## LOOKING DOWN AN OIL WELL

Ever wonder what oil looks like underground, down deep, hundreds or thousands of feet below the surface, buried under millions of tons of rock and dirt?

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—called an "**oil reservoir**"—looks very much like any other rock formation. It looks a lot like...well, rock.

Oil exists underground 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.

How do oil companies break these tiny droplets away from the rock thousands of feet underground? How does this oil move through the dense rock and into wells that take it to the surface? How do the tiny droplets combine into the billions of gallons of oil that the United States and the rest of the world use each day?

## SQUEEZING OIL OUT OF ROCKS

Imagine trying to force oil through a rock. Can't be done, you say?

Actually, it can.

In fact, oil droplets can squeeze through the tiny pores of underground rock on their own, pushed by the tremendous pressures that exist deep beneath the surface. How does this happen?

Imagine a balloon, blown up to its fullest. The air in the balloon is under pressure. It wants to get out. Stick a pin in the balloon and the air escapes with a bang!

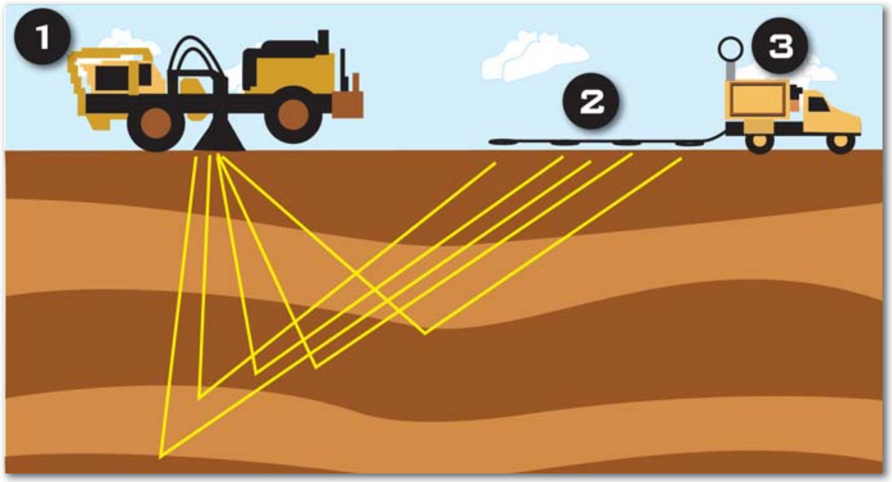
***Rock Pores***

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

Oil in a reservoir acts something like the air in a balloon. The pressure comes from millions of tons of rock lying on the oil and from the earth's natural heat that builds up in an oil reservoir and expands any gases that may be in the rock. The result is that when an oil well strikes an underground oil reservoir, the natural pressure is released—like the air escaping from a balloon. The pressure forces the oil through the rock and up the well to the surface.

If there are **fractures** in the reservoir (fractures are tiny cracks in the rock) the oil squeezes into them. If the fractures run in the right direction toward the oil well, they can act as tiny underground "pipelines" through which oil flows to a well.

Oil producers need to know a lot about an oil reservoir before they start drilling a lot of expensive wells. They need to know about the size and number of pores in a reservoir rock. They need to know how fast oil droplets will move through these pores. They need to know where the natural fractures are in a reservoir so that they know where to drill their wells.




***Modern-day oil prospectors use sound waves to locate oil.***

*In one technique,*

1. *a signal is sent into the rock by a vibrator truck,*
2. *the reflected waves are received by geophones, and*
3. *the data is transmitted to a laboratory truck.*

Today, scientists have invented many new ways to learn about the characteristics of an oil reservoir.

They have developed ways to send sound waves through reservoir rock. Sound waves travel 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 moves through the rock and determine where there might be rocks with oil in them.

Scientists also measure how electric current moves through rock. Rocks with a lot of water in the tiny pores will conduct electricity better than rocks with oil in the pores. Sending electric current through the rock can often reveal oil-bearing rocks.

