Petroleum Geologist

Task

As the geologist, you are responsible for understanding and explaining how oil formed and where it is found. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Petroleum Geologist

- **What geologic processes form petroleum?**
- **Where in the earth is petroleum found?**

Information

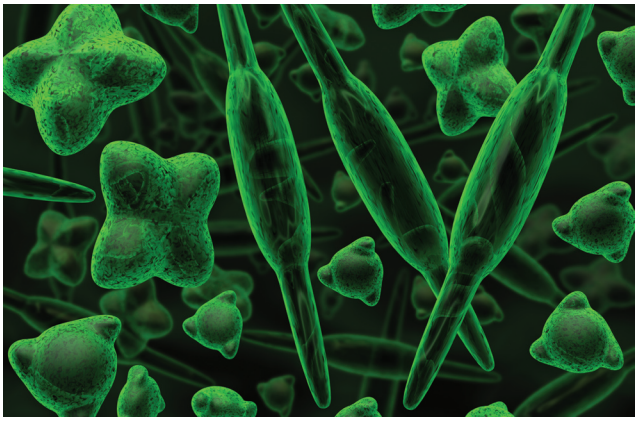
The story of petroleum begins millions of years ago in the warm seas of the Paleozoic Era (570–250 mya) when dinosaurs roamed Earth. Petroleum starts out as microscopic organisms composed of carbon, hydrogen, and oxygen—the building blocks of all living organisms—floating in the ancient seas. However, the structure of today's petroleum is very different from these ancient organisms. How did the organisms change into petroleum? How did petroleum end up in the ground, far away from the ocean?

Oil's Origins

The source of petroleum (also known as crude oil) can be traced back to microscopic marine organisms—foraminifera and diatoms. These organisms are one celled, have hard shells of either calcium carbonate (foraminifera) or silica (diatoms), and float with the ocean currents (plankton). When forams and diatoms die, they sink to the bottom of the water and form most of the sediment because bacteria did not decompose the organic material.

A New Form

While the life span of these organisms is very short, it takes millions of years to transform the organic material into petroleum. To change into petroleum, the material must be deeply buried under sediment. This sediment may be thousands of meters thick. When the heat and pressure compresses the sediment into sedimentary rock, it also transforms the organic material into petroleum. The carbon, hydrogen, and oxygen go through chemical changes to become hydrocarbons; hydrocarbon is the chemical that makes up petroleum. This sedimentary rock, usually limestone, is the source rock.



While these organisms lived in seas all over the world, if the waters were too cold, they would not have been as abundant. All ancient seas that contained these organisms did not necessarily produce oil! Photo: courtesy of the U.S. Department of Energy.

Oil gets trapped in the pore spaces in rocks. Photo: courtesy of the U.S. Department of Energy.

Oil Moves!

Oil is less dense than water. If you put oil and water in a jar, the oil will rise to the top. The same thing happens in rock. The pore spaces (spaces between the sediment particles) in underground sedimentary rocks usually contain water. The crude oil and gas in the source rock is less dense than the surrounding rock and water. The pressure forces the oil, gas, and water out of the source rock. Due to density differences, the oil and gas will travel upward. Over time, the oil and gas rise out of the source rock as they makes the journey to the top.

Reservoir Rock

As the petroleum (crude oil) makes its journey out of the source rock, it will continue to move upward, as long as there are porous rocks above it. Some rocks are more porous than others. Liquids such as petroleum and water move through sandstone more easily than limestone. Some rocks will not let liquids flow through at all; these are called impermeable rock layers and will trap the petroleum below them, as can be seen in the diagram to the right.

The rock in which the petroleum and water are trapped is called the reservoir rock. The reservoir rock may be very close to the source rock, or it can be many layers and many kilometers away. If a rock layer is tilted, folded, or faulted, the petroleum and water will continue to migrate upward until they are trapped beneath an impermeable rock.

