2014

Analysis of Lacustrine Deposits of Custer Lookout and Leftor Butte, Stark County, North Dakota

Andrea Dove

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THE STRATIGRAPHY AND OIL ACTIVITIES OF THE WILLISTON BASIN
IN SOUTHWESTERN MANITOBA

A senior thesis submitted to the Staff of the

Department of Geology
University of North Dakota

in partial fulfillment of the requirements for the degree of

BACHELOR OF SCIENCE

February 23, 1955

by

Wilfred Maurice De Yaegher

Approved:

Grade

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The purpose of this paper is to give the general stratigraphic succession and oil activities within the Williston Basin in the United States and Canada.

In view of the fact that the source material, such as samples, logs, etc., was unavailable to me, most of the material was derived from the literature.

Manitoba has within a few months leaped into prominence as a highly attractive region in which to look for oil. A great deal of attention has been attracted to this relatively small sedimentary basin - the northeastern fringe of the Williston Basin, which is right now experiencing considerable "growing pains", this basin is having a very hard time disposing of the oil which it is capable of producing- since the remarkable discovery rate of last summer and the early winter became generally known.

Location and Size

The Williston Basin, as it is known today, covers roughly 130,000 square miles (Laird, 1953). It is located in the southern part of Saskatchewan, southwestern Manitoba, the western two-thirds of North Dakota, the northwestern quarter of South Dakota and eastern one fourth of Montana.

History of Oil Activities in the Williston Basin

Up to the last few years the Williston Basin has been the most neglected potential oil producing area of its size in the United States. Despite exploration and drilling activity in all the major basins in the Rocky Mountain area there was only one
geophysical party and two or three small surface investigations in the entire Williston Basin area in 1947 (An Introduction to the Williston Basin, 1952).

However, since 1947, there has been feverish activity in the Williston Basin and it seems as overnight that the name "Williston" is on the lips of every oilman in the country. It is now known that this basin, vast in area and containing a large volume of sedimentary rocks, is potentially one of the world's great production regions.

The first oil tests in the Williston Basin were confined to the small sharp anticlines on the north, east, and the north flanks of the Black Hills. The first of these known structures was drilled in 1904, and the last one was drilled in 1942 until the recent activity (An Introduction to the Williston Basin, 1952). Most of the early tests were locally financed and nearly all were abandoned at depths of less than 1,000 feet when artesian water was encountered.

Oil was discovered in North Dakota on April 4, 1951, when the Amerada Petroleum Company drilled the now famous Clarence Iverson No. 1 well at Tioga, Williams County. This well touched off the greatest lease play on terms of volume of acreage in the history of the oil industry. An estimated 20,000,000 acres of land in North Dakota, South Dakota, Montana, Manitoba and Saskatchewan were leased. An estimated 40,000,000 acres had been leased previous to the discovery of oil in the Clarence Iverson No. 1 well (Smith, 1951). The basin contains some 75 to 100,000,000 acres in the states and provinces listed above, 50,000,000 of which are in the United States.
The overall picture of the Williston Basin is one favorable for the accumulation of oil. It is known that there is a gradual thinning of the sedimentary section going from west to east from the center of the basin. This thinning was caused by truncation, overlap or non-deposition, either of which may form favorable traps for oil.

After recovering the first "pint of oil" at 8,200 feet, the Iverson well was deepened below 11,600 feet after flowing an average of 350 barrels per day of 54 degree gravity oil with a gas-oil ratio of about 8,000 to 1 from perforations at 11,630 to 11,600 feet. Probably 70 feet of pay zone is present (Millikan, 1953).

Activities in the United States

During the last year, nearly every major-producing company in the United States has entered the picture in the Williston Basin and virtually all are exploring or drilling in the area. During the last three years, Amerada probably leads in this work, with Hunt, Texas, California, Shell, Stanolind, Phillips, Continental, Pure, Carter, and Union all having been quite active, especially during the summer months.

Since oil was discovered in the basin in 1951, major oil companies, wildcatters, and private citizens have been engaged in a wild scramble for oil leases; one of the places they are inundating is the Bureau of Land Management which controls a sizeable portion of territory in the basin.