Finally, oil companies will look at the rocks themselves. An exploratory well will be drilled, rock samples, called "**cores**," will be brought to the surface. Scientists will look at the core samples under a microscope. Often they can see tiny oil droplets trapped inside the rock.

When companies are convinced that they have found the right kind of underground rock formation that is likely to contain oil, they begin drilling production wells. When the wells first hit the reservoir, some of the oil begins coming to the surface immediately.

Many years ago, when oil field equipment wasn't very good, it was sometimes difficult to prevent the oil from spurting hundreds of feet out the ground. This was called a "**gusher**." Today, however, oil companies install special equipment on their wells called "**blowout preventors**," that prevent gushers, like putting a cork in a bottle.

When a new oil field first begins producing oil, nature does most of the work. 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, like the air leaving a balloon. The natural oil flow begins dropping off, and oil companies use pumps to bring the oil to the surface.

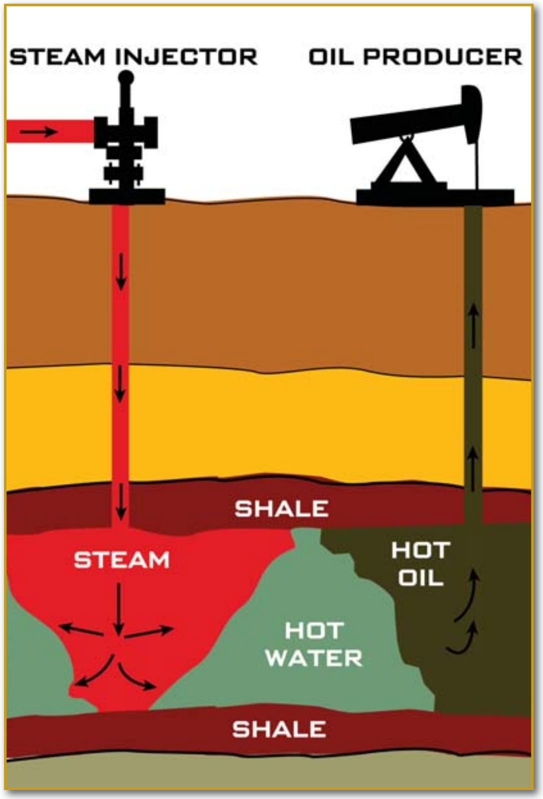
In some fields, natural gas is produced along with the oil. In some cases, oil companies separate the gas from the oil and inject it back into the reservoir. Like putting air back into a balloon, injecting natural gas into the underground reservoir keeps enough pressure in the reservoir to keep oil flowing.

Eventually, however, the pressure drops to a point where the oil flow, even with pumps and gas injection, drops off to a trickle. Yet, there is actually a lot of oil left in the reservoir. How much? In many reservoirs, as many as 3 barrels can be left in the ground for every 1 barrel that is produced. In other words, if oil production stopped after "primary production," almost 3/4ths of the oil would be left behind!

That's why oil producers often turn to "**secondary recovery**" processes to squeeze some of this remaining oil out of the ground.

What are "secondary recovery" processes?

## WASHING MORE OIL FROM ROCKS




***Injection Wells***

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

A lot of oil can be left behind after "primary production." Often, it is clinging tightly to the underground rocks, and the natural reservoir pressure has dwindled to the point where it can't force the oil to the surface.

Imagine spilling a can of oil on the concrete floor of a garage. Some of it can be wiped up. But the thin film of oil that's left on the floor is much more difficult to remove. How would you clean up this oil?

The first thing you might do is get out a garden hose and spray the floor with water. That would wash away some of the oil. That's exactly what oil producers do in an oil reservoir. 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. The process is called "**waterflooding**."

### *How effective is 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 (2½). "Waterflooding" will produce another one-half to one barrel.

That means that in our imaginary oil reservoir of 10 barrels, there will still be 6½ to 7 barrels of oil left behind after primary production and waterflooding are finished. In other words, for every barrel of oil we produce, we will leave around 2 barrels behind in the ground.