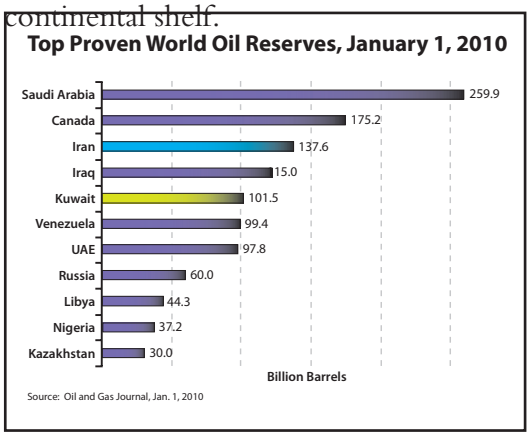
Folds in the rock layers trap oil, creating good drilling sites. Geologists determine where there might be the right combination of porous and nonporous rock. Then they examine seismic data to try to locate where the rock might be folded.

Where in the World Is Oil Found?

There is not a single type of climate or country in which oil is found. Oil is found in places where there are sedimentary rocks, which can be anywhere. However, not all sedimentary rocks contain oil.

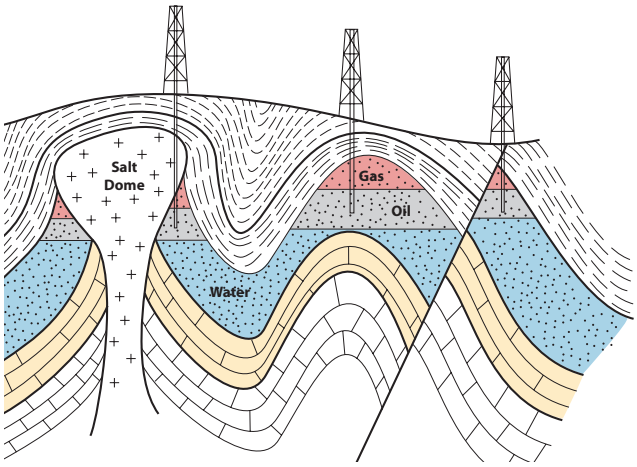
Oil in the United States

About one-third of the oil produced in the United States comes from wells in the federally administered waters of the Gulf of Mexico on the continental shelf.



Top Oil-Producing States:

Texas (21%) Alaska (12%)
California (11%) North Dakota (4%)
Louisiana (3.5%)



Events

210–190 mya, Late Triassic–Early Jurassic: Origin of the Gulf of Mexico basin is seafloor spreading and subsidence

160 mya, Late Jurassic: With seafloor spreading, there are times when the ridge is pushed upward, and the shallow seas evaporate. Thick salt beds remain. Deep carbonate deposits from foraminifera and reefs form in shallow Jurassic sea.

150–100 mya, Late Jurassic–Cretaceous: Reservoir rocks consist of sandstone, limestone, and thin layers of shale.

80 mya, Late Cretaceous: There is a global sea-level fall.

65 mya, Tertiary: Sandstones form reservoir rocks.

Vocabulary

hydrocarbons an organic compound consisting entirely of hydrogen and carbon

impermeable something that prevents liquids from passing through

petroleum (or crude oil) a naturally occurring mixture of hydrocarbons that are found in geologic formations beneath Earth's surface

plankton organisms that live in water and drift with currents (e.g., foraminifera and diatoms)

reservoir rock porous rock layer where oil is trapped beneath an impermeable upper layer

Petroleum Engineer

Task

Your job as the petroleum engineer is to understand and explain the story of oil and gas in the ground and its relation to the petroleum products we use. You will need to know how oil and gas is removed from rocks and what is done to it after it has been recovered from the ground. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Petroleum Engineer

- **How are oil and gas removed from the ground?**
- **How do oil and gas become usable petroleum products?**

Information

Before there were oil rigs and oil wells, oil came to the surface through natural seeps. People all over the world gathered oil.

The modern demand for petroleum products began with the desire to fuel lamps (not with the desire to fuel cars). New methods of drilling were developed to extract the oil near oil seeps. The first well drilled in Pennsylvania was only 21.2 meters (69.5 feet) deep and produced 20 barrels of crude oil a day. Oil was so abundant that the supply was far greater than the demand.

