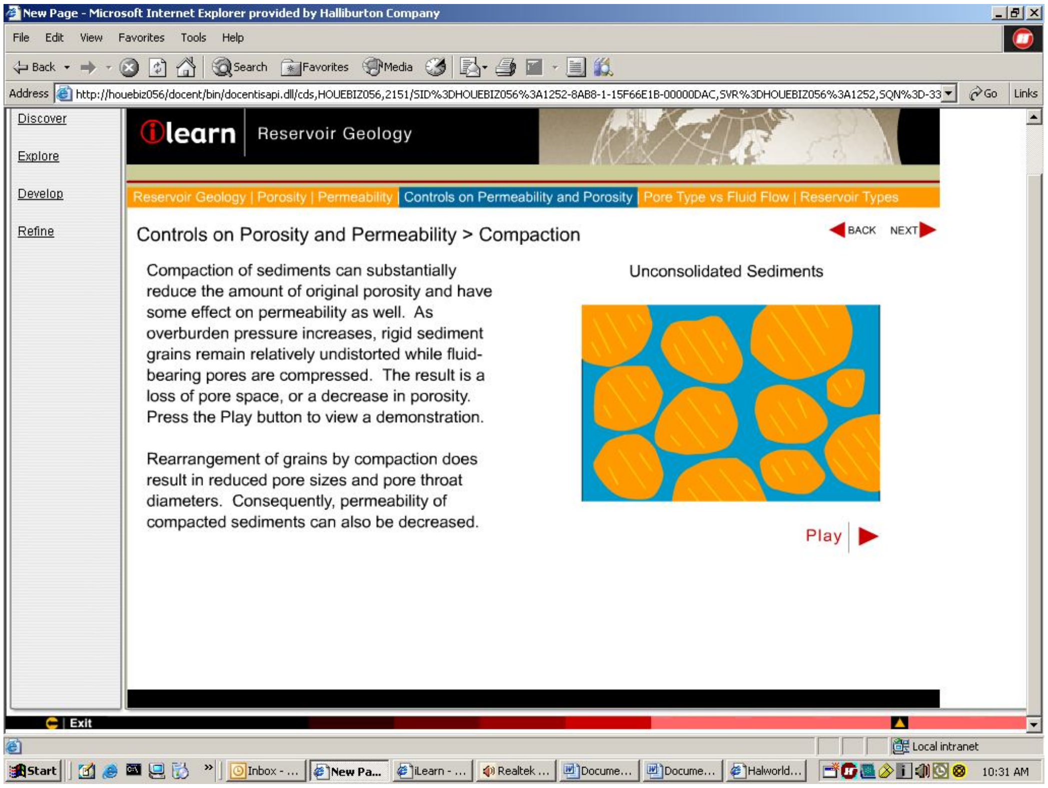
Controls on Porosity and Permeability > Grain Shape



Well Rounded Sand with Porosity in Blue
Width of sample = .28 mm.

The shape of grains may have a strong impact on both porosity and permeability. The maximum amount of pore space can be expected in a rock consisting entirely of spherical grains. In such a rock, pore throat diameters are usually large, and permeability is high.

