Oil and Gas Drilling 101

Information gathered from San Joaquin Geological Society, PetroStrategies, Inc., Society of Petroleum Engineers, How Stuff Works and the Oil and Gas Accountability Project

How are oil and gas formed?

Oil and gas, as well as coal, are types of **hydrocarbons**. Hydrocarbons are formed from dead plant and animal (organic) matter. Much of the hydrocarbons being recovered today were the result of decaying plants and animals millions of years ago. As plants and animals died, they were covered by layers of mud and rocks. The layers of mud and rocks prevented oxygen from reaching the organic material and thus, the organic material couldn't rot in the same way it does at the surface. As the layers of rocks and mud grew in thickness, they pushed down on the organic material with increasing pressure. The temperature of the organic material also increased. Under high temperatures, pressure, and lack of oxygen the organic matter slowly turned into hydrocarbons.

As oil and gas molecules form, they migrate through the pores of sedimentary rocks. Because oil and gas are less dense than water, when they encounter water, they rise through the water and settle as a layer on its surface. The hydrocarbons continue to move in an upward direction until they encounter a layer of material that is not porous. Here they are said to be trapped.

What is Oil?

Crude oil is a mixture of carbon (84%), hydrogen (14%), sulfur (1-3%), and nitrogen, oxygen, metals, and salts (less than 1%). Crude oil is processed to remove unwanted materials and produce products such as motor gasoline, diesel, jet and home heating fuels, waxes, asphalt, feedstock and other components.

What is Natural Gas?

Natural gas occurring underground is composed largely of methane (70-90%) and other hydrocarbons such as ethane, propane and butane. However, at natural gas processing facilities, most of these other substances are separated out so that the natural gas that we use is composed almost entirely of methane. Natural gas can be produced from either natural gas wells, which primarily produce raw natural gas, or from oil wells where natural gas is recovered along with oil.

Natural gas can also be produced from coal-bed methane (CBM) wells. Coal-bed methane, a type of natural gas, is located within coal seams. To be extracted, the seam has to be depressurized by pumping huge volumes of groundwater to the surface. According to one Montana Department of Environmental Quality study, a single well can produce more than 23,000 gallons of water a day. The water has been difficult to manage because of the large quantity and the potential for poor quality - it contains sodium and other salts that can kill plants and damage soil.

What are the Stages of Oil and Gas Development?

1. Obtaining a lease
2. Locating Oil and Gas
3. Drilling an Exploratory Well
4. Completing the Well

5. Site Development
6. Production
7. Site Abandonment

1. Obtaining a Lease:

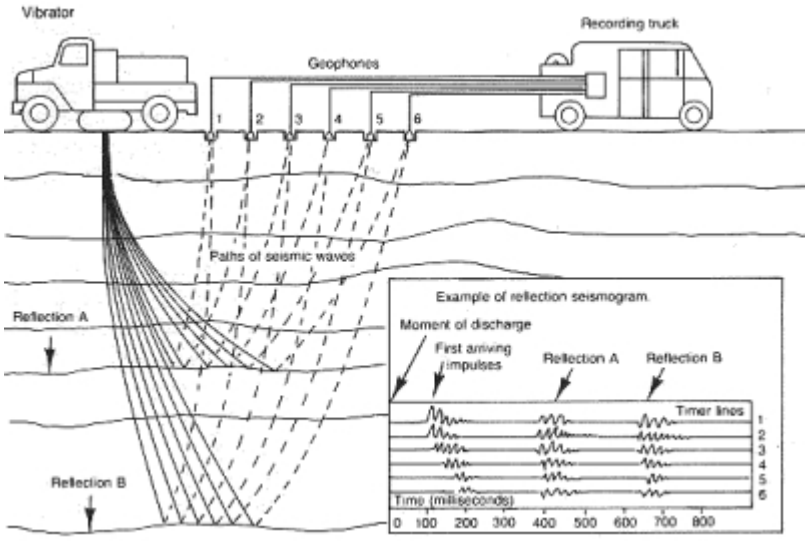
The first step in oil and gas development is for the company to have a lease for the land. This lease can be on public land where the government owns the minerals underneath the surface, on private land where the government owns the minerals underneath (called split-estate), or on private land where a private owner owns the minerals underneath.