A bureau spokesman stated that the sudden flood of lease applications has increased the work of its land office in Billings, Montana, more than 1,800 per cent in little more than a
year. Officials were unable to say how long the office will take to process all applications for leases in the basin. But they are certain its activities will play an important part in the Williston Basin development.

The agency already has received applications for leases which would cover this entire field. Under the Mineral Leasing Act, individuals and companies may obtain mineral rights to public domain lands and some other Federal lands by two means:

(a) competitive bidding if the land is in known geological fields,

(b) non-competitive lease offers if the land is not in known fields. At present leases in the Williston Basin are being granted on a non-competitive basis because still relatively little is known about the area.

The United States Government collects royalties of 12-1/2 per cent on all oil and gas produced under such leases. It also gets a yearly rental fee of 50 cents an acre for the first year of the lease, nothing for the second and third years and 25 cents for the fourth and fifth years.

Canadian Activities

Although oil prospecting in the Williston Basin was begun in the United States, it quickly spread to the Canadian provinces. The Canadian portion of the Williston Basin in southern Saskatchewan and southwest Manitoba is now receiving a good share of exploratory activity.

While the seismograph has located structural traps, it has not been successful on the flanks of the basin except in Canada. However, fields such as Daly are primarily structural, and the
outstanding shallow field was located by seismograph.

Manitoba's Roselea field, 40 miles north of Melita, was drilled on a sentimental hunch by the McIvor brothers on the family homestead near Virden when a rig owned by the brothers was idle. They opened the first prolific shallow production in the basin; some Roselea wells being brought in for as much as 2500 barrels per day from the Mississippian at 2100 feet. Roselea sparked an unprecedented Manitoba campaign; for the first time rigs ran all winter instead of closing up until spring. Discovered in July, 1953, Roselea in seven months had 26 producing wells with but one dry hole (World Oil, 1954, pp. 92).

Manitoba's largest field is Daly, 10 miles southwest of Roselea. California-Standard's 1951 discovery was suspended within a short time, but by moving westward, the Daly field was opened. Daly's limestone is tight; after disappointing experiments with acid, shooting and fracturing California-Standard found fracture treatment the most effective. Nearly all wells go on the pump immediately; however, several flowing wells have been completed south of what appeared to be edge wells. California-Standard has converted four wells to injection in an experimental water-flood. Four of these wells have been suspended and the number of producing wells is nearing 100.

Except for North Roselea and several successful extension developments around Roselea, Manitoba's other fields have only from one to three producers. Waskada and Lulu Lake have been suspended because they became non-commercial with transport trucks the only transportation.
Stratigraphy of Manitoba

As the area is still in a state of active development, it is believed that increased knowledge resulting from further drilling will change the stratigraphic concepts. In ascending order of the stratigraphic section, the Ordovician is the oldest and first formation encountered.

Ordovician

The Ordovician strata in southwestern Manitoba have been divided into three formations: Winnipeg, Red River, and Stony Mountain (Baillie, 1952).

The Winnipeg is the oldest Ordovician formation in Manitoba and rests directly on the Precambrian basement. The formation may be divided into two lithologic units; a basal sandstone unit and an upper unit composed of sandstone and shale. The two units are separated by a thin zone which contains much iron sulphide in the form of pyrite nodules and oolites. The basal unit, less than 20 feet thick, consists of a porous clean quartz sand, which has yielded large quantities of water on drill stem tests. The upper unit is about 35 feet thick, bluish green fossiliferous shale that contains thin hard sandstone beds.

The Red River formation consists of about 500 feet of dolomitic limestone and dolostone that has been divided into three members: the Dog Head, Cat Head, and Selkirk. The lowest member, the Dog Head, consists of thin-bedded fossiliferous subfragmental dolomitic limestone. The rock is bluish grey to yellowish grey and it may contain pyrite, and quartz grains.

The Cat Head member consists of yellowish grey fine-grained
calcitic dolomite that contains chert nodules.

The Selkirk member consists of thick-bedded fossiliferous dolomitic limestone. The associated material is a yellow-grey limestone with pale yellowish brown calcitic dolomite. The member contains large cephalopods and gastropods.