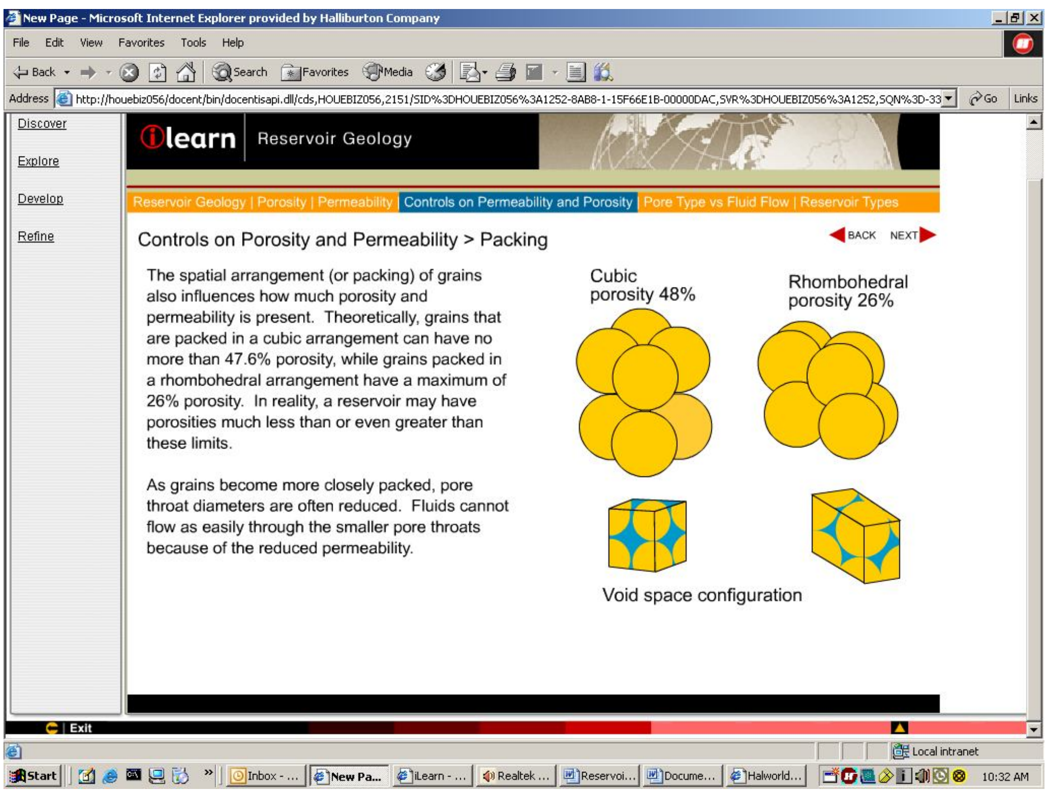
As the shapes of the grains become less spherical, edges of the grains fit more closely together. This results in not only lower porosities, but also lower permeabilities because of the reduced diameters of pore throats.



Controls on Porosity and Permeability > Compaction

Compaction of sediments can substantially reduce the amount of original porosity and have some effect on permeability as well. As overburden pressure increases, rigid sediment grains remain relatively undistorted while fluid-bearing pores are compressed. The result is a loss of pore space, or a decrease in porosity. Press the Play button to view a demonstration.

Rearrangement of grains by compaction does result in reduced pore sizes and pore throat diameters. Consequently, permeability of compacted sediments can also be decreased.



Controls on Porosity and Permeability > Packing

The spatial arrangement (or packing) of grains also influences how much porosity and permeability is present. Theoretically, grains that are packed in a cubic arrangement can have no more than 47.6% porosity, while grains packed in a rhombohedral arrangement have a maximum of 26% porosity. In reality, a reservoir may have porosities much less than or even greater than these limits.

As grains become more closely packed, pore throat diameters are often reduced. Fluids cannot flow as easily through the smaller pore throats because of the reduced permeability.

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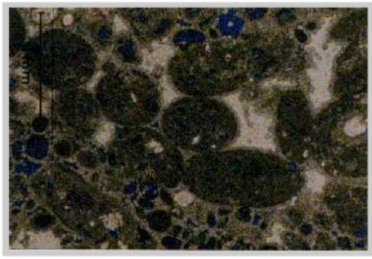
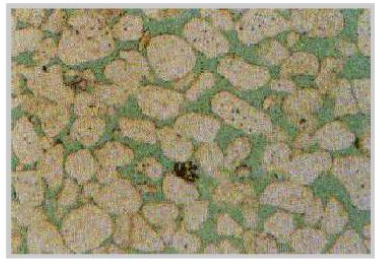
Controls on Porosity and Permeability > Cementation

Cementation of grains by minerals precipitating from pore water is, oftentimes, the chief agent of reducing porosity and permeability in a reservoir. Most sandstones consist of grains that are cemented together by either quartz or calcite. The presence of these cements in abundance can greatly decrease the amount of pore space preserved in a reservoir as well as the potential of fluids to flow between pores.



Carbonate with Pores Obstructed by Anhydrite (white)
Width of sample = 3 mm.



Sandstone with Well Preserved Pore Space (blue)
Width of sample = .27 mm.

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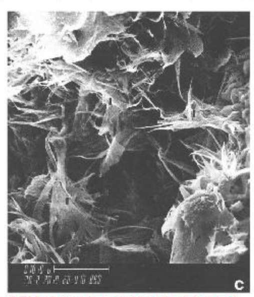
Controls on Porosity and Permeability > Clay Minerals

The presence of clay minerals in a reservoir has a tremendous impact on reservoir permeability. Very fine grained clay minerals may completely obstruct pore throats. While this may not greatly change the amount of porosity in the reservoir, it can completely destroy any permeability that might have been present.

