Petroleum—or crude oil—is a fossil fuel that is found in large quantities beneath the Earth's surface and is often used as a fuel or raw material in the chemical industry. It is a smelly, yellow-to-black liquid and is usually found in underground areas called reservoirs.

If you could look down an oil well and see oil where Nature created it, you might be surprised. You wouldn't see a big underground lake, as a lot of people think. Oil doesn't exist in deep, black pools. In fact, an underground oil formation—an "**oil reservoir**"—looks very much like any other rock formation. Oil exists in this underground formation as tiny droplets trapped inside the open spaces, called "**pores**," inside rocks. The pores and the oil droplets can be seen only through a microscope. The droplets cling to the rock, like drops of water cling to a window pane.

Rock pores

When reservoir rock is magnified, the tiny pores that contain trapped oil droplets can be seen.

WHERE IS OIL FOUND?

Oil reserves are found all over the world. However, some have produced more oil than others. The top oil producing countries are Saudi Arabia, Russia, the United States, Iran and China.

In the United States, petroleum is produced in 31 states. Those states that produce the most petroleum are Texas, Alaska, California, Louisiana and Oklahoma.

While the United States is one of the top producing countries, its need for petroleum surpasses the amount it can produce; therefore, a majority of our oil must be imported from a foreign country. The country we import the most oil from is Canada, followed by Saudi Arabia, Mexico, Venezuela and Nigeria.

Top Producing Petroleum States

USES FOR PETROLEUM

You are probably already familiar with the main use for petroleum: gasoline. It is used to fuel most cars in the United States. But petroleum is also used to make many more products that we use on a daily basis.

A majority of petroleum is turned into an energy source. Other than gasoline, petroleum can also be used to make heating oil, diesel fuel, jet fuel and propane. It can also be turned into petrochemical feedstock—a product derived from petroleum principally for the manufacturing of chemicals, synthetic rubber and plastics. It is also used to make many common household products, including crayons, dishwashing liquids, deodorant, eyeglasses, tires and ammonia.

DRILLING FOR OIL—EXPLORATION

The first step to drilling for oil is knowing where to drill. Because it is an expensive endeavor, oil producers need to know a lot about an oil reservoir before they start drilling. They need to know about the size and number of pores in a reservoir rock, how fast oil droplets will move through the pores, as well as where the natural fractures are in a reservoir so that they know where to drill.

While in the past it may have taken a few guesses and some misses to find the right place to drill, scientists have discovered new ways to determine the right locations for oil wells. Using sound waves, scientists can determine the characteristics of the rocks underground. Sound travels at different speeds through different types of rocks. By listening to sound waves using devices called "**geophones**," scientists can measure the speed at which the sound waves move through the rock and determine where there might be oil-bearing rocks. Scientists can also use electric currents in place of the sound waves for the same effect.

Scientists can also examine the rock itself. An exploratory well will be drilled and rock samples called "**cores**" will be brought to the surface. The samples will be examined under a microscope to see if oil droplets are trapped within the rock.

Drilling for Oil

A rig crew at work during drilling operations.

DRILLING FOR OIL—PRIMARY RECOVERY

Once the oil producers are confident they have found the right kind of underground rock formation, they can begin drilling production wells.

When the well first hits the reservoir, some of the oil may come to the surface immediately due to the release of pressure in the reservoir. Pressure from millions of tons of rock lying on the oil and from the earth's natural heat build up in the reserve and expand any gases that may be in the rock. When the well strikes the reserve, this pressure is released, much like the air escaping from a balloon. The pressure forces the oil through the rock and up the well to the surface. Years ago, when the equipment wasn't as good, it was sometimes difficult to prevent the oil from spurting hundreds of feet out of the ground in a "**gusher**." Today, however, oil companies install special equipment on their wells called "**blowout preventers**" that prevents the gushers and helps to control the pressure inside the well.

When a new oil field first begins producing oil, the natural pressures in the reservoir force the oil through the rock pores, into fractures and up production wells. This natural flow of oil is called "**primary production**." It can go on for days or years. But after a while, an oil reservoir begins to lose pressure. The natural oil flow begins dropping off and oil companies must use pumps to bring the oil to the surface.