Compare that to the amount of oil produced in the United States today. As of 2009, U.S. crude-oil production was 4,950,000 barrels/day, with an additional import of crude oil and petroleum products reaching 11,114,000 barrels/day. This is a total of over 16 million barrels of oil, gas, and petroleum products per day! The United States is the largest user of petroleum in the world.

It was the growth of the automobile industry in the early 1900s that led to a sharp rise in the demand for oil.

Extracting Oil from Earth

When a drill breaks into the reservoir (or sedimentary) rock that is holding the oil, enormous pressure is released, causing the oil to gush out. This is called a blowout or a gusher. The deeper an oil well, the higher the pressure of the oil in the reservoir. Oil companies use equipment called blowout preventers to avoid gushers because blowouts pollute the surrounding environment, waste oil, and are dangerous for workers and equipment. The April 2010 explosion of the *Deepwater Horizon* in the Gulf of Mexico was the result of a blowout underwater because the blowout preventer did not work correctly. Eventually, the pressure in a well will decrease, and the oil will stop flowing on its own. This may take a few days or a few years, depending on the size of the oil reservoir. When the flow of oil begins to slow down, large pumps are used to remove the oil from the ground.

A natural tar seep. Tar, also known as asphalt, is a dense by-product of crude oil.

Oil has come to the surface of this rock in Ventura, California. Photo by M.Dosch, courtesy of the USGS.

A gusher in Kern County, California (1914). Photo: courtesy of the USGS.

Going Offshore

In the early days of the oil industry, oil was found closer to the surface. The first well was barely over 20 meters deep. However, most of the oil in deposits closer to the surface have now been pumped out. Oil-drilling technology has advanced so that now most wells are drilled to a depth of several thousand meters. With the United States's growing dependence on oil as a fuel and as a raw material to manufacture so many products we use every day, oil companies began exploring new areas in which to find oil.

Oil Refining

After oil is removed from the ground, it is refined to make it usable. Refineries transform the oil into products such as gasoline, diesel, and the raw material used to manufacture plastics, fabrics, drugs, pesticides, and detergent.

Crude oil is essentially a liquid mixture of hundreds of chemicals that are the remains of ancient sea life. In order for the fuels and materials to be useful, they must be separated out. First, the oil is sent to a distillation tower where it is heated to very high temperatures. Each type of chemical has a different boiling point. The liquids that evaporate more easily boil off first. The vapor from each type of chemical is collected, cooled, and condensed into a more pure liquid, such as gasoline, jet fuel, diesel fuel, or asphalt. Once the liquid products are separated into different types of fuels and materials, they are stored in large tanks before being transported to gas stations and factories.

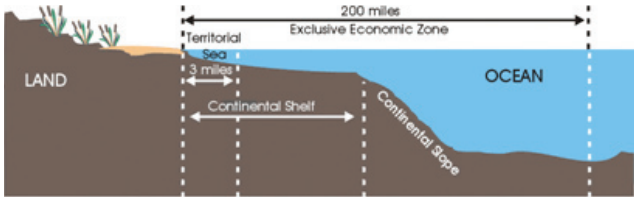
Events

347 AD: Oil wells up to 800 feet (240 m) deep are drilled in China by using bits attached to bamboo poles.

1594: Oil wells up to 115 feet (35 meters) deep are hand dug at Baku, Persia.

1750: A French military officer notes that Indians living near Fort Duquesne (now Pittsburgh) set fire to an oil-slicked creek as part of a religious ceremony.

1859: The first U.S. oil well is drilled 70 feet deep in Pennsylvania and produces 15 barrels a day.



This oil rig has drilled thousands of meters below the ocean floor in the hopes of finding oil. Oil-rig workers live on the rig for several days at a time. Oil rigs such as this one have blowout specialists and blowout-preventing equipment on board to prevent oil from gushing into the water.

1896: The first submerged oil wells in salt water are drilled from piers extending from land out into the Santa Barbara Channel, off the coast of California.

1901: The first U.S. oil boom begins with the drilling of the Spindletop oil field on the Texas Gulf Coast.

