PETROLEUM

A PRIMER FOR NORTH DAKOTA

BY
ERLING A. BROSTUEN

EDUCATIONAL SERIES 13
NORTH DAKOTA GEOLOGICAL SURVEY
LEE C. GERHARD, STATE GEOLOGIST

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Lee C. Gerhard, *State Geologist*

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ILLUSTRATIONS

INTRODUCTION

This publication has been prepared to assist the layman to gain a better understanding of the petroleum exploration, development and production activity that is taking place in North Dakota. The publication describes in nontechnical language the origin of petroleum, the manner in which it is explored for, and produced. A discussion of minerals, mineral rights, royalty, and leasing is included.

The North Dakota Geological Survey makes geological educational aids available to North Dakota schools and other organizations. These aids include taped lectures and collections of selected slides, both of which may be borrowed free of charge. Members of the Survey staff are available to give illustrated lectures on arrangement. Rock and mineral collections are available to schools. Numerous technical maps and reports dealing with various aspects of North Dakota geology are also available at nominal costs.

Further information may be obtained from the North Dakota Geological Survey, University Station, Grand Forks, North Dakota 58202.

PETROLEUM

Petroleum is an organic substance consisting of molecules composed of hydrogen and carbon atoms. These molecules are derived from the remains of living organisms such as plants and animals that thrived during prehistoric times. Materials composed of such hydrogen and carbon compounds are known as hydrocarbons. Because they are found in rock, they are also known as petroleum, a word derived from the Latin words for rock (petra), and for oil (oleum).

Most petroleum exists in one of two forms: liquid or vapor. The liquid form is known as crude oil, and the vapor form is known as natural gas. Some petroleum exists as a solid as tar sands and oil shale; however, no deposits of solid petroleum are known to exist in North Dakota.

Geologists believe that petroleum began with organic matter consisting of the remains of countless plants and animals that lived in the sea or were washed down into the sea with mud and silt from streams. They accumulated in the sediment as it built up on the sea floor. The organic matter contained the essential elements of hydrogen and carbon which, following gradual decay and subjection to bacterial and chemical action, radioactivity, intense heat and pressure, and with the passage of time, were converted to petroleum (fig. 1).

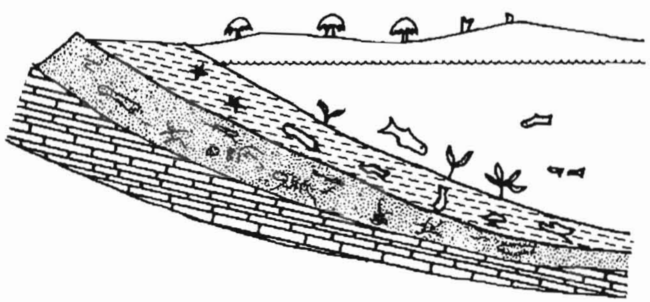
THE GEOLOGY OF PETROLEUM

Oil and gas occur in sedimentary rocks. Sedimentary rock is formed from materials resulting from the decomposition, weathering and wearing away of pre-existing rocks (sediments) which have been transported and deposited in seas or on land. It is generally believed that oil and gas originate within sedimentary rocks which have been deposited in the sea. Such sedimentary rocks are known as source rocks because oil and gas have their origin or source within them. Sedimentary rocks include a variety of rock types including shale, sandstone, carbonates, and evaporites. Typical carbonate rocks are limestone and dolomite. Evaporites include salt, potash, and anhydrite.

During much of geologic time, the area that is now North Dakota was covered by shallow seas. While the seas existed, materials that were eroded from then-existing nearby land masses were transported by streams either as suspended solids such as sand and clay particles, or in solution as dissolved salts. These eroded materials were eventually deposited as sediments within the seas. As the plant and animal life that flourished in these ancient seas died, it was buried beneath more sediment (fig. 1).

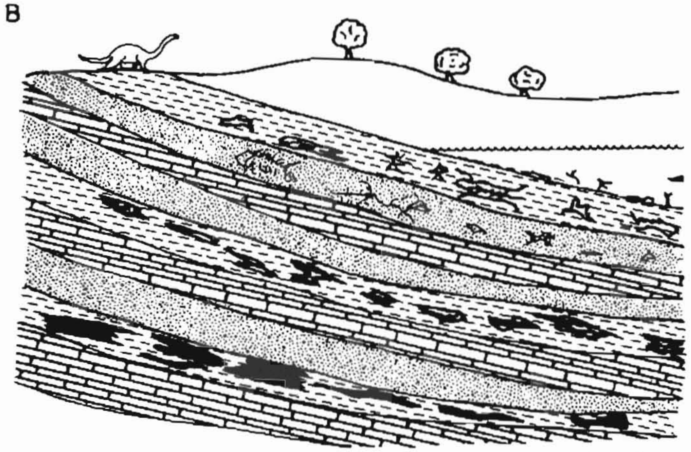
Periodically, the seas withdrew and the previously deposited sediments (then dry land) were subjected to erosion. When the seas again advanced, a new cycle of plant and animal growth, death, and burial by sediments occurred. The cycle was repeated many times over periods of hundreds of millions of years, and the deposited sediments built up to great thicknesses. In western North Dakota, the tremendous weight of the sediments resulted in compaction and downwarping of the earth's crust to form a bowl-shaped basin, known today as the Williston Basin. At the center of the

A



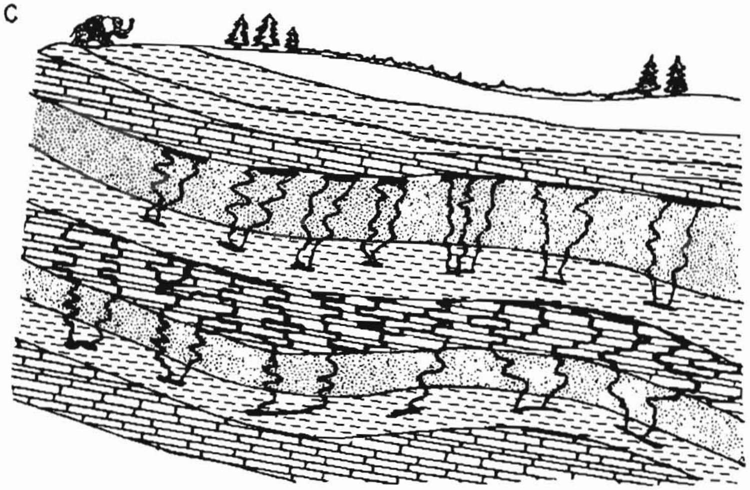
A. Shows life existing in an ancient sea hundreds of millions of years ago and the death and burial of organic matter in the sediments.

B



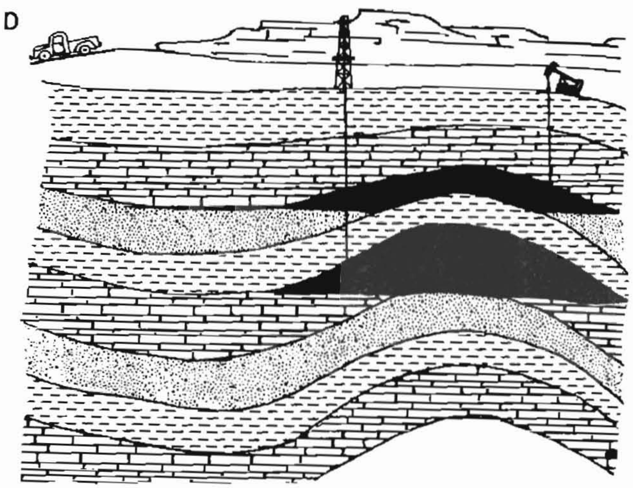
B. Millions of years later, life still exists in a shallow sea and the sediments have increased in thickness. The organic matter is being altered into petroleum.

C



C. The sea no longer exists. Petroleum is migrating from the source rocks into porous rocks.

D



D. The rocks have been folded forming an anticline. The petroleum is trapped at the crest of the anticline.

Figure 1. Diagrams showing the origin of petroleum.

basin the accumulated sedimentary rock layers are over 16,000 feet thick.

Sedimentary rocks differ in their physical characteristics. Shale is composed of fine-grained materials such as clay particles. It is one kind of source rock in which oil and gas originated, but it is too dense and too solid to retain oil and gas. Evaporites are composed of minerals that precipitated as the sea water evaporated and was therefore no longer able to hold dissolved minerals in solution. Evaporites do not contain organic matter, and they are not considered to be source rocks. They are also too dense and too solid to allow oil and gas to pass through them. Even so, shale and evaporites are important because they may form barriers necessary for the entrapment of oil and gas.

Sandstones and carbonates may contain void spaces--pores--and so are said to have porosity (fig. 2). Some porous rocks also have connecting channels between the pore spaces. These channels allow oil and gas to pass from one pore space to another. When these channels are present, the rock is said to have permeability (fig. 3). Sandstone, unless it is tightly cemented, usually has porosity and permeability, properties that the sand had as soon as it was deposited. For this reason, sandstone is said to have "primary porosity." Carbonates may also have primary porosity, but more often their porosity is the result of groundwater seeping through them, dissolving away some of the material and leaving void spaces. It may be caused by the chemical alteration of limestone to dolomite. Porosity formed in this way is referred to as "secondary porosity," meaning it developed sometime after the rock was deposited.

Porosity and permeability are two qualities required to form a reservoir rock, which is any rock that can contain oil and gas. Oil, gas, and water may move through porous and permeable rock until the movement is halted by some kind of a trapping mechanism (a trap). Traps may result from the buckling, folding, and fracturing of the earth, or they may be due to variations in rock characteristics or lithology resulting from cyclic periods of deposition and erosion, limited development of secondary porosity, or the filling of pore spaces with non-porous material. Regardless of how they form, all traps consist of porous rock layers covered by layers of non-porous rock.

Most North Dakota oil and gas traps fall into one of two categories (fig. 4). They may be either "structural" traps or "stratigraphic" traps, or they may be a combination of both. Structural traps include "anticlinal" traps or "anticlines" or they may be "fault" traps. Anticlinal traps formed when alternating layers of porous and non-porous rock were folded or arched into the form of an inverted trough or bowl. Oil and gas can accumulate at the crest of such a structure and be prevented from escaping by the overlying non-porous rock layers. A fault trap forms when layers of rock fracture and the rock on one side of such a fracture moves up or down relative to the rock on the other side of the fracture. This can result in an uptilting of a porous rock layer, which may be pushed into contact with (thrust against) a non-porous rock layer.

Stratigraphic traps can occur in many ways. Oil and gas that accumulates in porous rock layers is prevented from escaping due to changes in porosity and permeability, either in the rock layer itself, or by confinement against a non-porous rock layer. Typical stratigraphic traps may consist of ancient beaches, sand bars, or stream sediments enclosed within non-porous shales, or they may be uptilted, porous rock layers, which at some point in geologic time were partially eroded and subsequently buried beneath non-porous rock layers. Stratigraphic traps may also result from the partial filling or plugging of pore spaces within otherwise porous rock layers by non-porous materials such as salt and anhydrite. Still other stratigraphic traps may be due to the limited development of secondary porosity.

MINERAL RIGHTS AND LEASING

The ownership of minerals underlying the surface must be determined prior to their leasing for oil and gas exploration. In many cases, the minerals are owned by the surface owner, but sometimes the minerals have been severed, or separated, from the surface ownership. In this section we will

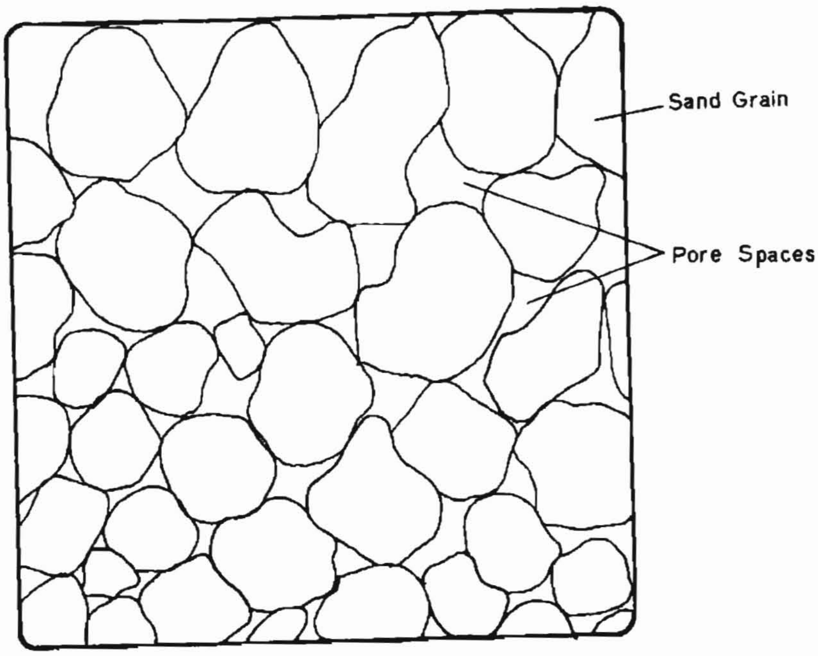


Figure 2. Illustrating porosity in a sandstone. Oil may accumulate within the pore spaces between the sand grains.

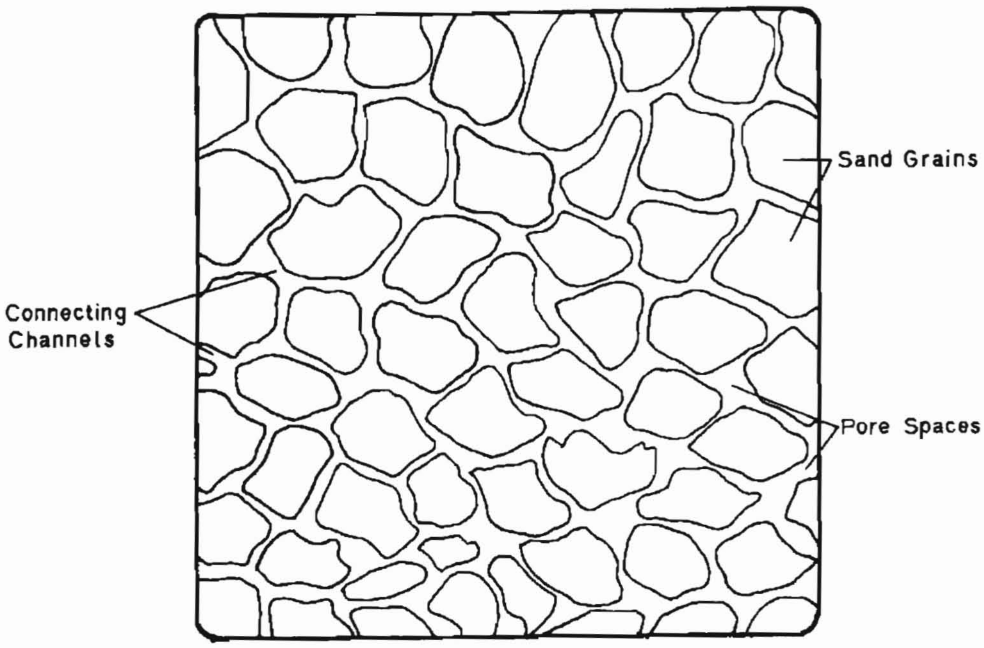


Figure 3. Illustrating permeability. The connecting channels between the pore spaces allow the passage of fluids or gases from one pore space to another through the rock. When these connecting channels are present, the rock is said to be permeable.

