REPORT No. 15

SUBSURFACE EXPLORATION GEOLOGY and DEVONIAN PROSPECTS

of the

Meadow Lake – Prince Albert Yorkton Area, Saskatchewan

By

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PROVINCE OF SASKATCHEWAN

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PREFACE

This report is a compilation of the subsurface geological and geophysical data available to the department and to the public in the northern belt of Saskatchewan sediments.

The department has made certain interpretations which it feels may be of interest to the petroleum industry, but it might be pointed out that the geological and seismic information available is very limited. All interpretations are therefore subject to future modifications. For the present these interpretations have been held to an objective minimum.

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SUBSURFACE EXPLORATION GEOLOGY AND DEVONIAN PROSPECTS

of the

MEADOW LAKE - PRINCE ALBERT - YORKTON AREA

INTRODUCTION

LOCATION OF AREA AND ACCESSIBILITY:

The area covered by this report is indicated in the title and in the index maps of Figs. 1 and 2 respectively. From the latter it can be seen that the area is triangular in shape, with the apex of the triangle slightly truncated by the Saskatchewan-Alberta border line. The north boundary of the area is along the edge of township 60 across the whole width of the province. The east boundary is from township 20 to township 60, while the west narrows to townships 56 and 57.

Accessibility is good for the greater part of the area. Thus even the northern part can be entered on an all-weather road from Prince Albert along Montreal Lake (Fig. 1) to Lac la Ronge. The more difficult area of access lies east and northeast of Nipawin (Fig. 1). Elsewhere there is a network of gravel-surfaced roads crossing the country in a variety of patterns. Subsidiary roads and trails lead off from the main network so that transport of drilling machinery into selected locations is unlikely to present more than routine problems.

PHYSIOGRAPHY:

The present relief of the area is due largely to drainage by the Saskatchewan River and its tributaries. Where the Saskatchewan River has diversified its channels in the Cumberland Lake area there are extensive swamps. Elsewhere, despite abundance of lakes which might suggest otherwise, drainage is relatively good. This area, which consists of rolling, well-timbered terrain, is known as the Park Lands of Saskatchewan, situated between 1,500 and 1,800 feet above sea level. In several localities there are remnants of higher land. Chief among these are the Thickwood Hills which cross the Saskatchewan-Alberta border, unnamed hills in Prince Albert National Park, the Pasquia Hills and Porcupine Mountain. All these hills exceed 2,000 feet above sea level with topographic maxima of up to 2,500 feet above sea level.

PREVIOUS WORK:

The area of this report has been included in broad stratigraphic analyses by Powley (1951), Kamen-Kaye (1952) and Baillie (1953). Both Powley and Baillie set up systems of nomenclature for the Devonian as illustrated in Fig. 3. The Devonian nomenclature used by Kamen-Kaye is comparable with general stratigraphic usage in the period 1949-1953. This also is indicated in Fig. 3.

PRESENT STUDY:

The present report gives geological background in the form of a typical subsurface column of sediments. Further background follows in the form of a summarized geological history of the area. Devonian stratigraphy is treated in a more specific manner by reference to Devonian formations in particular wells. Structure of the Devonian rocks and biohermal reef development in the Winnipegosis formation of the Devonian are then considered in some detail. Evidence of oil or gas is tabulated. Some exploration results are described and discussed.

DENSITY OF DRILLING:

Approximately 50,000 square miles of territory within the area under study can be considered as explorable without major difficulty. Within this 50,000 square miles 164 wells have been drilled as of April 30, 1954. The average drilling density is thus slightly less than one well per 300 square miles. In practice the density is variable, notably because of concentration of drilling in the Yorkton area, a result of search for Mississippian pinchouts. Making a reasonable allowance for this factor it may be assumed that the greater part of the area covered by this report has an average drilling density of less than one well per 500 square miles. These figures make it clear that the Meadow Lake-Prince Albert-Yorkton area has had only the most preliminary investigation by drilling. Since additional drilling is conditional upon the claims of this area to be desirable exploration territory, a few remarks in this connection are set out below.

INTERESTING ASPECTS OF AREA:

The area should be interesting to prospectors because of moderate depth to Paleozoic horizons. Admittedly, moderate depth results from removal of the total Mississippian section and some significant portions of the Devonian section (except in the Yorkton vicinity). On the other hand this condition allows penetration of the entire Paleozoic section down to the Precambrian surface by drilling to less than 4,000 feet in the eastern part of the area and to less than 5,000 feet in the western part.

There is an additional interest to prospectors in this area because of the presence of reservoir sands interbedded in shales at the base of the Paleozoic carbonate column. These sands in the Winnipeg and the underlying Cambro-Ordovician are known in many parts of the province to flow water on drill stem test. Therefore, many of these sands may be under water drive through direct connection with deeper parts of the basin.

On the basis of drilling already done the main interest in the area, from a stratigraphic point of view, is the proved biohermal reef development of the Winnipegosis formation of the Devonian. Further drilling will be needed to give a better idea of the continuity of this Winnipegosis bioherm. However, pending such further drilling it is a reasonable working hypothesis to expect and to explore for Winnipegosis biohermal reef development along a trend of about 250 miles (see Fig. 2).

The exploration status of the area on direct evidence of oil and gas is given by Table 1.

ACKNOWLEDGMENTS

The writers are greatly indebted to Mr. C. A. L. Hogg, deputy minister, department of mineral resources, and to Mr. J. T. Cawley, director of the department, for their advice during progress of the work and for their critical reading of the manuscript.

Mr. A. Cumming, department senior geologist, made valuable suggestions concerning the manuscript.