Vocabulary

blowout gusher, an uncontrollable release of oil pressure

hydrocarbons an organic compound consisting entirely of hydrogen and carbon

oil (also known as crude oil or petroleum) a naturally occurring mixture of hydrocarbons that are found in geologic formations beneath Earth's surface

reservoir rock porous rock layer where oil is trapped

Environmental Scientist

Task

Your job as the Environmental Scientist is to understand the benefits and risks of extracting oil for human use. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Environmental Scientist

- **Why are we so dependent on oil?**
- **What are the effects on the environment of using oil?**

Information

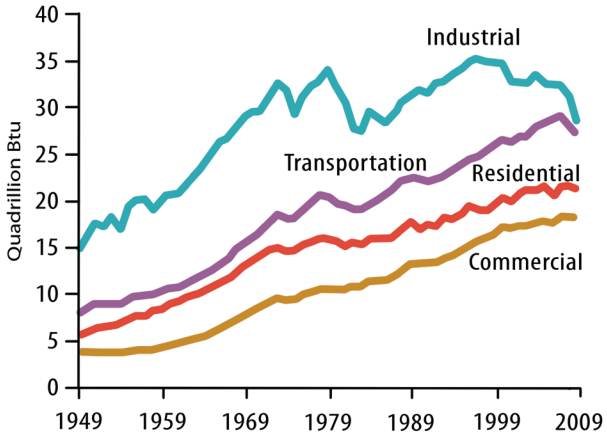
Whether we like it or not, we are currently oil dependent. Oil dependency means that we rely on this resource to maintain our way of life. Oil is the raw material for many of the products that we use—from the ink in your pen, to the plastic that your pen is made of, to a fleece jacket, to medicine you may have taken, to the plastic on your cell phone or video game. However, while oil is used to make a variety of products, most oil in the United States is used for transportation—as fuel for cars, trucks, and planes. Oil is a nonrenewable resource, which means that the oil supply is limited. There will come a time when there will be no more oil to fuel the cars that we drive. In order to deal with this issue, we will have to either change the technology around transportation or change the American lifestyle so we are less dependent on automobiles.

Oil Pollutes Air and Water

The effects of oil on the environment can be thought of in two ways—oil pollutes water, and oil pollutes the atmosphere. Crude oil can get into the water from offshore drilling, such as from the oil spill in the Gulf of Mexico. When oil leaks from cars, rainwater washes it into the water system as runoff. Oil and gas tanks buried underground can leak petroleum directly into groundwater, contaminating the drinking water.

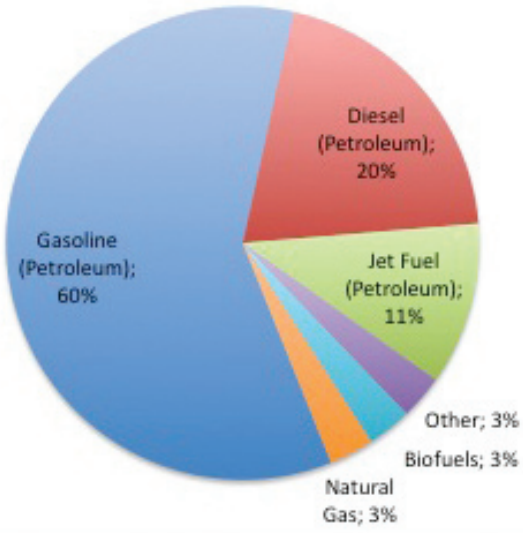
Whenever someone starts up a car, carbon dioxide (CO_2) is released into the atmosphere. CO_2 is released whenever gasoline is burned, and cars burn, or combust, gasoline in engines. While CO_2 is a naturally occurring gas that we depend on for life, too much CO_2 can have very negative consequences on global climate.

Energy Consumption by Sector, 1949-2009



Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 21a.

Fuel Used for U.S. Transporation, 2009



Carbon dioxide is a greenhouse gas that traps heat, which keeps Earth warm. An increase in greenhouse gases, such as CO_2, causes changes in climate. Over the last thousand years, there is evidence that both the levels of CO_2 and temperatures have increased.