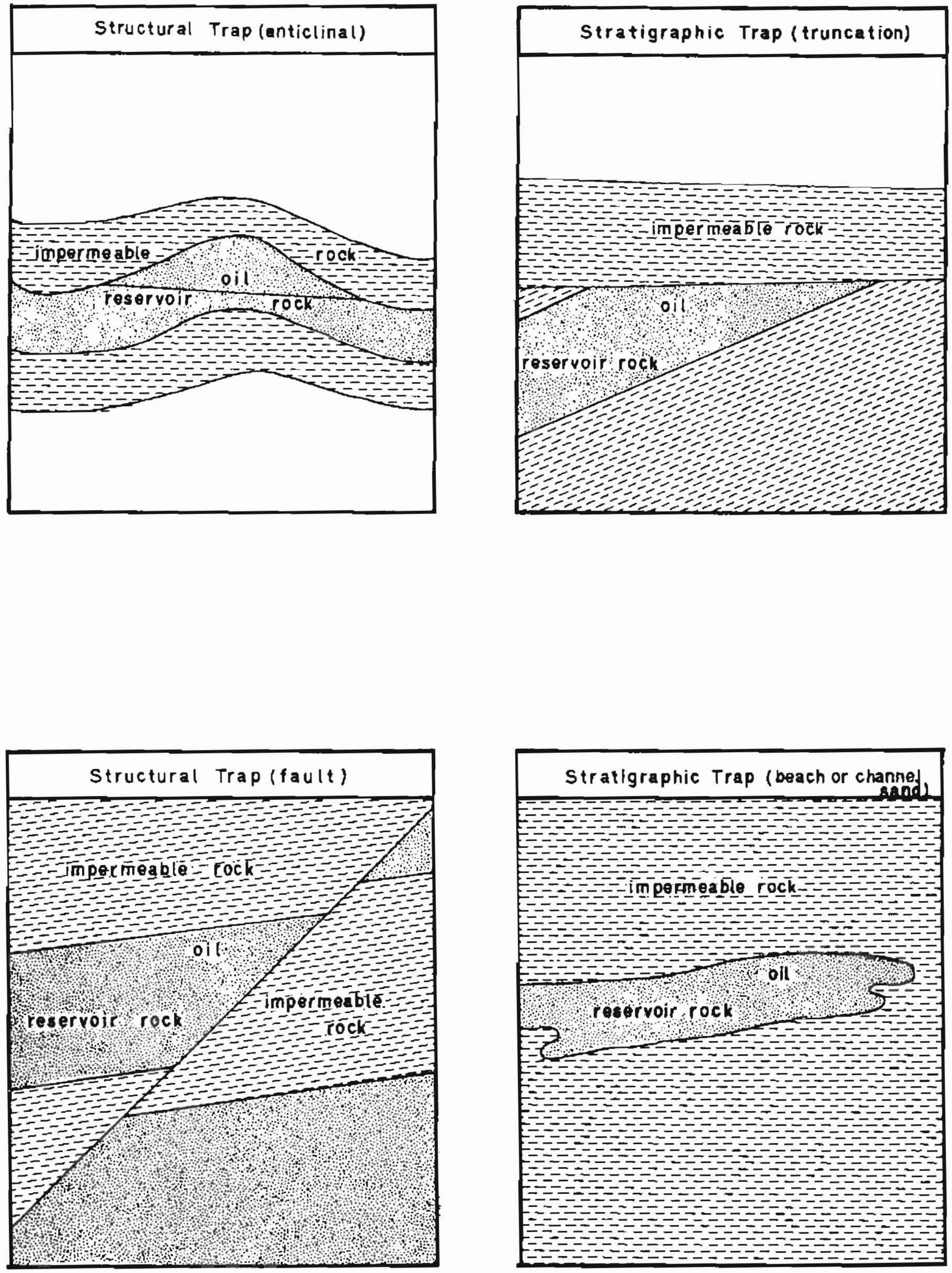


Figure 4. Illustrating kinds of traps in which oil and gas are known to accumulate.

discuss minerals, mineral rights, and leasing.

Minerals

The term minerals, as it is used in the discussion of mineral rights, has been defined to include some substances of organic origin such as oil, gas, and lignite as well as substances of inorganic origin such as sulfur, bentonite, and potash.

Mineral Rights

Mineral rights may be defined as the right of ownership of the mineral resources which underlie a tract of land. With the right of mineral ownership is the right to explore for, develop, and produce the mineral resources.

Because most minerals are found below the land surface, it is convenient to refer to mineral rights as subsurface rights to distinguish them from surface rights, such as land ownership and the right to use the surface for agricultural purposes, urban development, etc. Mineral rights are also sometimes referred to as the mineral estate, and surface rights as the surface estate.

Severed Mineral Rights

Mineral rights may be severed or separated from surface rights by mineral deed or by mineral reservation.

Severance by mineral deed occurs when a party owning both surface rights and mineral rights sells or grants by deed all or a portion of the mineral rights underlying his property. This deed, known as a mineral deed, is registered with the county register of deeds and will become a part of the abstract of title to the land involved.

Severance by mineral reservation occurs when a party owning both surface rights and mineral rights sells or grants by deed the surface rights of his property, but retains all or a portion of the mineral rights. Severance of minerals by mineral reservation has been widely practiced by federal and state governments, land-grant railroads, and lending institutions, as well as by individuals. Mineral reservations are recorded with the county register of deeds and are included in any abstract of title to the land involved.

Leases and Leasing

In most cases the expense of exploring for and developing oil and gas resources by the individual mineral rights owner is prohibitive. A single well may cost over a million dollars for drilling and well-completion operations. As a result, most exploration and development is undertaken by companies or individuals, which have sufficient capital to finance such ventures.

Before a company can begin an exploration program, it is necessary that it obtain valid leases to the oil and gas rights within the area in which it wishes to explore. This activity is called leasing.

Leasing is conducted by oil company landmen or by lease brokers. An oil company landman is a person in the employ of the company who is engaged in the negotiating of lease agreements with mineral rights owners. A lease broker is a person or a company which negotiates lease agreements on behalf of a company or individual. The lease broker may acquire leases in the name of the oil company or may acquire them in his own name and later assign them to the company that has retained his services.

An oil and gas lease agreement is a legal instrument which provides for the granting by the mineral rights owner (lessor) to the oil company (lessee) the right to explore for and develop the oil and gas resources which may underlie the area described in the lease. A lease agreement contains a number of stipulations usually including but not necessarily limited to:

1. A legal description of the area included in the lease and the number of acres involved.
2. An effective date of the lease agreement and the anniversary date for the lease on or before which annual lease rental payments must be paid to keep the lease in force.
3. A statement as to the primary term of the lease. This may be of any mutually-agreed-to period of time, but is usually for five or ten years.
4. A provision for the payment of annual lease rentals by the lessee to the lessor. These

rentals are paid in order to maintain the lease in effect throughout the primary term and are paid in lieu of royalty payments. In the event that oil or gas production is found, the lease will remain in effect so long as production continues, even beyond the primary term of the lease.

5. A royalty clause, which indicates the share of oil and gas production that is reserved to the mineral rights owner. Royalty is usually indicated as a fraction or percentage of the oil or gas that is produced. It may be any amount mutually agreed to between the lessor and the lessee but is usually 1/8 (12½%) of production. If a larger share is to be reserved to the lessor, it is usually provided for with a separate overriding royalty agreement and only the 1/8 (12½%) is stated on the lease. Royalty may be received in kind, that is, the lessor may take physical possession of the oil or gas, but usually the oil or gas is sold to a refiner and the lessor receives payment for his share.

EXPLORATION

Exploration for petroleum takes many forms. It is the responsibility of the petroleum geologist to search for, analyze, and interpret the geological clues that may indicate the presence of the three necessary conditions for the accumulation of petroleum. These conditions include: 1) a source rock such as shale that is rich in organic material; 2) a reservoir rock such as porous and permeable limestone, dolomite, and sandstone; 3) a trapping mechanism such as a structural or stratigraphic trap. The petroleum geologist is assisted in this work by geophysicists, paleontologists, and geochemists.

The surface of the earth may give clues as to what may lie hidden below. Rivers and streams eroding their way across the landscape may expose layers of sedimentary rock and give indications of geologic structures such as anticlines and faults. The study of river and stream drainage systems from aerial or satellite photographs may indicate patterns that are possibly related to subsurface structures. Geologic formations that are known to underlie a portion of North Dakota may be exposed on the surface in another part of the state or in an adjacent state. The study of these exposed rocks may give the geologist information about the characteristics of the formation where it lies buried beneath the surface (fig. 5).

The geologist will also search out all of the available geological information for the area in which he is exploring. In North Dakota, a wealth of geological information and data are available at the office of the North Dakota Geological Survey and the geology library at the University of North Dakota.

Geophysics

Geophysical surveys are a basic exploration tool. They include magnetic, gravity, and seismic surveys.

Magnetic surveys are conducted with the use of a tool known as a magnetometer. The magnetometer measures the variations in the earth's magnetic field. Sedimentary rocks generally have low magnetic properties compared to igneous and metamorphic rocks, which are more dense and contain more iron. Generally the earth's magnetic field is slightly stronger over the top of an anticline or the raised side of a fault because the more magnetic igneous and metamorphic rocks are closer to the surface. Magnetic surveys are conducted with small portable instruments which may be carried in light trucks on the surface or aloft in airplanes (fig. 6).

Gravity surveys are conducted with the use of a gravimeter. A gravimeter measures variations in the earth's gravity which are caused by differences in the density of various types of rock. Sedimentary rocks are generally less dense than igneous and metamorphic rocks. Gravity is slightly stronger over the top of an anticline or on the raised side of a fault because the denser igneous and metamorphic rocks are closer to the surface (fig. 7).

Gravity and magnetic surveys have similar applications even though they are measuring different characteristics

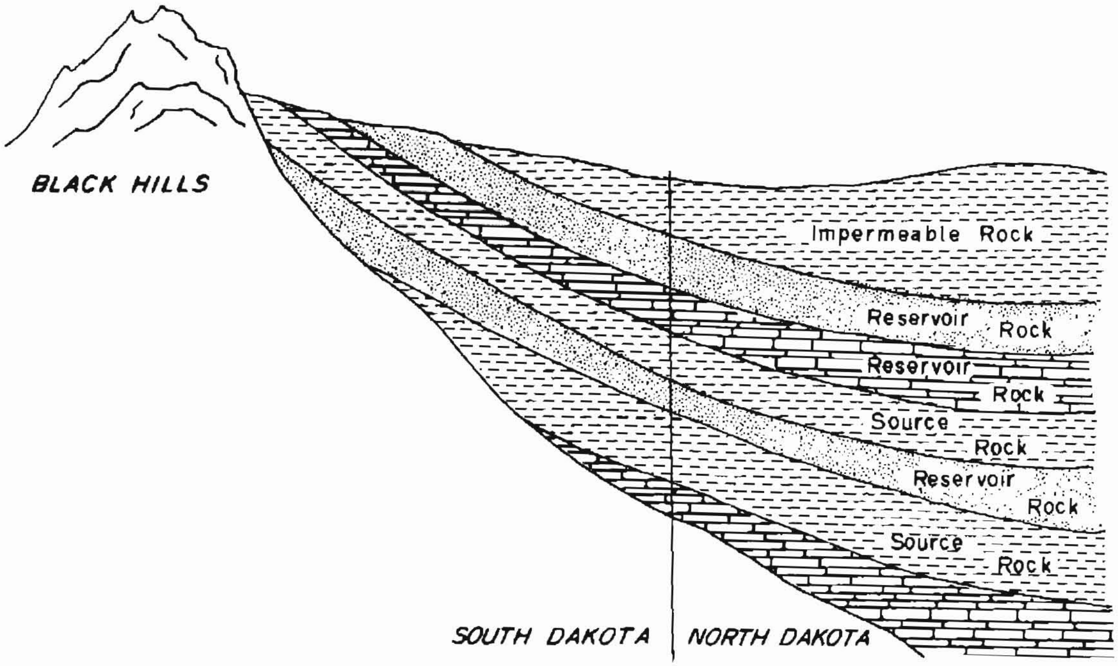


Figure 5. Geologic formations that underlie parts of North Dakota may be exposed at the surface elsewhere. Geologists study the rocks where they are exposed for information that may aid in the discovery of oil and gas in North Dakota.

of rocks. Both kinds of surveys generally cause little or no surface disturbance.

Seismic surveys, commonly known as seismographing, are the most popular method of obtaining subsurface structural information without the drilling of deep and expensive wells. Seismic surveys are conducted by creating a shock wave at or near the earth's surface and then recording the velocity at which the shock wave penetrates the layers of rock and is reflected back to the surface. The speed at which the wave travels changes whenever it reaches a change in rock characteristics such as when it passes from a shale into a limestone. The reflected signals or shock waves are detected and measured at the surface by seismometers, which have been placed on the ground at specific intervals. The seismometers are connected to a recorder truck where the reflected signal is recorded. The recorded signal is known as a seismogram (fig. 8).

Seismic shock waves travel through different rock types at different velocities. A seismic shock wave will travel through limestone at a different velocity than it will travel through shale, sandstone, or evaporite. By comparing the seismogram with the known velocity of a shock wave in various rock types, the geophysicist can determine the approximate depth of various formations and the possibility of the existence of subsurface structures, which may contain petroleum.

A seismic shock wave may be generated in any of several ways (fig. 9). The oldest method, and one that is still widely used, is the detonation of explosives. While both surface and subsurface explosions have been used, the most common practice is to detonate the explosive charge at the bottom of a hole which has been drilled for that purpose. These holes, known as shot holes, generally range from 25 feet to 200 feet in depth.

Other methods of generating a seismic shock wave include thumpers, vibrators, and surface explosions. These methods generally result in little surface disturbance.