2. Locating Oil and Gas:

Seismic technology, or **seismology**, allows scientists to learn about the formations bellow the earth's surface using the reflection of sound waves.

Thumper Truck, U.S. Department of Energy

In order to map the underground layers of rocks, the first step involves sending shock waves into the ground. Shock waves are generated by pounding the earth with a vibrator (or **thumping**) truck, or by exploding small dynamite charges in shallow holes. The next step involves using **geophones** at the surface to record the rate and strength with which the sound waves are reflected back from the underlying rocks. The rate and strength of the reflected sound wave varies depending on the type of rock it encounters. Computers are then used to process the data and convert it into a 2-D or 3-D picture of the subsurface.



How seismic exploration works, IGCP 474

3. Drilling an Exploratory Well:

Once a company identifies where oil and gas could be located, it then begins to drill an exploratory well to determine if oil and gas is indeed located beneath the surface and if it is in large enough quantities to make it economical to proceed with further development.

Drill Site Selection - Companies will choose a drilling site that allows them to easily and cheaply access the potential oil and gas underneath the surface.

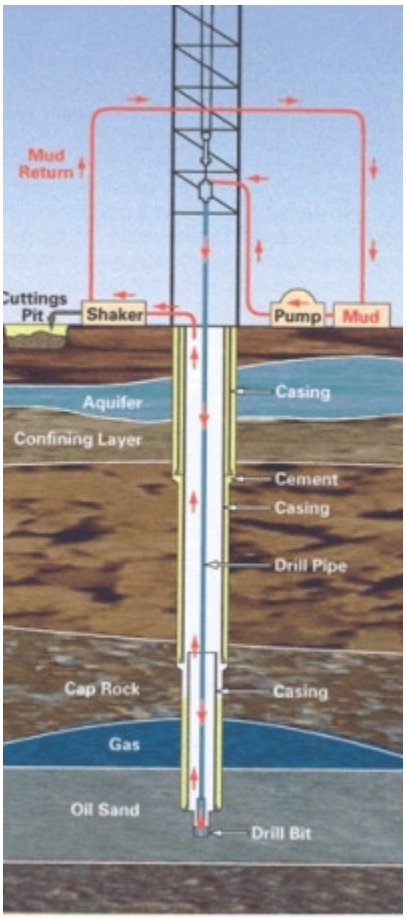
Historically, the best place to put a well was directly above the anticipated location of the oil or gas reservoir where the well would be drilled vertically to the targeted oil or gas formation. Technology now allows the industry to drill directionally from a site up to 5 miles (8 km) away from the predicted oil or gas reserve. **Directional drilling** thus allows industry to avoid placing wells in environmentally sensitive areas and still recover the oil and gas that lies underneath. Additional environmental benefits include concentrating development activities.

Drill Site Preparation - In order to drill an oil or gas well, the land must first be cleared and leveled and access roads built. Because water is used in drilling, a source must be located. If there is no natural source nearby, a water well may be drilled. Finally, **reserve pits** are dug to dispose of rock cuttings and drilling mud. These pits are either dug in the ground and lined to protect the environment or are steel tanks which serve the same purpose.

Drilling the Well - In order to obtain crude oil and natural gas from under the earth's surface, a **drill rig** or **derrick** must be erected in order to operate the hoist that raises and lowers the drill stem and bit. The rig is located and leveled over the well hole.

The next phase is called **'spudding in'**; and involves the use of a large-diameter drill bit to drill a hole called a **well bore**. The well bore can be several thousands of feet deep.

While the well bore is being drilled, a fluid, called **drilling mud**, is used to 1) lift rock cuttings from the hole, 2) keep the drill bit cool and lubricated and 3) fill the well bore with fluid to equalize pressure and prevent water or other fluids in underground formations from flowing into the well bore during drilling. Mud is pumped from the surface down through the inside of the drill pipe, passes through the holes in the drill bit, are travels back to the surface through the space between the drill bit and the walls of the hole. As the drill bit grinds rocks into **drill cuttings**, these cuttings mix with the mud and are carried to the surface through the mud flow. In order to reuse the mud, the solids must be separated from the mud. This is accomplished by circulating the mixture of mud and rock cuttings over vibrating screens called **shale shakers**. The liquid mud passes through the screens and re-circulates back to the mud pits from which it is withdrawn for pumping. The drill cuttings remain on top of the screens. Water-based drilling mud is composed primarily of clay, water, and chemical additives to address particular subsurface conditions that may be encountered. In deep wells, oil-based



