Oil 101: A Primer for Oil and Gas Investors

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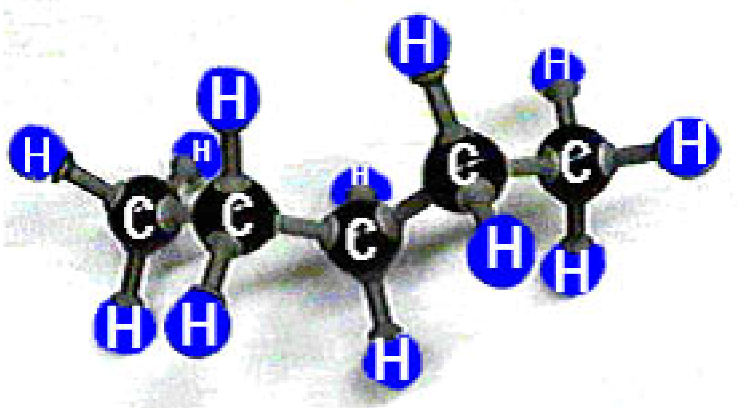
It's a remarkable fact of life that the one substance all of modern living depends upon is so little understood. When you have finished this article, you will understand more than most anyone you know about how oil was formed, is recovered, refined and consumed.

The Basics

All crude oils are mixtures of hydrocarbons - chains of different lengths (sometimes with rings attached) of carbon and hydrogen atoms, and other compounds including small amounts of sulfur, nitrogen, oxygen, metals and salts. Each carbon atom in the chain is bonded to two hydrogen atoms, except for the end ones which have three. Short-chain hydrocarbons (up to four carbons) are gases, longer ones are liquids - which get thicker and more gummy as the chains get longer. Very long chains are solids like wax.



An example of a Hydrocarbon Molecule

It is the sulfur content which determines whether the oil is classified as a light (sweet) or a heavy (sour) crude. (The OPEC basket price of seven different oils is an average of light sweet crude oils such as Algeria's Saharan Blend and heavier sour crudes such as Dubai's Fateh.)

Light crudes are easier and less expensive to recover and to refine. Heavy crudes are known as unconventional crude oils because they cannot be produced, transported, and refined by conventional methods due to high concentrations of sulfur and several metals, particularly nickel and vanadium. Heavy crude oils have a density approaching or even exceeding that of water. The largest heavy oil reserves known today are in the Orinoco oil belt of Venezuela, the Athabasca oil sands in Alberta, Canada, and the Olenik oil sands in Siberia, Russia. Due to the large variation in composition crude oil can be a straw-colored liquid or tar-black solid, but green, red or brown oils are not uncommon.

Why is crude oil called 'black gold'? What makes it so valuable? Its value lies in those hundreds of hydrocarbon "chains" of varying sizes, each of which creates a different petroleum by-product. The energy we crave is contained in the hydrogen; the carbon is generally emitted as waste.

There is no area of modern life that is not impacted by petroleum by-products. Some of the best-known are:

- Petroleum gas -- heating and cooking fuels like methane, butane and propane
- Kerosene -- fuel for jet engines, tractors and some heaters
- Naphtha or Ligroin -- intermediate compounds used to produce gasoline
- Gas oil or diesel distillate -- diesel fuel and heating oil
- Lubricating oil - used for motor oil, grease, other lubricants
- Residuals - coke, asphalt, tar, waxes
- Pesticides, fertilizers
- Plastics
- Less well known is that petroleum products are used in the manufacture of textiles, medicines, soap and food items.

How did this magical liquid, to which we owe so many useful and necessary products, materialize?

How oil was formed

Petroleum means "rock oil", from the Greek petros/Latin petra (rock), and the Greek elaion/Latin oleum (oil). Two theories exist as to how it was formed: the 'biotic' or organic theory, and the 'abiotic' or inorganic theory. The latter will be covered in a separate article, The Origin of Oil Controversy.

The more familiar in the western world is the organic theory which states that oil was formed under Earth's surface millions of years ago by the decomposition of plants and tiny organisms that lived in the sea—and, to a lesser extent, those of land organisms that were carried down to the sea in rivers. The marine portion of this equation is very important, as the salt water in the ocean is believed to be one of the contributing factors to the formation of petroleum.

All living organisms are composed of water, salts or minerals, and a large number of organic compounds, substances composed of carbon combined with varying amounts of hydrogen and usually also of oxygen. Nitrogen, phosphorus, and sulfur are likewise common constituents. These tiny marine organisms die, fell to the bottom of the sea and decayed in the sedimentary layers, where little or no oxygen was present and over eons of time mixed with the available sediments forming what geologists call source rock.