The thumper method involves the use of a heavy steel weight weighing approximately 3 tons, which is transported by a special truck. The truck is equipped with lifting equipment,

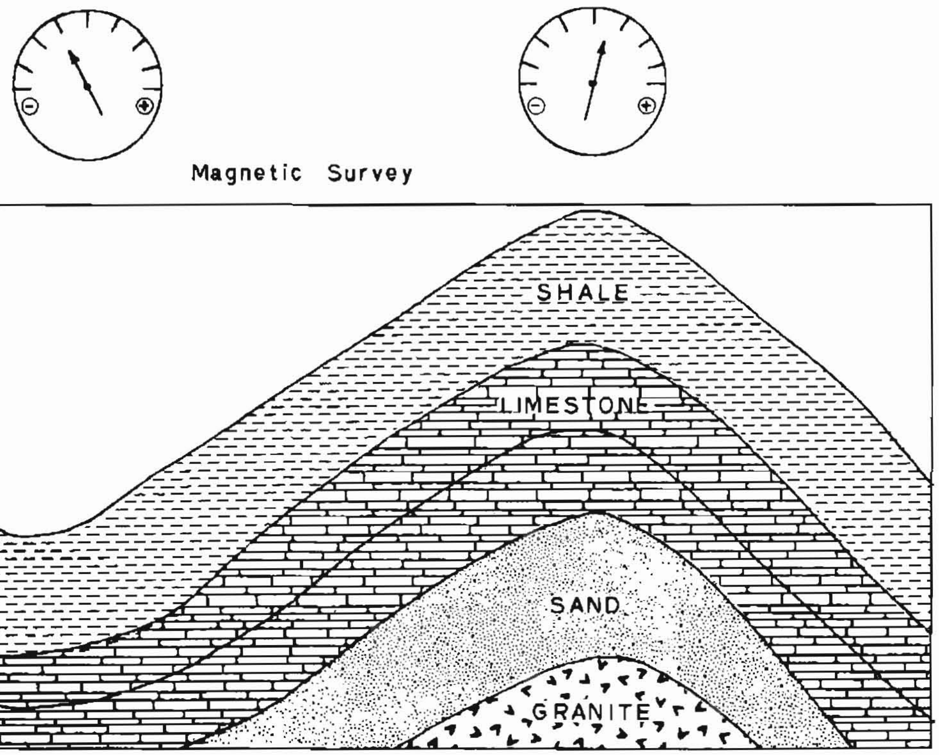


Figure 6. Magnetic surveys are conducted to measure variations in the earth's magnetic field. The magnetic field is stronger where more magnetic rocks, such as granite, are closer to the surface, as is the case in the anticline illustrated above.

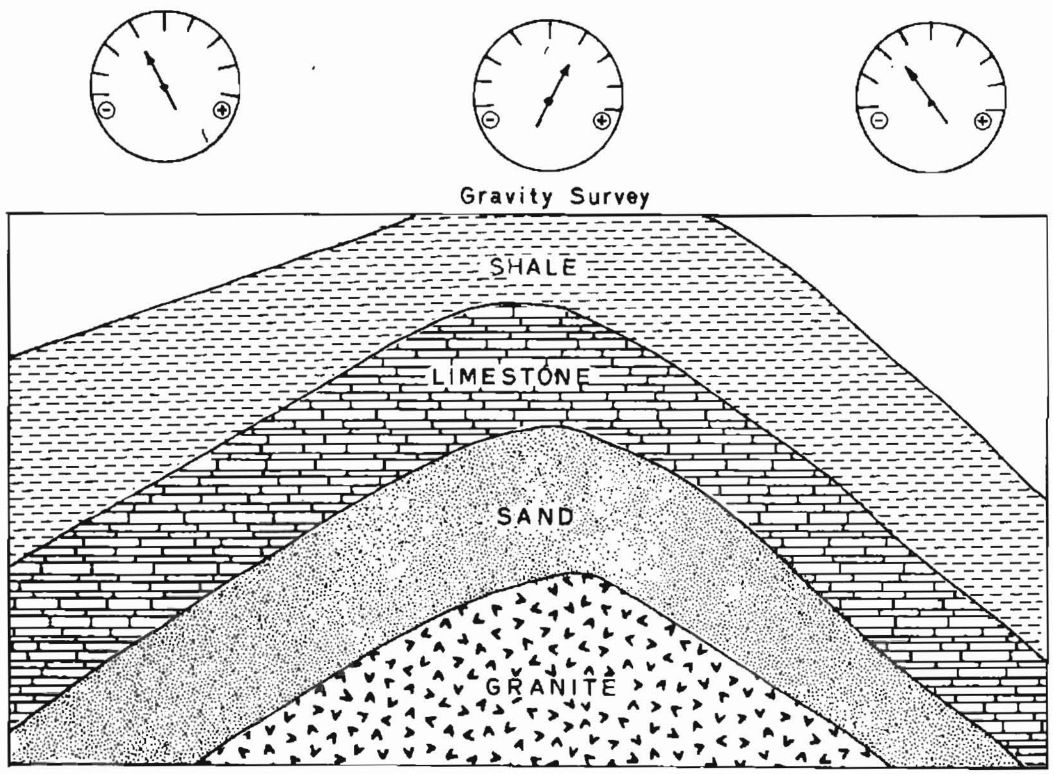


Figure 7. Gravity surveys measure variations in the earth's gravity due to differences in the density of various types of rock. Gravity is higher at the crest of the anticline because the denser granitic rock is closer to the surface.

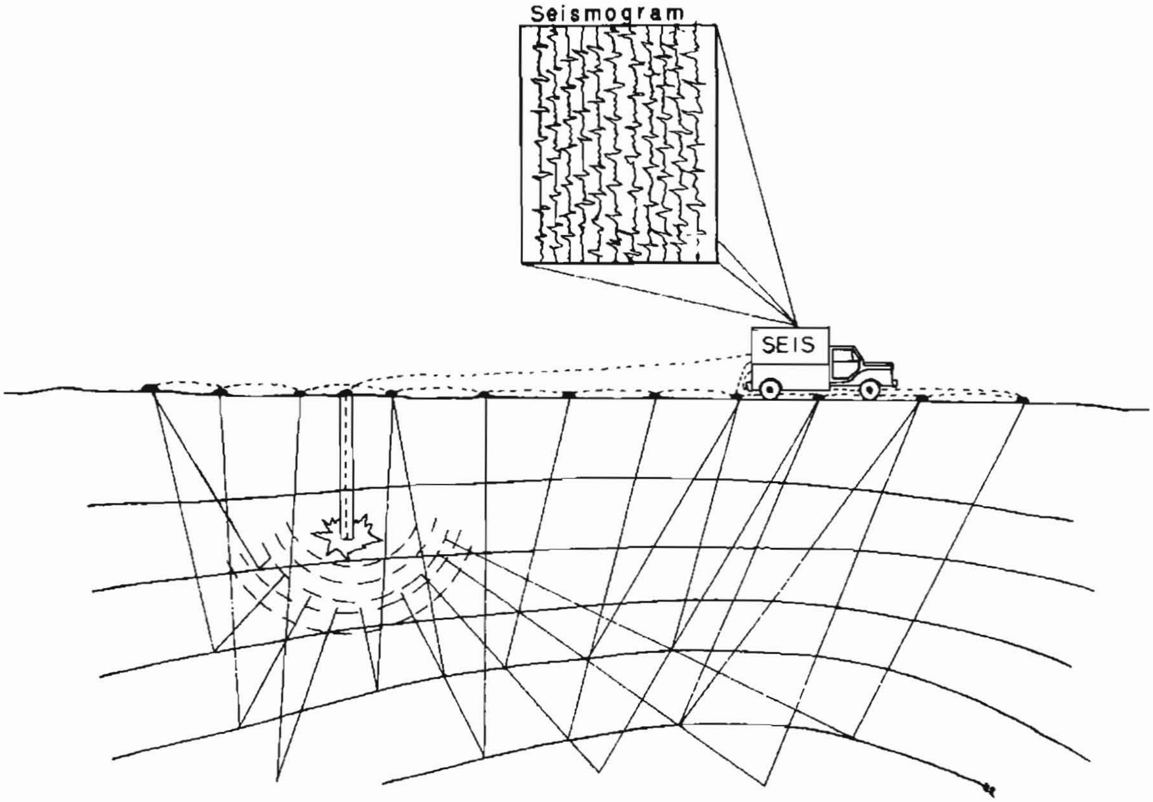


Figure 8. Illustrating a seismic survey. An explosive detonated in the shot hole produces shock waves that pass through the layers of rock and are reflected back to the surface. They are detected at the surface by seismometers and are recorded by equipment in the shooting truck, producing a seismogram.

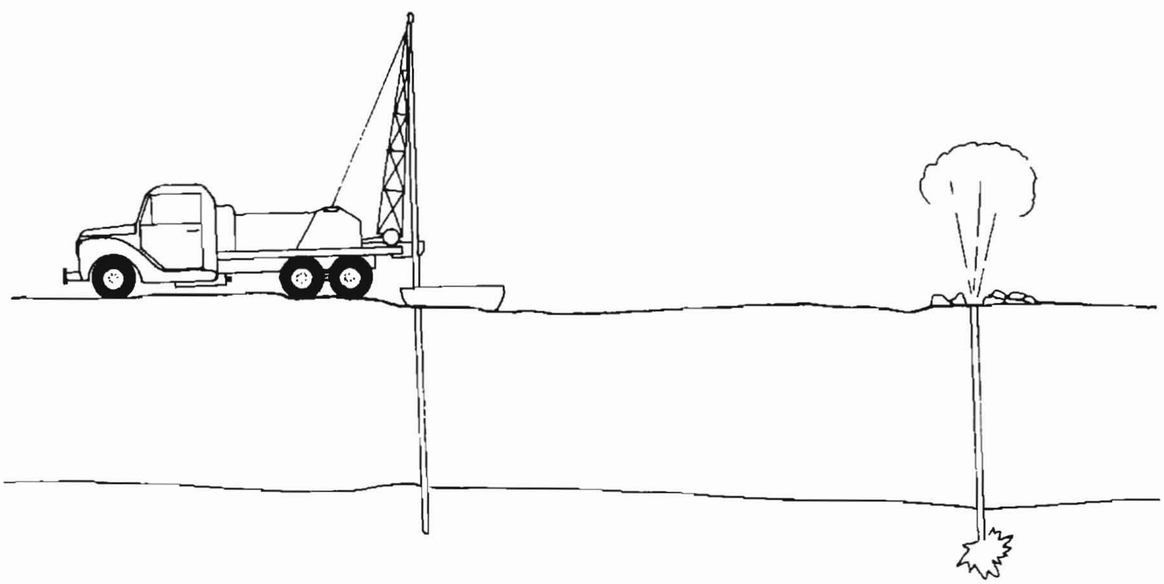


Figure 9. The most frequently used method of producing a shock wave in seismographing is the detonation of an explosive charge in a shot hole that has been drilled for that purpose.

which permits the weight to be lifted and then dropped to the ground, thereby creating the seismic shock wave.

The vibrator method utilizes three or four large trucks, each equipped with a vibrator pad mounted between the front and rear wheels. The vibrator pads are lowered to the ground and are vibrated on signal from the recording truck. The resulting vibrations generate the seismic shock wave.

The surface explosion method utilizes a bell-shaped chamber, which is mounted underneath a vehicle. A mixture of propane and oxygen is confined in the chamber and then ignited electrically on signal from the recording truck. The resulting detonation generates the seismic shock wave.

DRILLING THE WELL

All of the efforts of the petroleum landmen, the geologists, and geophysicists, and everyone else involved in leasing and exploration activities up to this point must culminate in a decision by the management of the petroleum company to either drill or not to drill a well. If the exploration activities conducted thus far have not found encouraging indications for the accumulation of petroleum in the area being explored, the leases held in the area will likely be dropped. If exploration activities have been encouraging, however, a decision will likely be made to drill an exploratory well. Such a decision may require the commitment of hundreds of thousands or even millions of dollars for the drilling program. In this section we will discuss the activities related to the drilling of an exploratory well. State regulations regarding drilling, development, and production will be discussed in a subsequent section.

Drill Site Selection

The selection of the drill site is based largely on the geological evidence indicating the possible accumulation of petroleum. The exploration company will want to locate the well at the most advantageous location for the discovery of oil or gas. Surface conditions, however, must also be taken into consideration when selecting the drill site. There must be a nearly level area of sufficient size on which to erect the drilling rig, excavate reserve pits; and to provide storage for all of the materials and equipment that will be required for the drilling program. All of the required legal matters will have to have been attended to, such as acquiring a drilling permit, surveying of the drill site, and so on. When all of these matters have been resolved, the work on site preparation will begin.

Drill Site Preparation

Once the drill site has been selected and surveyed, a contractor or contractors will move in with equipment to prepare the location (fig. 10). If necessary, the site will be cleared and leveled. A large pit will be constructed to contain water for drilling operations and for the disposal of drill cuttings and other waste. A small drilling rig, referred to as a dry hole digger, will be used to start the main hole. A large diameter hole will be drilled to a shallow depth and lined with conductor pipe. Sometimes a large, rectangular cellar is excavated around the main bore hole and lined with wood. A smaller diameter hole called a "rat hole" is drilled near the main bore hole. The rat hole is lined with pipe and is used for the temporary storage of a piece of drilling equipment called the kelly. When all of this work has been completed, the drilling contractor will move in with the large drilling rig and all of the equipment required for the drilling of the well.

Rigging Up

The components of the drilling rig and all necessary equipment are moved onto the location with large, specially equipped trucks. The substructure of the rig is located and leveled over the main bore hole. The mast or derrick is raised over the substructure and the other equipment such as engines, pumps, and rotating and hoisting equipment are aligned and connected. The drill pipe and drill collars are laid out on racks convenient to the rig floor so that they may be hoisted up when needed and connected to the drill bit or added to the drill string. Water and fuel tanks are filled. Additives for the drilling fluid (drilling mud) are stored on location. When all of these matters have been attended to, the drilling contractor is ready to begin drilling operations (spud the well) (fig. 11).

Spudding In

"Spudding in," or to "spud" a well means to begin drilling operations. The drill string, consisting of a drill bit, drill collars, drill pipe, and kelly, is assembled and lowered into the conductor pipe. Drilling fluid, better known as drilling mud, is circulated through the kelly and the drill string by means of pipes and flexible hose connecting the drilling fluid or mud pumps and a swivel device attached to the upper end of the kelly. The swivel device enables drilling mud to be circulated while the kelly and drill string are rotated. The mud pump draws fluid from mud tanks or pits located nearby. The drilling mud passes through the kelly, drill pipe, drill collars, and drill bit. It is returned to the surface by means of the well bore and the conductor pipe where it is directed to a device called a shale shaker. The shale shaker separates the drill cuttings and solids from the drilling mud, which is returned to the mud tanks to be circulated again (fig. 12). As the drill string is rotated in the well bore, the drill bit cuts into the rock. The drilling mud lubricates and cools the drill bit and drill string and carries the drill cuttings to the surface (fig. 12).