SEM photomicrograph of clean sand showing unobstructed pores between grains (width of photo = 0.75 inch)



SEM photomicrography of shaly sand showing clay minerals obstructing pores between grains (width of photo = 0.02 inch).

Controls on Porosity and Permeability > Clay Minerals

The effect of clay minerals on permeability is significant. With the addition of very fine clay-sized sediments, pore throat diameters within the reservoir decrease dramatically. Extremely high capillary pressures within these small pore throats may be sufficient to prevent water from flowing through them. In most reservoirs, if water is incapable of passing through a pore throat, then the chance of hydrocarbon passing through is small.

Clays do present favorable conditions, however, in some reservoirs. Because of their ability to adsorb large amounts of water on their surfaces, clays within a reservoir can prevent much of the water that is present from being recovered.

Clay minerals coating grain surfaces. Water can be adsorbed onto surfaces of clay minerals, preventing it from being produced (width of photo = 0.33 inch).

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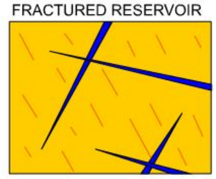
Controls on Porosity and Permeability > Dissolution and Fracturing

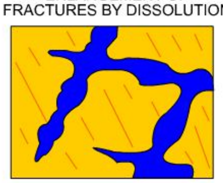
Apart from those factors that serve to reduce the amount of pore space and ability of fluid flow, there are a number of ways in which porosity and permeability can be increased. Water present within the pores or flowing through a porous rock can be capable of dissolving some of that rock, creating more porosity. Natural fracturing of the rock, caused by extreme geologic stresses, may also contribute to the porosity of the reservoir.

If the pores created by dissolution or fracturing are interconnected in any way, then they can also serve to increase the permeability of the reservoir.

FRACTURED RESERVOIR



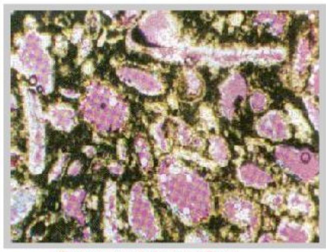
ENLARGEMENT OF FRACTURES BY DISSOLUTION



Pore Type vs. Fluid Flow

In terms of hydrocarbon recovery, the timing of porosity development is not important. What is important is the degree of interconnection between the pores in a reservoir.

Reservoirs may contain a large percentage of porosity, but unless these pores are interconnected, the fluids contained in them are not capable of flowing (no permeability). For this reason, it is beneficial to think of porosity in terms of whether or not it will allow fluids to flow.



Carbonate with Isolated Pores
Width of sample = .38 mm.

Sandstone with interconnected Pores
Width of sample = .20 mm.

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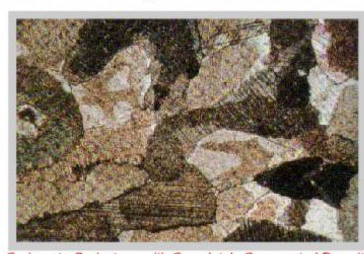
Pore Type vs. Fluid Flow > Effective Porosity