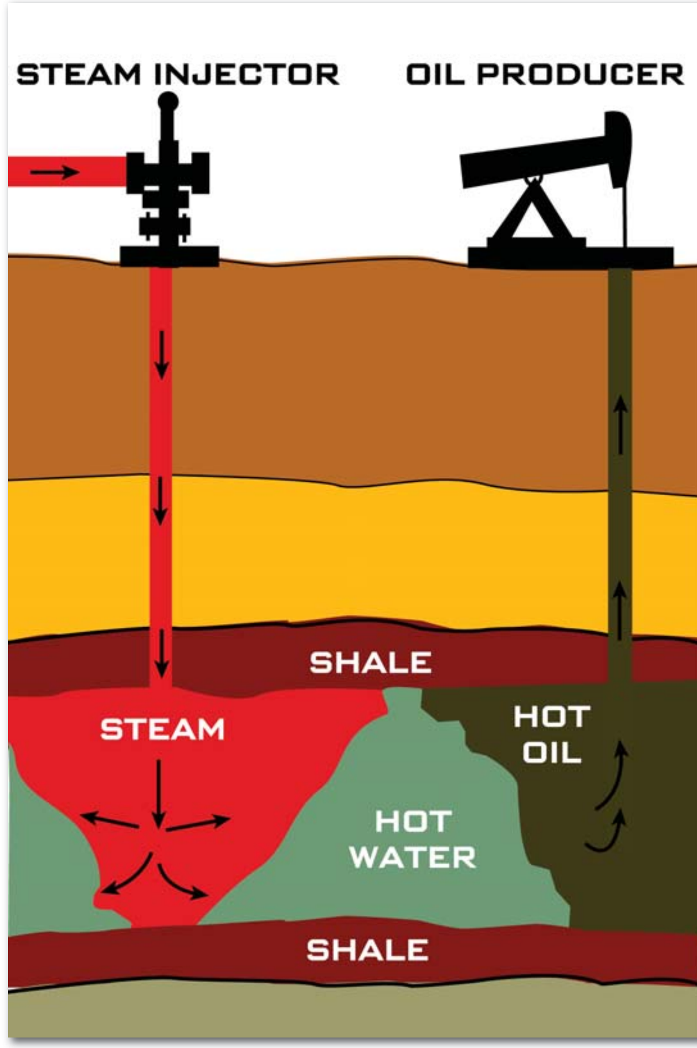
It is not uncommon for natural gas to be found along with the petroleum. Oil companies can separate the gas from the oil and inject it back into the reservoir to increase the pressure to keep the oil flowing. But sometimes this is not enough to keep the oil flowing and a lot of oil will be left behind in the ground. Secondary recovery is then used to increase the amount of oil produced from the well.

DRILLING FOR OIL—SECONDARY RECOVERY

Imagine spilling a can of oil on a concrete floor. You would be able to wipe some of it up, but a thin film of oil might be left on the floor. You could take a hose and spray the floor with water to wash away some of the oil. This is basically what oil producers can do to an oil reservoir during secondary recovery. They drill wells called "**injection wells**" and use them like gigantic hoses to pump water into an oil reservoir. The water washes some of the remaining oil out of the rock pores and pushes it through the reservoir to production wells. This is called "**waterflooding**."

Let's assume that an oil reservoir had 10 barrels of oil in it at the start (an actual reservoir can have millions of barrels of oil). This is called "**original oil in place**." Of those original 10 barrels, primary production will produce about two and a half barrels. Waterflooding will produce another one-half to one barrel. That means that in our imaginary oil reservoir of 10 barrels, there will still be six and a half to seven barrels of oil left behind after primary production and waterflooding. In other words, for every barrel of oil we produce, we will leave around two barrels behind in the ground.

This is the situation facing today's oil companies. In the history of the United States oil industry, more than 160 billion barrels of oil have been produced but more than 330 billion barrels have been left in the ground.



Injection wells

Steam is injected into many oil fields where the oil is thicker and heavier than normal crude oil.

DRILLING FOR OIL—ENHANCED OIL RECOVERY

Petroleum scientists are working on ways to extract the huge amounts of oil that are left behind after primary and secondary production. Through **enhanced oil recovery** (EOR) techniques, it may be possible to produce 30 to 60 percent of the reservoir's original oil in place. Current research in EOR techniques includes:

- **Thermal recovery**, which involves the introduction of heat such as the injection of steam to lower the viscosity, or thin, the heavy viscous oil, and improve its ability to flow through the reservoir. Thermal techniques account for more than 50 percent of U.S. EOR production, primarily in California.