Drilling the Surface Hole

When a well is spudded in, a large diameter drill bit is used to drill to a predetermined depth. This is for the purpose of drilling the surface hole. The surface hole is lined with casing. The casing protects aquifers which may contain fresh water, provides a mounting place for the blowout preventer, and serves as the support for the production casing that will be placed in the well bore if the drilling program is successful. The surface hole may be several hundred or several thousand feet deep. When the predetermined depth is reached, the drill string will be removed from the well bore. Steel casing of the proper diameter is inserted. Sufficient cement is pumped down the surface casing to fill the space between the outside of the casing and the well bore all the way to the surface. This is to insure the protection of freshwater aquifers and the security of the surface casing (fig. 13). The casing and the cement are tested under pressure for a period of twelve hours before drilling operations may be resumed. A piece of equipment known as a blowout preventer is attached at the top of the surface casing. This device is required to control the well in the event that abnormal pressures are encountered in the bore hole that cannot be controlled with drilling fluid. If high pressure gas or liquid blows the drilling fluid out of the well bore, the blowout preventer can be closed to confine the gas and fluids to the well bore.

Drilling to Total Depth

After the surface casing has been tested and the blowout preventer installed, drilling operations are resumed. They will continue until the well has been drilled to the total depth decided upon. Usually, the only interruptions to drilling operations will be to remove the drill string from the well bore for the replacement of the drill bit, a procedure known as tripping, and for the testing of formations for possible occurrences of oil or gas, known as drill stem testing. Other interruptions may be due to problems incurred while drilling, such as the shearing off of the drill string (known as "twisting off"), and the loss of drill bit parts in the well bore, known as "junk in the hole."

As drilling operations continue, a geologist constantly examines drill cuttings for signs of oil and gas. Sometimes special equipment known as a mud logger is used to detect the presence of oil or gas in the drill cuttings or drilling fluid. By examining the drill cuttings, the geologist determines the type of rock that the drill bit is penetrating and the geologic formation from which the cuttings are originating.

The conventional drill bit used today utilizes three revolving cones containing teeth or hardened inserts which cut into the rock as the bit is revolved (fig. 14). The teeth or inserts chip off fragments of the rock which are carried to the surface with the drilling fluid. The fragments or chips, while they are representative of the rock being drilled, do not present a clear and total picture of the formation being drilled or the characteristics of the rock being penetrated as to porosity and permeability. For this

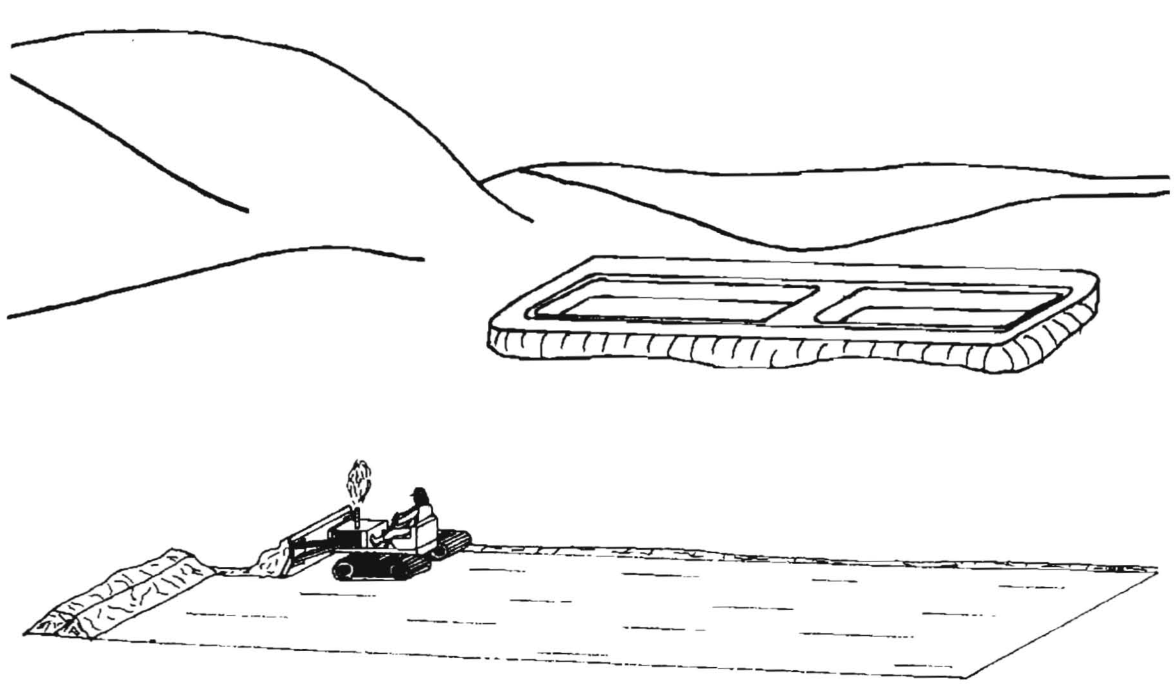


Figure 10. Illustrating the preparation of a drill site. A reserve pit is constructed and the ground is leveled for the erection of the drill rig.

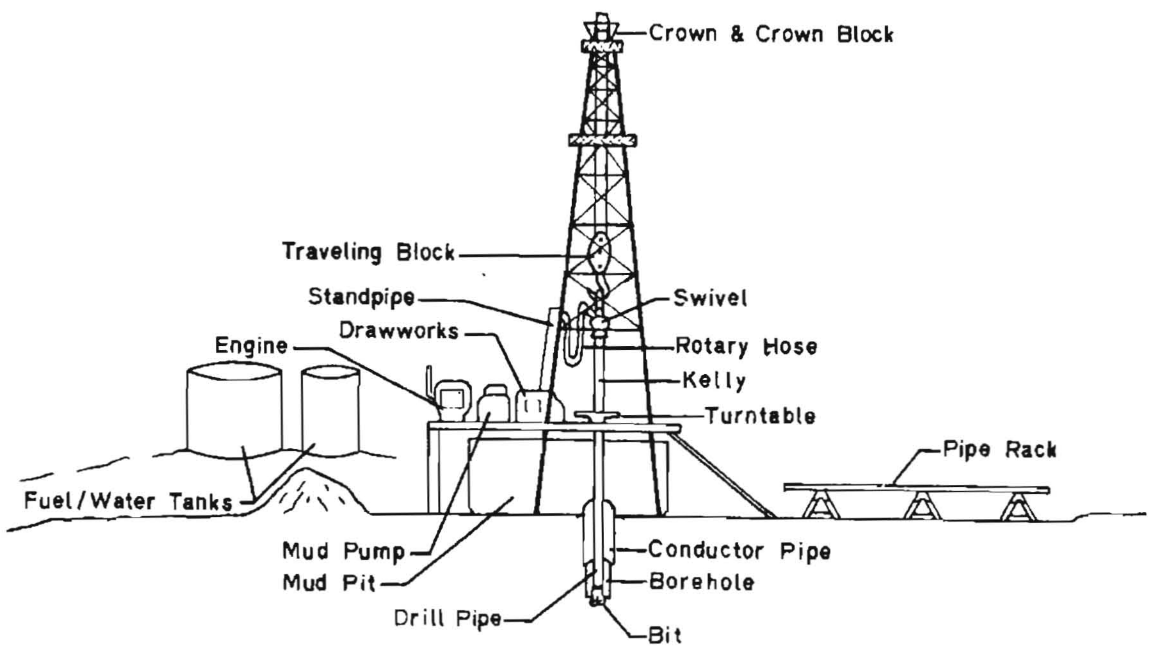


Figure 11. Illustrating a drill rig with its major components and related equipment.

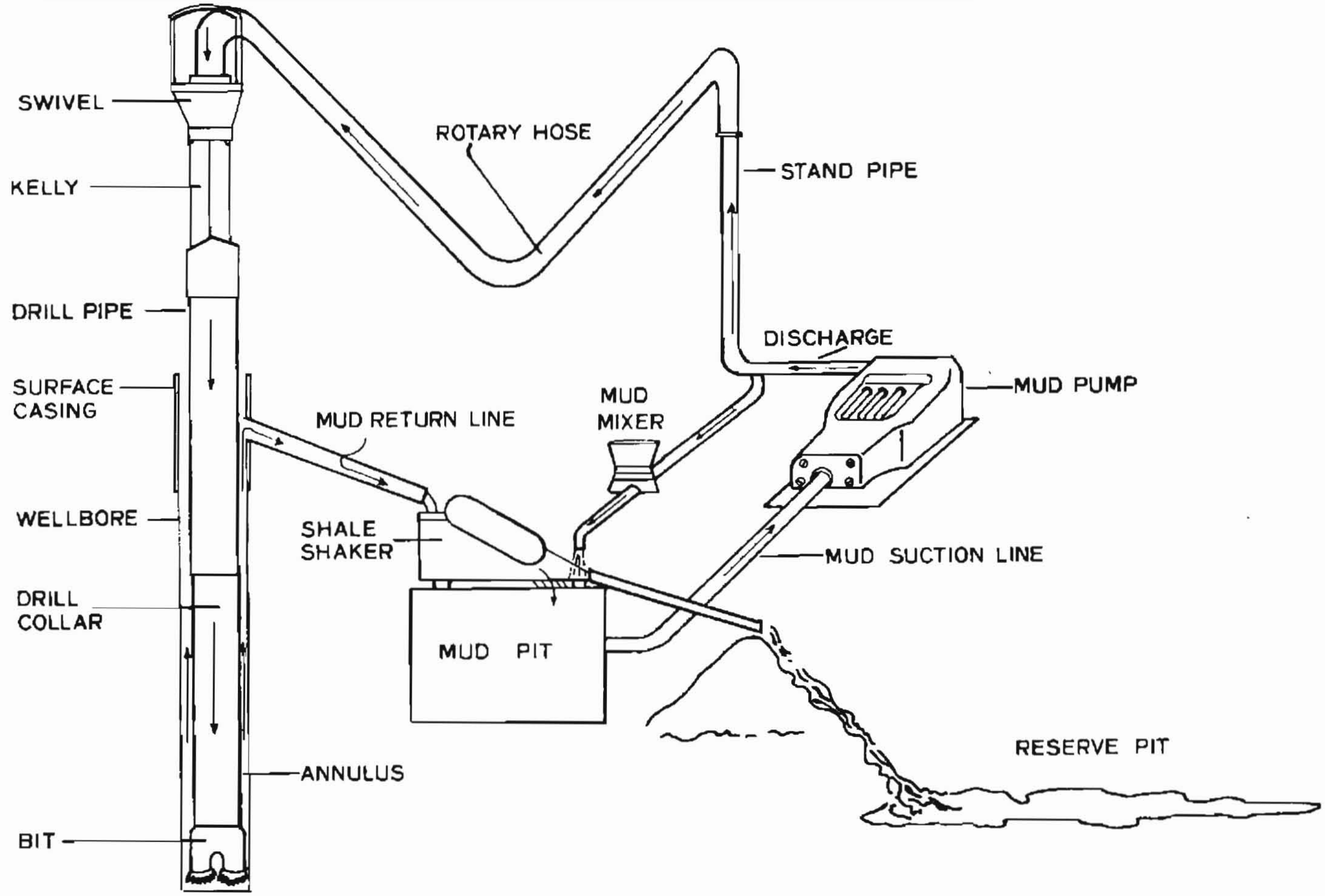


Figure 12. A diagram illustrating the drilling fluid (drilling mud) system and the flow of fluids through the system.

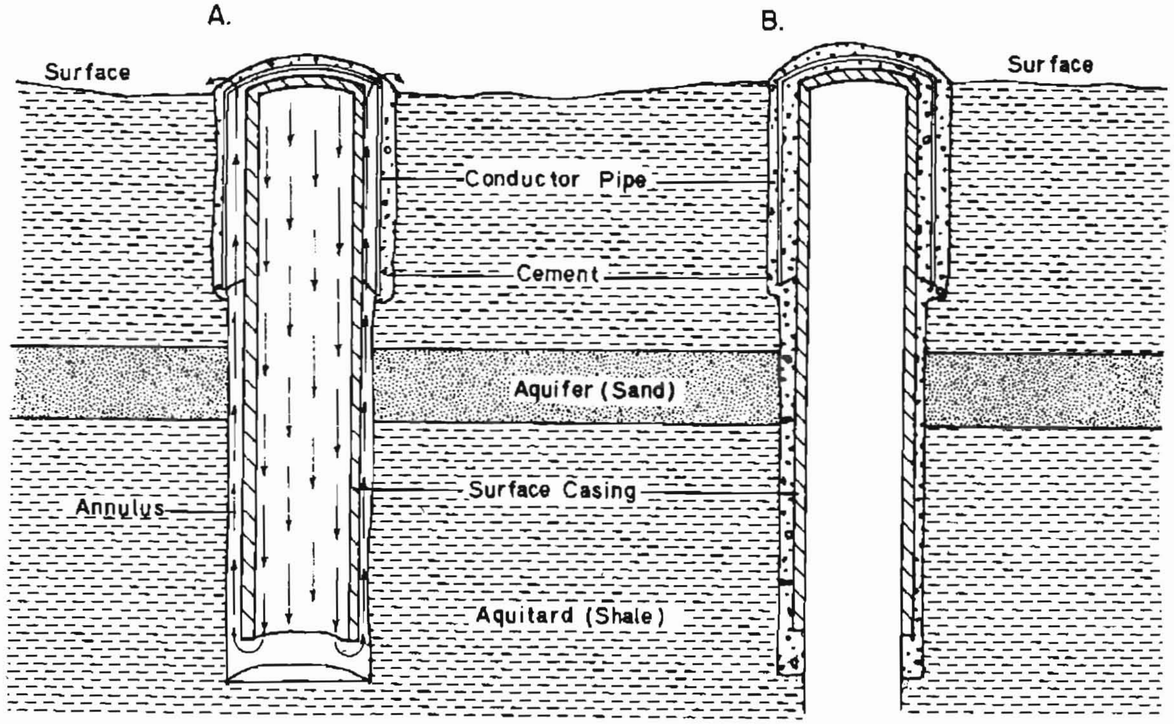


Figure 13. Illustrating the casing of the surface hole to prevent the contamination of fresh water zones and to support the production casing. A. Conductor pipe has been cemented into place. A predetermined amount of casing has been inserted into the well bore below the deepest fresh water zone. Cement is pumped down the inside of the casing until cement flows to the surface through the annulus. B. The cement has hardened and both casing and cement have been tested under pressure. The cement in the bottom of the casing has been drilled out so that drilling can be resumed.

purpose, a larger sample of the rock is required. Such a sample is acquired by using a diamond coring bit and a core barrel. The diamond core bit (fig. 15) is essentially a cylinder with industrial diamonds set into one end. The other end is threaded so that it may be connected to a core barrel, a device which contains equipment for holding the core as it is cut. As the drill stem and coring bit are turned, the diamonds cut the rock and a cylindrical core of the rock is cut. The core passes upward into the core barrel where it is held until the drill string can be extracted from the well bore. At the surface the core is removed from the core barrel where it is examined by the geologist. The core is usually sent to a laboratory for core analysis and testing.