Porosity is generally poor through the Red River. Thin porous zones 100 to 200 feet from the top have been encountered in a few wells, but no continuous porosity is present.

The Stony Mountain formation consists of three members: Stony Mountain Shale, Penitentiary, and Bumton (Baillie, 1952).

The Stony Mountain Shale member consists of red and greyish red highly fossiliferous calcareous shale that contains thin beds of reddish grey crystalline limestone. The member maintains a thickness of 70 feet throughout southern Manitoba, but west and north of this area lenses out and becomes unidentifiable.

The Penitentiary member consists of about 20 feet of fossiliferous bedded argillaceous dolomite. The color ranges from dusty yellow to shades of pale red and greenish yellow.

The Gunbn member consists of about 50 to 100 feet of yellowish orange dolomite. The upper-most part contains numerous rounded and frosted quartz grains, associated with thin red beds. The sand horizon is very widespread and makes an excellent subsurface marker at the top of the Ordovician.

Silurian

The Interlake group overlies the Stony Mountain formation of Ordovician age and underlies the Asher formation of Devonian age. The group is named for the Interlake area of Manitoba where most of the exposures occur.
The thickness of the Interlake group varies from 250 to 400 feet and the lithology consists of white, pink, cream and pale buff dolomites with scattered sand grain horizons in the lower part. The porosity is poor, and only a few wells have attained good porosity at the top of the Sillurian.

Devonian

The Devonian section is one of the thickest in Manitoba, with a total of 1400 to 1900 feet where not eroded.

The Devonian System is divided into four major lithologic units of group rank. They are: Elk Point Group, Manitoba Group, Saskatchewan Group and the Qu'Appelle Group.

The Elk Point Group is the basal major unit. In ascending order, the group includes the Ashern, Elm Point and Winnipegosis formations, and also the main Middle Devonian salt and anhydrite section for which the name Prairie evaporite is given.

The lower contact of the Ashern formation is very poorly exposed. In places the lower few feet of the formation contains angular fragments of the underlying dolomite, and the contact is unconformable, but elsewhere thin brick-red argillaceous rock appears to grade downward into a yellowish orange dolomite typical of the underlying unit.

The Ashern formation consists of 10 to 50 feet of poorly bedded argillaceous dolomite and slightly silty dolomitic shale that is characterized by a brownish red to brick-red.

Baillie (1953) was unable to differentiate between the Elm Point and Winnipegosis formations, so in this paper all the Elm Point strata overlying the Ashern formation are included in the Winnipegosis formation, although no doubt strata equivalent to
the Elm Point limestone are present.

The Elm Point and Winnipegosis formations show a considerable range in thickness owing to the presence of biohermal type reefs. In wells that do not penetrate reef strata the thickness ranges from 100 to 150 feet, whereas, in wells drilled on reef structures the formation may be as much as 400 feet thick. The inter-reef strata consists of light-yellowish grey, finely saccharoidal dolomite that commonly contains comminuted fossil fragments and may be interbedded with fragmental dolomite that has slight intergranular porosity.

In the Virden area, the Elm Point and Winnipegosis formations range from 40 to 100 feet thick. To the north and east these formations thicken somewhat; at California Standard Hartney 16-33 well, the formations are about 100 feet thick, and at California Standard Wawanesa, 130 feet. The cores showed much organic material with excellent porosity.

The Prairie evaporite formation is the name given to the salt and anhydrite beds that form the upper unit of the Elk Point group. In the Virden area the salt is about 400 feet thick, with some anhydrite, which can be traced into Saskatchewan.

North and east of Daly, this evaporite formation thins rapidly. At California Standard Hartney 16-33, the formation consists of 50 feet of anhydrite overlain by a small thickness of red shale, and at Wawanesa only 23 feet of anhydrite is present.