In places where new sedimentary layers were deposited intense pressure and heat distilled the hydrogen-rich material into natural gas and crude oil. (Crude oil requires a temperature of at least 150 degrees to form but is destroyed at temperatures above 500 degrees.)

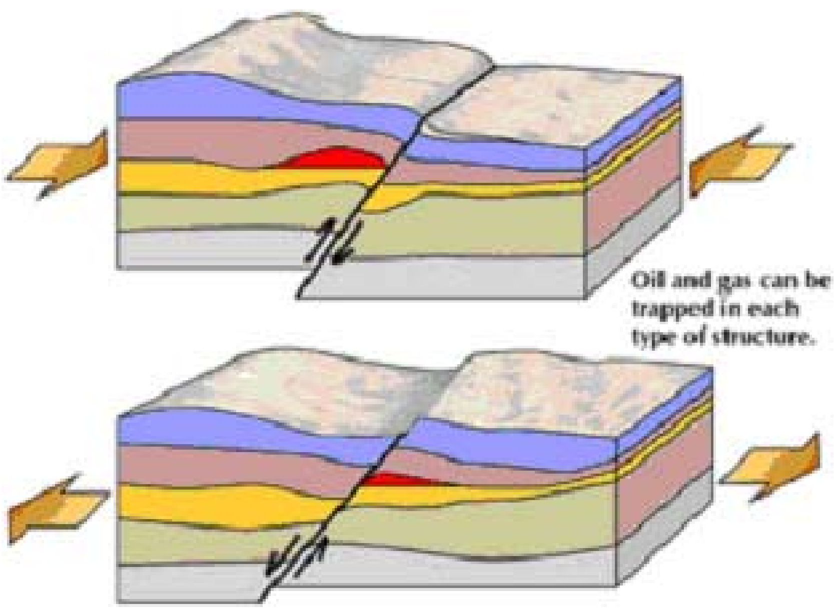


Illustration of oil tapped between layers of rock
http://www.beg.utexas.edu/vow/content/library.htm

The oil did not stay at its place of origin, but flowed from the source rock and accumulated in the hollows of limestone or sandstone, called reservoir rock. Because these porous rocks were usually filled with water, the liquid and gaseous hydrocarbons (which are less dense and lighter than water) migrated upward, through the earth's crust, sometimes for long distances except when trapped by a harder, impenetrable rock, called cap rock , such as granite or marble . An oil reservoir is not some vast underground lake, but rather a seemingly solid layer of rock that is porous. Oil fields have been found everywhere on the planet except for the continent of Antarctica. These fields always contain some gas, but this natural gas, methane, does not take nearly as long to form so it is also found in independent deposits within the ground as well as in swamps. Incidentally, methane (a greenhouse gas) is also the byproduct of animals' digestive system.

Interestingly, petroleum has been in use for thousands of years because a significant amount of the upward-migrating oil does not encounter impermeable rock but instead flows out at the surface of the earth or onto the ocean floor. These surface deposits were employed in various ways. Ancient Persians, 10th century Sumatrans and pre-Columbian Indians all believed that crude oil had medicinal benefits. Marco Polo found it was being used in the Caspian Sea region to treat camels for mange, and the first oil exported from Venezuela (in 1539) was intended as a gout treatment for the Holy Roman Emperor Charles V.

In Mesopotamia around 4000 B.C., bitumen - a thick, tarry crude - was used as caulking on ships, a setting for jewels and mosaics, and an adhesive to secure weapon handles. Egyptians used it for embalming, and the walls of Babylon and the famed pyramids were held together with it. Oil was also used for waterproofing cloth, and fueling torches. The Roman orator Cicero carried a crude-oil lamp. In North America, the Senecas and Iroquois used crude oil for body paint and for ceremonial fires.

The kerosene lamp, invented in 1854, ultimately created the first large-scale demand for petroleum. In 1859, at Titusville, PA, Col. Edwin Drake drilled the first successful well through rock and produced crude oil. What some called "Drake's Folly" was the birth of the modern petroleum industry. He sold his "black gold" for $20 a barrel. It took 140 years to breach that price threshold again.

How oil is discovered

Geologists bear the burden of finding the right conditions for all three oil-producing factors: source rock, reservoir rock and oil entrapment. Today, oil geologists can examine surface rocks and terrain with the help of satellite images. They can also use gravity meters and hypersensitive magnetometers to measure tiny changes in the Earth's gravitational field that could indicate flowing oil. They can even detect the smell of hydrocarbons using sensitive electronic noses called sniffers.

