IX. SAMPLING AND CORING IN PROSPECTING FOR OIL AND GAS.

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Modern methods of oil field prospecting and development involve an intensive study and interpretation of formation samples and cores brought to the surface during the drilling process.

Correct examination of formation samples involves not only identification of the fluid content of the strata, indicating in a qualitative and quantiative way their possible value for oil production, but also involves determination of their lithological properties as, per cent of pore space, per cent of saturotion, and permeability, in order that some prediction can be made as to the future production characteristic of the sand, as well as portray some idea of the possible production obtainable. Careful examination will also help predict what operating methods may be best adaptable to local underground conditions within the oil "sands."

Samples of unlerground formations are secured through three sources: (1) By using the diamond drill which is usually used when prospecting for favorable structures in areas where no outcrops are available; (2) by collecting bit cuttings from a cable-tool or rotary drilling well; and (3) by the use of various cordnig devices, or core barrels which are available for either cable-tool or rotary drilling.

Core Drilling for Structure

In probable petroliferous areas where the surface outcrops are poorly defined or absent entirely, as is the case in much of western Oklahoma and Kansas, as well as in parts of north and west Texas, the diamond core drill has been used with much success within the last few years. This method of sampling is popularly known as "core drliling for structure."

Most of the diamond drills used for "structure testing" are manufactured by the Sullivan and Longyear Companies, and are constructed to drill to depts ranging from 900 to 1000 feet. However, most of the prospect holes in Oklahoma and Kansas have not exceeded 600 feet; and in many cases the desired information as to the possible existence of structure is secured at depths as shallow as 300 to 500 feet.

The equipment is fitted with a two-inch core-barrel assembly, and 600 to 1000 feet of small drill stem or rods, which are cut and threaded in five-or ten-foot lengths. Fish-tail bits are used when drilling in soft formations; but hollow, circular steel bits set with four to eight black diamonds are used in hard strata. The latter type of bit cuts a continuous core, which is puched up into the core barrel attachment, and is held there by a self-locking core-lifter. A small double-action or duplex reciprocating pressure pump is used to circulate water down the inside of the drill pipe to keep the bitcool, flush out the cuttings, and prevent the walls of the bore hole from caving.

The diamond drill secures longer and less contaminated cores than any other coring device in use at the present time. This is due to several reasons: The diamonds are harder and tougher than the best qua'ity of steel used in core "heads" or cutters: and therefore, cut easier and more smoothly. Also, the hydraulic cylinder feeding device maintains a uniform pressure on the bit at all times, thus preventing the drilling string from "plunging." As it can easily be regulated for best speed and accuracy in either hard or soft rck. The hydraulic control thus eliminates the sudden jars and shocks common to rotary coring, resulting in longer unbroken cores. Another reason why the dimond dri'l secures more satisfactory cores is attributed to the design of the core barrel. It consists of two walls. The out wall is screwed to the drill rods, and rotates at the same speed. The inner wall or "barre'" which receives the core, is suspended on ball bearings and remain stationary, thus protecting the core from frictional heat, the washing action of the circulated water, and the vibration and whipping action of the drill rods.

When a stratum is encountered that is easily distinguished from the others, it is usually chosen as a key-bed or horizon marker. Its depth, together with the elevationand location of the bore hole, is recorded. Then the driil is moved possib'y a mile away, usually to another corner of the same section of land, where the same key-bed is sought again. At least three or four, and as many as seven or eight tests are often made in order to ascertain the dip and strike of the strata, and the amount and nature of folding that may exist. Ten to twelve tests will usually define the limits of most anticlines or domes.

The cores secured should be placed in metal or wooden trays, so constructed that the cores will fit into them, and be kept in their proper stratigraphic relationship. Each section of core should be carefully marked in sequence, so as to preserve the data for future study.

Sampling at a Cable-Tool Well

More satisfactory samples can be obtained from wells drilled with cable tools than is the case where rotary tools are used. This is true because there is usually less open hole, which precludes caving, the tools are pulled out more often, and the cuttings cannot be scattered and contaminated by the mud-circulating system, as is the case in rotary drilling.

