GEOPHYSICAL PROSPECTING FOR OIL

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The problem of locating oil is one of ascertaining the structural and stratigraphic relationships of the rocks near the earth's surface, and of correctly interpreting these data. This interpretation is based on a group of theories concerning the origin and accumulation of oil which have been formulated from a large amount of past experience and observation. The weight of evidence favors the theory of organic origin of oil from the remains of animal and vegetable material buried and disseminated in basins of sedimentary deposition. By a complex series of events this material has been transformed and collected into bodies of oil and gas.

The mode and place of accumulation are governed by two factors: stratigraphy and structure. The sedimentary rocks in which oil occurs are ordinarily deposited in layers or strata of alternating types — e.g., shale, sandstone, limestone, etc. Of these, sandstone is the most important as a reservoir rock for oil and gas because of its relatively high porosity and permeability. Shale strata, on the other hand, have an important effect on the migration and accumulation of oil. Because of the difference in specific gravity between oil and water in the rocks, the oil is subjected to an upward buoyant force. In alternating layers of shale and sand, however, the oil is largely constrained by the impervious shale layers to move in the more permeable sands, and aided by the driving force of circulating water, migrates up the dip or steepest slope of the strata until stopped by some "trap." The trap may be either structural or stratigraphic in nature, or both.

OIL TRAPS

The most common type of structural trap is the anticlinal fold or dome-shaped structure, formed by the warping and folding of rocks by horizontal compression. In this case, if the permeable reservoir rock extends over the entire structure, the oil and gas migrate to the top, being trapped by the buoyant force of the water on the flanks and by the impermeable rocks overlying the sand. Here the oil and gas remain, or at least escape only very slowly.

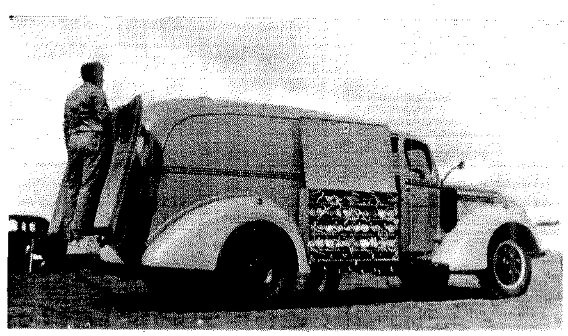
Another type of structural trap may be formed by faulting in sedimentary rocks. Oil may accumulate in upturned beds butting against impervious rock on the opposite side of the fault plane. Likewise, a trap may be formed by a fault cutting across a plunging nose-shaped fold, thus preventing further migration of oil up the structure.

In the Gulf Coast region of the United States a common type of structure is the salt dome. Here masses of salt have been forced up from considerable depth into the overlying sedimentary rocks, forming plug-shaped salt masses surrounded by the upturned beds of the disrupted sediments. Oil is then trapped in the sand members terminating against the salt, or may accumulate in arched beds above the salt plug.

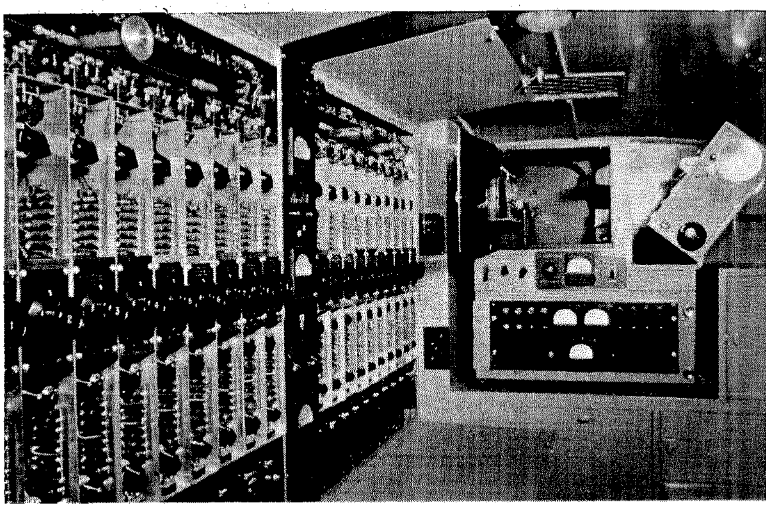
Stratigraphic traps are so-called because they have resulted from lateral changes in sedimentation at the time of the deposition of the strata. Thus coarse sands deposited near the shore of a basin may grade into finer sands off-shore and finally into impervious shales. On the other hand, near-shore sands in a slowly submerging basin may have been covered by overlapping shales as the shore line moved inland. In either case, there is a boundary, either abrupt or transitional in character, between sand and shale. Subsequently, when the sediments are deformed by warping and folding, traps for the accumulation of oil may be formed along the shale-sand boundary. For example, if the boundary cuts across a plunging nose-shaped structure, a trap may be formed where the shale-sand demarcation intersects the crestline of the fold. Likewise, a trap may be formed in a series of more or less uniformly tilted beds if the shale-sand boundary cuts obliquely up the slope of the beds and then bends obliquely down the solpe, forming a reentrant bay. The oil then accumulates in the apex of the reentrant, being prevented from further migration up the slope by the transition from sand to impervious shale.

