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Geology of the Crystal Oil Field
Montcalm County, Michigan

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GEOLOGY OF THE CRYSTAL OIL & GAS FIELD

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Introduction

The Crystal Field is located in Crystal and Ferris townships, Montcalm County, approximately twelve miles west of Ithaca. It is easily reached by good gravel and paved roads. Three railroads, the Grand Trunk Western Line and two branches of the Pere Marquette Railroad Company, are within six miles of the present producing limits of the pool and provide excellent transportation facilities. Five pipe line companies, the McClanahan Pipe Line Company, the Midwest Pipe Line Company, the Pure Transportation Company, the Old Dutch Refining Company, and the Simrall Pipe Line Corporation[1] serve the field. The production from the field is refined at Muskegon, Alma, Mount Pleasant, Midland, and St. Louis, Michigan, and Toledo, Ohio.

The Crystal field is unlike most Michigan fields: Production is very spotty, there is very little gas pressure, and a strong water drive is apparent.

Physiography

The Crystal field lies between two north-south hilly belts - the Fowler and the Lyons moraines of the Saginaw ice lobe.[2] The topography consists of gently rolling till plain and sandy or gravelly outwash plain. Surface elevations range from 780 to 850 feet. The area lies on the watershed of two drainage systems. The northeast part of the field is drained by Carpenter Creek which flows eastward into Pine River, a branch of the Saginaw River system. The central and southern part of the field is drained by Fish Creek, a branch of the Maple River, which flows southwestward into Grand River. The water table is very close to the surface, being at a depth of only a few feet in many places, and rises above the surface in Duck Lake along the edge of the field.

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(1) February 1936 report of Michigan Oil Producers Committee

(2) Leverett, F., Surface Geology of Michigan, Mich. Geol. and Biol. Survey, Pub. 25, Geol. Ser. 21, Plate I, 1917.

The Saginaw formation of Pennsylvanian Age includes dark and black shales, sandy shales, and occasional thin stringers of limestone. The black shales are usually carbonaceous. All members of the formation vary greatly in thickness, and in the few samples available no stratum can be traced laterally for any considerable distance.

The Parma formation at the base of the Pennsylvanian is generally a light gray to white sandstone, shaly in places, and ranging from 0 to 60 feet in thickness. The samples from the Fred Turner - McConkie No. 1 well indicate a thickness of 60 feet. A much greater thickness is given in several drillers' logs, but this is doubtful. In places, the Parma grades downward into the Bayport (Au Gres)(4) limestone of Upper Mississippian Age, and the contact is difficult to determine.

The Bayport formation in the Crystal area is an impure dolomitic gray limestone, and from the information available seems to be lenticular or patchy in distribution; the thick lenses are possibly old erosion remnants. According to the samples available, the thickness appears to range from 0 to 40 feet. About 100 feet of "lime" is given in some drillers' logs but no samples were available to verify such a thickness. The gradational contact between the Bayport and the overlying Parma sandstone indicates either a reworking of the Bayport limestone or continuous deposition with a slow, gradual change from limy to sandy sediments.

The Michigan Series, also of Upper Mississippian Age, is similar to that found in most of the other Michigan oil fields. From the sample records, the thickness ranges from 275 to 315 feet, averaging about 290 feet. The Michigan Series consists principally of gray shales and gypsum with occasional thin stringers of sandstone. Beds of sandy buff dolomites are somewhat common and a rather persistent bed occurs but a few feet above the top of the Marshall formation. In many drillers' logs, a green shale is reported at the top of the Michigan section. This stratum is easily recognized in the field because of the greenish gray color that the material imparts to the water bailed out during the drilling operations. This bed is the first marker in the field that can be used with any degree of reliability for determining underlying structure.