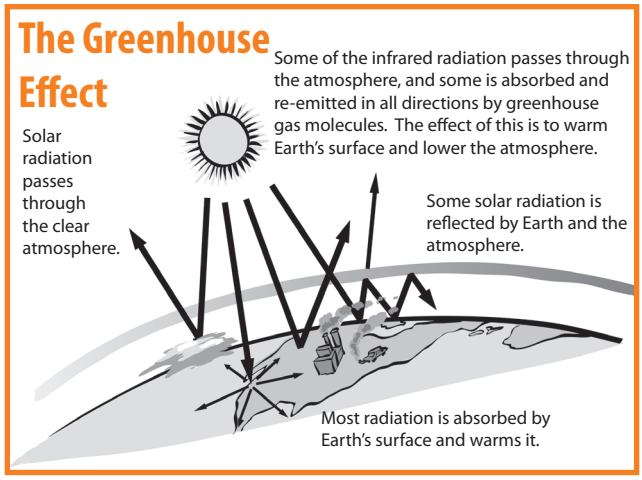
Events

1886: Karl Benz receives the first patent for a gas-fueled car.

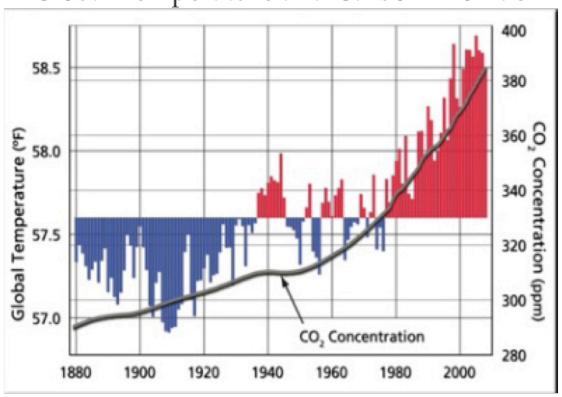
1908: The first Model T Ford car (a car for the masses) is introduced. This car used fueled gasoline, creating a higher demand for crude oil.

1950: With the growing use of automobiles, oil becomes (and remains) our most used energy source.

1960: The Organization of Petroleum Exporting Countries (OPEC) is formed by Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. The group has since grown to include 11 member countries.



Global Temperature and Carbon Dioxide



Notice how well the temperature rise follows the rise in the carbon-dioxide level. CO_2 levels are now higher than they have ever been.

1993: Due to increasing demand and declining production, the United States imports more oil and refined products from other countries than it produces.

2005: The Gulf of Mexico, one of the nation's largest sources of oil and gas production, is dealt a one-two punch by Hurricanes Katrina and Rita. Gasoline prices break $3.00 per gallon for the first time.

2010: On April 20, an explosion on the offshore drilling rig *Deepwater Horizon*, which had been drilling an exploratory well in the Gulf of Mexico, kills 11 crew members and gushes oil from the unfinished well into the ocean for a period of many months.

Vocabulary

greenhouse gases gases that absorb the Sun's radiation, creating a general atmosphere warming called the greenhouse effect. The main greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

nonrenewable resource resources for which the rate of our use far exceeds the rate of formation

renewable resource natural resource (such as sunlight, wind, wood, water, and geothermal heat) that can renew or replace itself and, therefore, can be harvested forever with proper management

Energy Policy Analyst

Task

As the energy policy analyst, your job is to explore how petroleum has been used as a resource over time and how that may change in the future. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for Energy Policy Analyst

- **How has our use of petroleum changed over time?**
- **How do you think it will change in the future?**

Information

Oil has played many roles as a resource throughout human history. Crude oil in the form of asphalt was used to build roads and construct walls and towers. In the Middle East, elements of natural oils were used for medicinal purposes.

Events

4000 BC: Egyptians use oil to embalm mummies.

3000 BC: The Mesopotamians use asphalt in architectural adhesives, ship caulks, medicines, and roads.

2000 BC: The Chinese refine crude oil for use in lighting and heating.

600–700 AD: Arab and Persian chemists discover that petroleum's lighter elements could be mixed with quicklime to make "Greek fire," the napalm of its day.

800: The Persian scholar Razi distills crude oil into the first kerosene.