Drill Stem Testing

If the geologist detects the presence of oil or gas in the drill cuttings, a drill stem test is frequently performed to evaluate the formation or zone from which the oil show was observed. Drill stem tests may also be performed when the driller observes a decrease in the time required to drill a foot of rock, known as a "drilling break." Since porous rock may be drilled easier than non-porous or less porous rock, a drilling break indicates the presence of porosity, one of the qualities of reservoir rock. A drill stem test enables the exploration company to obtain a sample of the fluids and gases contained in the formation or interval being tested as well as pressure information, which is determined by special gauges within the test tool.

Drill stem testing is accomplished by removing the drill string from the bore hole. The drill bit is removed and a drill stem test tool with a packer is attached. The test tool, packer, and drill string are inserted back into the bore hole to the desired depth. The

Figure 14. A conventional rock bit or cone bit. As the bit is rotated, the teeth on the cones turn and bite into the rock and chip off fragments. Drilling fluid passes through the bit to cool and to lubricate it and to carry the rock chips to the surface.

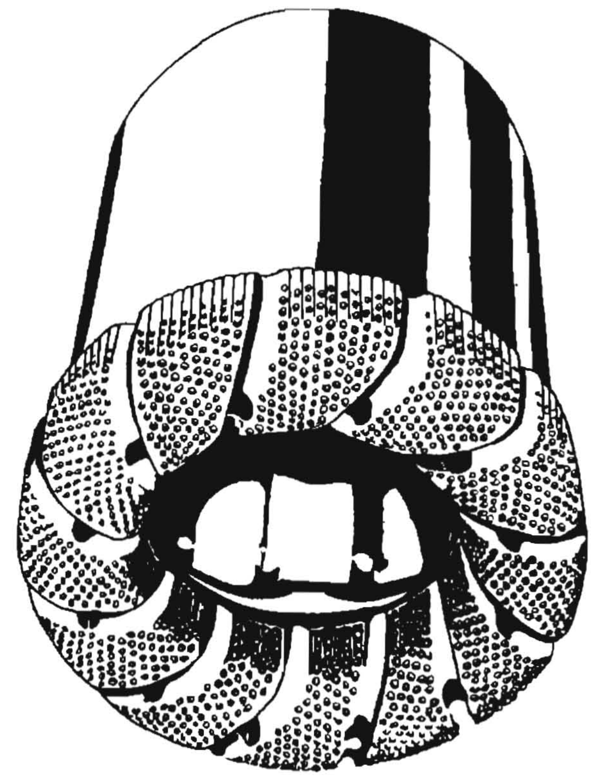


Figure 15. A diamond bit that is used for cutting a core out of the rock. It is used in conjunction with a core barrel. The surface of the bit is covered with industrial diamonds. The bit is hollow so that as it cuts into the rock, a core of rock is cut which passes through the bit and into the core barrel.

packer, which is an expandable device, is set and expanded at a predetermined depth to isolate the zone to be tested. The test tool contains a valve which may be opened and closed to allow formation fluids to enter the test tool and drill string. If there is sufficient fluid and pressure within the zone being tested, the formation fluid (oil, gas, water) may rise to the surface and flow into special test tanks used for that purpose. If gas is present, it is burned at the surface as a flare. By analyzing the rate of flow or the amount of formation fluid recovered in the drill string and the formation pressures recorded, it is possible to obtain a good indication of reservoir characteristics such as porosity, permeability, and the nature of the fluids or gas contained therein.

Well Logging

Drilling operations continue until the predetermined total depth of the well is reached. A logging company is then called to the well site. The drill string is removed from the well bore to allow the insertion of logging tools, which are lowered all the way to the bottom of the hole by means of a special cable. This cable contains numerous electrical circuits. The tools are reeled slowly back to the surface. Specific properties of the formations are measured as the tools are retrieved. Signals detected by the tools are recorded in a recording truck at the surface by means of the electrical circuits contained in the cable.

Electrical logs measure the natural electric potential and the effect of induced electricity on the formations. Radioactivity logs measure the natural radioactivity and the effect of induced radioactivity on the formations. Sonic logs measure the velocity of sound waves in the formations. By analyzing these logs, the experienced geologist and engineer can determine the depth from the surface to various formations and intervals, formation characteristics such as rock type and porosity, and indications of the presence of oil or gas and how much there may be.

Completing the Well

When drill stem testing and well logging operations have been completed and the results have been analyzed, the company management must make a decision whether to complete the well as a producing well or to plug it as a dry hole. If the evidence indicates that no oil or gas are present, or they are not present in sufficient quantity to allow for the recovery of drilling, completion and production costs and provide a profit on investment, the well will probably be plugged and abandoned as a dry hole. If, on the other hand, the evidence indicates the presence of oil or gas in sufficient quantity to allow the recovery of these costs and provide a profit to the company, an attempt will be made to complete the well as a producer.

If the well is to be plugged and abandoned as a dry hole, a cementing company is called to the drill site. The well bore is filled with drilling fluid, which contains additives which give it special properties that prevent its movement from the well bore into the surrounding rock. Cement plugs are required within the well bore at intervals where porosity has been detected to isolate these porosity zones and prevent the movement of formation fluids from one formation to another. The cement is pumped into the well bore through the drill string. The cement is mixed at the surface in special trucks which are equipped with high volume pumps. The pumps are connected to the drill string which has been inserted into the well bore to a predetermined depth. A quantity of cement is pumped into the well bore through the drill string and displaced out of the bottom of the drill string with drilling fluid. The drill string is then pulled up to the next interval that is to be cemented. This process is repeated until all of the required plugs have been set. A cement plug is also set at the base of the surface casing, which remains in the hole, and another plug is set at the surface. In cultivated areas the surface casing is cut off below plow depth. A steel plate is welded at the top of the surface casing. All drilling equipment and materials are removed from the drill site. The pits are allowed to dry up and are backfilled and the site is restored as nearly as possible to its original condition.

If a decision is made to attempt to complete the well as a producer, casing is delivered to the site and a cementing company is called. The well bore is filled with drilling fluid that contains additives to prevent corrosion of the casing and to prevent the movement of the fluid from the well bore into the surrounding rock. The casing is threaded together and inserted into the well bore much in the same manner as the drill string. Casing may be inserted to the total depth of the hole or a cement plug may have been set at a specific depth and the casing set on top of it. Cement is mixed at the surface just as if the well were to be plugged. The cement is then pumped down the casing and displaced out of the bottom with drilling fluid or water. The cement then flows up and around the casing, filling the space between the casing and the well bore to a predetermined height. Special tools are sometimes used with the casing which allow the setting of cement between the outside of the casing and the well bore at specific intervals. This is done to protect the casing and to prevent the movement of formation fluids from one formation to another (fig. 16).

After the cementing of the casing has been completed, the drilling rig, equipment, and materials are removed from the drill site. A smaller rig, known as a workover rig or completion rig, is moved over the well bore. The smaller rig is used for the remaining completion operations.

A well perforating company is then called to the well site. It is necessary to perforate holes in the casing at the proper position to allow the oil and gas to enter the casing. The perforating company is commonly the same company that has performed the logging of the well. A special perforating tool is inserted into the casing and lowered to the desired position on the end of a cable. The cable contains a number of electrical circuits and is connected to a recording and control truck at the surface. The perforating tool contains a number of shaped charges which are spaced at specific intervals. When the perforating tool has been lowered to the desired position, the shaped charges are fired remotely from the control truck at the surface and jets of high temperature and velocity gas perforate the casing, the cement, and the surrounding rock for some distance away from the well bore.

A smaller diameter pipe, called tubing, is then threaded together and inserted into the casing. If it is expected that the oil or gas to be produced will flow to the surface naturally, the tubing is equipped with an expandable packer at the lower end. The tubing is inserted into the casing and the packer is expanded or set at a predetermined point above the perforations. At the surface, a well head is installed which is equipped with valves to control the flow of oil or gas from the well. The well head is known as a Christmas tree (fig. 17).

If there is not sufficient reservoir pressure to cause the oil and gas to flow naturally, pumping equipment is installed at the lower end of the tubing. Various types of pumping equipment are used including piston pumps, submersible pumps, and jet pumps. Power to operate the pump may be supplied by a gas engine or an electrical motor.

During well completion operations it is sometimes desirable or necessary to treat or stimulate the producing zone in order to improve the permeability of the rock and increase the flow of oil or gas into the casing. This may be accomplished by the use of acid or by the injection of fluid and sand under high pressure in order to fracture the rock. Such a treatment usually improves permeability and facilitates the flow of oil or gas into the casing. At this point, the drilling and completion phase have ended. The well is about to enter the production phase which, hopefully, will continue for many years.

PRODUCTION

While the well completion operations were taking place, production equipment was being installed on the surface. This usually consists of a separator, a heater treater, storage tanks, circulating pump, and a facility for the storage or disposal of water that is produced with the oil. The various production equipment and the producing well are connected by pipes known as flow line (fig. 18).

After the oil, gas, and water have flowed or pumped to the surface, they pass as an emulsion or mixture to the production separator, a piece of equipment which separates the gas from the oil and water. The gas may then travel by pipeline to a gas plant for processing into natural gas liquids such as propane and butane and natural gas for residential and commercial use. The oil and water emulsion then goes to the

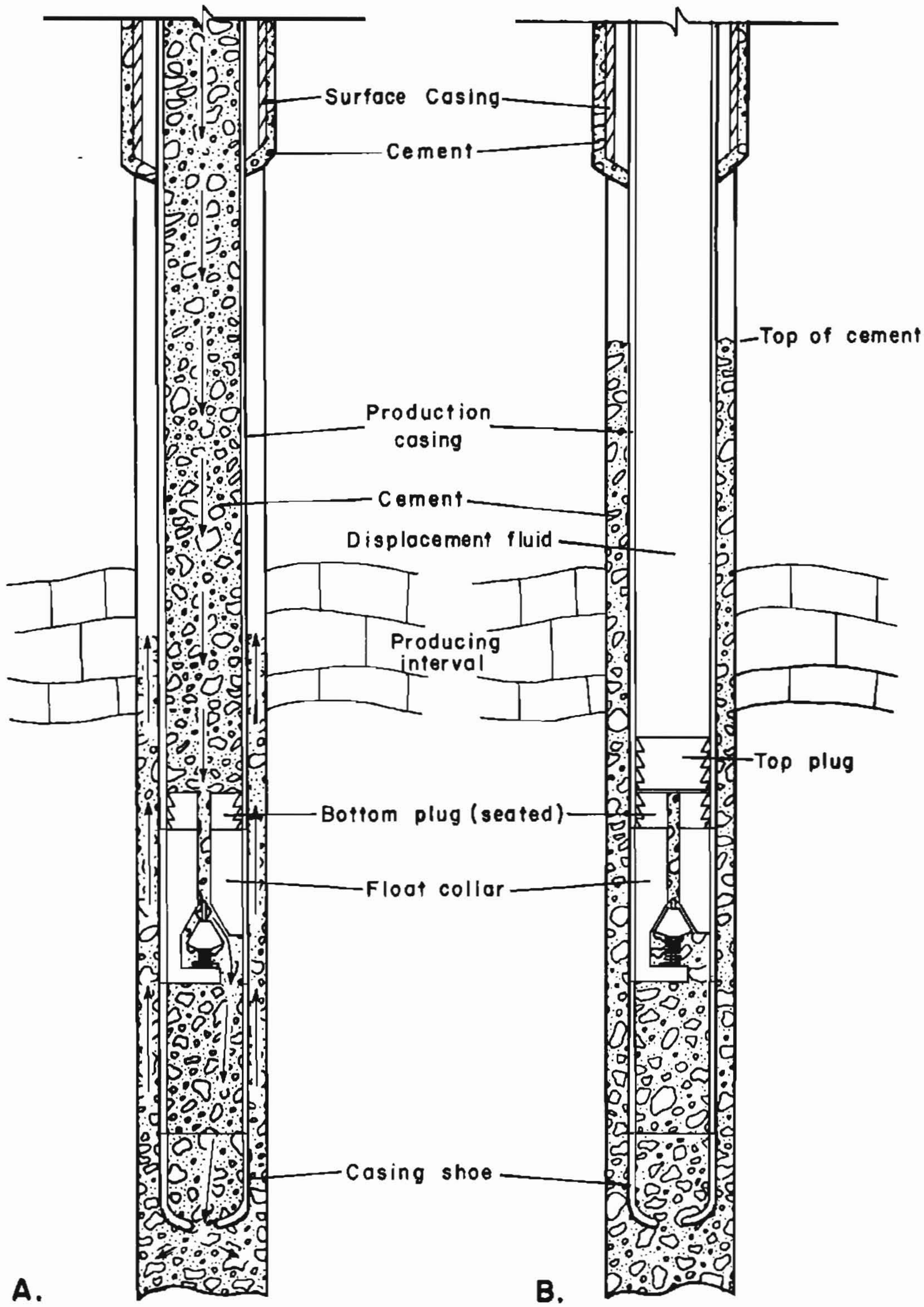


Figure 16. Cementing production casing. A. Illustrates cement being pumped down the casing. The casing shoe facilitates the insertion of the casing into the bore hole. The float collar prevents drilling fluid from entering the casing. The bottom plug precedes the cement down the casing. The top plug follows the cement and precedes the displacement fluid. B. Illustrates the completed cementing operation.