Near the base of the Michigan Series is what is known as the Michigan "Stray" gas sand. It consists of gray to white fine sandstone with a limy cement. The thickness is reported to be 0 to 30 feet, although no section thicker than 25 feet was found in the samples studied. This sandstone is believed to have been formed by the erosion of old Marshall islands in the seas of early Michigan Series time. In many of the oil and gas fields in tha State, gas

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(4) Ehlers, G. M., Reclassification of the Paleozoic System of Michigan: Presented at Michigan Acad. Sci., March 20, 1936

is found on the flank of the oil structure, indicating that the "stray" sand is possibly a system of off shore bars or barriers. Usually, it is separated from the Marshall by a shale break or shaly limestone, although in some wells there is no visible separation. Several geologists believe that the "stray" sand is part of the Marshall where there is no shale parting present. Because of the different lithologic characteristics of the "stray" and the Upper Marshall, especially the lime cementing material, it seems more logical to include the Michigan "stray" in the Michigan Series.

The Marshall section, including the Napoleon and Lower Marshall or Red Rock, has a total thickness of 132 to 266 feet, averaging about 200 feet. The Napoleon is a white to light gray sandstone, but in some wells it is stained a brownish pink near the base. In several wells in the field, shale beds separate the formation into two or three members. The sand grains are for the most part angular, although well rounded and frosted grains were observed in small amounts in several samples. The Lower Marshall consists of red shales and brownish red and dark red ferruginous sandstones. The base of the Lower Marshall, which can be used as a marker in other areas, cannot be used with accuracy in the Crystal field because the Lower Marshall varies in thickness more than 130 feet in the field.

The Coldwater formation consists of gray and blue-gray shales, averaging about 1,050 feet in thickness. A bed of red limy shale 10 to 20 feet thick is near the base of the formation. This bed is persistent, being present in every set of samples examined and noted in most driller's logs.

The Sunbury-Berea-Bedford section is not well defined in the Crystal area. From samples available, it appears to consist of gray shales, gray limy shales, and thin limestone stringers. Study of drillers' logs and field reports indicates that the beds reported as Sunbury are the red limy shales at the base of the Coldwater. In a few wells, a typical brownish black Sunbury shale is found. No typical Berea sandstone has been observed, although according to several drillers' logs, "grit" occurs below the Coldwater shale. "Grit" is a term used by drillers and has little to do with the composition of the rock.

The Antrim formation consists of brownish black to black shales, averaging 440 feet in thickness. Pyrite and calcite were noted in a very few samples, indicating the possible presence of concretions. Formations reported by drillers as "shell" seem to support this possibility.

The Traverse Group includes gray and white limestones, gray shales, and gradations between shaly limestones and limy shales, with limestone predominant. The top of the group is usually a gray shale or shaly limestone. The thickness of the group is variable, ranging from 350 feet on the east side of the field to 493 feet in the Caldwell - Bailey No. 1 well on the west flank of the field.

The Bell formation is a dark gray, or blue to black shale, ranging in thickness from 12 feet to over 100 feet in the Mammoth Petroleum Company - Graham No. 1 well in section 31, Sumner township, Gratiot County. In some wells the formation is split into two or three members by thin limestone or shaly limestone stringers.

The "Dundee" formation is represented by a light and dark brown dolomite or dolomitic limestone, and some grayish buff dolomite. In only one well within the producing limits of the field has a typical Dundee limestone section been found. This was in the Snowden and McSweeney Company - Wight Heirs No. 1 well in section 10, Crystal township. In this well, the "Dundee" section is a light buff to light gray pure limestone from the bottom of the Bell shale to the total depth. The thickness of the Dundee ranges from 0 to 38 feet. A 38-foot section was found in a dry hole in section 17, Crystal township, on the southwest flank of the structure. This variation in thickness is thought to be caused by erosional unconformities at the base of the Bell shale and also at the top of the Detroit River (Upper Monroe) formation; however, very little direct information is available to prove an unconformity at the top of the Detroit River (Upper Monroe). Several very porous zones which were observed in the Monroe tests drilled near the edge of the field may be suggestive of such an unconformity. These wells are in section 34 of Ferris township on the Martin - Strait lease and in section 22, Crystal township, on the Van Keuren - Evans lease.