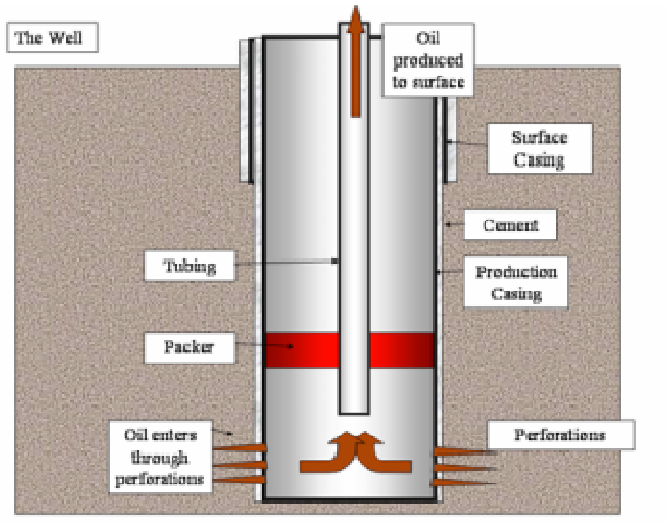
Drilling Process, U.S. Department of Energy

drilling mud is used because water-based muds cannot stand up to the higher temperatures and conditions encountered (Society of Petroleum Engineers).

Drilling a well does not always mean that oil or gas will be found. If oil or gas is not found in commercial quantities, the well is called a **dry hole** and it is plugged with cement.

4. Completing the Well:

If a well is found to have commercial amounts of oil or gas, the well is completed.
After a well is drilled, the drill is removed from the well bore. Next, the well bore is lined with a steel tub called **casing**. The casing runs the entire length of the well and completely seals off the well from the surrounding water aquifers. It also prevents the hole from collapsing.



Completing the well, Wikipedia, licenced under the GNU Free Documentation Licence.

Next, cement is pumped down into the space between the outside of the casing and the well bore to further ensure the protection of ground water and to hold the casing in place.

Small holes, called perforations, are made in the portion of the casing that passes through the zone where oil and gas is located to provide a path for it to flow from the surrounding rock to the production tubing.

Next, a small-diameter **tubing** is centered in the well bore and held in place with **packers**. This tubing will carry the hydrocarbons from the reservoir to the surface.

Evaporation Pit, Daly Edmunds

Reservoirs are typically at elevated pressure because of underground forces. To equalize the pressure, a series of valves and equipment is installed on top of the well. This wellhead, or **"Christmas tree,"** as it is sometimes called, regulates pressures, control flows, and access to the well bore. From the outlet valve of the Christmas tree, the flow can be connected to a distribution network of pipelines and tanks to supply the product to refineries or natural gas compressor stations.

At this stage, a percolation or **evaporation pit** is typically constructed to dispose of produced water (water composed of by-products from drilling such as mud, drilling lubricants, and oil).

5. Site Development - Well Spacing:

Once a site is determined to have commercial amounts of economically recoverable oil and gas, well testing and geologic analysis take place to estimate the volume of oil and gas that can be drained by a single well.

From this estimate, the number of wells needed to drain all of the oil or gas from the reservoir can be determined.

Using these calculations, it can be determined how close together the wells need to be located to most efficiently and economically drain the reservoir. Some states have regulations on how close wells can be drilled.

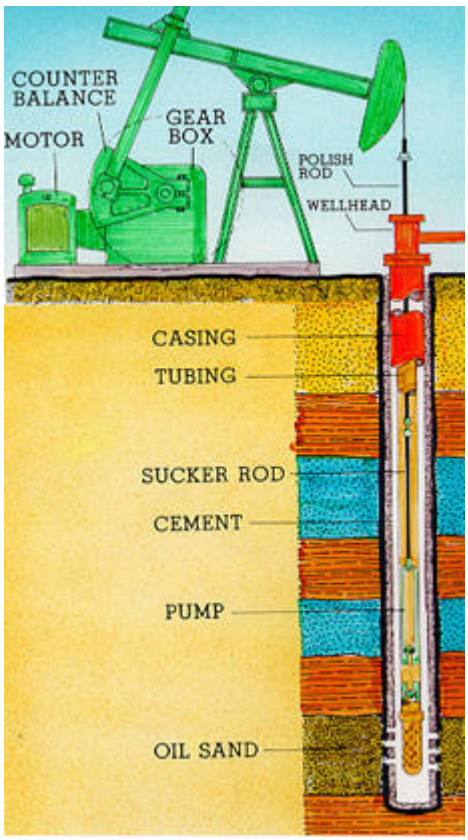
6. Production:

Early in its production life, the underground pressure will often push the hydrocarbons all the way up the well bore to the surface. This **natural flow** may continue for many years.
Stimulation techniques may also be used. These are methods to increase the permeability of the rock formation so more oil and gas can be recovered.

One such technique is **hydraulic fracturing**. Hydraulic fracturing or 'fracking' involves high pressure injecting of fluids and sands into the ground to fracture rock formations and prop the formations open with sand to enable more oil or gas to flow to the well. If done improperly, fracking can contaminate freshwater aquifers situated above oil and gas producing formations.

When oil and gas no longer naturally flows to the surface, mechanical methods are used. This process is often referred to as artificial lift.

Artificial lift involves the placement of a pumping unit on the surface which creates an up-down motion to a string of rods called sucker rods. The top of the sucker rod is attached to the pumping unit while the sucker rod pump is located near the bottom of the well.



Artificial Lift, California Department of Conservation

As the rate of production decreases, **waterflooding** can be used to increase the production again. Waterflooding is a technique where water is injected into the formation using wells that have ceased production. The injected water enters the reservoir and builds up the pressure in the reservoir such that more oil and gas are forced out of the formation. The producing wells then pump up the oil and water.

Storage Tanks - Most oil wells produce oil, gas, and water. This mixture is separated at the surface. Initially, the mixture may be mostly oil with a small amount of water. Over time, the

percentage of water increases. On average in the United States, oil wells produce 8 barrels of water for each barrel of oil (Society of Petroleum Engineers).

Once it is produced, oil may be stored in a tank and later moved by means of truck, barge, or ship to where it will be sold or enter the transportation system. Most often, however, it goes from the separation facilities at the wellhead directly into a small pipeline, which then feeds into a larger pipeline.

Natural gas is almost always transported through a pipeline.

Most states require that water resulting from drilling and other methods such as fracking be re-injected into deep injection wells or placed in lined evaporation pits. This water can contain acids, diesel fuel, metals, salts, radioactive materials, and other added chemicals. Evaporation pits are usually required to be lined. However, concerns remain among some about the potential for holes or tears to develop. In addition, these pits can overflow from stormwater. Once the water evaporates, the chemicals remaining are usually folded up on the liner and buried.

7. Well Abandonment:

Reclamation Area, Bureau of Land Management

When a well no longer produces or produces so little that it is not cost effective, it is **abandoned**. When a well is abandoned, it can be plugged or converted to an injection well. If the well is **plugged**, the tubing is removed from the well and sections are filled with cement to prevent the flow of oil, gas and water zones from each other as well with the surface. If the well is converted to an **injection well**, it can be used either for disposal of the produced water from other wells or to enhance operations in the production field.

Additionally, the site should be **reclaimed**. Full reclamation of the site means that the land, air and water should be returned to the same condition as before oil and gas development began. However, this is rarely the case.

Resources:

San Joaquin Geological Society, Box 1056, Bakersfied, CA 93302. Information accessed July 1, 2007 at http://www.sjgs.com/exploration.html

PetroStrategies, Inc., Box 260415, Plano, TX 75026. Information accessed July 1, 2007 at http://www.petrostrategies.org/Learning%20Center/Oil_and_Gas_Basics.htm

Society of Petroleum Engineers, Box 83386, Richardson, TX 75083. Information accessed July 1, 2007 at http://www.energy4me.org/oilgas/questions/how_find.htm

How Stuff Works, One Capital City Plaza, 3350 Peachtree Road, Suite 1500, Atlanta, GA 30326. Information accessed July 1, 2007 at http://science.howstuffworks.com/oil-drilling.htm

Oil and Gas Accountability Project, "Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development." 2005.

Created by Lisa Eadens, National Wildlife Federation, July 9, 2007