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SPECIAL OIL AND GAS ISSUE

The increased activity of the oil and gas industry in this area is posing many new problems for Colorado lawyers. The work of the industry in this state may still be classified as exploratory. As exploration continues and development becomes more widespread through better marketing facilities, legal problems are expected to multiply greatly. Familiarity with this field of law is increasingly important to lawyers and, to meet this need, the Weld County Bar Association recently sponsored an Institute on Oil and Gas. Because of the excellence and popularity of this Institute and a general demand for more information on the subject, the speakers were asked to prepare their remarks for publication. The product is here printed in the following five articles.—EDITOR.

OIL GEOLOGY AND THE DENVER BASIN

M. J. BOREING*

It is doubtful if a Geologist has ever been asked to preach a sermon, but if so, his Scripture reference certainly would have been Genesis 1:1, "In the beginning God created the heavens and the earth." About one billion years later the geologist came along and began explaining this first week's work; it was probably a pretty full week, and the Creator doubtless got in some overtime. In any event, the earth was created as a round mass of basic material surrounded by a gaseous envelope which we call the atmosphere. Without the atmosphere it might have remained a barren ball, but the atmosphere furnished changes of climate—rain, snow, ice, and wind—all great erosion agents; it made possible the glaciers, rivers, lakes, and oceans, including a warm body of water, somewhere, where a spark of life first appeared. Basic rocks were being cut down by erosion and were being deposited in seas and lakes in the form of shales and sandstones, while plants and animals were living and dying, leaving their remains as organic material in the deposits—in the form of coal, oil, and gas. When the conditions on earth were such as to allow the lush development of plant life, similar to our present jungles, the dead plants formed a mass of material, which later was subjected to pressure, heat, and plenty of time, to become our present coal beds.

Elsewhere on earth, plants and animals, mostly microscopic, were living and dying in the shallower portions of the oceans. Their number was greater by trillions than Washington can conceive. As they died and sank to the ocean bottom, each carried with it a minute particle of fatty material . . . and at the same time, sands and shales from the rivers and shores were settling

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on the ocean bottom, too. Larger animals, which had developed protective shells, were dying and their remains likewise formed deposits of animal matter and limey material on the sea floor. So came the sedimentary oil bearing rocks of this earth—sandstones and shales from the basic rock, and limestones and carbinaceous materials from the once living plants and animals. As erosional conditions on the surface of the earth varied, successions of deposits were laid down—first a series of sandstones, then shales, perhaps then a limestone, and so forth—all the while the sea plants and animals were making a great effort to live, produce, and die. Their contribution to the oil business was the tiny bit of fatty stuff they carried to their ocean graves. More sediments poured in, pressure mounted, time passed, and Mother Earth furnished sufficient heat for a slow "simmer". The fatty stuff became a complex hydrocarbon which we call *petroleum,* which is made up of a combination of carbon and hydrogen—the lower the percentage of carbon, the lighter, or, higher gravity, the petroleum. The simplest form is CH_4 or pure natural gas. When petroleum contains considerably more carbon than hydrogen, the Highway Department mixes it with sand and dirt, and builds black-top roads.

Porosity and Permeability

The sandstones, shales, limestones, and petroliferous materials deposited in the seas are called *"source"* beds. All these are stationery except the fluids—oil, gas, and water. These fluids occupy the voids in the rocks, and ratio of the void spaces to the solid mass of the rock is the *"porosity"* of the formation. In a sandstone the porosity is formed in the space between the sand grains or in fractures; in a limestone the porosity may be formed in voids between crystals, by voids in, and adjoining, fossils, or in tiny Carlsbad Caverns. Porosity in shale is rare, and usually occurs only after there has been a crushing and fracturing of the formation. In order for there to be a commercial accumulation of oil and gas, these fluids in the rocks must become segregated, and nature has solved this problem, simply by giving oil and gas the good old Ivory Soap treatment, whereby "It Floats."