Mr. Boyd Wettlaufer, department geologist, kindly photographed the specimens shown in Plate No. 1 and Plate No. 2.

GENERAL STRATIGRAPHY

A brief survey of general stratigraphy and of the geological sequence, including not only the Devonian but also overlying and underlying systems and formations, is best given by reference to a single, suitable, and centrally located well. Fortunately, such a well is available in Marysburg No. 1 (Sohio). The location of this well is shown in Fig. 2. Details of electric log development can be seen by reference to Correlation Profile No. 4.

SOHIO MARYSBURG NO. 1
Lsd 16-29-38-22-W2
K. B. 1,825 ft.

System	*Formation*	*Thickness*	*Description*
Pleistocene	Drift	480 ft.	Unconsolidated sands with interbeds of clay, shale and silt.
Cretaceous	Lea Park & U. Colorado	675 ft.	Mainly shale, silty or sandy, grey, olive, sl. mic., plant remains, bentonite. Occ. siltstone bands, minor calc. content. Strong calcareous development at base from 1st to 2nd white specks zones.
	L. Colorado	230 ft.	Mainly shale, blk. or dk. grey. Silt increasing at base.
	Blairmore	360 ft.	Sandstones and shales interbedded. Sandstones of varying grain size; glauconite and pyrite in upper sandstones, kaolin and siderite in lower sandstones.
Devonian	Duperow	423 ft.	Limestone dominant. Buff, chalky, sucrosic or argillaceous. Intermittent dolomitic bands. Frequently marly or argillaceous. Fossils such as brachiopods and algae relatively common. Spores and Chara notable in lower part.
	Souris River	436 ft.	Limestone dominant. Consistently argillaceous. Fossils present, including some algal development. "1st Red Bed", 30 ft., at base. Red shale, part dolomitic, part silty.
	Dawson Bay	136 ft.	Limestone, dolomite, shale. Occasionally stromatoporoid. Characteristic spores. Chara present. "2nd Red Bed", 25 ft., developed at base in red shale, dolomitic.
	Prairie Evaporites	493 ft.	Dominantly salt. Anhydrite and gypsum also present in this evaporitic facies. Potash may be absent in this well but is commonly present in adjoining areas of this report. Interbedded dolomites are also present within the salt in adjoining areas.
	Winnipegosis	102 ft.	Dolomite is the dominant development, probably biostromal in this case, and in others where Winnipegosis is under the salt. Spores are common and characteristic.
	Ashern	23 ft.	Shale, dolomitic, red and green.
Silurian	Interlake	162 ft.	Dolomite. Characteristic white or cream colour.
Ordovician	Stony Mountain, Red River & Winnipeg	436 ft.	Dolomite dominant. Sand grains in dolomite concentrated near top in this locality but may occur at lower horizons elsewhere. Bottom 30 ft. in Winnipeg sandstone, variable sorting, rounded frosted grains.
"Cambro-Ordovician"	Not named	120 ft. plus	Fine-grained glauconitic sandstone, interbedded green shale.

GEOLOGICAL HISTORY

The geological sequence described above may be united with similar sequences in the area of this report and with common elements from the sequence in areas to the south to build up a geological history which may be briefly described as follows:

(1) Basement:

An initial basement, presumably of granite, metamorphic rocks or Precambrian sediments (little is known of basement composition from drilling to date).

(2) Cambro-Ordovician and Winnipeg sands and shales:

A clastic episode during which basement was progressively covered with Cambro-Ordovician glauconitic sands and interbedded shales, and finally with clean Winnipeg sand in the sand phase. The nature of these clastics suggest that their source was in relatively low-lying Precambrian lands containing a large percentage of Precambrian Athabasca Series type of Precambrian sandstone. These lands may have lain in more than one direction. However, a consideration of Alberta Rockies and Alberta Plains geology suggests that the balance of marine transgression was from west to east. Regarding the clastic episode as a whole this conception would agree with the known fact that combined Cambro - Ordovician and Winnipeg clastics thicken from a feather edge in eastern Saskatchewan to about 1,600 feet at Imperial Eychill-1 in Alberta, seven miles west of Township 35 on the Saskatchewan border.

(3) Dolomitic carbonates, Ordovician to Devonian:

A long geological episode with dominant carbonate deposition. Clear waters and little or no influx of sediment from land suggested. Dolomite is the resultant carbonate from this episode whose deposits fill the interval from the top of the Winnipeg to the base of the Prairie Evaporites. The Ashern intervenes in this episode. On the basis of similarity with other areas of the province (Kamen-Kaye, 1952), it is probable that the Ashern represents a coastal plain condition following emergence of previously deposited carbonates.

(4) Devonian evaporites:

An episode during which precipitation of up to 700 feet of evaporites took place. In many places desiccation was so complete that potash-bearing salts came out of solution and capped previously precipitated evaporites. Among these were minerals such as sylvinite and sylvite (Williams, 1952), known from

PLATE 1

Core from the Winnipegosis reef in Sayese No. 1, (x 1) chemical analyses of cores. Previous to potash the main precipitation was of salt, frequently with a basal anhydrite and with minor dolomite. It is assumed that Winnipegosis biohermal reefs grew near the northern edge of the basin in which the evaporites were precipitated (Fig. 2).

(5) Devonian carbonates and clastics:

A second prominent carbonate episode which lasted from the close of Prairie Evaporite to the end of Nisku times. Chemical balance, or absence of diagenesis after deposition, resulted in limestone as the dominant carbonate. The end of Devonian deposition was marked by clastic and evaporitic Three Forks deposition.