Structure

The Crystal Field is on one of the principal northwest-southeast structural trends common to the Michigan Basin. The gas fields in Belvidere township, Montcalm County, the gas fields in Austin, Hinton, and Millbrook townships, Mecosta County, and the oil field in Home township, Montcalm County are all on this same trend.

The local fold of the Crystal Field is a flat-topped anticline with the steeper dip on the northeast basinward side. The southwest flank has a very gentle slope and wells drilled for a distance of six miles in this direction show but a few feet of dip in the formations. No definite elongation of the field in any direction is apparent, although small closures on structure apparently have a northwest elongation. This lack of extensions or elongations characteristic of other Michigan fields might be explained in two ways:

First, that a cross fold exists between the major trend through the Crystal Field and the Jetter Oil Company - Long No. 1 well in Section 1, Bushnell township. Second, that this comparatively flat, broad surface is due to a widespread disconformity on the top of the "Dundee" beds. Both hypotheses may be correct, but the erosional factor apparently is of the greater importance. The regional dip of the formations is gentle, both in its northwest and in its northeast components. The broad level Dundee surface on the southwest flank of the field seems to be a structural terrace or flat nose, extending northeasterly into the field and culminating in steep dips on the basinward side of the pool. If a land surface similar to this existed at the end of "Dundee" time, it would have lent itself readily to the action of ground and surface waters, with the resulting dissolving of the more soluble minerals in the limestone and the alteration of calcite to dolomite.

The presence of an erosional unconformity is shown conclusively in wells drilled by the Gulf Refining Company on the Rule[5] lease in the E½ NE¼ SW¼ section 2, Crystal township. The operators attempted to increase production in their Rule No. 1 well by acid treatment, but the acid could not be pumped into the well except under very high pressure while their No. 2 well directly north was shut in. When the No. 2 well was opened up and put on the pump, the No. 1 well took acid very readily. This indicates that there was a continuous passage, probably a solution channel or fissure, between the two wells.

A contour map, drawn on top of the "Dundee", closely resembles a topographic map. Conditions and expressions strikingly similar to those formed by running surface and ground waters are apparent. (See Fig. 1). Features similar to those existing in regions of Karst topography are present, as, for example, a possible sink hole at the Caldwell - Bailey No. 1 well in the NE¼ NW¼ SW¼ section 33, Ferris township. This feature might also be a deep erosional valley, opening northwestward, instead of a sink hole, as no other wells have been drilled north of the Bailey No. 1, which might provide more definite evidence as to its origin.

The thickening of the Bell shale over these sinks or depressions would also indicate the possibility of a disconformity.[6] Considerable structure is shown on the top of the Bell shale, but this may be due in part to settling over buried erosional remnants of the "Dundee" surface.

Figure 2 shows a cross section of the Crystal Field from the southwest corner of section 17, Crystal township, northeast to the Mammoth Petroleum Corporation, Graham No. 1 well in section 31, Sumner township, Gratiot County, thence east to the Crystal Oil and Gas Company, Shaver No. 1 well in section 4, New Haven township, Gratiot County. All formations from the top of the Michigan Series to and including the Detroit River (Upper Monroe) are shown. The relationship between the "highs" in the Michigan Series and those in the "Dundee" are clearly shown. It is also apparent that shallow drilling, using the Marshall as a marker, would lead to incorrect interpretation of the deeper structure in this field. The solid black shows what is believed to be remnants of the old "Dundee" surface. The sequence of events advanced to explain the stratigraphic and structural features of the field is:

1. Deposition of Dundee limestone on a slightly arched Detroit River (Upper Monroe) surface.

2. Uplift with a slight upwarping along the crest of the present structure. This was followed by a period of extensive erosion during which time the Dundee surface was deeply cut, in places entirely eroded away, and the limestone altered to dolomite with the resulting development of porosity. That the erosion was extensive is indicated by the presence of several very porous zones in the upper 200 feet of the Detroit River (Upper Monroe) formation.