However, there can be no movement of fluids through a formation unless there is a connection, or *channel,* from one bit of porosity to the next. This quality of a rock to allow the flowage of fluids is called its *"permeability"*. There cannot be a good oil field, regardless of the thickness of the reservoir, the porosity, or the amount of oil saturation, unless the reservoir rock has permeability. An example of this is the Clark's Lake Pool over northwest of Denver. Amerada found almost 100 feet of saturated sand with good porosity, but was able to complete only small wells because the permeability of the sand was very low. Similar conditions exist at Buckingham, east of Greeley.

Now, we will assume we have a sandstone formation, deeply buried, which is underlaid and overlaid by impervious beds, and which is completely saturated with a mixture of water, oil, and gas. This sandstone has good porosity and permeability. If the bed is absolutely horizontal, the oil and gas will form a scum on top of the water, but if the bed dips in any direction, then the oil and gas will slowly, *very slowly,* start the uphill journey to reach the top of the water column, and if these conditions remain constant, eventually the sandstone will outcrop, and the oil and gas will be dissipated into the air. However, when conditions do not remain constant, an oil pool might be formed. Thus it becomes apparent why geologists seek the abnormal rather than the normal conditions. If the sandstone does not outcrop, the oil and gas will continue the journey to a point beyond which movement is impossible and that point would be the place to stake out a homestead.

Following is a list of typical oil traps. Illustrations of these may be found in any book on Petroleum Geology:

1. Dome, or anticline (Rangely).
2. Pinchout (East Texas).
3. Unconformity (Many pools).
4. Change of porosity or permeability (Many fields).
5. Faulting (Many pools).
6. Salt plugs (Gulf Coast).
7. Reefs (Canyon Reef in Scurry County, Texas).
8. Fractured Shale (Florence, Colorado).

Many of the large oil pools have been discovered by *surface* geology. This type of geology is only possible in areas where there are persistent rock beds out-cropping on the surface. Levels are run on the surface beds, and if there is an indication of an anticline, or a dome, on the surface, these structural conditions may extend downward, and may form an oil trap. Of course, a huge structure, as that at Rangely, Colorado, is very evident on the surface. There the outcropping rocks form escarpments many feet high, which encircle the field, dipping away from the center at all points.

In the vast areas in which it is impossible to do surface geology, other means of exploration must be tried—the most successful of which is with a measuring device called the *seismograph.* Unfortunately this device acts exactly the same over oil as it does over salt water, as far as its own actions are concerned. However, it is a great implement for finding deep-seated structures in the earth's crust. Many of the aforementioned oil traps may be indicated by a seismic survey.

There is a particular group of geologists continually looking for oil, but they, like the attorneys, wear their Sunday suits all week. They represent the "Sub-Surface Department", and they find a lot of oil. Any hole drilled, regardless of its economic merit, becomes a yard-stick, geologically, as the depths of all horizons may be ascertained from the well log and can be compared with depths of similar horizons in wells drilled in the same area. The samples and cores of beds drilled can be studied and also compared with other well data. From this information, preferred areas are located, which can be worked in detail by field methods.

The recent happy hunting ground for oil is in basins. Geologically, a basin is an area surrounded by up-lift barriers, such as mountains, in which sediments have been deposited during the past ages. Some of these areas are topographic basins even today; however, many are indicated only by outcropping formations. The current publications continually refer to new discoveries in one basin or another.

For years, many geologists have thought the Denver basin should produce. In the early 1920's the Wellington and Fort Collins pools were discovered as a result of surface geology. These pools are producing from folds in the rock formations directly east of the front range of the Rockies. Production is from a sandstone at a depth of about one mile. To date these two pools have produced 8,200,000 barrels of oil and a considerable amount of gas.

EXPLORATION INCREASES

The next discovery, and the last for several years, was the Greasewood pool. Production at Greasewood is from a thin sandstone at a depth of 6300 feet. The first wells in this pool were good producers (two have produced over 100,000 barrels each), but subsequent tests were discouraging, as were the economic conditions in the early 1930's, so, in spite of several concerted efforts, nothing productive happened in the basin until the spring of 1948. The Ohio Oil Company had been quietly working in southwestern Nebraska for several years, and made their first discovery on the Egging farm northeast of Sidney. Russell Volk of the Plains Exploration Company of Denver, has been active in the area for years, and his efforts have surely contributed to the developments on the Colorado side of the basin.