(6) Mississippian deposits, erosion:

Initial phase of this episode yielded Bakken clastics followed by shallowing of waters to give typical limestones of the Madison group. In many areas emergence and erosion removed all Mississippian and part of the Devonian sequence. The highest Madison group preserved was a remnant of Lodgepole above the Bakken (for which see Fig. 1) in the Yorkton area.

(7) Jurassic deposition and erosion, Blairmore deposition:

An episode of varying Jurassic deposition followed by erosion of Jurassic beds. Deposition was renewed after this erosion and Blairmore sediments were laid down in (a) lower Blairmore sediments of coastal swamp environment; (b) upper Blairmore sediments of more transgressive, marine type. Transgressive conditions and dominantly shale deposition were prevalent in post-Blairmore Cretaceous times up to the base of the overlying Drift (Pleistocene).

DEVONIAN

STRATIGRAPHY:

Devonian terminology used in this study has already been illustrated in describing the geological sequence of Sohio Marysburg No. 1. This terminology corresponds to the latest available system, that used by the AAPG Williston Basin Committee of 1953 (see Fig. 3). In the cross-sections accompanying this study an older term such as Ireton (see Fig. 3) has been retained for purposes of correlation.

In addition, selected sample descriptions are given below for further illustration and for more detail on the Devonian itself.

Winnipegosis:

HUDSON'S BAY SAYESE NO. 1
Lsd 10-10-49-21 W2
K.B. 1,432 feet

1471-76	Limestone, fine crystalline, grey. Dolomite fine crystalline, porosity vuggy.
1476-81	Dolomite, yellow brown, saccharoidal, coquinoid. Porosity vuggy, calcite infilling occasional.
1481-86	Dolomite, saccharoidal, brown, vuggy.
1486-91	Dolomite, medium crystalline. Small vugs. Spores and bryozoa.
1491-1501	Dolomite, medium crystalline, spores brown.
1501-06	Dolomite, coquinoid.
1506-11	Dolomite, crinoidal.
1511-26	Dolomite, tan, vuggy.
1526-31	Dolomite, medium crystalline, vugs slight.
1531-71	Dolomite, medium crystalline, brown. Fossils include crinoids and brachiopods.
1571-91	Dolomite, saccharoidal, brown, fossiliferous. Crinoids.
1591-1616	Dolomite, medium crystalline, yellow, brown. Crinoids, corals.
1616-45	Dolomite, crinoidal, vuggy.
1645-60	Dolomite, brown, bituminous, crinoidal.
1660-75	Dolomite, saccharoidal, bituminous. Crinoids, bryozoa, minute amber spores.
1675-85	Dolomite, medium crystalline, argillaceous, crinoidal.
	Total Winnipegosis .... 204 ft.

Note: This thickness of 204 ft. compares with 102 ft. in Marysburg-1. The increase is due to build-up of reef material in bioherm form.

Dawson Bay:

VOSS-ZENA DEBDEN 14-31
Lsd 14-31-53-5 W3
K.B. 1,679 feet

1510-20	Dolomite, crystalline, fine to saccharoidal. Buff to brown. Fair porosity.
1520-30	Dolomite, saccharoidal, greyish brown, vuggy in part, good porosity.
1530-70	Dolomite, saccharoidal, buff to brown, good vuggy and intergranular porosity. Reefoid.
	Total carbonates, as above .... 60 ft.
	Second Red Shale .... 20 ft.
	Total Dawson Bay .... 80 ft.

Note: This formation in Debden 14-31 has thinned considerably compared with Marysburg-1 which showed 136 feet of Dawson Bay.

Souris River:

HUSKY-PHILLIPS FITZMAURICE NO. 1
Lsd 16-18-27-8 W2
K.B. 2,046 feet

2630-60	Limestone, fine crystalline, grey, argillaceous.
2660-70	Limestone, fine crystalline buff to brown, fossiliferous in part.
2670-80	Anhydrite, white. Limestone as or from above.
2680-90	Anhydrite, white. Limestone fine to saccharoidal, crystalline. Porosity fair to good.
2690-2710	Dolomite, finely crystalline, buff to grey-brown.
2710-30	Dolomite, saccharoidal, buff to greyish buff. Porosity fair.
2730-60	Anhydrite, white to buff. Limestone, cream to buff, fine crystalline, anhydrite inclusions.
2760-70	Limestone, fine crystalline, greyish buff, fossils include crinoid stems.
2770-2810	Limestone, fine crystalline, argillaceous, light grey to buff. Anhydrite, clear.
2810-40	Anhydrite, cream to buff. Dolomite, fine crystalline, buff, with anhydrite inclusions.
2840-60	Anhydrite, buff.
2860-70	Anhydrite as above. Dolomite, dense, fine crystalline, buff.
2870-90	Anhydrite, cream to buff. Limestone, fine to medium crystalline, fossils, including crinoid stems, bituminous.
2890-3000	Limestone, saccharoidal, cream to buff bituminous. Fossils including bryozoa. Vuggy porosity.
3000-3040	Shale, red, calcareous, blocky; green, calcareous, soft.
	Total Souris River .... 410 feet

Note: The above thickness compares closely with that of 436 feet for the Souris River in Marysburg No. 1. Anhydrite accompanied by dolomite in Fitzmaurice No. 1 suggests that the Souris River formation becomes more evaporitic in character going from west to east.