Samples can be secured from the bottom and corners of the bit after it is pulled from the hole, or by catching a bucket full of the sludge that is brought up in the bailer after the hole has been bailed down. Also, there are various cab'e-tool core barrels or so-called "biscuit cutters," which can be successfully used when drilling in comparatively soft formations. While these core barrels obtain the core in "biscuits," which usually range from one to four inches in length, due to the jarring action as the tools are spudded, they secure a larger and more representative sample of the formation being drilled.

After the bailer samp'e has been collected, it should be placed in a clean bucket and washed. This is usually done by placing the nozzel of the derrick hose on the bottom of the bucket, and a slow stream of water turned on to float out the mud. Hot water, if available, will cause the oilcolor to show up more readily and to the best advantage. After the sample has been washed in this manner until the overflow water becomes clear, it is ready for examination and testing.

Bailer samples should be examined first to ascertain the color, texture, and hardness. They should be examined carefully for small fossils, impressions of leaves, plant remains, salt, pyrites, mica, gypsum, and sulphur. If they are sand grains, the size, shape and impurities should be noted. One must always be on the alert as to the possibility of contamination by cavings from the upper part of the hole below the casing shoe.

Frequently the samples are so finely ground by the bit that they are confusing unless certain chemical tests are applied to them. For example, a calcareous sandstone may resemble a limestone, and oolitic limestone may appear to be sand grains. Dilute hydrochloric acid will cause chalk, limestone and calcareous sandstone to effervesce rapidly; whereas, dolomite, the calcareous clay, and marl will react slowly with cold acid. Sand grains coated with calcareous material are often misleading when this test is applied; that is, the effervescing of the surface coating may cause the casual observer to conclude that the sample is calcareous instead of siliceous. Well cuttings that may be sandstone, quartzite, chert, flint, gypsum, clay, shale, and igneous rocks will not react to this test.

When calcite and dolomite have been so finely pulverized by the bit that they cannot be distinguished by use of a hand lense, the Lemberg Solution test maybe used at the well to good advantage. It is prepared by mixing four grams of aluminum chloride and six grams of extract of logwood with sixty grams of water, stirring and boiling for twenty minutes. A few of the previously washed cuttings may be placed on a watch glass, and one or two drops of the solution placed upon them . If the calcite is present, it will be stained purple after two or three minutes. The dolomite, if present, will remain unchanged.

Such samples may be tested at the well by heating a small portion in a shovel at the derrick forge. They should be washed well before heating, and all pieces of iron and rusty scale should be picked out. A magnet may be used to good advantage in this process. If coal, asphalt, or oil is present, the sample will fume and them flame. Shale, clay, chert, quartzite, or sandstone will not be affected by heating to redness if they are removed from the fire before they begin to fuse. Limestone and dolomite will slake if placed on a small amount of water after heating to redness. Gypsum will change to a lighter color, but will not slake in water.

If the samples present evidence of containing oil, the chloroform or carbon tetrachloride test should be applied. The unwashed samples are pulverized, placed in a glass bottle, and covered with one of these liquids. The bottle is then corked, and the contents shaken at intervals during a period of fifteen or twenty minutes. After this the contents may be filtered into a white dish or saucer. If oil is present, a dark-colored ring will be left on the filter paper. If any liquid residue remains in the dish after the chloroform or tetrachloride has evaporated, it is the oil that was in the sample.

After the preliminary testing at the well, it may seem advisable to take the samples to a laboratory where more accurate flame tests can be applied. Or, it may be necessary to subject the cuttings to detailed microscopic examination, or to separate and float out the heavy minerals by using hydrochloric acid, bromoform, and benzol. (1).

In areas where correlation of strata is doubtful, all samples should be carefully marked, and then saved for future reference. An ideal arrangement would be to have a supply of short, wide-mouthed four-ounce bottles having a screw top, as they make ideal containers. A filing cabinet having long, narrow, but shallow drawers should be available in the field office. On the front of each drawer a label should be placed, showing the well number and the depths between which the samples were secured. Within each drawer the sample bottles should be arranged in rows according to depth. Each bottle should be labeled to show the well number, depth, name of formation, if known, date collected, and kind of drilling equipment used: that is, whether cable or rotary-tools. All samples should be logged as they appear when wet.