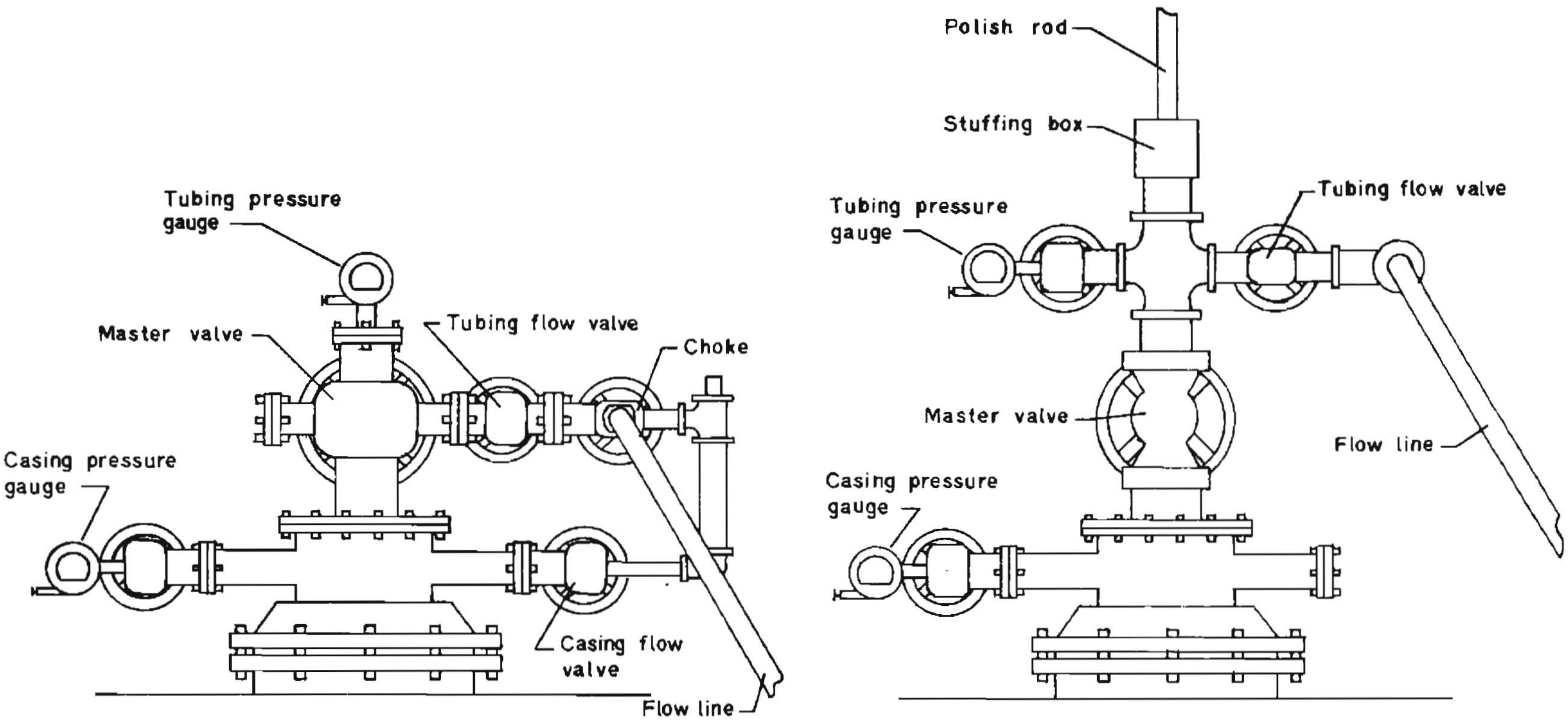


Figure 17. Illustrating two types of well heads or "Christmas trees." The well head on the left is for a flowing well and the well head on the right is for a pumping well.

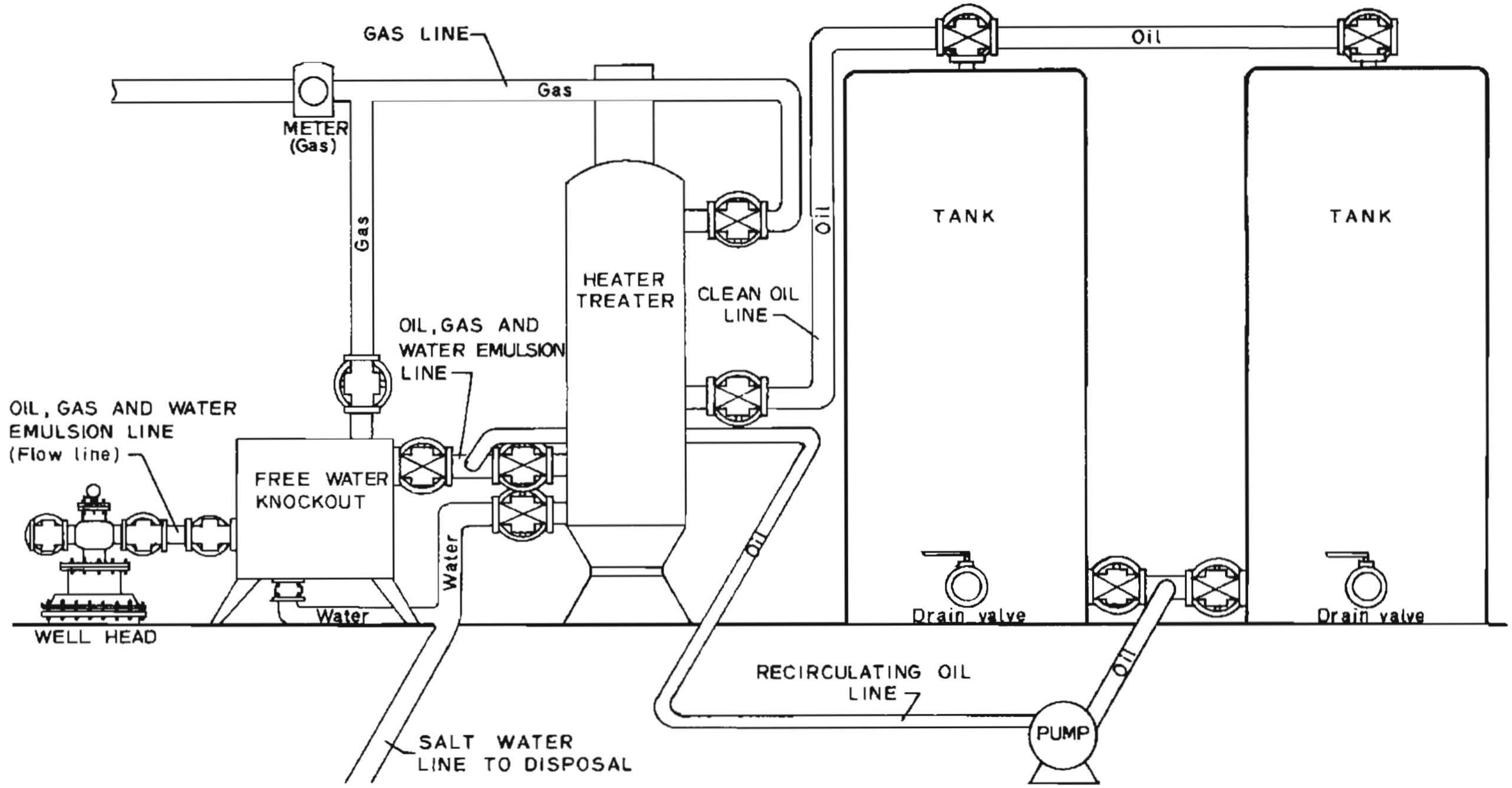


Figure 18. Surface equipment. Oil, gas, and water, as an emulsion, enter the free water knockout. Some gas and water are separated from the emulsion at this point. The remaining emulsion enters the heater treater where it is heated and the emulsion is separated into oil, gas, and water. The water is drained off and sent to disposal. The gas passes into the gas line, where it is metered and sent to market. The oil passes into the tanks. The oil may be loaded into trucks from the drain valves or connected to a pipeline. The pump is used for recirculating oil that may have impurities in it back through the heater treater and into the tanks.

heater treater for the separation of the oil from the water. The oil then is placed in the storage tanks where it remains until it is transported off the site by trucks or by pipeline. The water is either put into a salt water handling facility such as a lined pit or tank, or into a flow line to a disposal well where it will be disposed of underground. Before the oil is removed from the storage tanks, it is tested to determine if it still contains an excessive amount of water. If it does, it is circulated by the circulating pump through the heater treater until the water content is at or below the acceptable level.

The quantities of oil, gas, and water that are produced from the well are measured and recorded. Oil production may be measured with special metering equipment if it is produced into a consolidated tank battery or it may be gauged by measuring the height of the oil level in the storage tanks. When a tank full of oil is delivered to a refiner or crude oil purchaser by pipeline, truck, or tank car, the oil is measured by gauging the height of oil in the tank. At that time the oil will be tested to determine its gravity (density) because the price paid for crude oil varies with its gravity. The temperature of the oil is determined as well as its content of basic sediment and water. This is done so that the quantity of oil in the tank can be converted into net barrels of oil delivered.

The quantity of gas produced is measured by a meter before it enters the pipeline to the processing facility. The quantity of water produced may be measured by a meter at the heater treater before it enters the salt water handling facility or the flow line to the disposal well. Water production is also determined by periodically testing the oil, gas, and water emulsion before it is separated to determine the percentage of water or "water cut" in the produced fluid.

Reservoir Energy

In order for oil and gas to flow into the casing or well bore, energy is required. This energy may be derived from one or more of the following mechanisms: by dissolved gas in the oil which expands and escapes, driving the oil through the porous and permeable rock toward the well or wells; a gas cap, which consists of a cap of gas overlying the oil, may expand as the oil is produced, filling the pore spaces occupied by the oil and gas as it is produced; and by water drive resulting from the expansion of water underlying the oil which may expand to fill the reservoir as the oil is produced (fig. 19).

The driving mechanisms discussed above are capable of pushing only a fraction of the oil and gas present in the reservoir rock into the well bore. As soon as the first barrel of oil is produced, reservoir energy begins to decline, and it will continue to decline until insufficient energy exists to force enough oil and gas into the well to warrant continued production. When this occurs, the well must be plugged and abandoned unless the reservoir energy can be restored or replenished in some artificial or secondary way.

Reservoir energy has been replenished in some cases by the injection of gas or fluids into the reservoir. This practice is known as pressure maintenance or secondary recovery. The production of oil and gas without pressure maintenance is known as primary recovery.

Pressure maintenance is not without its problems, however. When gas or liquids are injected into a producing formation or interval, oil and gas are pushed across property lines. A means must be provided to protect the rights of all persons who have royalty or production interests. This is done by unitizing the reservoir. In order to do this a detailed engineering study of the reservoir or oil pool is conducted to determine the amount of oil that is produced that should be allocated to the various operators and mineral rights owners. In North Dakota, a plan of unitization must be developed which includes specific provisions. The plan must be approved or ratified by at least 80 percent of the lessees or operators and by 80 percent of the persons owning interests in the production such as royalties, overriding royalties, and production payments. The plan of unitization must also be approved by the North Dakota Industrial Commission, which is the state regulatory body governing oil and gas matters.

Pressure maintenance, or secondary recovery, is accomplished by injecting air or water into the producing formation through wells which

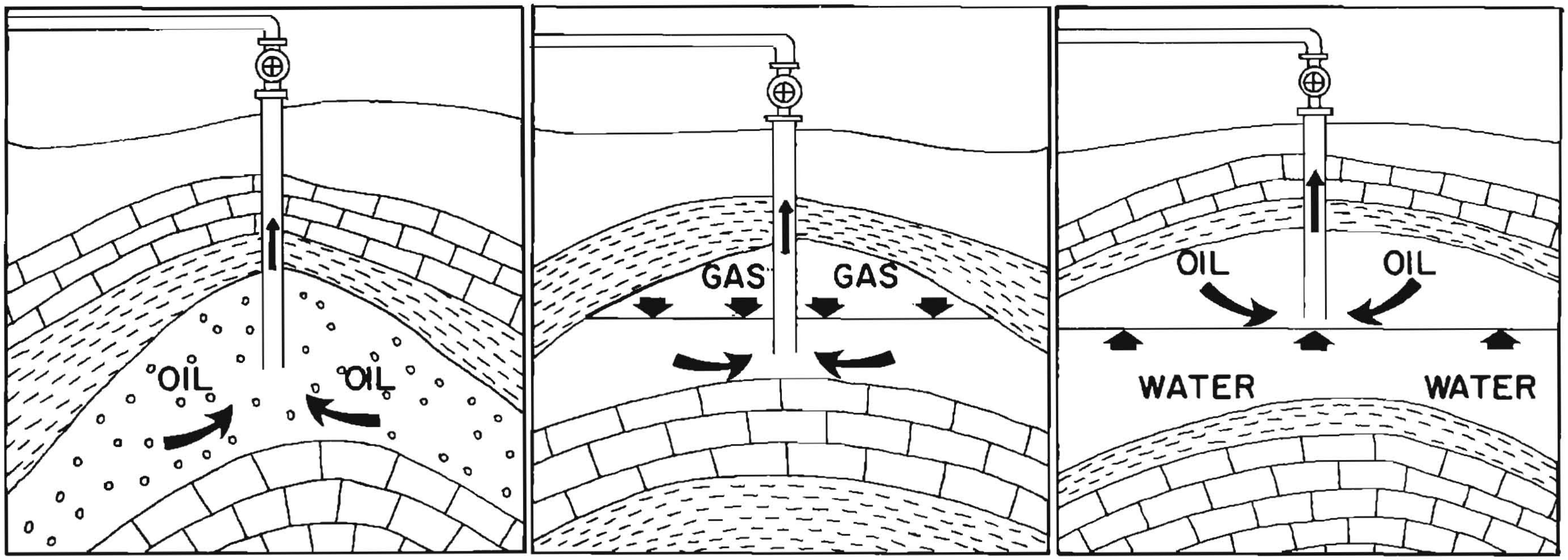


Figure 19. Reservoir drive mechanisms. Dissolved gas drive is the result of the expansion of gas that is dissolved in the oil. Gas-cap drive is the result of the expansion of gas which is contained in the reservoir above the oil. Water drive is the result of the upward pressure of water, which is under pressure, as it expands and moves into the regions of lowered pressure as oil is produced.

are located at strategic positions. The injected air or water results in an increase in pressure within the producing formation relative to the pressure in the well bore of the producing wells (fig. 20). Secondary maintenance will not restore reservoir energy to its original condition, but it can and does result in a significant increase in the production of oil and gas from a reservoir.

Even after the application of pressure maintenance, a considerable amount of oil may be left in the reservoir. This is residual oil that cannot be moved into the producing wells by pressure alone. Methods are being developed that will enable much of this residual oil to be flushed from the reservoir rock and into the producing wells. This is known as tertiary recovery.

DRILLING AND PRODUCING IN NORTH DAKOTA

The drilling of exploration and development wells and the producing of oil and gas is regulated in North Dakota by the Industrial Commission. The Commission consists of the Governor, the Attorney General, and the Commissioner of Agriculture.

The Industrial Commission has established rules and regulations for the exploration, development, and production of oil and gas. These rules and regulations are applicable to: the drilling of oil and gas wells; oil and gas production; the plugging or abandonment of wells; and the reclamation of exploration and production sites.

Before any company or individual can begin to drill a well for the purpose of discovering or producing oil and gas in North Dakota, it is necessary that they acquire a permit to drill. The permits are issued by the Industrial Commission only after the applicant has complied with certain requirements.

Drilling Permit Requirements

Organization Report

An organization report is required of any company or individual that is engaged in the drilling of wells for oil and gas or in the production of oil and gas in North Dakota. Out-of-state companies and individuals must also name an in-state resident agent.

Bonding

Any company or individual that intends to drill wells or produce oil and gas in North Dakota must submit a bond to the Industrial Commission. The bond for a single well is five thousand dollars. The bond for multiple wells is twenty-five thousand dollars. A multiple well bond is called a blanket bond and it is limited to ten dry holes that have not been properly plugged and the sites restored.