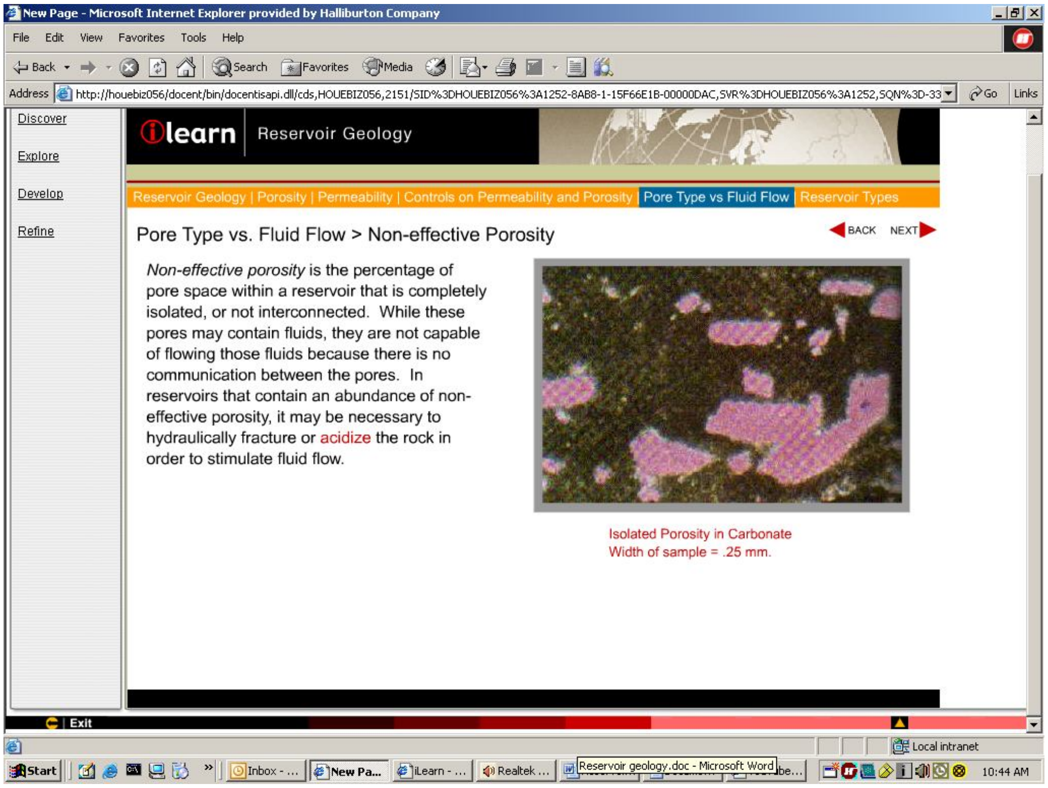
Effective porosity refers to the percentage of pore space in a reservoir that is interconnected. If pore throats are unobstructed and large enough, then fluids have the potential of flowing from one pore to another.

Sandstone with Very Effective Porosity
Width of sample = .27 mm.



Carbonate Grainstone with Completely Cememnted Porosity
Width of sample = .38 mm.

Unfortunately, many factors work to reduce the amount of effective porosity. For example, sand sediments may be deposited with large amounts of effective pore space between the sand grains. However, cements precipitated from waters within those pores may eventually restrict any communication between pores.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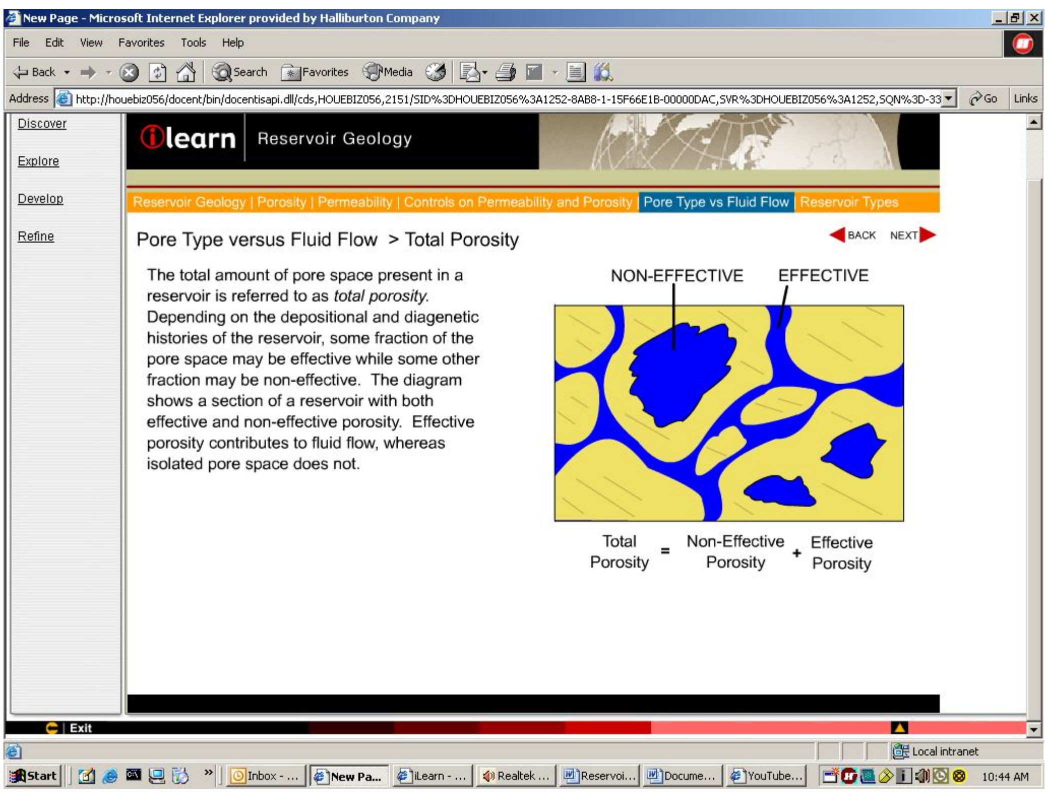
Pore Type vs. Fluid Flow > Non-effective Porosity