Logging samples as they appear when wet, eliminates the test and care needed to dry them satisfactorily. If it is generally understood by the drillers, geologists, and others who may study the samples that they are to be bottled and labelled at the well while wet, there will be less danger of scattering, confusing, or contaminating them during the drying process, as they will be bottled immediately after being washed. Then, if it is necessary to examine the samples at some future time—after they have been dried out in the containers—it is a simple matter to re-wet them before an examination is made This will be necessary to avoid confusion, since the color of a dry sample will appear quite different when wet.

Accurate depth measurement must be kept at all times. The care and precision exercised in washing and labelling the samples will be of little value if the drillers are careless in recording the exact depth from which the samples are secured. Steel line measurements are not very accurate if taken in deep holes of small diameter. Accurately measuring over the derrick and "flagging" the drilling line is the best method in deep wells. It would materially assist the geologist in correlating strata if all drillers in a particular area would use the same method of determining the depth of drill holes.

Sampling at a Rotary-Tool Well

While it is more difficult to obtain representative well cuttings when rotary tools are used; nevertheless, more accurate samples than those usually secured can be obtained if proper methods and care are used.

In cable-tool drilling it is a simple operation to cease drilling at any depth, and then run the bailer to secure samples of the formation being drilled. But when drilling with rotary equipment, the bailer cannot be readily used. Furthermore, the bit is usually many

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1. Tickell, F. G.—"Correlative Value of the Heavy Minerals." A. A. P. G., Vol. 8, No. 2-1924.

feet below the top of the formation before the cuttings begin to appear in the slush trench. Even then, the cuttings may be so completely coated with mud and contaminated that their proper identity may not be ascertained unless they are examined very carefully. The writer has seen small cuttings of oil sand so completely plastered with mud that they were mistaken for shale cuttings upon casual preliminary examination at the slush trench. Then, too, cuttings may be so badly scattered and dsiseminated throughout the mud fluid as to become inaccurate and misleading.

Formation samples at a rotary drilled well may be secured by several methods: (1) If it is necessary to change the bit, the pumps may be shut off and drilling continued for two or three minutes before beginning to pull the drill pipe. Due to the absence of pump pressure, some of the cuttings will cling to the bit, and can be secured at the derrick floor. (2) Flow samples can be trapped in the slush trench as the mud fluid emerges from the hole. And thirdly, by using one of the better types of core barrels that are available.

Accurate flow samples can be obtained by two methods: If a change in formation occurs, the careful driller will notice it by the change in the reaction of the mud pumps, the drill pipe, and the rotary table. The drilling string can be swung several feet above the bottom of the hole while all the cuttings are flushed out at the surface. After the slush returns are flowing free of all cuttings, drilling may be resumed. The first cuttings to appear in the trench will be from the new formation. Of course this method, as well as all other methods of sampling and coring at rotary wells takes time, and is therefore expensive. In a 12-inch hole at a depth of 3500 feet, it will require about one and one-half to two hours to flush out the hole. The other method of obtaining flow samples is to "time the returns."

When using this method it is necessary to know the efficiency of the mud pump and its capacity per minute. The volume of the drill pipe must be calculated in arder to be able to estimate the time interval required to displace the mud fluid and the cuttings in the drill pipe; that is, the time in minutes for the fluid to reach the bottom of the hole. Then, since the volumes of two cylinders are in the same ratio as the square of their radii, the time to expect the returns at the surface can be readily computed. A permanent pump displacement table posted in the rig will make such calculations easy for most drills. Of course, the depth drilled during this time interval must be noted, so as to log the change of formation at the proper depth. This method has been checked in several fields in Oklahoma and Texas by introducing shelled corn under the suction line of the pumps, and has been found to be accurate within from 2 to 3.5 per cent.

Within the last few years it has become common practice t drun in some kind of core barrel when formation samples are desired. This practice is very expensive, but it is usually more satisfactory than any of the methods mentioned above. And if properly executed, it should eliminate most of the uncertainty of drilling through oil-bearing strata, and will make correlation work much easier.