- **Gas injection**, which uses gases such as natural gas, nitrogen, or carbon dioxide that expand in a reservoir to push additional oil to a production wellbore, or other gases that dissolve in the oil to lower its viscosity and improve its flow rate. Gas injection accounts for nearly 50 percent of EOR production in the United States.

Inside an Oil Refinery

An engineer stands inside an oil refinery surrounded by pipelines and pumps.

- **Chemical injection**, which can involve the use of long-chained molecules called **polymers** to increase the effectiveness of waterfloods, or the use of detergent-like surfactants to help lower the surface tension that often prevents oil droplets from moving through a reservoir. Chemical techniques account for less than 1 percent of U.S. EOR production.

The EOR technique that is attracting the most interest is **carbon dioxide** (CO_2)-EOR. Injecting CO_2—the same gas that gives soda pop its fizz—into an oil reservoir thins crude oil left behind, pressurizes it, and helps move it to producing wells. When all remaining economically recoverable oil is produced, the reservoir and adjacent formations can provide sites for storage of CO_2 produced from the combustion of fossil fuels in power plants and other processes that generate large amounts of CO_2. By capturing the CO_2 emissions from these sources and then pumping it into depleting oil reservoirs, we not only increase the production from the well but store the CO_2 underground to prevent it from being released to the atmosphere, where it may affect the climate. The potential for CO_2 sequestration in depleted oil and gas reservoirs is enormous. The Department of Energy has documented the location of more than 90.8 billion tons of sequestration potential in the United States and Canada from CO_2-EOR.

REFINING OIL

When crude oil is removed from the ground, it does not come out in a form that is readily useable. Before it can be used, it must be refined, where it is cleaned and separated into parts to create the various fuels and chemicals made from oil. Within the oil are different hydrocarbons which have various boiling points, meaning they can be separated through distillation. To do this, the oil is piped through hot furnaces and based on the hydrocarbon's weight and boiling point, various liquids and vapors will be created. The lightest components, such as gasoline, will vaporize and rise to the top, where they will condense and turn back into liquids. The heavier components will sink to the bottom. This will allow the components to be separated from each other and turned into their respective product or fuel.

After the refinery, the gasoline and other fuels created are ready to be distributed for use. There is a system of pipelines that runs throughout the United States that transport oil and fuels from one location to another. There are pipelines that transport crude oil from the oil well to the refinery. At the refinery, there are additional pipelines that transport the finished product to various storage terminals where it can then be loaded onto trucks for delivery, such as to a gas station.

Offshore platform

Currently, there are more than 3,700 active platforms drilling for oil in the Gulf of Mexico.

OFFSHORE DRILLING

Sometimes the oil is located deep underneath the ocean floor and offshore drilling must be used to extract the crude oil. A platform is built to house the equipment needed to drill the well; the type of platform used will depend on a variety of characteristics of the location, including the depth of the water and how far underwater the drilling target is located. A blowout preventer is used just like on wells built on land. This helps prevent petroleum from leaking out of the well and into the water.

Currently, there are more than 3,700 active platforms drilling for oil in the Gulf of Mexico. While a majority of them are located in waters less than 200 meters (650 feet) in depth, nearly 30 are located in areas where the water is more than 800 meters (2,400 feet) in depth.

HISTORY OF PETROLEUM

1990	For the first time, the United States imports more oil and refined products than it produces domestically.
1970s	Production of petroleum in the United States' lower 48 states reaches its highest level of 9.4 million barrels per day.
1950s	Oil becomes our most used energy source due to the demand for gasoline.
1920s	With more than 9 million automobiles on the roads in the United States, gas stations begin opening.
1890s	Mass production of automobiles begins, creating a demand for gasoline.
1859	First oil well drilled near Titusville, Pennsylvania, by Edwin L. Drake.
Mid-1800s	Expanding uses for oil extracted from coal and shale begin to increase the knowledge of the value of crude oil and exploration for it is encouraged.
1750	Oil is found in Pennsylvania and New York by well-owners who are digging for salt brine. However, its uses are little known at this point.
2000 B.C.	The Chinese use crude oil to light lamps and heat homes.

Strategic Petroleum Reserve

A technician at the Strategic Petroleum Reserve inspects crude oil transfer pipes.

STRATEGIC PETROLEUM RESERVE

Oil is a very important commodity to the United States. It fuels our cars and buses, as well as the machines at many factories and refineries. With a majority of the oil we use today being imported, what would happen if we weren't able to get enough oil to keep up with the demand? In the 1970s, an oil embargo happened in which the supply of oil imported to the United States from the Middle East was cut off, leading to long lines at the gas stations and even some fuel shortages. While the idea of creating a stockpile had come up before, the embargo helped cement the idea that an oil reserve was in fact needed.

