GEOLOGY

Where Does Oil Come From?

Before It Reaches the Tank of Your Automobile, It Must Be Found and Taken From the Reservoir Rock

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WHEN the gas in your tank begins to get low you hunt for a filling station. Usually you don't have to hunt very long, and if you have the price, your worries are all over until you have gone another 150 miles or so. But how about the oil company that sells you the gasoline—where does it get its gas? Does it have any worries when its supplies run low? Everybody knows that gasoline is made from oil that came out of wells, but how about these wells—how long do they last?

Unfortunately, oil wells don't last very long. After ten or fifteen years they usually don't produce so much oil. Then the oil company has to find new wells, which means locating new oil fields, because when an oil field is discovered, all the wells that can profitably be drilled on it are brought in as fast as possible.

Finding new oil fields costs a lot of money. Oil just isn't found everywhere. Most parts of the United States have produced no oil and offer little promise of ever producing any oil. Even in regions where oil is present, the oil is found in scattered places called fields or pools. Why should oil be so spotty? The answer is that it forms under very special conditions.

Three Essentials

Three things are necessary in order for an oil pool to form. First, there must be something present—source beds—to make the oil. Second, there must be some sort of a container—reservoir—to hold the oil after it has been generated. Third, there has to be a trap—structure—to prevent the oil from escaping, once it has collected in the reservoir.

Since oil is found in the ground, the three things needed for it to accumulate in commercial quantity have to be in the rocks beneath the surface. The substances that make the oil—the source materials—are in shales, sandstones, and limestones; the containers or reservoirs for the oil are sandstones and limestones; and the traps or structures are arrangements of the rock strata in such a way that the oil can not escape.

Strata containing oil-forming substances are similar to the sandstones and shales at the surface, but are buried at some depth. Sandstone and shale are composed of fine particles of sand and silt that have been carried by streams and have settled at the mouths of the streams at the bottom of some quiet body of water, such as a bay or lagoon. Most rivers are muddy, but the oceans are clear. The sediment carried in suspension by streams disappears after the water reaches the sea. The only place for this sediment to go is down to the bottom, so along the coast line the sediment brought down by rivers is dumped in bays and lagoons or close to shore in the ocean. Year after year the rivers carry sediment and drop it when they reach the sea. The sediment deposited last year is buried by the sediment brought down this year, and that in turn by the sediment supplied next year, and so on for countless ages. In this way the bays and lagoons and even the sea near the shore are filled with sediment. If the land sinks as the sediment is supplied, several thousand feet of sandy and silty material may accumulate.

Turn to Rock

In the course of time, the sediments consolidate and change to hard rock. The sand becomes cemented together and forms sandstones and the silts and muds are compacted to form shales. The substances that make oil are deposited in the sediments along with the sand and silt particles and become a part of the rock.

Oil collects in minute droplets, widely distributed through the sands and shales. Before the oil can be recovered at a profit, it must gather into relatively large quantities. Very rarely does oil accumulate in an actual pool underground. Instead, it saturates a porous rock bed.

Ordinarily, oil collects in sandstone. Sandstone is composed of grains of sand cemented together. The cement usually does not fill in all the space between the sand grains, and the oil gathers in the open spaces between the grains. The process is analogous to filling a glass with bird shot. After the glass has been filled with shot, considerable water can be poured into it. In fact, the amount of water that can be poured in is more than one-fourth the capacity of the glass.

CRUDE OIL TO GASOLINE

Crude oil will not run the ordinary automobile. Parts of it are distilled off for motor fuel, then the oil is destructively distilled, "cracked", to give more gasoline. This tower, photographed by Socony-Vacuum Oil Co., makes possible still greater recovery of gasoline from the crude oil.