After the Ohio Oil Company's first discovery, most of the major oil companies, and many independents, entered the area, and several million acres of land were leased for prospecting. At the present time there are 60 drilling rigs in the area, and there are many seismograph crews working. Last year over 1600 crew weeks were spent in the basin. The area is now producing around 8,000 barrels per day, in spite of adverse marketing conditions. The crude is classified as being *"sweet oil"* with very little, if any, impurities, and is of high specific gravity. The oil is being delivered to the refineries, or to the Stanolind Pipeline at Bridgeport, Nebraska, by trucks. Transportation is costing the producers and royalty owners from 25¢ a barrel *up*, depending on the mileage from markets. The posted price for this crude is $2.65 per 42 gallon barrel for 40 gravity oil, *at the well.*

Considerable gas reserves are being developed in the basin. The Big Springs Gas Field in Duell County, Nebraska, was produced and sold to the Kansas-Nebraska Gas Company, which delivers the gas eastward through its lines. Incidentally, this pool is being developed on a spacing pattern of one well to the 640-acre unit. The gas company is taking one million cubic feet per well per day, paying at the rate of 10¢ per 1000 cubic feet. Any well which might be completed on acreage less than the prescribed unit will be pro rated accordingly.

GAS MAY SUPPLY DENVER

The gas, which has been developed in the Sidney, Nebraska, area, is being purchased by the Rocky Mountain Gas Company, and is being used locally, or is being delivered in that company's lines, serving the area to the northwest. Gas reserves in the Colorado portion of the area have been shut-in for lack of markets. Reports indicate that the line which has been built from northern Logan County, Colorado, into Sterling, Colorado, may be extended southwest towards Denver, if sufficient gas reserves are developed.

The recent oil and gas discoveries in the basin have resulted, chiefly, from seismic surveys. Some of the better structures have not produced, but considering the results in general, it must be admitted that the seismograph is here to stay. One long producing trend extends from the Gurley area in Nebraska, southwest towards Fort Morgan, Colorado. Several factors enter into the accumulation of this production: structural conditions are right, in that there appears to be a flattening in the regional dip, and spotted along this terrace are a series of small domal structures . . . and the reservoir conditions along the trend are better than in some adjoining areas. These domal structures are comparably small, and the majority of them have less than 100 feet of closure.

There seems to be another parallel trend, as far as structure is concerned, extending from the Big Springs Gas Field, southwest through Sedgwick, Phillips, Yuma, and Washington counties, Colorado. Excepting for the gas field, this trend is not proven to be productive from the few wells which have been drilled, even though most of these tests were located after seismic surveys. However, several of the holes have had shows of oil, which, although not commercial, are encouraging.

The oil pools in southern Kimball County, Nebraska, and in northeastern Weld County, Colorado, may be on similar structural and productive trends. However, until more wells are drilled, there is not enough subsurface control to prove, or disprove, this theory.

Oil and gas production in the basin is coming from the Dakota Series of lower Cretaceous Age. The series is usually divided into three main sand horizons locally named from the top down as follows: *"Muddy"* or *"D"* sand, the *"Dakota"* or *"J"* sand and the *"Lakota"* sand. The two top Dakota sands produce oil and gas in many places. The Lakota, to date, has been found to be a poor reservoir bed in this area. In one well, the British-American Segeleke, in north central Logan County, the lower sand tested over 50 barrels of black, low gravity oil per day. Other than this, there does not appear to be any shows in the lower sand. However, it produces in many places in Wyoming.

Below the Dakota sands, several formations are present that produce much oil in Kansas and Wyoming. These deep beds have been tested in only a few wells here, but all have been non-productive. Deep production probably will be developed in the basin in the future.