The first type of coring device used in rotary drilling was the "basket core barrel," which is simply a short length of drill pipe notched out at the bottom and screwed to the lower end of the drill pipe; this replaced the bit. It is inexpensive and simple in operation, but is objectionable because the frictional heat generated often burns out all traces of oil. Then, too, the cores are usually short, as the weight of the drillpipe causes the teeth of the barrel to close-in rapidly. Basket cores are rarely more than 15 or 18 inches long, the average being about 4 to 8 inches. This, of course, depends largely upon the character and hardness of the formation, and upon the skill and technique of the driller.

There are many types of core barrels on the market today, but only a few af them are satisfactory. However, the type of core barrel that permits the flushing of the hole before beginning to cut the core, as well as the double-walled core container type are quite satisfactory, so far as securing a representative sample of uncontaminated core is concerned. It is difficult indeed to manufacture core head steel that is tough enough to prevent chipping and breaking and at the same time be hard enoughtocut hard sediments with any degree of consistency. However, Stellite and especially Borium (2) probably will do much toward eliminating this disadvantage. If it were mechanically possible to take perfect cores with any degree of consistency, correct interpretation of sub-surface conditions could be easily and readily accomplished.

Until coring devices are perfected mechanically, many cores will continue to misrepresent the formation from which they are taken. A perfect core would be a continuous, unbroken sample, the diameter of which is large enough to show the true lithologic character, texture, and dip of formation, and whose characteristics are unaltered in any manner while securing the sample. But as a matter of fact, much of the core of a soft formation is either washed away or pushed aside by the pump pressure and the rotation of the drill pipe, thus leaving a stratigraphic gap in the formation sample secured.

Also, the heat generated in the bottom of the hole may "burn" a loosely consolidated sand to a quartzite, a sandy shale may be changed to a hard mass resembling igneous material, and rich oil sands have been known to be fused into a black carbon-like substance. The vibration and whipping or rotary drill pipes may cause the core to be broken-up and churned around in the inner barrel until little of its original form and texture remains. Drilling mud may be pressed so hard and made so compact by pump pressure that it may resemble a shaley formation. Also, the pump pressure may be so great in deep holes as to drive all salt water out of the core, and thus lead one to believe that a fresh-water sand has been encountered. Pump pressure can also cause a core from a rich oil sand to appear as one not worthy of commercial possibilities.

Core samples should be examined at the well immediately after they are removed from the core barrel, for at this time they usually portray certain characteristics that cannot be observed later. If gas

(2) Garretson, R. G.—"Oil Field Engineering," December, 1917.

is present, it will be noticed by bubbling as part of the liquid content is expelled. If the core presents evidence of containing oil, a test should be made at once, of the sample should be sealed in a Mason jar to prevent loss by evaporation and oxidation.

The cores that are to be taken to the field office or laboratory for examination should be wrapped in wax paper, and then placed in metal or wooden trays. This will preserve them in storage and during transportation.

Before intensive examination is begun the outside of the core should be thoroughly washed, scraped, and brushed to remove the outer coating of mud and other foreign material which usually obscure the real character of the formation sample. The core should then be split lengthwise. This can be done with a hammer and chisel, but a hack saw or ordinary hand saw is much better. At this time a binocular microscopic or good hand lens should be used to aid in the examination.

If a core is found to contain oil, a porosity test (3) should be made, at the rate of production and the storage capacity of the "sand" are directly dependent upon the size and amount of the pore space between the grains. If the sample to be tested for porosity should contain oil, it should be thoroughly washed in carbon tetrachloride or petroleum ether before the test is begun.

As has been intimated in this article, up to the present time sampling and coring methods and devices have not been developed to a very high degree of perfection. But this phase of production methods is now receivnig more careful study tha never before. The driller, the petroleum geologist and petographer, and the petroleum engineer, as well as the core barrel patentees are all co-operating favorably toward more efficient methods and devices for securing samples, as well as toward a more thorough and complete interpretation of them.

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(3) Melcher, A. F.—"Determination of Pore Spaces in Oil and Gas Sands." A. I. M. E. Vol. 65.

Russel, W. L.—"A Quick Method of Determining Porosity." A. A. P. G Vol. 10, No. 10.