Another widely used technique is Seismic imaging, or "vibroseis" in which large metal plates mounted under large trucks, are lowered from beneath each vehicle to the ground. With the entire weight of the truck resting on the plate, a hydraulic system vibrates the plate, which transfers the energy into the ground. The returning ‘echos’ are picked up by seismic detectors (geophones) arrayed along the line of survey. An instrument truck equipped with a seismograph records the seismic information which geologists can interpret as to the structure of the underground formations.

This technique, while useful in relatively flat areas such as those found in Texas, is of no benefit in the hilly, highly fractured Appalachian Basin.

It should be noted, however, that although modern oil-exploration methods are more advanced than ever, geologists still expect to achieve only a 10 per cent success rate in finding new oil fields. Oil exploration is still a highly speculative enterprise.

Permitting a well

After a promising site has been determined, a number of steps must be taken before drilling can begin. The exact location is marked and a well permit application is sent to the Department of Mines and Minerals, Oil & Gas Division along with three copies of a surveyors plat indicating the location of other wells in the vicinity, the property lines, location of buildings or other structures, names of adjoining property owners and the name of the mineral lease holder.

When approved, two copies of the permit are sent, one is posted at the drill site as required. During the drill a well completion form must be filled out and submitted to the state recording all the pertinent data including the well depth and the result. If the well is a dry hole a plugging and filling form must be completed indicating how the hole was plugged. This allows us to drill another well within the 400 foot spacing normally required between producing wells.

If the well is a producer a tank battery needs to be constructed and bermed. Gathering lines need to be buried and electric power run to the site. A Spill Prevention Control & Countermeasure plan must be established as required by the Environmental Protection Agency. Monthly production reports are provided to Mammoth's Compliance Director for each well for annual filing with the state.

The Drill

Site Preparation

Finding a likely oil location is merely the beginning of a sometimes arduous process. After the paper trail has been laid, the Mammoth Field Service crew goes about preparing the land:

1. If necessary, the land is cleared and leveled, and access roads may be built.

2. Because water is often used to keep down the dust from the drilling process there must be a source of water nearby. If there is no natural source, water is trucked in.

3. A reserve pit(s), used to contain the oil or water encountered during the drill is dug to protect the environment.

Now it’s time to drill. These are the major components of a land oil rig:

• Hoisting system consisting of a mechanical winch with a large steel cable spool for lifting heavy loads such as the 20 foot sections of drill pipe.

• Rotating equipment including:

- Kelly -- four- or six-sided pipe that turns the turntable and drill string
- Swivel -- bears the weight of the drill string, and forms a pressure-tight seal on the hole
- Turntable or rotary table -- drives the drill rotation
- Drill string -- consists of drill pipe in 20 foot-long sections and drill collars
- Drill bit(s) -- tip of the drill that chews up the rock

• Circulation system – Instead of using a drilling ‘mud’ Mammoth Field Services uses a technique called ‘air drilling’ in which compressed air is injected into the bore hole to cool the drill bit and lift cuttings out of the well. The advantages of air drilling are that it is usually much faster than drilling with mud.

• Other important components include the derrick, or support structure that holds the drilling apparatus, and the blowout preventer which seals the high-pressure drill lines and relieves pressure when necessary to prevent an uncontrolled gush of gas or oil to the surface.

Drilling

There are six basic steps to drilling the surface hole:

1. Place the drill bit, collar and drill pipe in the hole.

2. Attach the kelly and turntable and begin drilling.

3. As drilling progresses, compressed air is forced through the pipe and out of the bit to float the rock cuttings up and out of the borehole.

4. Add new sections of drill pipe as the hole gets deeper.

5. Cement sections of steel casing pipe into the hole past the level at which water was struck, providing support to the hole, and preventing water from contaminating the well.

6. Remove the drill pipe, collar and bit when the pre-set depth is reached.

Drill depth is determined by the location of the remnants of the Ordovician Sea. In the Appalachian Basin if oil is not discovered by the time the drill reaches the Knox formation at 1800-2500 feet down the well is considered a dry hole, because to drill deeper would require the expense of a much larger drill rig with no indication that oil will be found.

Post Drill Completion Activities

The drillers have reached the specified depth, the drill rig is removed and a service rig is brought in. This is a truck with a series of cables and pulleys hooked up to a motorized winch and boom rig that is centered over the well shaft to allow for various operations. Regardless of whether oil was discovered or not, an outside contractor is called in to run an electric well log.

- Electric Well logging -- uses the marked differences in electrical properties between fine-grained sediments (shale, clay, and silt) and coarser-grained material (sandstone, sand, and gravel) to identify formations traversed by the borehole. It can also determine the nature and amount of fluids they contain, and estimate their depth. On a dry hole it provides outside confirmation that no oil was found.