Duperow:

SOHIO-STANDARD QUILL LAKE NO. 1
Lsd 15-11-35-17 W2
K.B. 1,711 feet

1760-80	Shale, dolomitic, reddish brown, fissile. Shale, dark grey, fissile.
1780-1840	Limestone, dolomitic, fine to medium crystalline, dense, buff to brown. Fine calcite stringers, part pyritic.
1840-50	Limestone, fine crystalline, light grey, argillaceous.
1850-1910	Dolomitic limestone, fine crystalline, buff, dense, part oolitic. Limestone, fine crystalline, grey, argillaceous, part pyritic. Shale, grey-black, fissile.
1910-60	Dolomitic limestone, fine to medium crystalline, cream to buff, dense.
1960-2010	Dolomitic limestone, fine to medium crystalline, buff dense. Occasional vugs filled with calcite. Calcite stringers.
2010-50	Dolomitic limestone as above.
2050-2110	Dolomitic limestone, fine crystalline, buff to grey-buff. Fossils including brachiopods.
2110-2190	Dolomitic limestone, buff to greyish buff. Anhydrite, white to buff, dense.
	Total Duperow .... 430 feet

Note: The above thickness may be compared with that of 423 feet in Marysburg. However, the equality of the two figures may be more apparent than real because erosion may have removed some Duperow at Marysburg No. 1. From the point of view of sedimentation the two columns suggest regularity of conditions east-west.

Nisku:

B.A. HUSKY-PHILLIPS PLAINVIEW NO. 1
Lsd 2-4-25-7 W2
K.B. 1,945 feet

2080-2100	Dolomitic limestone, fine to medium crystalline, cream to buff. Porosity poor to fair.
2100-70	Dolomitic limestone, crystalline, fine to saccharoidal, cream to buff. Shale inclusions apple green. Porosity fair to good.
	Total Nisku .... 90 feet

Three Forks:

B.A. HUSKY-PHILLIPS PLAINVIEW NO. 1
Lsd 2-4-25-7 W2
K.B. 1,945 feet

1890-1930	Dolomite, medium crystalline, pink to tan, grading down to dolomitic sandstone. Porosity good.
1930-40	Shale, arenaceous or calcareous, maroon. Dolomite and dolomitic sandstone, pink, with shale, apple green, calcareous.
1940-70	Dolomite, medium crystalline, pink. Inclusions of shale, apple green.
1970-2080	Shale, calcareous, maroon. Dolomite, medium crystalline, buff to pink. Inclusions of shale, apple green, calcareous.
	Total Three Forks .... 190 feet

Note: Maroon shales together with apple green shale inclusions in the Three Forks suggest restriction of marine conditions leaning toward coastal or coastal swamp conditions. Similar restricted facies occur in the post-Devonian Watrous. Therefore, where the Three Forks and Watrous paleogeographies approach each other (Fig. 1) some confusion is possible. The apple green shale inclusions, while not an unfailing criterion, are certainly useful in distinguishing between the Three Forks and the Watrous or between the Three Forks and any other variegated lithology.

STRUCTURE:

Fig. 1 shows an interpretation of the present attitude of the Paleozoic surface. In the Yorkton area the paleogeological lines of Fig. 1 show that only a relatively small area of the Paleozoic surface is preserved in Mississippian strata. A great part of the Paleozoic surface is a surface of Devonian strata, progressively older to the north because of increasing erosion in this direction. A rough quantitative picture of erosion may be obtained by considering section cut-out in several Correlation Profiles at varying angles across the strike. These are as follows:

Correlation Profile -2:	From H. P. Fitzmaurice -1 to Sohio Canora -1, 300 feet of Bakken, Three Forks and Nisku removed in 33 miles, or about nine feet of erosion per mile.
Correlation Profile -3:	From T. W. Wynot Crown -1 to White Sands -1, 215 feet of Bakken and Three Forks removed in 41 miles, or about five feet of erosion per mile.
Correlation Profile -4:	From Marysburg -1 to Peesane -1, 400 feet of Duperow removed in 73 miles, or from five to six feet of erosion per mile.
Correlation Profile -5:	From Britalta Rosthern -1 to Brockington -1, 240 feet of Duperow removed in 80 miles, or three feet of erosion per mile.
Correlation Profile -6:	From Sohio Standard Langham -1 to Debden 14-31, 400 feet of Duperow removed in 90 miles, or four to five feet of erosion per mile.

Removal of sediments by erosion is evidently of the order of less than 10 feet per mile on the Paleozoic surface. Locally this rate may be exceeded, especially on the flanks of individual structures. However, the above analysis of Correlation Profiles shows that the regional effect of erosion on the present attitude of the Devonian surface is quite small.

The relatively small effect of erosion may be studied further in the Correlation Profiles by noting that there is frequently parallelism of the eroded Devonian surface and underlying Devonian horizons which did not suffer erosion. In Correlation Profile -1 there is parallelism of the Devonian surface and the top of the Souris River from St. Walburg -1 to Pelican Lake -1. The distance between these two wells is 156 miles. In Correlation Profile -4 there is convergence yet essential parallelism of the Devonian surface and the top of the Souris River from Marysburg -1 to Peesane -1. The distance between these two wells is 72 miles. Convergence yet essential parallelism is again illustrated in Correlation Profile -6 from Langham -1 to Debden 14-31. The distance between these two wells is 83 miles.

From these examples, and from others which may be seen by studying Correlation Profiles Nos. 1-6 inclusive, it is permissible to conclude that large segments within the area of this report contain a Devonian surface planed down to essential parallelism with underlying Devonian strata. In these segments the rise, fall, roll and/or tilt of the Devonian surface may be accepted as due to the effect of structure imposed simultaneously on the Devonian surface and on underlying Devonian beds in post-Devonian times. A map on the surface of the Devonian such as Fig. 1 is thus largely a regional structure map of the Devonian. (The Devonian surface has been chosen for contouring in Fig. 1 because more control points are available than for deeper Devonian beds.) The decrease in contour values on the Devonian surface from north to south in Fig. 1 is an expression of post-Devonian tilt in the same direction. Kamen-Kaye (1954) has shown continuation of this tilt on the Mississippian surface down to and beyond the international border. (In effect this tilt from north to south is the north flank of a great structural basin lying between the Precambrian Shield on the north and the Black Hills of South Dakota in the south. In structural terms the "Williston Basin" is at the bottom of this great trough.)