The standard Williston Basin nomenclature, is to discard the Manitoba Group and call it the Beaverhill Lake Group which includes the Dawson Bay formation, for the lower unit and Souris River formation for the upper unit (Ower, 1953).
Using the Williston Basin nomenclature, the Dawson Bay formation is the lowest unit of the Beaverhill Lake Group, and ranges in thickness from 100 to 200 feet. Dawson Bay formation consists of a lower, dense, buff and grey limestone overlain by brown sucrose dolomite or buff organic and stromatoporoids. This upper part is usually highly porous, but porosity may be absent and the shale formation dense.

Southis River formation consists of limestones, dolomites, shaly carbonates, and anhydrite alternating in thin beds. The beds of this formation seem to have been deposited under conditions of rapid oscillation between semi-clastic and carbonate to semi-evaporate conditions. A granular, brown, sucrose dolomite with excellent porosity usually occurs at the base of the zone and thin beds of granular dolomite with good porosity occur intermittently in various parts of the formation.

The Saskatchewan group is divided into two formations, the lower unit is the Duperow formation, the upper unit the Nisku formation.

A complete section of the Saskatchewan group occurs only in the western part of the area, as it is progressively truncated to the east. The Duperow formation consists of 100 to 200 feet of fragmental dolomite and dolomitic limestone with many inter-beds of dense limestone and some anhydrite. The zone has widespread porosity. Stromatoporoids, corals, bryozoa, ostracods, and other marine organisms have been noted from cores.

Between the Duperow and Nisku formation there is a thin but persistent red bed, which occurs throughout the area. This red bed can usually be picked up on samples and is especially notice-
able in gamma-ray logs.

The Nisku formation is about 100 feet thick, and consists of limestone and dolomites with inclusions and bands of anhydrite and usually contains one or more bands of good porosity. This porosity at the top of the Saskatchewan group appears to be fairly widespread but is better developed northward.

The Qu' Appelle group is the upper strata of the Devonian System in the Williston Basin area in southwest Manitoba. The group includes all the silty, argillaceous and anhydritic strata that overlie the Nisku formation of Saskatchewan group and underlie dark grey to black bituminous shale considered to represent the base of the Mississippian and invariably present throughout the area.

In this area, the Lyleton formation comprises all the strata between the Nisku and the overlying extensive black shale and constitutes the complete Qu' Appelle group. The Lyleton formation is about 100 feet thick in the Daly area and thins eastward, being less than 60 feet thick at Wawanesa 3-A well and apparently absent in some wells in North Dakota.

The Lyleton formation is composed of red and brownish red dolomitic shale, argillaceous siltstone, and silty argillaceous dolomite. The siltstone is usually fine-grained but in some places may contain silt and very fine quartz sand.

Mississippian

The Mississippian is confined to the southwest part of the area and, in general, it has a thickness of less than 400 feet. At Daly it is approximately 300 to 340 feet thick, while at Link-later it thickens rapidly, and at Waskada it is approximately
800 feet thick (Ower, 1953).

The Mississippian is composed of a lower, very thin, clastic zone, the Bakkan formation, and an upper carbonate zone, termed the Madison Group.

The Bakkan formation, the base of the Mississippian, is composed of a few feet of grey to black shale, often containing conodonts, which is underlain by as much as 20 feet of fine silt, sand, and limy silt. The silt is absent in the Daly oilfield but is present in the Etwart well and in wells to the south. The shale, but not the sand, is present in the California Standard Wawanesa 3-l well.

South of Daly, in the California Standard Etwart and Linklater well, the silt was cored and was found to be saturated with light oil, but tight and non-productive.

The Madison Group is divided into three formations: Lodgepole, Mission Canyon and Charles. However, only in the Daly oilfield is it possible to recognize the three formations of the Madison Group. The lower formation of the Madison Group is equivalent of the Lodgepole of the Bakotas or the Banff shale of Alberta (Ower, 1953, pp.740.).

The Lodgepole, or lowermost formation, is termed the shaly zone and consists of 100 to 200 feet of shaly limestone which is often mottled greyish green and purple to red. Occurrences of tripolitized chert nodules are common, especially near the base. A very localized organic and porous zone has been found in a few wells where it contained water with live oil show.