1846: New methods of refining kerosene from petroleum provide a cheaper alternative to whale oil for lighting. Around the world, the demand for petroleum as a fuel for lighting quickly grows.

1910: Thomas Edison invents the first electric car, but production stops when the gas-fueled, internal-combustion Model T Ford becomes the car of choice.

1930s: Widespread use of plastics increases the demand for petroleum.

1950: With the growing use of automobiles, oil becomes (and remains) our most used energy source.

2005: The Energy Policy Act of 2005 passes, requiring increased use of renewable fuels for transportation and new measures to reduce pollution from gasoline and diesel.

2010: As crude oil continues to gush uncontrollably into the Gulf of Mexico, the Secretary of the Interior, Ken Salazar, announces a six-month hold (or moratorium) on all deepwater drilling.

Oil-lamp light.

Old-fashion kerosene lamp.

Model T Ford.

A massive parking lot.

Facts about Oil Use

Transportation: About 55% of oil goes to power the world's transportation system. While more renewable options are becoming more prevalent, 95% of the world's transportation currently depends on oil in the form of gasoline, diesel, or kerosene.

Food: It is estimated that people in the industrial world consume about 10 calories of fossil fuel for every calorie they eat. This is because oil powers the equipment that grows, processes, and transports that food. Even fertilizers and herbicides are oil based and gas based.

Electricity and Heat: About 70% of the electrical power in the United States comes from fossil fuels. In the northeastern United States, about 40% of the homes are heated by oil.

Chemicals and Plastics: We take for granted how much our modern lifestyle depends on petroleum products, such as plastics, drugs, detergents, synthetic rubber and fibers, asphalt, solvents, lubricants for machinery, etc.

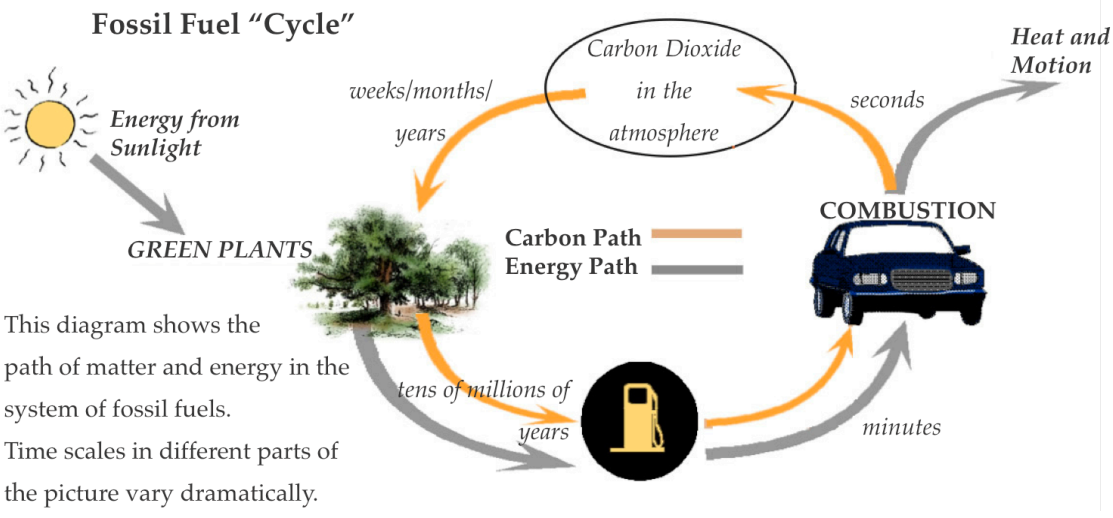
Vocabulary

asphalt a sticky, black, semi-solid substance that can exist in natural deposits or is created when purifying crude oil

crude oil (or petroleum) a naturally occurring mixture of hydrocarbons that are found in geologic formations beneath Earth's surface

deepwater drilling drilling in water more than 1,000 feet deep

kerosene a purified petroleum product used for heating, lighting, and jet fuel



This diagram shows the path of matter and energy in the system of fossil fuels. Time scales in different parts of the picture vary dramatically.