Other products produced from wells are *casing head gas* and *casing head gasoline.* Under the high pressures in the reservoir, the gas which is in the oil zone is actually in solution. As the oil is produced, the gas in solution is released, and flows from the well as casing head gas. This gas carries with it some of the higher gravity constituents of petroleum and when these are condensed, the resulting fluid is known as casing head gasoline.

In the recovery of oil within the proven pools, and the effect of redrawal of fluids on the reservoir, several observations must be made. The producers attempt to obtain the maximum oil production, and this includes gas, with the minimum of expenditure in holes and equipment. This is especially the case now, as steel and metals are so very scarce. But never-the-less, each producer must drill a sufficient number of wells to protect his lessor's interest in the reservoir. The ideal way to develop an oil pool is to have it in the center of a large ranch, or on a large block of State or Federal land, all under one basic lease. Then there are no land lines to protect, or separate lessors to satisfy, and the wells can be drilled, without restrictions, on the most promising locations, where ever they fall within the producing area.

SPACING PATTERNS SHOULD BE VARIABLE

The *spacing pattern* within any pool is economically important. The fewer acres allotted per well increases the ultimate yield per acre, but this does not necessarily increase the ultimate profit per well. In many pools the most economic spacing pattern can be determined only by experience; thus, in a new pool, it is more satisfactory to develop the leases with too *few* wells rather than too many, as more wells can be drilled, if necessary, as production history develops. When a pool is being developed under an even spacing pattern, it is possible for one lessee to have an offset obligation fall on a location which appears, geologically, to be on the edge, or even outside, the producing area. The lessee does not want to complete an unprofitable well (or a dry hole) and on the other hand, the lessor does want his offset drilled. So they both go to see their lawyers.

Pressure within the reservoir is created by the overlying rock column, and by the hydrostatic head, if the formation carries water, as do these Dakota sands. When a hole is drilled through a reservoir, pipe is set on the bottom of the hole, and cemented so that the cement is well above the top of the sand. When the pipe is perforated opposite the sand, pressure is immediately released from the surface of the reservoir and oil squirts into the well because of the pressure differential. This movement of oil will continue until the differential becomes zero, or if the bottom hole pressure is great enough, the well will flow at the casing head. As the pressure is released, gas in place and gas in solution will expand and migrate toward the well, forcing the oil with it. As the oil is produced, the gas pressure encircling the well is decreased in proportion to the volume of fluids withdrawn. The water table under the oil will rise as the pressure is released, and should the pressure be released too suddenly, by over production of oil and gas, the water will *"cone"*, and entirely envelop the well, thereby greatly hindering further oil production.

If there were a perfect oil pool, produced perfectly, all wells would be evenly spaced, and would be drilled simultaneously. Each well would be produced in the proportion of its potential productivity as compared to the productivity of the field. Then gas pressure would be dissipated evenly, and the water table would encroach upon the reservoir in a flat plane lifting the oil above it.

DRAINAGE PROBLEM

However, perfection is rarely achieved, and herein lies the problem of *"drainage"*—as the judge hears it. Drainage is not entirely the actual stealing of a neighbor's oil, barrel by barrel, but is more like *freezing it* down under, so that the owner cannot get out the oil he actually owns. But his *reservoir pressure* can be stolen, and this pressure is the motivating force behind his oil. When this force is reduced to a certain point, *natural* movement of oil through the reservoir bed is impossible.

There are no proration regulations in the basin, other than those practiced by the operators and those caused by market conditions. Stanolind has been taking about 50 barrels per day, per well, in the pipeline at Bridgeport. The amounts being delivered elsewhere depend on the economic productivity of wells, and the individual purchase contracts. However, within the separate pools the producers have working agreements among themselves to produce their wells in an orderly manner.

It is to be hoped the new Platte Valley Pipeline, to be completed soon, will create a greater market for basin crude, and that sufficient new oil will be developed to warrant a gathering system to the various pools. It is very probable that these developments *will* materialize, and will insure a great future in the basin.