The middle member, is locally termed "the crinoidal zone" and gives rise to most of the production in the Daly field. (Ower,
The zone is 50 to 100 feet thick and consists of alternation crinoidal, silicious, and shaly limestones, with partings of red shale which are thinly bedded. In the Daly 16-20 well, the zone tends to be replaced by red and maroon shale or shaly limestone.

The uppermost zone, the Charles formation, is termed the microcrystalline or anhydrite zone and is 70 to 100 feet thick. It consists of microcrystalline dolomite with numerous bands and lenses of bluish white crystalline anhydrite. Thin bands and nodules of chert are common, especially at or near the base of the zone (Ower, 1953, pp. 740).

In the Daly field, the uppermost zone is usually stained and partially saturated with oil, but lacks good porosity and is not thought to be productive.

In the southern part of the province, and at Waskada, the Mississippian thickens, and the three members of the Daly area are unrecognizable. A lower, shaly limestone zone, dark grey in color and about 200 feet thick, grades upward into a thick series of microcrystalline, fragmental, and oolitic limestones, with good porosity. At the top are found beds of anhydrite, 20 feet thick, which have been correlated by some workers with the base of the Charles formation. The oil production in this area seems to come from the top of the fragmental and oolitic limestones (Ower, 1953).

Throughout southwestern Manitoba, the Jurassic lies unconformably on the Charles formation.

Jurassic

The Jurassic can be divided into two formations. The lower
formation, the Amaranth, or Gypsum Springs (Amaranth was used by Kirk, 1929, in Manitoba, but according to Ower, 1953, it is probably correlative of the Gypsum Springs formation of the Dakotas), consists of a thin limestone member underlain by anhydrite and shale, which in turn are underlain by red beds; the upper formation, the Sundance, is composed mainly of clastics.

Red beds form the basal member of the Amaranth, or Gypsum Springs. They vary greatly in thickness, and there is reason to believe that the thickness is related to the original topography of the top of the Palaeozoic. In the Daly field they are only a few feet thick, but thicken rapidly to the east of the field and at Daly; 6-20 well are 100 feet thick. In the southern part of the Province, they are 120 feet thick.

The base of the Amaranth, or Gypsum Springs, consists of red silt and fine sand, with round, frosted quartz grains. This grades upward into red and green shale, with anhydrite stringers, which grades up into the evaporites.

The lithology and correlation of the Sundance at the present time in Manitoba is not fully understood. Most of the Jurassic study in the Williston Basin area has come from the Swift Current area in southwestern Saskatchewan, where the major part of Jurassic oil production is found to date.

The Jurassic in the Swift Current area, has four formations, which, in ascending order are: Davidson, Gravelbourg, Shaunavon, and Vanguard. The Davidson has been correlated with Amaranth, or Gypsum Springs, but above the Davidson the formational breakdown of southwest Saskatchewan fails when an attempt is made to apply it to Manitoba. It is uncertain whether all or only part
of the upper formations are present in the Manitoba area, and it may be possible that the Sundance formation, contains beds of Lower Cretaceous age as well as Jurassic.

In the Daly field, the contact between the Cretaceous and the underlying Jurassic is well defined by a thin red bed. At Daly field, the Sundance consists of clastics of considerable variability, which, although predominantly shale, contain numerous lensing sands, fine limestone stringers, and thin beds of white clay.

The lower member of the Sundance consists of calcareous and variegated nature of the shales, while the upper member contains non-calcareous, dull colored shales. Whether these two members should be classified as formations is uncertain at this time.

Certain parts of the Daly field, and north of Daly, the lower member tends to become very sandy, and lenticular sands of over 100 feet in thickness have been found. Some of these sands have been found to be saturated with salt water.

About ten miles south of Daly, the upper member consists of a series of coarse sands, lying between it and the Cretaceous. These sands thicken rapidly to the south and are 120 feet thick at Linklater. At Waskada the two sands are separated by a shale layer in an interval of 170 feet. These sands are absent at Daly, north of Daly, Hartney 16-33 and Wawanesa 3-1 wells, and generally are absent in the northern part of the area.

