Reservoir Drive Mechanisms

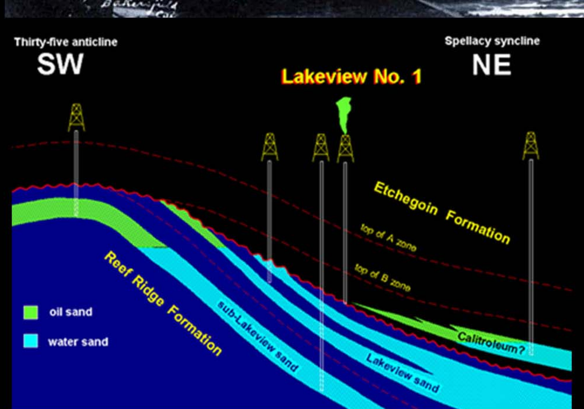
The energy that moves crude oil and natural gas from the subsurface rock to the production well is called the reservoir drive.

"The general performance of oil-producing reservoirs is largely determined by the nature of the energy available for moving the oil to the well bore, and the manner in which it is actually used during production."

Morris Muskat
Physical Principles of Oil Production, 1949
Awarded the Society of Petroleum Engineers' "Anthony F. Lucas Gold Medal", 1953

Natural Drive Mechanisms

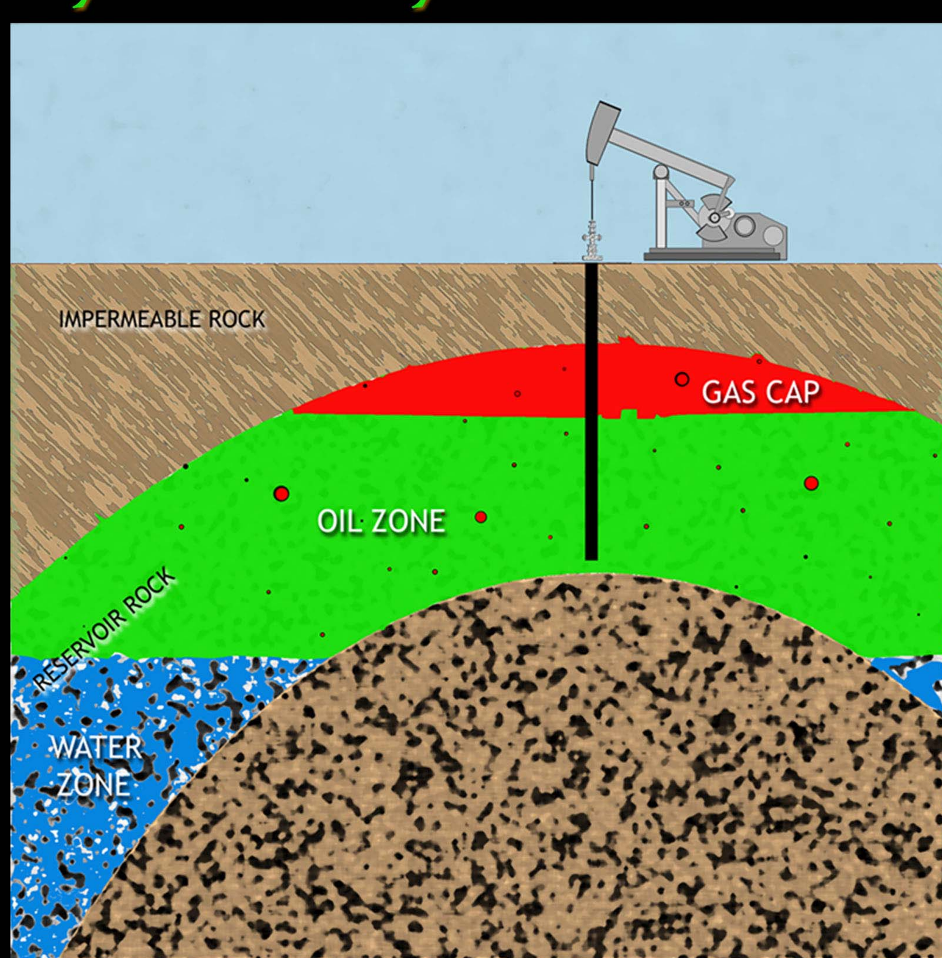
Hydrocarbons produced by a reservoir's original, or natural, drive energy are referred to as *primary* production.



Lakeview No.1 (drilled near Maricopa, California) struck oil on March 15, 1910. The well blew an estimated initial flow of 125,000 barrels a day, spraying a column of oil and sand 20 feet in diameter and 200 feet high into the air. The gushing well was brought under control by October, while flowing an estimated 48,000 barrels a day. When the bottom of the well caved in on September 10, 1911, Lakeview No.1 died. During the 544 days it flowed, Lakeview No.1 produced 9.4 million barrels of oil.
(San Joaquin Geological Society, 2005, www.sjgs.com)

Dissolved Gas Drive
5% to 30% recovery efficiency

Natural gas is dissolved in oil at subsurface pressures in the reservoir. When oil is produced from the reservoir, reservoir pressure decreases and dissolved gas bubbles out of the reservoir oil. This gas expands in the pore spaces and pushes the reservoir oil through the pores to a production well.



Gas Cap Drive
20% to 40% recovery efficiency

Because it is less dense than crude oil and water, natural gas segregates and occupies the higher zones within a reservoir. Natural gas forms a "gas-cap" over fluids in the reservoir. As oil is produced, reservoir pressure decreases and natural gas in the gas cap expands and pushes the oil through the reservoir pores to a production well.