Similarly, if a gallon pail is completely filled with birdshot, it will still hold a quart of water without overflowing. Grains of sand are roughly rounded, and although they are not as spherical as birdshot, the vacant space between them is about one quarter of the volume of the space enclosing them. Whether the rounded objects are cannon-balls or pansy seed, the space left vacant between them is always about one quarter of space occupied, as long as all the spheres packed are of the same size. As some of the space between the sand grains in a sandstone is filled with cement, the vacant space is never more than one quarter the volume of the rock, and may be much less. Ordinarily, the pore space is from one tenth to one fifth the volume of the rock. If all the pores in a rock are filled with oil, a cubic foot of rock would hold from one tenth to one fifth of a cubic foot of oil, and it would take from twenty-five to fifty cubic feet of rock to hold a barrel of oil.

Oil can also accumulate in limestones. Water percolating through limestone may dissolve some of the limestone, leaving cavities. These cavities may act as suitable reservoirs and later become filled with oil.

Traps

Oil moves freely through the pore spaces of a reservoir rock, and unless a trap is present, it will not accumulate in commercially-valuable quantities. Wherever oil is formed, with a very few exceptions, water is present, going through all the pore spaces. If both oil and water occupy the open spaces in a reservoir rock, the oil, being lighter than water, rises to the top.

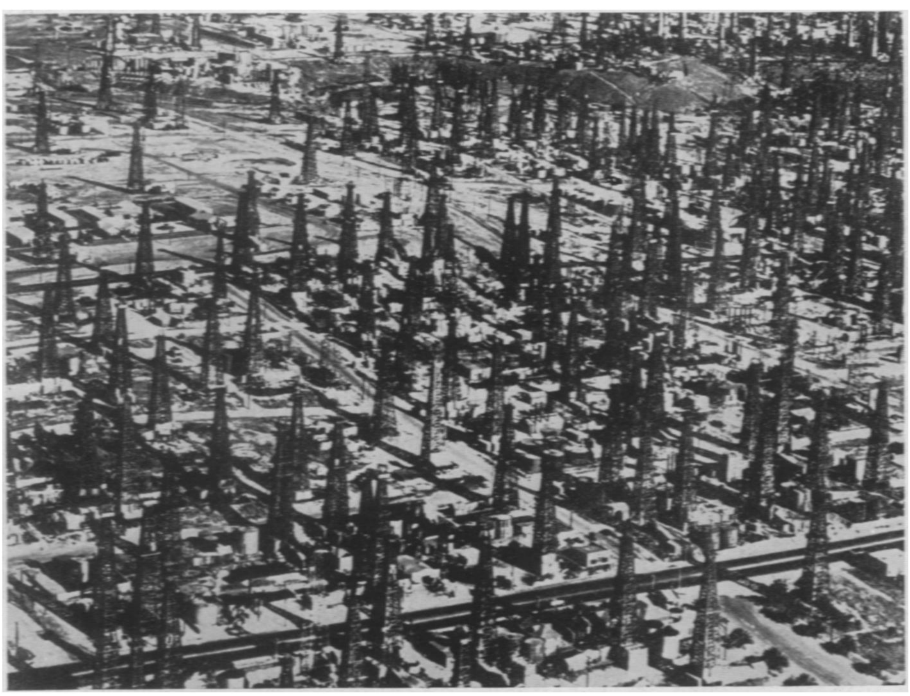
If the pore spaces in the rock are continuous to the surface of the ground, the oil passes upward through the water until it reaches the surface, where it may escape. In order for the oil to accumulate in sufficient quantity to make an oil pool, it has to be caught in a trap where it can not escape. These traps are called structures and are what the oil prospector tries to find while searching for oil. The commonest type of trap is the anticline.

An anticline is the arch formed when a series of rock strata have been folded. Oil is found in many such arches. If the rock layers overlying a sandstone consist of shale that has no pore spaces, oil that accumulates in the sandstones can not escape upward through the shale that lies above it.

If such an impervious shale overlies a sandstone in an anticline, any oil in the sandstone passes upward through the water until it reaches the overyling shale and then rises up the flank of the anticline immediately beneath the shale until the top of the arch is reached, where it can go no higher. There at the crest it meets oil particles that have moved upward from the other side of the anticline. The oil thus is trapped at the top of the arch and as more and more oil rises up the flanks, the quantity of oil at the crest increases until it forms a pool in the solid rock.