These sands are usually tight, and composed predominantly of quartz. In some cases they contain fresh or slightly brackish water.
Cretaceous

Most of the Cretaceous is well exposed at various localities in Manitoba, and formational names have been given to the various units by Tyrrell, Kirk (1930), Wickenden, Tovel, and other workers, the latest classification being by Wickenden (Ower, 1953).

The Cretaceous is divided into four formations: the Ashville, Favel, Horden and Boyne combined and the Riding Mountain. No unit corresponding to the Swan River formation is recognizable in this area.

The Ashville formation consists mainly of dark grey to black shale. It can be divided into two units, the upper one of which is very radio active on gamma-ray logs.

The lower unit contains a number of occurrences of coarse quartz sand. In the Daly field no sand is present, but at Linklater a 20 foot sand bed at the base of the unit contained fresh water, while at California Standard Wawanesa well a sand 100 feet thick, contains fresh water, occurred only 30 feet from the top of the member. It was underlain by shale and no basal sand was present.

The upper unit consists mainly of grey shale, in which shell fragments and fish scales are common. The Ashville of Manitoba, has been correlated with the Graneros shale of the Black Hills.

The Favel formation maintains a uniform thickness and its top and base form two of the most reliable marker points for structure contouring on the Cretaceous beds. The formation consists of calcareous speckled shale with thin limestone beds, and is correlated with the Greenhorn limestone of the United States.
The Morden and Boyne formations consists of two units, an upper and lower. The lower half of the lower unit is a grey non-calcareous shale, or is the Morden member of the Manitoba surface section. It gives a high anomaly on the gamma-ray log.

The upper part of the unit is the Boyne or first white specks, consisting of calcareous speckled shale. This unit is not well developed and in a great many cases is difficult to pick, both in samples and electric logs.

The Morden and Boyne formations are correlatable with the Niobara and Carlile formations of the United States and are therefore equivalent to the uppermost part of the Colorado group.

The Riding Mountain formation is a thick, grey shale, which outcrops over most of the area, and is equivalent to the Pierre shale of the Montana group in the United States.

Oil Fields in Manitoba

The Daly field, largest in Manitoba, was discovered in February, 1951, eight miles west of Virden. It opened up an exploration and production program in Manitoba. Production from the field is found in the top of the Lodgepole formation. The Lodgepole formation is about 300 feet thick in the Daly area. The Daly field indicated an average thickness of 55 feet of pay zone, with an average porosity of 9 per cent. Permeability in the Daly field is rather low, but some places have been found to contain a few hundred millidacies. Up to the end of November 1953, 513,111 barrels of 34 degree A.P.I. oil had been produced from this field (Sproule, et.al., 1954). Total production for the Daly field for March, April and May, 1954 was as follows:

March.....................83,365 bbls.
April..........................82,820 bbls.
May............................83,606 bbls.

By the end of May there were 96 wells in operation with a daily average production of 28 bbls. per well and 2,688 barrels for the entire field.

Production from the Virden-Roselea and North Virden-Roselea fields is obtained from the thin, porous oolitic limestone beds of the Lodgepole formation.

It is believed by some that the Virden-Roselea and North Virden-Roselea fields represent two separate accumulations. Their structural relationship to one another is not entirely clear at the present time.

Virden-Roselea field has an average pay zone of 85 to 90 feet in thickness, with a minimum of 20 feet in the producing zone.

North Virden-Roselea field has a net pay thickness averaging from 20 to 24 feet on the flanks of the productive area to 38 to 40 feet in central portion of the field.

The following data has been released on the Virden-Roselea and North Virden-Roselea fields (Sproule, et.al., 1954):

<table>
<thead>
<tr>
<th>Field</th>
<th>Porosity</th>
<th>Connate Shrinkage</th>
<th>Pay Thickness</th>
<th>Oil per Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Virden-Roselea</td>
<td>9.5%</td>
<td>28%</td>
<td>0.95%</td>
<td>28'</td>
</tr>
<tr>
<td>Virden-Roselea</td>
<td>8%</td>
<td>25%</td>
<td>0.95%</td>
<td>20'</td>
</tr>
</tbody>
</table>

The Whitewater field is located southeast of Daly and fourteen miles north of the North Dakota line. The Standard Oil Company of California's well was Manitoba's second 1953 strike. It pumped about 75 bbls. of 34 degree gravity oil
per day from the Lodgepole formation at 2,439 feet.