Gravity Drive
50% to 65% recovery efficiency

Gravity drive is present in all reservoirs; it is simply the gravitational force of the Earth pulling oil downward within the reservoir. Gravity drive can be an important mechanism for a production well located on a flank of a reservoir, or for production over a long time, after the reservoir's original drive mechanism has been depleted.

Water Drive
35% to 60% recovery efficiency

Because it is denser than oil or gas, water occupies the lower zones within a reservoir. As oil is produced, reservoir pressure decreases and underlying water pushes overlying oil upward through the reservoir pores to take the place of produced oil.

Combination Drive
20% to 65% recovery efficiency

A reservoir may be controlled by a combination of drive mechanisms, both natural and artificial, and dominance of one drive mechanism over another may change, or be altered by enhanced recovery, as production continues and reservoir pressure changes.

(photograph courtesy of Office of Fossil Energy, DOE, www.fe.doe.gov)

Artificial Drive Mechanisms

Enhanced Oil Recovery

If a reservoir's natural drive mechanism becomes insufficient in aiding hydrocarbon production, a supplemental drive mechanism may be introduced to increase the production rate and recovery efficiency.

Water Injection
5% to 50% recovery efficiency of remaining hydrocarbons

Water injected into a hydrocarbon reservoir sweeps the less-dense hydrocarbons through reservoir pore space.

Miscible Gas Injection
up to 35% recovery efficiency of remaining hydrocarbons

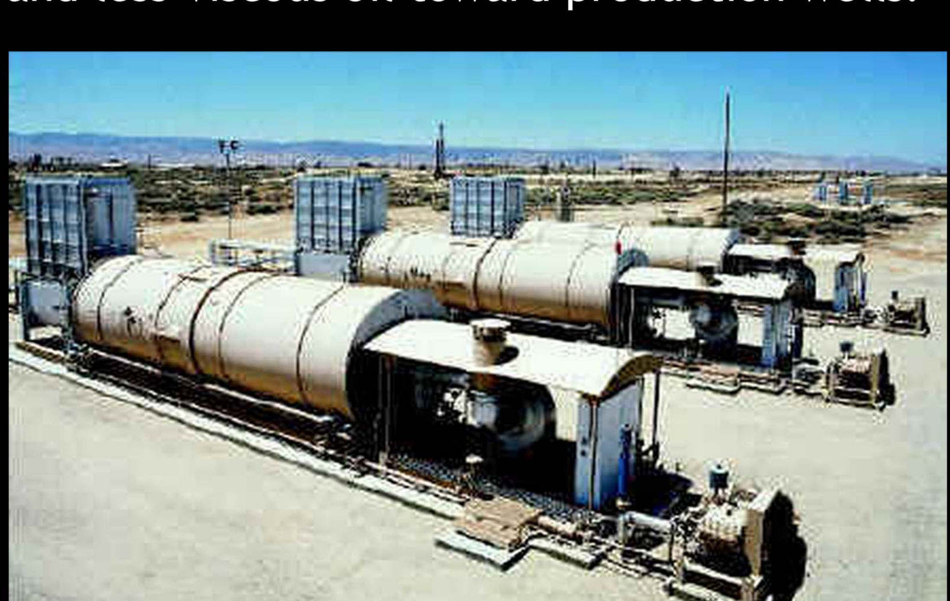
Rich gas which can be dissolved in (i.e., is miscible with) hydrocarbons is injected into the reservoir. As the gas mixes with the hydrocarbons it makes the hydrocarbons more fluid and pushes the more-fluid oil through the reservoir pores.

Chemical Injection
25% to 40% recovery efficiency of remaining hydrocarbons

Chemicals injected into a reservoir reduce the hydrocarbons' surface tension from the reservoir rock. A subsequent flush of injected water into the reservoir sweeps the freed hydrocarbons through the reservoir pores.

Steam Injection
25% to 65% recovery efficiency of remaining hydrocarbons

Injected steam heats the reservoir hydrocarbons. Some oil is vaporized into gas and some oil is made less-viscous. The steam in the reservoir cools and condenses into water, which drives the gas and less-viscous oil toward production wells.



Generators used in steam injection operations at Kern River oilfield, near Bakersfield, California, burn natural gas to produce steam and generate electric power. The steam is used to steamflood the subsurface hydrocarbon reservoir to heat the heavy oil and make it flow more easily to the production wells. The electricity is used to run the oil field equipment and any remaining electricity supplies the Southern California power grid with enough power to light 600,000 homes.
(En-Fab, Inc., 2005, www.en-fabinc.com)

Elk Hills, California (Naval Petroleum Reserve No. 1)
Natural and Artificial Drive Combination

At the Elk Hills field, production from one of the shallow oil reservoirs was initially driven by dissolved gas drive with lesser components of gravity drive and water drive. In the southern area of the Shallow Oil reservoir, oil and gas were produced predominately by gravity drive. To enhance production from this part of the reservoir, natural gas was injected to create a free-gas cap. The resultant gas cap drive aided in pushing additional oil through the reservoir to production wells.

In the northern part of the Shallow Oil reservoir, the dissolved gas drive was soon overpowered by a strong water drive mechanism which threatened to leave bypassed oil behind in the reservoir rock. To lessen the strength of the water drive and allow gravity drive to be more effective in this area, reservoir water was extracted from the water zone at the periphery of the oil reservoir.

SI INTERNATIONAL

Recovery efficiency estimates from *Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production*, 2nd Edition, by Norman J. Hyne, Ph.D., PennWell Corporation, Tulsa Oklahoma, 2001.