Seismograph work has indicated local structures. However, contouring of the Devonian surface, as in Fig. 1, shows that in addition to local structures there are structures of regional dimensions which intervene in the overall tilt from north to south. Thus, Fig. 1 shows an anticline trending from north of Yorkton to north of Humboldt in a WNW direction, thereafter swinging west and finally WSW as it passes north of Saskatoon. Fig. 1 also shows that this regional anticline is accompanied on its northern side by a regional syncline. By comparing Fig. 1 with Fig. 2 it is seen that the regional syncline is closely associated with the edge of the Biggar or Prairie Salt. It is therefore probable that salt-tectonic or salt-solution effects are the cause of emplacement of the regional syncline and anticline in the southern portion of the report area. Kamen-Kaye (1954) has suggested similar tectonic and/or solution effects over large segments of Saskatchewan down to and across the international border.

North of the Biggar or Prairie Salt edge the Winnipegosis takes over as a structure-forming agent owing to its biohermal reefing and build-up. Effects on the Devonian surface of biohermal reefing are best illustrated in the Prince Albert-Hudson Bay region where subsurface control is better. In this region a long anticline with accompanying syncline on the north are the expression of draping of the Devonian surface over the Winnipegosis biohermal back-reef edge (Fig. 1). Intervening Devonian horizons must also drape over the bioherm in view of parallelism of Devonian surface and Devonian horizons already discussed.

Northwest of Prince Albert, the contours, as drawn in Fig. 1, do not suggest draping over a Winnipegosis biohermal reef. If more subsurface control were available a greater draping effect might appear in these contours. A complication in this area arises from the fact that the Winnipegosis bioherm may have been grooved or channeled WNW of Prince Albert (Fig. 2), before overlying sediments were deposited. Such a condition would contribute to reduction of the draping effect.

Northwest of Saskatoon draping of the Devonian surface reappears and is shown by a high structural condition north of the North Saskatchewan River (Fig. 1). This reappearance is in accordance with the south swing of the salt edge and with a high Winnipegosis isopach value (Fig. 2).

Draping of beds continues above the Devonian surface and persists in some cases to the shallowest correlatable horizons. In fact, when ground elevations are plotted, as in Fig. 4, there is a suggestion that draping effects over the Winnipegosis biohermal reef may persist up to the present surface. With regard to possible surface effects attention is drawn to Profiles 4 and 5 of Fig. 4. Also with regard to possible surface effects caused by draping over a buried biohermal reef, it is noted that in Alberta the Leduc-Woodbend Devonian reef (of approximate Duperow age) is more or less outlined by a striking geomorphic pattern on a photomosaic of the Leduc-Woodbend area. Unfortunately no photomosaic of the area of this report has yet been seen. Nevertheless, some of the indications of Fig. 4 suggest that interesting geomorphic patterns might emerge on a photomosaic of the Prince Albert-Yorkton-Saskatoon area.

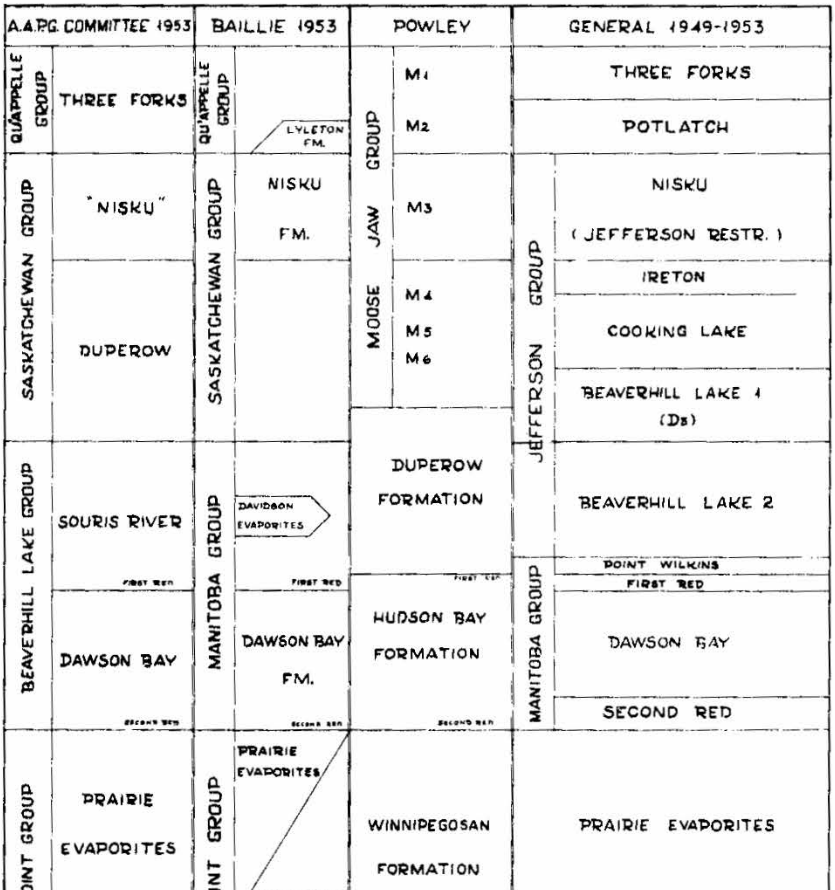
REEF DEVELOPMENT:

Reef description has been available for many decades because geologists have repeatedly examined reefs in outcrop during routine or academic surveys. On this continent, interest in reefs has revived continuously in the wake of successive oil discoveries in reefs from New Mexico to Canada inclusive. Subsurface studies of oil-bearing reefs have been pursued intensively in the process of oilfield development following discovery. Simultaneously, recognition of the mass of reef material available for investigation has brought geologists back to outcrops to study problems of structure, stratigraphy and content. Among the latest of these outcrop studies is that by Newell et al (1953) on the paleoecology of the great Permian reefs which come to surface in New Mexico and Texas. In this study special interest attaches to description of stagnant conditions in the basin fronting the reef, also to description of relatively sudden filling of the basin by chemical precipitation of evaporites, due to an assumed cutting-off of connection with inflowing waters. In an earlier study Wilson (1950) offers a definition of a reef which is basic to an understanding of the subject. This definition follows:

> "A reef is a sedimentary rock aggregate, large or small, composed of the remains of colonial-type organisms that lived near or below the surface of water bodies, mainly marine, and developed relatively large vertical dimensions as compared with the proportions of adjacent sedimentary rocks. The organisms, generally corals and algae and less commonly crinoids and bryozoans, creating the essential features of a reef, lived their mature lives on it and their hard parts remain in place there after death. Reefs tend to develop in mounds or ridges, but also grow in irregular, asymmetrical forms. In all, however, a rigid framework enables a reef margin to grow upward and outward at much steeper angles (even vertical) than is the case with sedimentary clastic rocks. Reefs are commonly characterized by lack of well developed stratification. Differential settling in rocks adjacent to them usually causes draping of strata over reefs. The extra weight of reefs may cause bending of strata under them. Clastic materials or chemically precipitated sediments may be substantial constituents of reefs but are not distinctive parts of them."

In citing relatively large vertical dimensions, also mounds, ridges, and irregular asymmetrical forms, Wilson was apparently referring to biohermal reef development. In the case of the Winni-

DEVONIAN NOMENCLATURE



· FIG. 3 ·

pegosis of this report there is definite development of vertical or biohermal growth which occurs in contrast to background Winnipegosis development where sheet or biostromal growth is the controlling factor, even though reef or reefoid material contributes to the material of the biostrome. Some relationships between biohermal thickening in the Winnipegosis and biostromal background development are summarized in Fig. 4, especially Profiles 4 and 5. In both these latter profiles biohermal thickening is seen to occur back from the Prairie Evaporite salt-containing basin. These relationships are repeated with electric-log detail in Correlation Profiles Nos. 4 and 5 respectively. The build-up of the reef and consequent draping of overlying sediments are again apparent. The electric-log detail also shows that the Ashern and Interlake formations are relatively structureless below the reef. Another example of these relationships may be seen in Correlation Profile No. 6.

Where cores are not available and only drill samples can be examined it may be difficult to distinguish between biostromal and biohermal development in the Winnipegosis. In this case, recourse must be had to the total thickness of Winnipegosis in each well examined. An analysis of all the results, using this method, shows that the background thickness value of the Winnipegosis biostrome is about 100 feet. When the thickness builds up to 200 feet or more, it may be assumed with some confidence that biohermal development has taken place. An increase in bryozoan or crinoidal development may help in developing the analysis. (Typical crinoidal development in a bioherm core is shown in Plate 2).

Using the available data, admittedly scarce in certain localities, a trend is shown in Fig. 2 along which the Winnipegosis is likely to equal or exceed 200 feet in thickness because of biohermal development. It is reasonable to suggest that the bioherm may prove to be continuous along this trend. Even if this is not the case, Fig. 2 is considered significant in indicating where exploration can logically be concentrated in the search for Winnipegosis oil and gas trapped in biohermal maxima.

Reef Relationships:

In terms of paleogeography and paleoecology three provinces may be described, as is usual with biohermal and/or barrier reef development:

(1) The shelf province, located north and east of Prince Albert.

(2) The bioherm or barrier reef province, having a NW trend from the Manitoba border to Prince Albert.

(3) The basinal province, with a "salt" edge paralleling the bioherm or barrier reef, as shown in Fig. 2.

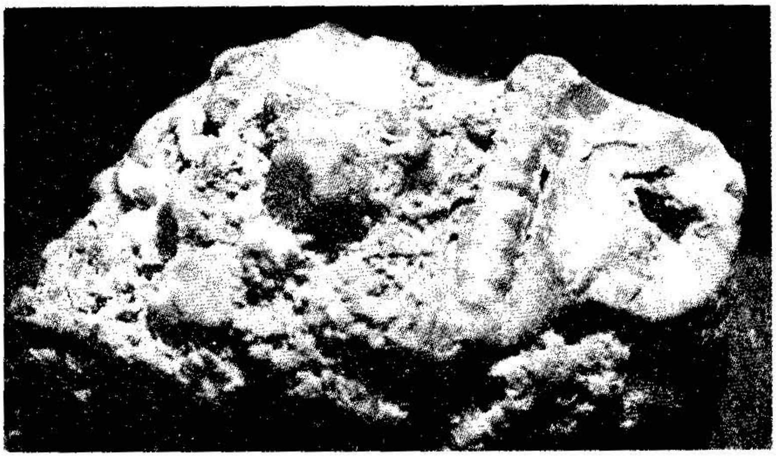


PLATE 2

Portion of core from the Winnipegosis reef in Sayse No. 1 showing crinoidal development and vugs, (X 6.5)

Relatively little is known about the Winnipegosis in the northeastern or shelf province because drilling has been sparse there. From information to date it may be suggested that the Winnipegosis of the shelf province is more or less dolomitic, biostromal and stromatolithic in character. Conditions may be classed as reefal but not classed as biohermal reef build-up.