- Drill-stem testing -- cameras and density equipment are lowered into the shaft to test for infiltration, density, temperature, and shaft volume as well as other readings.

- Bail Test -- used to recover bottom hole fluids by lowering a cylindrical vessel called a bailer to the bottom of the well, filling and retrieving it, and can be used to determine the amount of and identity of a fluid already in the well bore.

Calendar of Upcoming Events

If the well has had a good show of oil during the drilling process, or tests have indicated that the well may be commercially productive, two well treatment techniques may be used by Mammoth Field Services as part of the completion process if the driller feels it would be beneficial:

GasGun™ Stimulation : The Gas Gun™, developed by J Integral Engineering, Inc., is a cylindrical shaped tool, which comes in a standard diameter of 3 ⅜ inches and in lengths from 1 to 10 feet in one-foot increments. The gas gun is lowered by cable into the well bore to the production level and detonated, generating high pressure gases at a rate that creates a fracturing behavior dramatically different from either hydraulic fracturing or explosives.

The solid propellant used in the gas gun does not actually detonate, it deflagrates, burning with great heat and intense light. The high gas pressure creates multiple radial fractures in a star shaped pattern extending 10 to 50 feet or more from the well bore. Minimal vertical fracturing avoids the problems often associated with hydraulic fracturing, and the rock is not pulverized or compacted as is experienced with high explosives such as nitroglycerine.

There are little or no cavings, the integrity of the well bore is maintained, and cleanup is usually minimal. The techniques of hydraulic fracturing and use of high explosives are not used by Mammoth for reasons explained below.

Alternative techniques

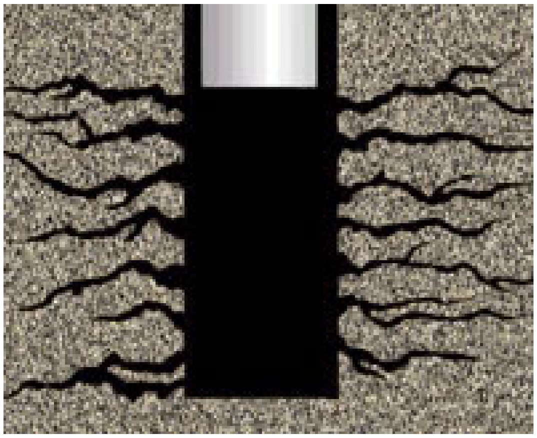
Hydraulic fracturing creates a single fracture at the point of least resistance. The technique consists of pumping a thick, water-based fluid containing a proppant (usually sand) into the wellbore. When the pressure becomes great enough the rock fractures. The proppant prevents the fracture from closing up after the pressure is relieved while being porous enough to allow oil movement into the wellbore.

Unfortunately, the fracture propagates vertically as well as laterally seeking the path of least resistance. Many hydraulic fractures have been known to break out of the producing formation and into nearby aquifers allowing water to enter into the bore and, conversely, opening up the possibility of oil contaminating the aquifer.

High explosives, such as nitroglycerine or gelatin, on the other hand, detonate and create a shock wave. Extensive research has shown that the pressure pulse created by high explosives enlarges the wellbore by crushing and compacting the rock. The enlarged wellbore is left with a zone of residual compressive stress. These residual stresses and compacted rock can actually reduce permeability near the wellbore. Extensive cavings often fill the well bore with debris that require days, even weeks, to clean up.

Acidizing

Acidizing is a technique sometimes useful, although wells producing from the Knox formation are not a good candidate because the acid cannot penetrate the hard, flint-like rock found there. The process consists of placing two expanding plugs, called packers, into the well. Then a large quantity of hydrochloric acid is pumped into the well, followed by 60-80 barrels of salt water. (Fresh water will make the acid gel.) The acid dissolves channels in the limestone walls of the well, thereby opening larger avenues for the oil to enter into the well bore. The salt water, which is heavier than the acid, helps push the acid farther into the porous limestone formations.



Swabbing

Occasionally, after the acid treatment is complete the oil may start flowing automatically. More frequently the well needs to be swabbed. A swab is a large wire brush tool that is attached to a steel cable and lowered into the wellbore. At the desired depth, the motor is reversed. Swabbing accomplishes two things: Often the blow out (lime dust) from the drilling will mix with water and oil in the shaft and form a cement like coating on wall that prevents the free flow of oil to the bore and the swab scrubs these deposits from the wall.

In the process, as the swab tool is raised a vacuum is created which pulls fluid and debris from the well and discharges it into one of the pre-dug pits.