Application to Drill

Before any drilling operations may begin, an application to drill must be filed with and approved by the Industrial Commission. The application must be accompanied by an accurate plat showing the location of the drill site with reference to the nearest governmental section lines. The application must include pertinent information as to the proposed drilling depth, depths to tops of geologic formations or horizons, proposed casing program, and the amounts of cement to be used. The Industrial Commission may request additional information if it is deemed necessary.

Well Spacing

The minimum spacing of a well is dependent upon whether it is a "wildcat" well or a development well and whether it is to be drilled for oil or for gas. A wildcat well is one that is located outside of an established field and pool. A development well is one that is located within an established field and pool.

A wildcat well drilled for oil must be located within a governmental quarter quarter section or governmental lot containing at least thirty-six acres. The well may not be located closer than five hundred feet to any boundary of the quarter quarter section or lot. It must not be closer than one thousand feet to the nearest well that has been permitted to or is capable of producing oil from the pool or producing horizon to which the well is to be drilled.

A wildcat well that is drilled for gas must be located within a govern-

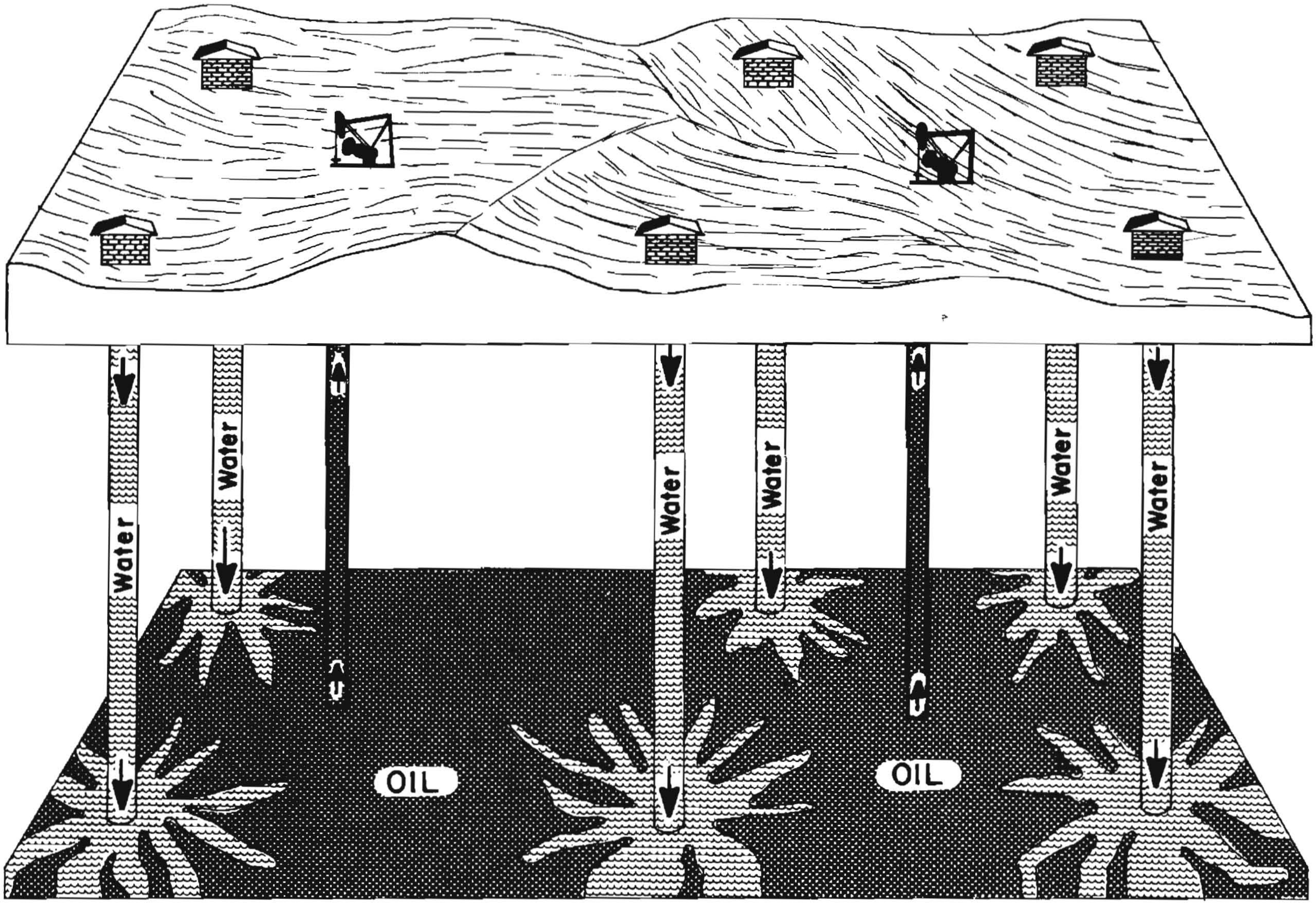


Figure 20. Secondary recovery. A water flood is illustrated here. Water injected into the producing horizon increases reservoir pressure and pushes the oil towards the producing wells.

mental quarter section which contains at least one hundred and forty-five acres. The well must not be located closer than one thousand feet to any boundary of the quarter section. It must not be closer than fifteen hundred feet to a well that has been permitted to or is capable of producing gas from the pool or producing horizon to which the well is to be drilled.

A development well that is drilled for oil or gas must be located according to the spacing regulations that have been set by the Industrial Commission for the field and pool in which the well is to be drilled. When a wildcat well has been successfully completed as a producing well, the Industrial Commission is required to hold a hearing to determine the spacing and special operating rules for the newly discovered field and pool. During the hearing, the Commission receives testimony and evidence regarding the geology, the reservoir characteristics, and the economic characteristics of the pool. The Commission then sets well spacing requirements and special field rules and boundaries for the new field and pool.

Surface Owners (Tenants) Notice

State law (Chapter 38-11.1 of the North Dakota Century Code) requires that before any drilling operations may begin, the company or individual contemplating the drilling must give written notice to the "surface owner" (defined as "the person who has possession of the surface of the land either as an owner or as a tenant") as to the nature of the work and drilling operations that are contemplated. The notice must contain sufficient information so as to enable the surface owner to evaluate the effect of the drilling operations on his property. A form prepared by the State Geologist (fig. 21) advising the owner of his rights and options must be included with the notice.

Drilling

When a drilling permit application has been approved by the Industrial Commission and a notice of intention to drill has been filed by the operator, drilling operations may begin.

As drilling operations progress, the operator is required to file reports with the Industrial Commission and the State Geologist. Reports are required: when surface casing and production casing is inserted and cemented into place; when the well is to be completed as a producer or is to be plugged and abandoned as a non-producer (dry hole); if the operator intends to depart from the drilling procedures contained in the application to drill; to notify the Industrial Commission of any fires, breaks, leaks, or blowouts; or whenever the Industrial Commission requires additional information.

During drilling operations, the drill site is periodically inspected by field inspectors from the Enforcement Division of the Industrial Commission. The inspectors determine if drilling operations are being conducted in compliance with state regulations. If violations are noted, the operator and the drilling contractor are notified immediately so that corrective measures can be taken. Field inspectors are stationed at Bismarck, Dickinson, Minot, and Williston.

Data that is acquired during drilling operations must be preserved and furnished to the State Geologist. These data include: samples of drill cuttings, any cores that have been cut, and copies of geophysical well logs.

The Industrial Commission and the State Geologist's office maintain a complete record of all permits, notices, and reports that have been issued or received on every well that is drilled for oil and gas in the state. The records and data are public information; however, an operator may request that they be held confidential for a maximum of six months.

Well Completion

After a well has been drilled to its total depth, the operator must evaluate all of the data that has been acquired such as: well cuttings, cores, drill stem tests, and geophysical logs. The operator must then make a decision to either complete the well as a producer or to plug it as a non-producer or "dry hole."

Plugging

If the well is determined to be unproductive, the well must be plugged. The operator must notify the Industrial Commission of his intention to plug the well and secure appro-

SURFACE OWNERS (TENANTS) NOTICE

RIGHTS OF DAMAGES—OIL & GAS DRILLING OPERATIONS

NORTH DAKOTA GEOLOGICAL SURVEY
UNIVERSITY STATION · GRAND FORKS, N. DAK. · 58202

The 46th Legislative Assembly passed a law (codified as Chapter 38-11.1 of the North Dakota Century Code) which provides that all persons should be justly compensated for injury to their persons and property and interference with the use of their property occasioned by oil and gas drilling operations commenced after June 30, 1979, and any production operations that follow. This letter is furnished you so that you will be advised of your rights and options under this law.

The law provides that a "surface owner" (defined as "the person who has possession of the surface of the land either as an owner or as a tenant") shall be paid by the mineral developer a sum of money equal to the amount of damages sustained for loss of agricultural production and income, lost land value, and lost value of improvements caused by drilling operations. These payments cover only land directly affected by drilling operations and are intended to compensate the person who is actually in possession of the land as an owner or tenant. Reservations or assignments of these payments to someone other than the person in possession of the surface estate is prohibited.

The amount of damages may be determined by any mutually agreeable formula. When determining damages, you may consider the period of time during which the loss occurs, and you may elect to be paid damages in annual installments over such period of time; except that you are entitled to be compensated for harm caused by exploration only by a single sum payment.

Except for certain exploration activities governed by other law (such as seismograph exploration) you are entitled to written notice of any contemplated drilling operations. This notice is given by obtaining your address from the land records of the appropriate county register of deeds office. This form and the information disclosing the plan of work and operations contemplated by the mineral developer are intended to assist you in evaluating the effect such activity will have on the use of your property. You are responsible for negotiating the terms of any settlements. You should consult private counsel if you need advice or assistance in making a settlement.

Other provisions of this law provide that the mineral developer shall be responsible for damages to persons or property (real or personal) resulting from the mineral developer's "lack of ordinary care" or resulting from a "nuisance" caused by drilling operations. In the event any person (not just a "surface owner") suffers damage, notice of the damage sustained must be given the mineral developer within two years after the damage occurs or should have been discovered. Unless a written agreement made between the mineral developer and injured person provides otherwise, a mineral developer has 60 days to offer to settle a claim for damages. If the injured person receives a written rejection from the mineral developer, rejects the offer of the mineral developer, or receives no reply from the mineral developer, a court action for damages may be commenced; if the injured person receives a court award greater than the offer of settlement made by the mineral developer the court shall also award reasonable attorneys fees and any court costs in addition to the damage award.

The remedies provided by this law do not preclude seeking other legal remedies. This law, however, does not apply to damages resulting from the operation, maintenance, or use of a motor vehicle on highways (e.g. public road rights-of-way).

Lee C. Gerhard
State Geologist

Figure 21. Surface owners notice.

val of the plugging procedure that is to be used. When plugging operations have been completed, the operator must file a detailed plugging report with the Industrial Commission and the State Geologist within thirty days.

When a well has been plugged, the operator must, within a reasonable amount of time, restore the drill site as nearly as is practically possible to its original condition. When restoration has been completed, the operator may request that the bond, under which the well was drilled, be released. A field inspector will then inspect the site. If all regulations have been complied with, the bond can be released.

Completing a Producing Well

When a well is to be completed as a producer, the operator must insert and cement into place the production casing and install other production equipment. The production casing and equipment must meet specifications as to working and test pressures, and condition as may be required by state regulations. For wildcat wells, the specifications and requirements are contained in the general rules and regulations. For development wells, the specifications and requirements are contained in the special rules and regulations that have been set by the Industrial Commission for the field and pool in which the well will be completed. When a well has been completed as a producing well the operator must file a detailed completion report with the Industrial Commission and the State Geologist within thirty days.

Producing

Producing oil and gas wells must be operated in compliance with the special field rules and well spacing requirements that have been set by order of the Industrial Commission for the field and pool from which the wells are producing. The order or orders stipulate the following:

* The described tracts of land that are included within the designated field boundary.
* The vertical limits of the producing horizon within the field boundary.
* The size of the well spa units in acres.
* The location of wells within the well spacing units.
* The specific tracts of land to be included within a well spacing unit.
* The quantity and quality of well casing, tubing, cement, well head fittings and other equipment.
* Pressure testing requirements for casing and cement.
* The manner and frequency of conducting and reporting reservoir tests including gas-oil ratio tests and reservoir pressure tests.
* The manner in which salt water that is produced with the oil and gas is to be disposed of.
* Restriction on producing rates if they are deemed necessary to prevent the waste of oil and gas.

Producing oil and gas wells are periodically inspected by field inspectors from the Industrial Commission. The inspectors determine if the wells are being operated in compliance with the state regulations.

Salt Water Disposal

Salt water that is produced with oil and gas must be disposed of in a manner which will not cause damage to the land surface or pollution of surface or ground waters. The most common methods of disposal are by surface pit evaporation, underground injection, and the utilization of the brine as drilling fluid.

Surface evaporation pits must be constructed in such a manner and of such materials as to prevent surface damage and water pollution. A permit issued by the Industrial Commission is required for each salt water handling facility. The permit is issued only after inspection of the facility by a field inspector who must be satisfied that the construction and materials comply with state regulations.

Subsurface injection may only be utilized when it has been approved by the Industrial Commission after hearing. A salt water injection well must comply with the same surface casing, production casing, and tubing requirements as an oil or gas well. The salt water is injected into a formation or zone of a formation which does not contain water that is suitable for domestic, livestock or irrigation purposes.

Produced salt water is sometimes utilized as drilling fluid in the drilling of oil and gas wells. This is a satisfactory method of disposal which provides an additional benefit of reducing the quantity of salt that must be added to the drilling fluid when drilling through formations that contain salt. Produced salt water is also used in secondary recovery operations. This reduces the quantity of water that must be supplied from other sources for the secondary recovery program.

Reports

The operator of an oil or gas well is required to make periodic reports to the Industrial Commission and the State Geologist on special forms which are furnished by the Industrial Commission. These reports include:

* Monthly reports of oil, gas and water production.
* Gas-oil ratio test reports which state the cubic feet of gas that is produced per barrel of oil.
* Reservoir pressure tests.
* Reports of the quantity of salt water that is disposed of by underground injection.
* Any other information that may be requested by the Industrial Commission or the State Geologist.

Pooling

The owners of interests within a well spacing unit share in the production from the well according to their proportion of ownership within the well spacing unit. If there is only one owner of an oil and gas lease in the spacing unit and only one mineral rights owner in the spacing unit, they will share in the proceeds from production according to the terms of the lease agreement that has been negotiated between them. However, if there are more than one oil and gas lease owner and/or mineral rights owner within the spacing unit, all of the interests must be pooled in order that the proceeds from production from the well can be properly distributed to all of the interest owners.