Non-effective porosity is the percentage of pore space within a reservoir that is completely isolated, or not interconnected. While these pores may contain fluids, they are not capable of flowing those fluids because there is no communication between the pores. In reservoirs that contain an abundance of non-effective porosity, it may be necessary to hydraulically fracture or acidize the rock in order to stimulate fluid flow.

Isolated Porosity in Carbonate
Width of sample = .25 mm.

Exit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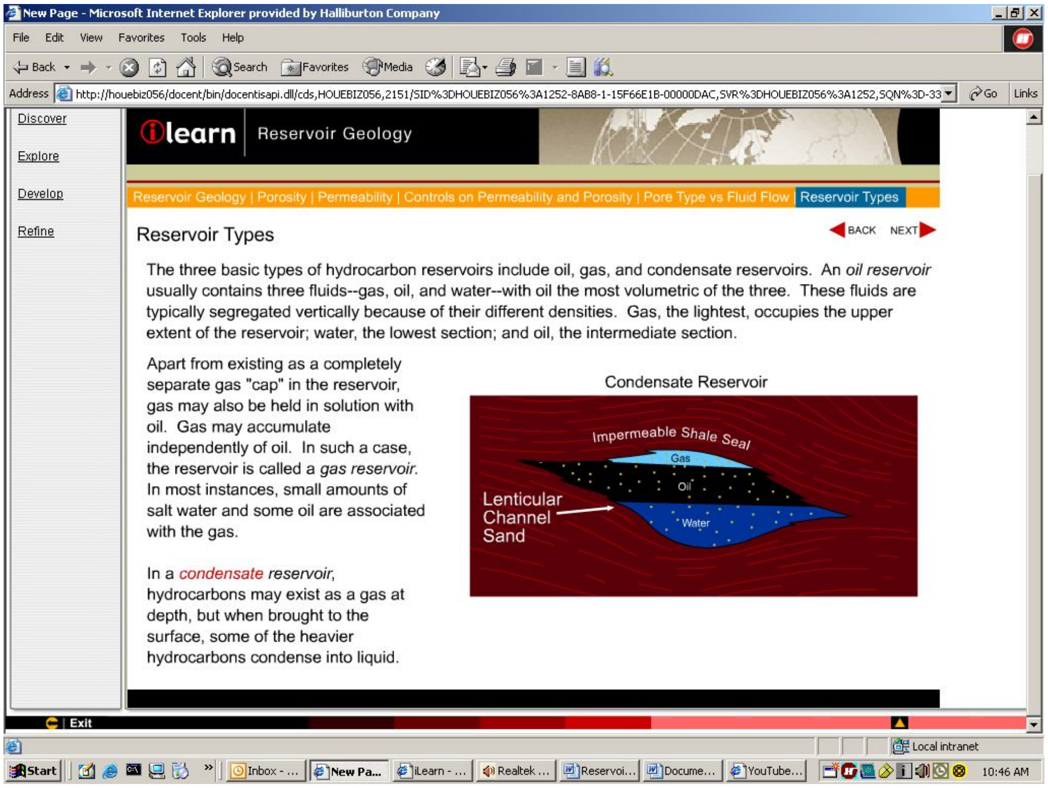
Pore Type versus Fluid Flow > Total Porosity

The total amount of pore space present in a reservoir is referred to as *total porosity.* Depending on the depositional and diagenetic histories of the reservoir, some fraction of the pore space may be effective while some other fraction may be non-effective. The diagram shows a section of a reservoir with both effective and non-effective porosity. Effective porosity contributes to fluid flow, whereas isolated pore space does not.