In 1975, Congress passed the **Energy Policy and Conservation Act**, which made it policy for the United States to establish a reserve of up to 1 billion barrels of crude oil. By 1977, oil was being delivered to the new **Strategic Petroleum Reserve** (SPR). Currently, there are four SPR sites located in Texas and Louisiana, which have a total capacity to hold 727 million barrels of crude oil, making it the largest emergency oil stockpile in the world. An expansion of the SPR is planned, including the creation of a new site.

STORING THE OIL

At the SPR sites, the crude oil is stored in underground salt caverns. **Salt caverns** are carved out of underground salt domes by a process called "**solution mining**." Essentially, the process involves drilling a well into a salt formation then injecting massive amounts of fresh water. The water dissolves the salt. In creating the SPR caverns, the dissolved salt was removed as brine and either reinjected into disposal wells or more commonly, piped several miles offshore into the Gulf of Mexico. By carefully controlling the freshwater injection process, salt caverns of very precise dimensions can be created.

Besides being the lowest cost way to store oil for long periods of time, the use of deep salt caverns is also one of the most environmentally secure. At depths ranging from 2,000 to 4,000 feet (610 – 1,220 meters), the salt walls of the storage caverns are "self-healing." The extreme geologic pressures make the walls rock hard, and should any cracks develop in the walls, they would be almost instantly closed.

Oil Storage

Pipes at a refinery transport oil to its storage tanks.

An added benefit of deep salt cavern storage is the natural temperature difference between the top of the caverns and the bottom—a distance of around 2,000 feet. The temperature differential keeps the crude oil continuously circulating in the caverns, maintaining the oil at a consistent quality.

The fact that oil floats on water is the underlying mechanism used to move oil in and out of the SPR caverns. To withdraw crude oil, fresh water is pumped into the bottom of a cavern. The water displaces the crude oil to the surface. After the oil is removed from the SPR caverns, pipelines send it to various terminals and refineries around the nation.

FILLING THE SPR

Oil for the SPR can be purchased by the government from oil companies, as was done in the 1970s and the 1980s. In the late 1990s, the SPR also began using **royalty-in-kind oil**, which is oil that is given to the government by petroleum operators as payment on leases they hold on the federally-owned Outer Continental Shelf in the Gulf of Mexico. Instead of paying for the leases with money, the companies give the government oil, which is then put into the reserves.

USING THE SPR

In an emergency, when the nation's oil supply is limited leading to an adverse impact on national safety or on the national economy, the president may order oil to be withdrawn from the reserve. The president can issue a full "**drawdown**" in which all the oil from the reserve is released. A limited drawdown may be issued in times where the event threatening national energy supplies and the economy is less severe or expected to be of short duration. A limited drawdown has restrictions on the amount of oil that can be released, as well as for how long.

The president may also order a **test sale**, in which the process of releasing the oil into the marketplace is tested to ensure all personnel know the procedures for a drawdown and all equipment is operational.

In the event of a drawdown, the Department of Energy—which manages the SPR—will offer a specific number of barrels of crude oil from the reserve for sale. The department will select those companies to sell to and can begin delivering the oil within 13 days. Oil can be pumped from the reserve at a maximum rate of 4.4 million barrels per day for up to 90 days before the drawdown rate begins declining as the caverns empty out. At 1 million barrels per day, the reserve can release oil into the market continuously for nearly a year and a half.

Using the SPR

The president can issue a drawdown (release of oil in the reserve) when events threaten national energy supplies.

There have been two emergency drawdowns from the reserve. The first took place in 1991 during the Persian Gulf War. In order to maintain a stabilized petroleum market during Operation Desert Storm, the government offered 33 million barrels of oil from the SPR for sale; a little more than 17 million barrels were bought and deliveries began within a month. The second emergency drawdown occurred in 2005 after Hurricane Katrina damaged oil refineries in the Gulf Coast region.

The Department of Energy is also authorized to exchange oil from the reserve. These exchanges have been used in the past to replace less suitable types of crude oil for higher-quality crude oil. It has also been used for limited, short-duration actions to assist petroleum companies in resolving oil delivery problems, such as the CITGO/Conoco Exchanges in 2000, when a commercial dry dock collapsed, cutting off shipping channels to the refineries.