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(5) Maebius, J. B., Gulf Refining Co., Personal communication

(6) Newcombe, R. B., Middle Devonian Unconformity in Michigan., Bull. Geo. Soc. America, Vol. 41, P. 734-35, 1930

3. Submergence and deposition of shale over the eroded Dundee surface. The undulations in the top of the Bell shale reflect the buried valleys and hills, and possibly form zones of weakness. In these areas it seems reasonable that folding would be more pronounced because of the tendency of rocks to buckle or fold adjacent to old structures.(7) It is believed that these zones of weakness were an important factor in determining the position and degree of later folding.

Production

Oil is produced from both the dolomitized limestone and from the underlying pure dolomite. The "pay" horizon conforms but roughly with the "Dundee" surface, indicating that the porosity was developed prior to the folding.

Production is spotty with several dry holes offsetting commercial wells within the producing limits of the field. Initial production ranges from approximately ten barrels to 8,000 barrels per day, as estimated from hourly gauges. The best wells are found in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ section 3, Crystal township. This 40-acre lease with four producing wells has yielded over 500,000 barrels of oil. This is also the highest part of the field structurally, and for this reason would have the thickest "pay" section above the water level. Water drive is the principal source of energy causing the wells to flow naturally, very little gas pressure being present. Almost all wells in the field produce considerable water with the oil. This brings up the problem of brine disposal.

Because of the danger of contamination of fresh water supplies, the damaging of property of riparian owners along the streams that drain the Crystal area, and because of the danger to fishing and other recreational interests, brine cannot be dumped into the streams. However, some method of disposal must be used. To date, much of the brine has been confined to ponds, but this has proved unsatisfactory because of the porous nature of the soil. Numerous test holes drilled show the soil to be principally sand and gravel. Any water put into ponds readily seeps through the wells and bottom of the pond and mingles with the ground water. Eventually it would find its way to the Grand and Pine rivers and many communities downstream.

Recently, experiments have been made in putting the brine back into the water horizon below the productive zone. Considerable success has been obtained in two wells on the edges of the field, one well taking brine at the rate of 130 barrels an hour and the other at a much higher rate. In fact, the water bearing stratum absorbed the brine faster than the pumps could fill the hole. At the present time, this method of brine disposal seems to be the most satisfactory for this area.

An interesting method of drilling in wells has been pioneered by the Gordon Oil Company. Drilling is stopped when the top of the "pay" is reached. At this point, the well does not usually flow and acid is then pumped in through tubing and is forced out laterally into the "pay", rather than downward into the water level. Using this

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(7) Willis, Bailey, Geologic Structures: McGraw-Hill Book Co., First Edition, pp. 260-275, 1923.

method, more oil per barrel of brine is recovered, and the ultimate encroachment of bottom and edge water is retarded. This practice is more successful than drilling into water and plugging back because in plugging off bottom hole water, it is very difficult to avoid sealing off all or a part of the thin oil "pay".

Summary

In summary, present evidence indicates that:

1. Folding in the Crystal Field is important, chiefly in controlling accumulation from neighboring areas. Structure in the upper formations is believed to be due to (a) slumping over irregular topographic surfaces, and (b) folding along these zones of weakness.

2. A widespread disconformity is present at the base of the Bell shale with the resulting development of secondary porosity in the limestone.

3. Production is obtained from beds of doubtful "Dundee" age and possibly from dolomite beds of the Detroit River (Upper Monroe) formation. This question is unsettled because the contact between the "Dundee" and the Detroit River apparently cannot be determined from the magnesia content of the limestone.

Acknowledgments

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