The Whitewater field at the present time has five producing wells. Although very little is known about the field, some geologists believe that it is a porosity pinch-out. The total production of the field for October thru December of 1953 was 4,420 bbls.

The following table shows the total production for the Manitoba fields up to the end of October, 1954 (Modified from the Department of Mines and Natural Resources, November, 1954).

<table>
<thead>
<tr>
<th>Field</th>
<th>Total Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daly</td>
<td>1,665,235</td>
</tr>
<tr>
<td>Virden-Roselea</td>
<td>529,900</td>
</tr>
<tr>
<td>North Virden-Roselea</td>
<td>118,008</td>
</tr>
<tr>
<td>Whitewater</td>
<td>23,156</td>
</tr>
<tr>
<td>Pierson</td>
<td>15,473</td>
</tr>
<tr>
<td>Tilston</td>
<td>25,689</td>
</tr>
<tr>
<td>Woodworth</td>
<td>23,671</td>
</tr>
<tr>
<td>Lulu Lake</td>
<td>1,484</td>
</tr>
<tr>
<td>Waskada</td>
<td>4,007</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,406,623</strong></td>
</tr>
</tbody>
</table>

Conclusions

Exploration and development activity in Manitoba showed an increase in 1954 over 1953 which resulted in:

1. Additional discoveries.
2. Establishment of greater reserves.

Operators have had many problems in Canada, some of which are inherent to the petroleum industry. Some of these are:

1. Insufficient outlets for petroleum and natural gas. The Interprovincial Pipeline to Sarnia has assisted to a material degree and undoubtedly the pipe line eventually will be increased in capacity.
2. Insufficient refining facilities have been another problem in Canada and at the east end of the pipe line.
Such facilities are now being enlarged; construction of a new refinery at St. Boniface; construction work is being done on a new catalytic reforming unit at the refinery of the Anglo-Canadian Oils Ltd. in Brandon, which will increase the octane rating of gasoline produced at this plant; expansion of Imperial Oil Ltd.'s refinery capacity at Regina to 22,500 B/D; and expansion of the capacity of the Consumers Co-operative Refineries Ltd. refinery at Regina to 14,000 B/D.

3. Competition with other supplies. The movement of crude into Sarnia brought Canadian oil into competition with the many and varied supplies entering the Great Lakes market. With major pipe-line systems from the Gulf, Mid-Continent and the Rocky Mountain areas, plus off-shore supplies moving west from Montreal and the Hudson River Canal, this area represents worldwide oil competition.

To my estimation, in the years to come, Western Canada's markets will grow city by city, and refinery by refinery, rather than by the tremendous leaps they have taken in the last few years. What we can look forward to is steady growth and consolidation.

The need for more petroleum in both Canada and the United States, undoubtedly will cause a continuation of exploratory activity in Canada. New discoveries and an enlargement of reserves should follow.
<table>
<thead>
<tr>
<th>AGE</th>
<th>ROCK UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRETACEOUS</td>
<td>RIDING MOUNTAIN</td>
</tr>
<tr>
<td></td>
<td>MORDEN AND ROYNE</td>
</tr>
<tr>
<td>2300' max</td>
<td>FAUVEL</td>
</tr>
<tr>
<td></td>
<td>ASHVILLE</td>
</tr>
<tr>
<td>JURASSIC</td>
<td>SUNDANCE</td>
</tr>
<tr>
<td>400' - 1200'</td>
<td>AMARANTH OR GYPSUM SPRINGS</td>
</tr>
<tr>
<td>MISSISSIPPIAN</td>
<td>MADISON GROUP</td>
</tr>
<tr>
<td>0 - 1000'</td>
<td>CHARLES</td>
</tr>
<tr>
<td></td>
<td>MISSION CANYON</td>
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<td>Dog Head</td>
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Figure 2.- Stratigraphic section, southwest Manitoba (modified from Laird, 1953).
Bibliography


Bibliography (cont'd.)