That is the situation faced by today's oil companies. In the history of the United States oil industry, more than 195 billion barrels of oil have been produced. But more than 400 billion barrels have been left in the ground. Unfortunately, we don't yet know how to produce most of this oil.

Petroleum scientists are working on ways to produce this huge amount of remaining oil. Several new methods look promising. Oil companies, in the future, might use a family of chemicals that act like soap to wash out some of the oil that's left behind. Or possibly, they might grow tiny living organisms in the reservoir, called microbes, that can help free more oil from reservoir rock. Sound interesting?

## SOAP, BUGS, AND OTHER WAYS TO PRODUCE OIL

Remember the oil spilled on the garage floor? Washing it with water would only remove some of the oil. There would still be a black, oily stain on the floor. How would you get that oil up?

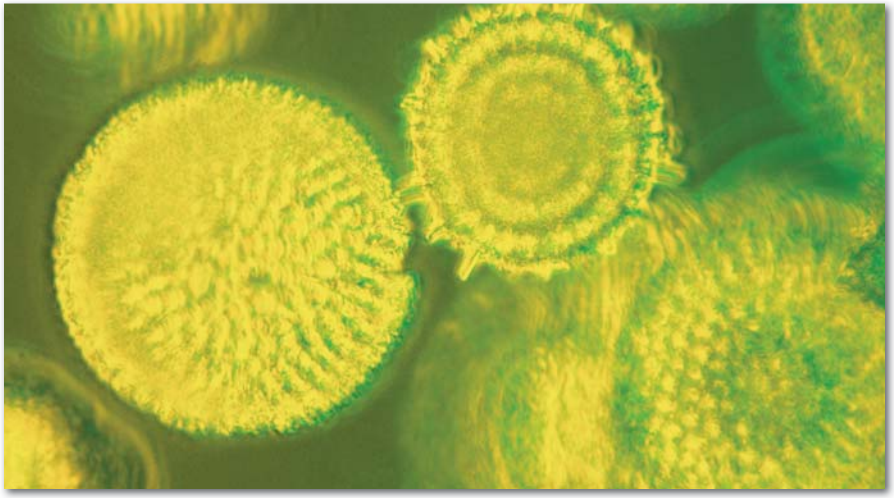
You would probably add some soap to the water—perhaps some detergent that you use in a washing machine. That would help wash away a little more of the oil. Oil researchers are studying ways to inject chemicals similar to detergents into an oil reservoir. The researchers call these chemicals "**surfactants**." Surfactants keep the tiny oil droplets from clinging to the rock much like a soapy film keeps water droplets from clinging to the side of a glass.

Temperature can also be important in freeing oil from underground reservoirs. In some oil reservoirs (in much of California, for example) the oil is thicker and heavier. It hardly flows out of a jar, much less out of an oil reservoir. But if the oil is heated, it becomes thinner and more slippery. To heat heavy oil in a reservoir, oil companies boil water in huge pressure vessels on the surface and send the steam down wells. The steam works its way through the oil reservoir, heating the oil and making it easier to pump to the surface.

Another way to free trapped oil is to inject carbon dioxide. Some carbon dioxide exists naturally underground, and companies often pump it out of the ground, then back in to oil reservoirs to help produce more oil. Carbon dioxide is also given off when anything burns. Many power plants that produce our electricity burn coal, natural gas, and other fuels. These plants produce large amounts of carbon dioxide as do factories. Even you produce carbon dioxide when you breathe. It would be very hard to capture the carbon dioxide of every breathing person, but it may be possible in the future to capture carbon dioxide from big power plants or factories. This carbon dioxide can be injected into an oil reservoir to mix with the oil, break it away from the underground rock, and push it toward oil wells.

Still another technique being studied uses microscopic organisms called "**microbes**." Even though some scientists jokingly call these tiny microbes "bugs," they really don't have heads or legs or bodies. Instead, they are more like bacteria—tiny, single-cell organisms that can grow and multiply inside the rocks deep within oil reservoirs.