The interests may be voluntarily pooled by the interest owners to accomplish this. However, it is sometimes not possible to get all of the interest owners to agree to such pooling. When this occurs, any of the persons with an interest in the spacing unit may apply to the Industrial Commission for an order that will pool all interests. The Industrial Commission is then required to give public notice and hold a hearing on the matter. The applicant must then appear and present evidence that all attempts to secure a voluntary pooling of interests have failed. The Industrial Commission must then issue an order pooling all interests in the spacing unit. The order must provide for the just and reasonable division of the proceeds from production from the well in the spacing unit among all of the interest owners.

Plugging Producing Wells

All producing wells eventually decline in production until it is no longer economically feasible to continue to operate them. When that time arrives, it is necessary that the well is properly plugged and that the surface location is returned as nearly as is practically possible to its original condition.

The operator must comply with the same requirements for plugging, well site restoration and bond release as the operator of an unproductive well.

GLOSSARY

A

abandon v: to cease producing oil and gas from a well when it becomes unprofitable. A wildcat well may also be abandoned if it has been proved unproductive.

acidize v: to treat oil bearing limestone or dolomite with acid in order to enlarge pore spaces and improve permeability. Acid is injected under pressure.

adjustable choke n: a special valve by which the rate of flow from a well may be regulated.

air drilling n: a method of rotary drilling that uses air under pressure to cool the bit and remove cuttings from the bore hole.

American Petroleum Institute: founded in 1920; a national trade organization which maintains offices in Washington, D.C. and Dallas, Texas; the leading standardizing organization for the petroleum industry.

annular space (annulus) n: the space surrounding a cylindrical object within a cylinder such as tubing inside of casing or casing inside of a bore hole.

anticline n: an arched, inverted trough configuration of folded and stratified rock layers.

API: abbr. the American Petroleum Institute.

B

back off v: to unscrew one threaded section of pipe from another.

back pressure n: the pressure resulting from restriction of full natural flow of oil or gas.

barrel n: a measure of volume for petroleum products. One barrel is the equivalent of 42 U.S. gallons.

bed n: a specific layer of earth or rock in contrast to other layers of material lying above or below it.

bit n: the cutting or boring element used in drilling oil and gas wells.

blowout n: an uncontrolled flow of gas, oil or other well fluids into the atmosphere.

blowout preventer n: equipment installed at the surface on drilling rigs to prevent the escape of pressure from the well during drilling or completion operations.

bore hole n: the well bore; the hole made by drilling or boring.

bottom-hole pressure n: the pressure in a well measured at or near the bottom of the hole.

BS or BS&W: abbr. basic sediment or basic sediment and water; refers to contaminants in produced crude oil.

C

cable tool n: a drilling method in which the hole is drilled by dropping a sharply pointed bit on the bottom of the hole. The bit is raised and dropped by means of a cable attached to it.

cap rock n: impermeable rock overlying an oil or gas reservoir. It is part of the trapping mechanism.

cased hole n: a well bore in which casing has been inserted and cemented.

casing n: steel pipe placed in a bore hole to prevent the walls from collapsing and to provide a means of extracting oil and gas if the well is productive.

casing head n: a heavy, flanged steel fitting that connects to the first string of casing and provides a housing for the slips and packing assemblies by which intermediate strings of casings are suspended and the annulus sealed off.

casinghead gas n: associated and dissolved gas produced along with crude oil.

casing pressure n: gas pressure built up between the casing and tubing.

casing shoe n: a short, heavy, hollow cylindrical steel section with a rounded bottom, which is placed on the end of the casing string to facilitate the insertion of the casing into the well bore.

catch samples v: to obtain cuttings made by the drill bit. The cuttings are obtained from the drilling fluid as it emerges from the well bore. The cuttings are examined by geologists to determine the nature of the rock being penetrated and the possible presence of oil or gas.

cellar n: a pit in the ground to provide additional space between the well head and the rig floor to accomodate the installation of equipment such as blowout preventers, etc.

cement casing v: to fill the annulus between the casing and bore-hole wall with cement to support the casing and to prevent the migration of fluid between permeable zones.

cementing n: the application of a liquid slurry of cement and water at various points between the casing and the bore-hole wall.

choke n: a device inserted in a flow line to regulate the rate of flow.

Christmas tree n: the control valves, pressure gauges, and chokes assembled at the top of a well to control the flow of oil and gas.

circulation n: the movement of drilling fluid out of the mud pits, down the drill stem, up the annulus, and back to the mud pits.

condensate n: hydrocarbons which are in the gaseous state under reservoir conditions but which become liquid in passage up the hole or at the surface.

conductor pipe n: a short string of large diameter pipe or casing that is used to keep the top of the well bore open and to provide a means of conducting the drilling fluid to the mud pit from the well bore.

connate water n: water that is inherent to the producing formation; or fossil sea water that was trapped in the pore spaces of sediments during their deposition.

core n: a cylindrical sample taken from a formation for geological analysis during the drilling of a well.

core analysis n: laboratory analysis of a core sample to determine its properties such as porosity, permeability, type of rock, fluid content, and probable productivity.

core barrel n: a tubular device attached to the bottom of the drill pipe with a core bit on the end to cut a core sample.

crown block n: an assembly of sheaves mounted on the top of the derrick over which the drilling line is reeved.

cuttings n: fragments of rock which are dislodged by the drill bit and returned to the surface by the drilling fluid.

D

deadman n: a piece of wood or concrete which is buried and to which a guy line is attached for bracing a mast or tower.

degasser n: the equipment that is used to remove gas from the drilling fluid.

density n: the weight of a substance per unit volume.

derrick n: the large load-bearing structure which rises above the derrick floor on a drill rig, from which the drill pipe is suspended. The derrick is equipped with sheaves and blocks on which the drilling line is reeved.

desander n: a centrifuge used to remove fine particles of sand from the drilling fluid.

desilter n: a centrifuge device, much like a desander, that is used to remove silt-sized particles from the drilling fluid.

development well n: a well drilled in proven territory to complete a desired pattern of production.

deviation n: the inclination of the well bore from the vertical.

deviation survey n: an operation to determine the angle of deviation from the vertical.

diamond bit n: a steel bit that has a surface of industrial diamonds.

directional drilling n: the intentional deviation of a well bore from the vertical.

displacement fluid n: in oil-well cementing, the fluid, usually drilling mud or salt water, that is pumped into the well after the cement to force the cement out of the casing and into the annulus.

drawworks n: the hoisting equipment on a drilling rig. It is essentially a large winch.

drill collar n: a heavy, thick walled section of pipe that is used between the drill bit and the drill pipe to put weight on the bit.

driller n: the employee directly in charge of the rig and the drilling crew during a shift or tour. He is responsible for the drilling rig and the downhole condition of the well.

drilling crew n: a driller, a derrickman, and two or more helpers who operate a drilling rig for one tour each day.

drilling fluid n: the circulating fluid used in the drilling of oil and gas wells. Its purpose is to cool and lubricate the drill string and bit, to return the cuttings to the surface, and to confine formation fluids to their respective horizons.

drill pipe n: the heavy, seamless tubing used to rotate the bit and to circulate the drilling fluid.

drill stem n: the entire length of tubular pipes composed of the kelly, drill pipe, and drill collars.

drill string n: the column of drill pipe, not including the drill collars or the kelly.

DST: abbr. drill-stem test. (See formation testing.)

disposal well n: a well through which water (usually salt water) is returned to subsurface formations.

dissolved gas n: natural gas which is in solution with crude oil in the reservoir.

dry hole n: an exploratory or development well that contains insufficient amounts of oil or gas to justify completion as an oil or gas well.

E-F

electric well log n: a record of certain electrical characteristics of formations penetrated by the bore hole, made to identify the formations, determine the porosity, determine the nature and quantity of the fluids that they may contain, and their estimated depth.

fault n: a fracture in the subsurface strata along which movement has taken place.

field n: a geographical area in which a number of oil or gas wells produce from one or more oil pools.

fish n: an object left in the hole during drilling operations. It must be removed before drilling operations can be resumed.

fishing tool n: a tool designed to recover equipment lost in the well.

fire wall n: a wall of earth built around an oil tank or other surface equipment to hold the oil if a leak should occur.

float collar n: a device used in cementing casing. It is attached to several joints above the bottom of the casing and prevents the entry of drilling fluid into the casing as it is inserted into the well bore, allowing the casing to float during its descent, thus decreasing the load on the derrick.

flow by heads v: a well that flows at irregular intervals.

flowing wells n: wells that produce oil or gas without artificial lift.

flow lines n: the surface pipes through which oil or gas flow from well head to storage.

fluid injection n: injection of liquid into a reservoir to force oil toward and into producing wells.

fluid level n: the distance between the well head and the point to which fluid rises in the well.

formation n: a bed or deposit composed throughout of substantially the same kinds of rock. Each formation is given a name.

formation fracturing n: a method of stimulating production of oil or gas by fracturing the rock with a combination of high pressure, acidic fluid, and propping agents such as sand and glass beads. The purpose is to increase the permeability of the producing formation.

formation pressure n: the pressure exerted by fluids in a formation.

formation testing n: a method of determining the potential productivity of a formation or portion of a formation prior to installing casing in the well. By means of drill pipe, packers, and special valving equipment, a sample of the formation fluid can be recovered and analyzed at the surface. Pressure data is also acquired from the formation.

G-H

gas cut mud n: drilling mud that has formation gas entrained in it. The gas must be removed prior to returning the mud or drilling fluid to the well bore.

gas lift n: a method of producing oil by injecting gas into the casing and allowing it to force the oil to the surface through the tubing.

gas/oil ratio n: a measurement of the amount of gas produced for a specific quantity of oil. The measurement is given in cubic feet per barrel.

gravity - API n: the specific gravity or density of oil expressed in terms of a scale developed by the American Petroleum Institute. The formula is: degrees gravity API = $\frac{141.5}{\text{Specific gravity}} - 131.5$. The lighter the oil, the higher the gravity.

hydrocarbons n: organic compounds of hydrogen and carbon, whose densities, boiling points, and freezing points increase as their molecular weights increase.

I-K

impermeable adj: preventing the passage of fluid. The absence of connecting channels between pore spaces in rock causes its impermeability.

intermediate casing n: the string of casing that is sometimes inserted into the well bore after the surface casing to prevent caving and further hole problems as drilling continues.

kelly n: the heavy steel member, four or six-sided, suspended from the swivel through the rotary table and connected to the topmost joint of the drill string; the kelly turns the drill stem as the rotary table turns.

kelly bushing n: a device fitted to the rotary table through which the kelly passes and by which the turning motion of the rotary table is transferred to the kelly.

L-M

LACT-acronym-"lease automatic custody transfer": Automatic measuring equipment that allows for the transfer of oil or gas from lease to pipeline without any manual activity or witnessing.

location n: the place at which a well is to be or has been drilled.

log n: a systematic recording of data, as from a driller's log, electric well log, radioactivity log, mud log, etc.

make a connection v: to connect another joint of drill pipe to the drill string.

make a trip v: to withdraw all of the drill pipe, drill collars, and drill bit from the well bore and to insert it back into the well bore again. This is frequently done to change drill bits.

marginal well n: a well whose production is barely sufficient to pay its operating costs.

miscible flood n: the injection of a solvent that lowers the viscosity of the crude oil in a formation which is followed by a displacing fluid.

mouse hole n: an opening through the rig floor, usually lined with pipe, into which a length of drill pipe is placed temporarily for later connection to the drill string.

mud n: the drilling fluid circulated during drilling operations. It may consist of water and native mud or may contain many additives that give the mud certain properties.

mud cake n: the sheath of mud solids that forms on the wall of the bore hole when the liquid from the mud filters into the formation.

mud pit n: a reservoir or tank, usually made of steel, through which the drilling fluid is circulated. Additives are mixed with the mud in the pit.

mud pump n: the pump which circulates the drilling fluid throughout the drilling system.

multiple completion n: a well equipped to produce oil and/or gas separately from more than one reservoir.

N-O

natural gas n: a mixture of hydrocarbons and varying quantities of nonhydrocarbons that exist either in the gaseous state or in solution with crude oil in natural underground reservoirs.

natural gas liquids n: those portions of reservoir gas which are liquefied at the surface in lease separators, or gas processing plants.

offset well n: a well that is drilled close by another producing well. An offset well is usually only one spacing unit away from a producing well.

oil field n: the surface area overlying an oil reservoir or reservoirs.

oil pool n: the accumulation of oil in the pores of sedimentary rock that yields petroleum on drilling.

open hole n: the uncased portion of a well.

operator n: the person or company, either proprietor or lessee, actually operating an oil well or lease.

P

pay zone n: the producing formation or interval within a formation.

perforate v: to pierce the casing wall and cement so as to enable the formation fluids to enter the well bore.

permeability n: a measure of the ease with which fluids can flow through porous rock.

petroleum n: oil or gas obtained from the rocks of the earth.

plug and abandon (P&A) v: to place cement plugs into a dry hole and abandon it.

pore n: an opening or space within a rock or mass of rock, usually small and often filled with fluid.

porosity n: a state of voids or open spaces existing in rock.

positive choke n: a choke in which the orifice size must be changed to change the rate of flow through the choke.

potential test n: a test of the maximum rate at which a well can produce oil.

pressure gradient n: a scale of pressure differences in which there is a uniform variation of pressure from point to point.

pressure maintenance n: repressuring of an oil field to maintain pressure or to slow the decline of reservoir pressure as oil is produced.

R

radioactivity well logging n: the recording of the natural or induced radioactive characteristics of subsurface formations.

rat hole n: a hole in the rig floor from 30 to 35 feet deep, lined with casing that projects above the floor. The kelly and swivel are placed in the rat hole when hoisting operations are in progress.

reserve pit n: a pit in which a supply of drilling fluid is stored.

rig n: the derrick, drawworks, and other surface equipment of a drilling unit.

rig down v: to dismantle a drilling rig.

rig up v: to assemble a drilling rig.

roughneck n: a worker on a drilling rig, a subordinate to the driller.

round trip n: to pull out and subsequently run back into the hole a string of drill pipe or tubing.

S-T

samples n: the well cuttings obtained at designated footage intervals during drilling.

seismograph n: a device that detects vibrations in the earth, used in prospecting for probable oil-bearing structures.

shale shaker n: a device that separates the coarser well cuttings from the drilling fluid when it returns to the surface.

spud in v: to commence drilling operations.

stripper n: a well that produces a small quantity of oil, usually less than ten barrels per day.

swab n: a device that is inserted into the tubing and lifts oil as it is pulled up.

swab v: to pull a swab through the tubing in order to lift oil to the surface.

trip n: (see round trip).

U-Z

unitization n: a system of operating a certain oil and condensate reservoir in order to conduct some form of pressure maintenance, repressuring, waterflood, or other cooperative form to increase ultimate recovery.

well bore n: a bore hole; the hole drilled by the bit.

well completion n: the activities and methods necessary to prepare a well for the production of oil or gas.

well head n: the equipment installed at the surface of the well bore.

wildcat n: a well drilled in an area where no oil or gas production exists.

WOC: abbr. waiting on cement.