The types of traps for the accumulation of oil described above are only a few of the many which occur. Usually the trap is much more complicated than those described, with a combination of factors present. Thus, dome-like structures are often cut by faults which affect the accumulation of oil. Furthermore, the porosity of the sand reservoir rock may vary over the extent of the structure, greatly influencing the accumulation. Accumulation is not always limited to one sand member. Often there may be a number of sand strata at various depths, some giving rise to separate accumulations of oil or gas, others containing only water.

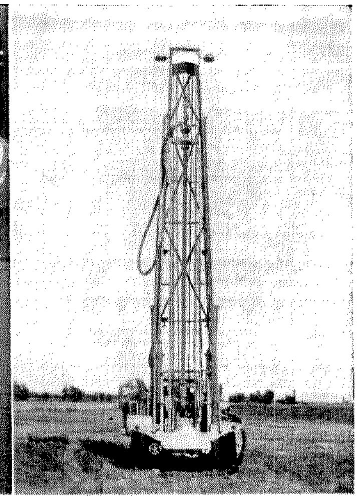
The problem of the geologist in exploring for oil is first to ascertain whether or not there are strata present which would be likely to contain oil or gas, and secondly, to locate the structural and stratigraphic traps which are the most probable locations for oil and gas accumulation. He has available two sources of information: observations at the surface of the ground, and subsurface information from previously drilled wells. The amount of information available from surface observations varies with the locality. In elevated regions, considerable areas may be exposed to observation by erosion which has removed the mantle of surface soil.



Exterior of recording truck, showing racks with geophones.



Interior of recording truck, showing amplifiers and oscillograph.



Portable shothole drill.

SURFACE MAPPING

The first step in exploration is to prepare an accurate surface map showing the rocks exposed; measuring their thickness; noting their composition (whether shale, sandstone, limestone, etc.); noting their fossil content; showing the location of surface oil seeps, if any; showing the bedding planes, and particularly the boundaries between different types of rock; showing the direction and amount of slope or dip of the bedding planes in the rocks; and showing the location of folds, warps, and faults in the rock. Where information is concealed by a shallow mantle of surface soil, it may be obtained by digging ditches or taking auger samples. Mapping is often done with the use of a plane-table, the elevations as well as locations of important points being obtained. In many places, airplane photographs serve as excellent base maps and reveal many features not readily apparent from the surface. After the surface map has been completed, subsurface contour maps on significant horizons may be constructed by extrapolation from surface data. The geologist also attempts to reconstruct the past geological history of the region, outlining former seas and basins of deposition, and noting the location and extent of sands and shales. With all this information assembled, he is in a position to make an intelligent recommendation as to the most desirable location for drilling an exploratory well.

SUBSURFACE MAPPING

A great many oil fields have been discovered by the above described procedure of surface mapping and extrapolation from surface data. However, it so happens that many areas of potential oil production are located in depressed regions which are being subjected to surface deposition rather than erosion at the present time. That is, the areas are covered by flat-lying deposits of alluvium, recent stream deposits of gravel, sand, and silt which almost, if not completely, mask the underlying rocks.

It is also many times true that even in areas where rocks are exposed by erosion, the information obtained at the surface does not give a reliable or complete indication of the structure at depth. Here the information obtained from previously drilled wells is of considerable value. In practically all drilling of wells a careful log is kept of the mud and cuttings washed from the hole. Also, at critical points actual rock samples are cored from the bottom of the hole as drilling progresses. These core samples are carefully studied as to their content of microscopic fossils, composition and mineral content, porosity, permeability, the dip of bedding planes, etc. In addition the well is surveyed electrically by recording variations in current and potential across a set of travelling electrodes lowered in the hole. This record shows in minute detail the boundaries between various strata — e.g., sands and shales — as revealed by the measured changes in resistivity and porosity of the wall rock. By comparing all the assembled data from a number of wells not too distant from each other, it is possible to correlate similar points, as for example, the top of a particular sand stratum which may be important as a reservoir rock for oil. If the wells are close enough together, subsurface contour maps may be drawn showing accurately the elevations and structure of pertinent horizons.

When wells giving subsurface information are widely separated, however, the interpolation of data between wells becomes more uncertain, and there are large areas for which the subsurface structure remains unknown. In some regions with shallow oil production, exploration is conducted by drilling a number of relatively shallow core holes, one or two thousand feet in depth, and correlating information obtained. In general, however, with the increasingly greater cost for deeper wells, it is not economically feasible to carry out detailed exploration by drilling.

GEOPHYSICAL PROSPECTING

One of the main objects of all methods of prospecting is to furnish a guide for the successful location of wells so as to minimize the number of dry holes and keep the cost of discovery as low as possible. It is in this regard that the physicist and engineer have been of invaluable assistance to the geologist. Various types of rocks show appreciable differences in physical characteristics — e.g., in density, magnetic permeability, electrical resistivity, elastic rigidity, etc. It is

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