Reef character along the biohermal trend of Fig. 2 is exemplified in the systematic description of Winnipegosis samples from Sayese No. 1 presented earlier in this study. From this description the material appears in the main as crinoids, corals, bryozoa, brachiopods, algae and the fossil debris from this combined faunule. Algal spore cases or algal spheres are an additional feature, not only at the base of the bioherm but also in the biostrome of the area under study, and of areas elsewhere in Saskatchewan. Dolomitization is a feature of the bioherm in Sayese No. 1, shown also in other wells of the trend. Such dolomitization apparently changes the nature and position of porosity and apparently destroys part of the evidence of algal remains.

Bituminous banding is frequent at the base of the biostrome in the general Winnipegosis background. The banding suggests cyclical variation in quantities of marine organic matter available. The bitumen content suggests that there was a basinal environ-

TABLE *1*

Well and Location	*Gas or Oil*	*Interval*	*Formation*	*Source of Information*
Albercan. Lsd 10-7-52-16w3.	Gas.	2418-2446	Souris River.	Drill stem test No. 2 slightly gas-cut mud.
Brightholme—1. Lsd 5-29-44-9w3.	Oil.	2029-2075	Souris River.	Well geologists' report. Intermittent oil staining.
Craigmore—1. Lsd 13-4-44-9w3.	Oil.	2870-2880	Souris River.	Well geologists' report. Slight oil fluorescence in cuttings.
Fitzmaurice—1. Lsd 16-18-27-8w3.	Oil.	2725-2782	Souris River.	Drillstem test No. 1. Rainbow of oil on mud.
	Oil and gas.	2875-2892	Souris River.	Drillstem test No. 2. Mud slightly oil and gas-cut.
	Oil.	2941-2959	Souris River.	Drillstem test No. 3. Slight film of oil on salt water; cuttings slightly petroliferous; fluorescence.
	Gas.	3102-3114	Souris River.	Drillstem test No. 4. Mud slightly gas-cut.
Green Lake—1. Lsd 8-14-62-13w3.	Gas.	650-660	Blairmore.	Geologists' report.
	Oil.	530-540	Blairmore.	Geologists' report.
	Oil.	590-610	Blairmore.	Geologists' report.
	Oil.	1020-1030	Blairmore.	Geologists' report.
Gronlid—1. Lsd 15-32-47-17w2.	Oil.	1777-1791	Winnipegosis.	Drillstem test No. 3. Slightly oil-cut mud.
Marysburg—1. Lsd 16-29-38-22w2.	Gas.	1494-1502	Blairmore.	Geologists' report. Fluorescence in cuttings.
	Oil.	2010-2014	Duperow.	Geologists' report. Fluorescence in cuttings.
	Oil.	2022-2030	Duperow.	Geologists' report. Fluorescence in cuttings.
	Oil.	2048-2092	Duperow.	Geologists' report. Fluorescence in cuttings.
Pelican Lake—1. Lsd 2-2-44-26w2.	Gas.	2055-2080	Souris River.	Drillstem test No. 6. Recovered 300 feet salty, very slightly gassy mud.
	Oil.	2517-2554	Prairie Evaporites.	Drillstem test No. 8. Recovered 40 feet mud slightly spotted with heavy oil.

ment in part of Winnipegosis times. Where the bioherm is built up over a bituminous base, as in Sayese No. 1, this may be interpreted to mean that the bioherm grew out horizontally over the edges of an initial Winnipegosis basin. Newell et al (op. cit.) present evidence for a similar type of horizontal biohermal growth in their description of Permian reefs at outcrop.

The absence of black shales in the Winnipegosis can be taken to mean that the initial basin was shallow. However, in order to prepare for eventual reception of salt precipitation the basin south of the bioherm must have deepened considerably in later Winnipegosis times. The process of salt (and potash) precipitation cannot be demonstrated with the amount of information to hand. Nevertheless, by analogy with other salt basins, the process must have been initiated by cutting off of the normal inflow of saline waters and by subsequent rapid evaporation under arid atmospheric conditions.

EVIDENCE OF OIL AND GAS

Apart from recognized oil and gas accumulations within the area of this report such as those at Barlow, Kakwa, Kamsack, Big River, etc., Table 1 has been compiled to show the record of staining in samples, of oil and gas cutting in mud, of oil and gas cutting of fluid from drill stem tests and of sample fluorescence reported by geologists.

EXPLORATION FOR WINNIPEGOSIS OIL AND GAS

The observations which follow are comments on methods which are already familiar to the majority of those operators who have explored or who are about to explore the area of this report. For these operators such observations are little more than recapitulation. Therefore, the following observations on Winnipegosis exploration are directed more particularly to those who are interested in the area but who may not be familiar with its exploration.

It has been illustrated previously that in the first instance the Winnipegosis biohermal reef affects both overlying Devonian strata and the Devonian erosional surface by causing them to drape over the biohermal structure. It has also been illustrated previously that this draping effect continues into the highest correlatable strata and quite possibly up to the present surface. On this premise it would seem advisable to include photogeological examination of segments across the bioherm trend of Fig. 2 when particular petroleum mineral lands are being considered for exploration.