Salt Domes

The anticline is only one of several types of traps. Another kind is the salt dome. Salt domes are found in several places along the Gulf Coast of Texas and Louisiana. Salt Domes are formed when a mass of salt hundreds or thousands of feet in diameter shoves its way upward from the depths toward the surface. As the salt rises through the rock strata, it bends them upward and breaks some of them off. Oil enclosed in porous sandstones between impermeable shales rises up the inclined strata until it reaches the salt, which it can not penetrate. As a result, the oil is trapped against the salt and gradually enough accumulates to form an oil pool.



AN OIL FIELD

This California oil field shows the great concentration of wells on a productive area over a structure. When a structure is found, every owner drills his leased area immediately, for the oil migrates, and unless the leased area is put into immediate production, other wells will take all the oil from beneath it.

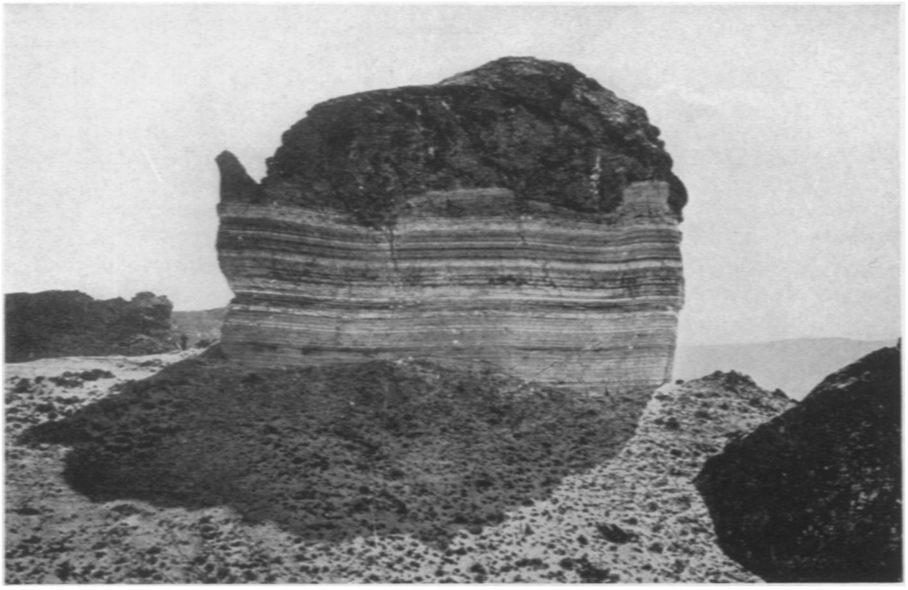
Source Beds

The main thing in the accumulation of oil is to have something to make the oil. If there are no substances in the ground that can generate oil, no oil field will form. Not much is known about these mother substances of oil except that some sandstones, shales, and limestones contain them, other sandstones, shale and limestones do not. It is very advantageous to an oil company in trying to find a new oil field to know how plentiful source materials of oil are in the area it is considering prospecting. Dry holes cost a lot of money. Formerly it cost only a few thousand dollars to drill an exploratory well for oil, but now $50,000 is a common figure, and as much as $500,000 has been spent on some wells. Hence, if no oil is found in a well, a lot of money has been wasted.

If the people who explore for oil could know in advance that there was no possible source beds of oil in the area they had in mind, they could save much money by not drilling. Or if, after drilling one well, they could tell from the rock cuttings that there was nothing in the ground to make oil, they would be saved the expense of drilling additional wells. On the other hand, if they could ascertain from the cuttings that good source materials were present, they would be encouraged to do further drilling in the hope of finding an adequate trap or structure.

Good Region

In areas such as the Gulf Coast of Texas, oil has been found over such a widespread area that a person drilling for oil is reasonably certain that if he can locate an adequate trap — a salt dome—he has a good chance of finding oil. Favorable source material seems to be present under most of that region. But when he tries to extend the limits of known producing territory toward Mississippi, Alabama, Georgia, and Florida,



TEAPOT ROCK

This rock, from which Teapot Dome Oil Field took its name, is a mass of sandstone and shale, capped with a thick layer of sandstone. These sandstones and shales are similar to those which produce and contain oil at some depth below the surface. Photo by William H. Jackson

where little oil or gas has been found, he is by no means certain that even in a suitable structure or trap he will find oil.