Exit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The three basic types of hydrocarbon reservoirs include oil, gas, and condensate reservoirs. An oil reservoir usually contains three fluids--gas, oil, and water--with oil the most volumetric of the three. These fluids are typically segregated vertically because of their different densities. Gas, the lightest, occupies the upper extent of the reservoir; water, the lowest section; and oil, the intermediate section.
Apart from existing as a completely separate gas "cap" in the reservoir, gas may also be held in solution with oil. Gas may accumulate independently of oil. In such a case, the reservoir is called a gas reservoir. In most instances, small amounts of salt water and some oil are associated with the gas.
In a condensate reservoir, hydrocarbons may exist as a gas at depth, but when brought to the surface, some of the heavier hydrocarbons condense into liquid.
Condensate Reservoir
Impermeable Shale Seal
Gas
Oil
Water
Lenticular
Channel
Sand
Exit
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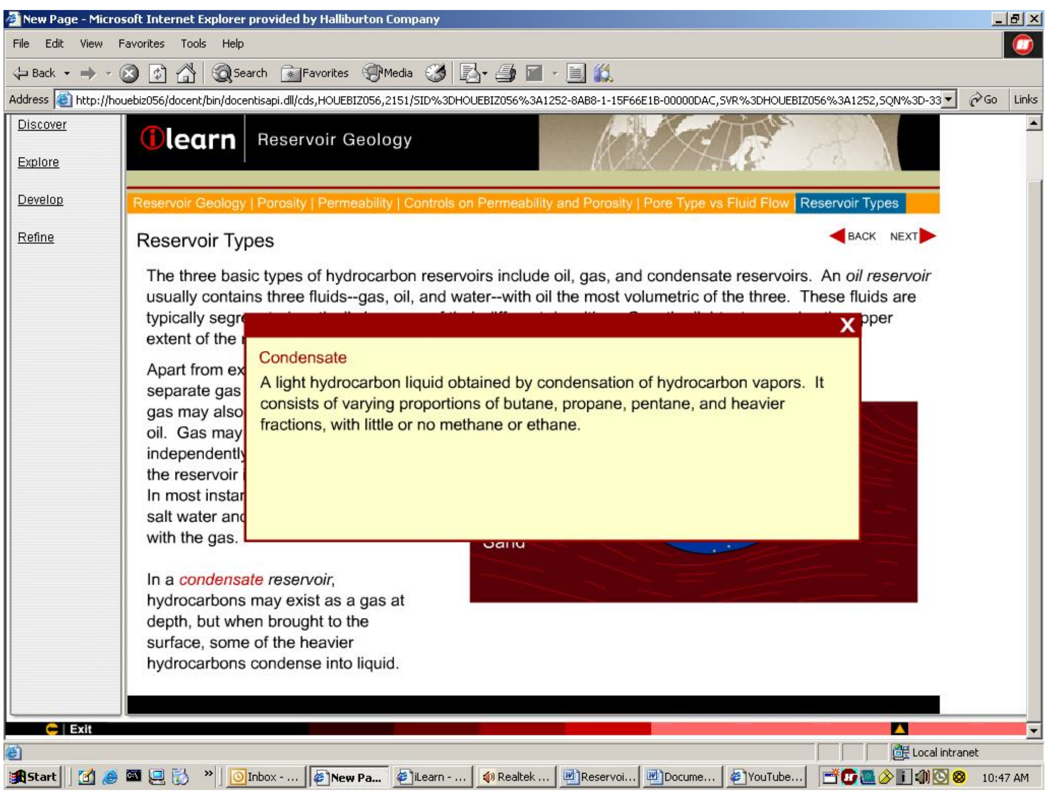
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Condensate
A light hydrocarbon liquid obtained by condensation of hydrocarbon vapors. It consists of varying proportions of butane, propane, pentane, and heavier fractions, with little or no methane or ethane.
In a condensate reservoir, hydrocarbons may exist as a gas at depth, but when brought to the surface, some of the heavier hydrocarbons condense into liquid.
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The economic quality of a reservoir depends upon the volume of hydrocarbons that can be recovered. This volume is not just a function of the geologic characteristics of the rock itself, but is also a function of many other characteristics that fall beyond the realm of geology.

Porosity is required for a reservoir to contain hydrocarbons. Permeability is required for those fluids to flow. There must also be an impermeable seal to contain these fluids within the reservoir. However, the pressure of the reservoir as well as the types of fluids it contains and their relative abilities to flow also play an important role in determining whether commercial quantities of oil and gas can be recovered.

West Texas Pump Jack

Click on Develop in the menu to go to the Quiz.