Extracting the Oil

In preparation for the oil recovery, storage tanks of usually 110 or 210 barrels capacity – one barrel equals 42 gallons - are set in place. A well with enough pressure to flow on its own is called free flowing; more often a pump jack is needed to bring up the oil.

The pump jack is powered by an electric (usually) motor, which drives a gearbox that moves a lever. The lever pushes and pulls a polishing rod up and down. The polishing rod is attached to a sucker rod, which is attached to the pump. This system forces the pump up and down, creating a suction that draws oil up through the well bore. In most cases the pump is on a timer, coming on at a predetermined interval.

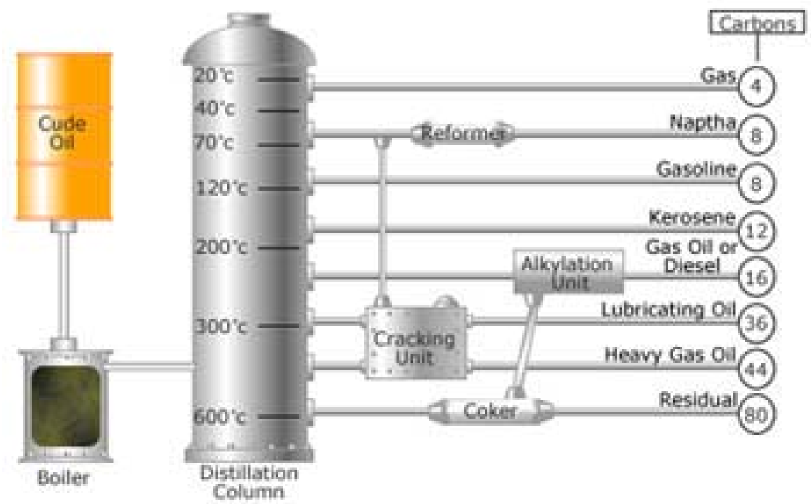
Enhanced Oil Recovery – There are many options for extracting oil that is not recoverable under normal conditions. If in the future it becomes necessary for Mammoth to utilize any of these techniques they will be explained fully.

Oil Refining

As noted earlier, crude oil contains hundreds of different types of hydrocarbon chains all mixed together ha ving different sizes, weights and boiling temperatures. In order to have anything useful you have to separate the different types of hydrocarbon chains. For conventional oil, there is an easy way to separate the chains called fractional distillation, and that is what oil refining is all about .

First the crude oil is heated then passed into a distillation tower, where the volatile molecules turn into vapors and rise up the tower. The top of the tower is cooler than the bottom so that the vapors gradually condense as they rise. The tower contains a series of shallow trays that collect the liquid as it condenses.

The liquid on each tray, is piped off separately. Shorter chains have lower boiling points, so the higher the tray the shorter the chain lengths that collect there.



Refineries must then treat the fractions to remove impurities such as organic compounds containing sulfur, nitrogen, oxygen, water, dissolved metals and inorganic salts. This generally involves passing the fractions through the following:

- A column of sulfuric acid - removes unsaturated hydrocarbons (those with carbon-carbon double-bonds), nitrogen compounds, oxygen compounds and residual solids (tars, asphalt)
- An absorption column filled with drying agents to remove water

- Sulfur treatment and hydrogen-sulfide scrubbers to remove sulfur and sulfur compounds

After the fractions have been treated, they are cooled and then blended together to make various products. F or example, different mixtures of chains can create gasolines with different octane ratings. Using a chemical process called conversion, some of the fractions can be turned into others. For example, conversion allows a refinery to turn diesel fuel into gasoline if there is a bigger demand for gasoline. (For a more detailed discussion see the following article Pain at the Pump.)

Now that you have some understanding of crude's journey from deep inside the earth to it's appearance as a useful product, let's take the next step and investigate how circumstances converge to effect the near daily price fluctuations which confront us at the gasoline pump.

Congratulations

You probably now know more about oil and how it is discovered and extracted than anyone in your acquaintance outside the oil industry. For our part, our mission for sharing this information with you is simple: to help you make the most informed decision possible when considering an oil and gas investment.

We hope you won't hesitate to call us with any questions or concerns you may have about oil and gas partnerships and their investment potential.

Dr. Roger L. Cory is a noted authority in the field of energy depletion, having first spoken publicly on the topic in March 2000. Dr. Cory earned a Doctor of Jurisprudence from Pepperdine School of Law, and is both founder and President of Mammoth Resource Partners. Mammoth accepts partnership participation primarily from the broker/dealer industry, and is one of the most active and successful energy exploration companies in the Appalachian region.