Knowledge of source material is especially worthwhile to companies exploring in foreign lands. Such companies commonly are given concessions to prospect in a large region with the privilege of selecting some small part of the general area for development of oil. Often the selection of the particular areas for development has to be made within a certain time limit, before extensive drilling to test the areas can be completed. Knowledge of source beds would be especially helpful in such a case. The company then could be much more certain that they would be likely to find oil in the areas they had chosen than if they had proceeded according to present conditions of inadequate knowledge of source beds.

In the United States more than $50,000,000 a year is spent on dry holes—on wells that yield no oil. Except for the information obtained from these wells this money is wasted. Many of these dry wells are drilled in areas where little or no source material for oil is present. If we just knew what areas were deficient in source material, the petroleum industry could be saved millions of dollars.

The main problem is to find a way of recognizing source beds of oil. The problem is attacked in just the same way as a detective tries to solve a mystery. Clues have to be found and followed until they lead to the successful unravelling of the mystery. Each clue eliminates some of the possibilities that originally had to be considered, and as clue after clue is found, the possible solutions become fewer and fewer until only one—the right answer—is left.

Our first clue is that we know oil comes from certain types of sandstones, shales, and limestones, but these types of rocks, though all derived from material deposited in some body of water, can form under so many different conditions that thousands of samples have to be studied in order to be sure that any particular substance in a sediment really is an oil-forming substance.

The rocks in which oil is found are now many millions of years old. The mother substances of oil they contain have undergone changes while the rocks have lain in the ground. The source materials may have been almost completely destroyed during the process of generation of oil and the things left may have very little to do with the formation of oil. Therefore, in order to tell whether a rock is a source bed, it may be necessary to find things which themselves perhaps cannot yield oil, but yet which indicate that the rock once contained substances that could yield oil.

Examine Sediments

In order to study these changes in the possible mother substance of oil, it is necessary to examine the sediments now being deposited along the present coast line. We have reason to believe that the things now accumulating on the sea bottom are similar to the things that were laid down in the ocean millions of years ago. The first study undertaken was of the sediments now being deposited along present sea coasts.

The conditions under which oil is found today make it apparent that mother substances of oil are commonly laid down close to shore. So many oil fields are located so near the shore at the time the sediments were deposited that nearness to the present coast was a good clue to use in trying to unravel this mystery of oil.

Petroleum consists of substances that contain carbon. Carbon is one of the 90-odd chemical elements of which the earth is composed, and is the element most necessary to life. In fact, except for the carbon dioxide in the air we breathe and in the mineral carbonates in limestone, the main source of carbon is the tissues of plants and animals. Another clue in our mystery, therefore, is that petroleum must come from carbon compounds that are derived from the remains of plants and animals.

The next problem, then, is how the remains of these plants and animals got into the rocks. The answer is that they were deposited in the sediments along with the silt and clay brought down by the streams.

The main source of the carbon compounds in the sediments was found to be small microscopic plants that live by the billions and trillions in the surface water of the ocean. These small plants are eaten by animals in the sea, but these animals, just like any other animals, cannot digest everything they eat, so they excrete parts of the original plant material as indigestible residues. Most of these ultimately sink to the sea bottom and become buried in the sediments. Some of the plants are attacked by germs, or bacteria as they are technically called, and the parts of the plants the germs can not destroy likewise sink to the sea bottom, where, together with all the other organic matter (carbon compounds) that have accumulated in the sediments, they are attacked by yet other animals and germs, and still more indigestible residues are formed. It is from these unusable residues that oil is generated.

Oil is not formed in soft sediments. No trace of petroleum is found in sediments now being deposited. A considerable time after the sediments accumulate, perhaps millions of years afterward, chemical changes take place which transform the bacterial excrements into oil. Today, oil chemists believe that only certain of these undigested residues can be transformed into oil.