How can microbes be used to produce more oil? Actually, several ways. Some microbes can feed on nutrients in a reservoir and release gas as part of their digestive process. The gas collects in the reservoir, like air inside a balloon, building up pressure that can force more oil droplets out of the rock pores and toward oil wells. To get microbes to grow and multiply fast enough, oil scientists are testing ways to inject nutrients, or food, for the microbes into a reservoir.



***Microbes***

*inside an oil drop. The average size of these single cell organisms is about 25,000ths of an inch.*

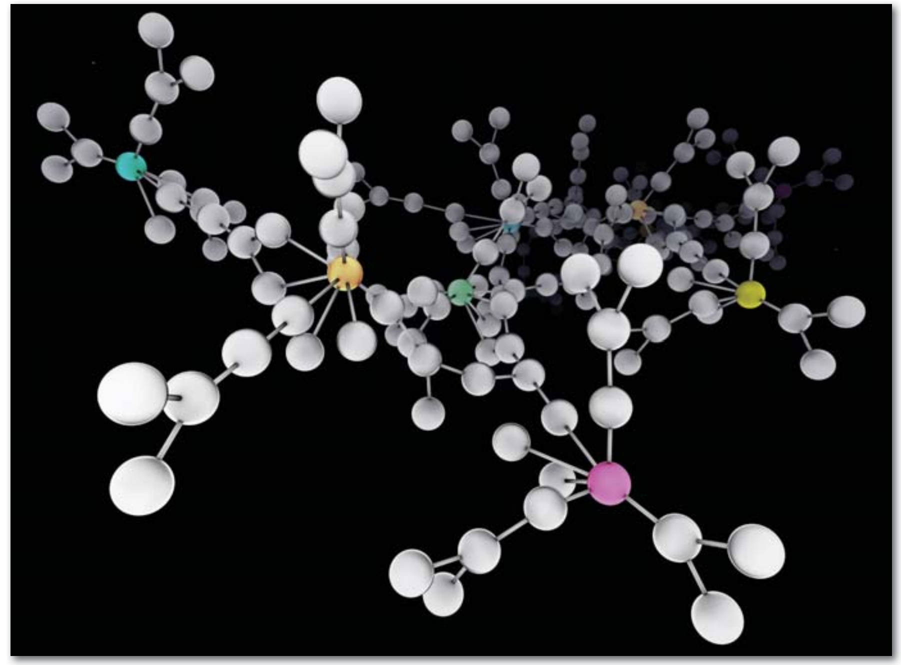
Microbes can also be used to block off portions of a reservoir. After many years of waterflooding, most of the water eventually finds the easiest path through the oil reservoir. Oil trapped in the rocks along that path is washed out of the reservoir, but oil in other parts of the reservoir may be left untouched. To send the water to other parts of the reservoir, scientists mix microbes, along with food for the microbes, into the waterflood. As the microbes move along with the water, they ingest the food, grow and multiply. Eventually, enough microbes are created to block off the tiny passageways. Now, scientists can inject fresh water and send it to portions of the reservoir that haven't been swept clean by the earlier waterflood, and more oil can be produced.

Scientists are also developing new chemicals called "**polymers**" that can help produce more oil. A "polymer" is a long chain of atoms joined together in one large molecule. The molecule is small enough to fit through the pores of a reservoir rock, but large enough to break loose an oil droplet. In fact, scientists are developing a special type of polymer that performs two functions: one end of the molecule acts like a microscopic "sledgehammer" to break loose the oil droplet, while the other end acts like a surfactant to keep the oil sliding through the rock to an oil well.

All of these techniques show promise, but all add costs to the oil production process. Not every technique can be used in every oil reservoir. Some are better than others. But even if some, or all, of these techniques are proven to be practical, they won't get out all of the oil remaining in a reservoir.

In fact, the very best methods being tested today will allow oil companies to produce only one-half to, in some cases, three-fourths of the oil in a reservoir. It may not be possible to get the rest of the oil out. But even getting this amount of additional oil out of our oil fields can be very important for our energy future.

And who knows? Someday, scientists might find a way to get even more of the vast quantities of oil that we leave behind today down at the bottom of oil wells.



***Polymers***

*are long chains of atoms joined together in one large molecule.*