Studies of more than 30,000 samples of rock, mostly from drill-cuttings, have shown geologists that a complex chemical property of the rock, called the nitrogen-reduction ratio, is a valuable clue to its oil possibilities. While not an infallible clue, the presence of a high nitrogen-reduction ratio is a good indication of no oil, while a low ratio indicates a good possibility of oil production from a suitable trap in the rock layer.

The nitrogen-reduction ratio is the best known clue to the oil possibilities of a rock. It does not work for every sediment, just as radium will not cure every cancer, but the "batting average" of the nitrogen-reduction ratio test is high. Like radium in the cure of cancer, the nitrogen-reduction ratio offers promise in the finding of oil, but further research will be necessary on both radium and the nitrogen reduction ratio before their full possibilities become useful.

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Many peoples of the world have used gourds as bottles and dippers.

METEOROLOGY

New Observatory Can Stand 200-Mile-an-Hour Winds

By DR. CHARLES F. BROOKS

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See Front Cover

AFTER five years in the stage office of the Mount Washington Auto Road Company, the famous weather observatory on the summit of this stormy mountain has just moved into a building of its own.

By direction of Col. Henry N. Teague, president of the Mount Washington Railway Co., an extraordinarily sturdy building has been constructed. People who have ridden on the cog railroad have noted the size of the timbers making up the trestle on Jacob's Ladder and elsewhere—9 x 10 inches and 24 feet long. These same timbers when replaced have been cut to 22 feet and mortised for the framework of the new building.

It is probably safe to say that nowhere in the United States is a frame building of more solid construction to be found.

The Observatory wants to take no chances of being blown away if another 200 mile-an-hour wind comes along! In such a wind in April, 1934, the Stage Office danced about as much as its heavy chains would permit, and its walls now and then bellowsed in and out. The pressure inside the building varied between gusts by 0.2 inches on the barometer. This is the equivalent of a change of pressure of a ton on the surface of the building in the course of a few seconds.

Mt. Washington, highest peak in the northeastern United States and therefore a mecca for summer tourists and hikers, has had many buildings erected on its summit during the course of the last century. Everyone of the old-timers with the exception of Tip Top House burned down in the great fire of 1908. Two of them blew down. Today most of the buildings atop the peak are chained down.

The basal frame of the new building is fastened to ten long bolts that extend downward at least five feet into rock or huge blocks of concrete poured in holes among the rocks. The corners of this frame are bound with heavy diagonal steel rods.

The frame consists of twelve big uprights suitably connected by horizontal timbers at the level of the second floor and all braced by 6 x 6's. The rafters are 3 x 8's closely spaced. It is obvious that if the building is to blow away it will have to go as a unit and take a chunk of the mountain top with it.

The windows for the Observatory are of double plate glass presented by the Pittsburgh Plate Glass Company, which will have a chance to prove their strength and insulating qualities under the severe conditions experienced on the mountain in winter. Several of the window units are fitted with thermocouples.

The building is now completed except for minor inside work. It has for walls one layer of shingles much overlapped, two layers of boarding, two layers of paper, one layer of Cabot quilting (a gift of a warm-hearted friend), and one layer of fireproof wallboard. It is not anticipated that much wind will come through this!

Heat is supplied from a hot-air furnace, and water from a 2,500-gallon tank inside the building, filled with water from the Base Station by the pump of the Mt. Washington Club. Before spring, water obtained from melting rime will probably be more palatable than the tank water.

The building is to be rented from the cog railway company by the corporation which has been formed to operate the observatory building. The corporation aims to "make, summarize and report scientific observations, chiefly geophysical, in the vicinity of Mt. Washington, New Hampshire; to conduct radio studies on Mt. Washington; and to further public safety and public appreciation of scientific work on Mt. Washington."

The U. S. Weather Bureau will continue to maintain half of the personnel of the observatory and a portion of the instrumental equipment as well, while the Blue Hill Observatory of Harvard University will direct the scientific activities and supply such special apparatus as may be needed.

The financial support of the observatory, outside of the Weather Bureau's participation, is chiefly from the state of New Hampshire, which has appropriated $1,500 toward expenses this year; various interested organizations and in-