Seismograph investigation can be considered a valuable exploration tool in the study area, including particularly the area of the bioherm trend in Fig. 2. The use of seismograph investigation in conjunction with regional geology may be illustrated by work done in the Kinistino-Brockington area of the Winnipegosis bioherm (Fig. 2). In this area a group of detailed seismograph coverages was linked by seismograph traverses to the extent that the several coverages could be considered as more or less on the same reflecting horizon. It was found that the reflecting horizon displayed the tilt from north to south already known from regional mapping of the Devonian surface (Fig. 1) or from underlying and overlying beds. It was also found that the back-reef edge, as shown by the two Brockington wells of Correlation Profile No. 5, had its counterpart in critical reversal of seismograph dip to the north at the same locality.

Around Kinistino -1 (Fig. 2) the seismograph again showed a structure with critical northern reversal of the dip. On grounds of geography this structure could not be due to a back-reef edge. Therefore, this structure might be due to a local knoll or local maximum on the Winnipegosis bioherm in this locality. However, the Kinistino -1 structure was not alone in its locality. Thus, the seismograph indicated that there were a half-dozen or so structures near to Kinistino -1 and that any or all of these structures might be used as exploratory drilling locations with advantage equal to Kinistino -1, the well actually drilled.

A similar situation of several seismograph structures and only one drilled appeared in the Yellow Creek area between Kinistino -1 and Pelican Lake -1 (Fig. 2).

These considerations suggest that, within the limitation of exploration economy, several wells might be drilled relatively close together in the hope that one of them might find the bioherm developed higher than in the others, with consequent accumulation of oil and/or gas.

Exploration by seismograph and by the drill need not be confined to the Winnipegosis bioherm itself. For example, Table 1 shows evidence of oil in the Winnipegosis of Gronlid -1 back from the bioherm, on the biostrome. To judge from the investigations of Newell et al (op. cit.) this position immediately back of the reef may have considerable significance, since, in the Permian reefs, it was found that some of the best available porosity was developed in back-reef dolomites.

CONCLUSIONS

1. The subject area is of interest to prospective operators in the broad sense that its total sedimentary column does not exceed 5,000 feet. In the eastern sector the total sedimentary column may frequently not exceed 4,000 feet. At the base of the sedi-

mentary column is a wedge of interbedded Cambro-Ordovician sands providing good reservoirs in which water drive may be expected.

2. Evidence of oil is varied within the sedimentary column. Thus evidence of oil has been found above, at, and below the Devonian (and Mississippian) surface.

3. In the Devonian the Winnipegosis reef develops vertical-building or biohermal characteristics either continuously or intermittently along a trend of at least 250 miles.

4. Biohermal reef development over a possible trend of 250 miles greatly enhances the prospects of the subject area from the standpoint of oil and gas.

5. Drilling to date has investigated only a small percentage area of the possible Winnipegosis biohermal reef.

APPENDIX

GEOPHYSICAL AND OTHER DATA AVAILABLE

GEOPHYSICAL DATA:

A large percentage of the area of this report has been covered by one or other of the current methods of geophysical investigation. Localities investigated and the areas covered in these localities are given below for each of the geophysical methods. The results are in the form of contour maps (time, milligals or gammas). Data is on file at the Department of Mineral Resources, Regina, where most is available for public inspection. Confidential data is marked with an asterisk.

SEISMOGRAPH

Locality	*Approx. Area (Acres)*
Quill Lake	87,000
Insinger	40,000
Lintlaw-Invermay	379,000
Englefield	23,000
Devil's Lake-Ebenezer	253,000
Humboldt	49,000
Brithdir	54,000
Plunkett-Watrous	277,000
Yorkton	46,000
Scrip	17,000
Speddington	31,000
Romance	16,000
Langham	52,000
*Arran	111,000
Neshem-Weirdale	70,000
Brockington-Prestfoss	22,000
McKague	4,000
*Sturgeon Valley-Briarlea	49,000
*Canwood-Clonfert	404,000

(*—Confidential Information)

GRAVITY

Locality	*Approx. Area (Acres)*
Meath Park	414,000
Birch Lake	125,000
St. Walburg	645,000
Turtleford-Edam	1,264,000
Ravenhead-Speers	392,000
Leask-Tallman	461,000
Tisdale	685,000
Shell Lake	68,000
Melfort-Tisdale	204,000
Saskatoon-Prince Albert	150,000
*Edam	62,000
*Wroxton	173,000
*Preeceville	230,000
*Burton Lake-Humboldt	124,000

(*—Confidential Information)

AEROMAGNETOMETER

Locality	*Approx. Area (Acres)*
Mudie Lake-Makwa Lake	645,000
Saskatoon-Prince Albert	589,000
Cold Lake-Sukaw Lake	1,152,000

MAGNETOMETER

Locality	*Approx. Area (Acres)*
Tisdale	507,000
Meacham-Humboldt	346,000
Alvena-Smuts	230,000
Norbury	134,000
Wood Hill-Shell Lake	421,000
*Kamsack	77,000
*North Battleford	109,000
*Battleford	12,000
*Glaslyn	318,000
*Norquay	138,000
*Humboldt	230,000
*Preeceville	115,000
*Bronson Provincial Forest	549,000

(*—Confidential Information)

WELL DATA:

The locations of all wells drilled within the area of this report are shown on the North Saskatchewan and South Saskatchewan Well Map sheets, scale eight miles to the inch, on sale at the Department of Mineral Resources, Regina.

The Schedule of Wells, on sale as above, includes minimum detail on every well drilled within the report area. This minimum detail consists of date, location, ground elevation K. B. and surface casing. Many wells also show geological tops and drill stem test results. This additional data becomes available one year after the date of abandonment of each unsuccessful exploratory well.

OTHER DATA:

The area of this report has complete vertical air photo coverage. A large file of photos is maintained by the Division of Surveys, Department of Natural Resources, Regina. In some cases it may be possible to loan available photographs from the Division of Surveys. Where this is not possible the division can arrange for purchase of desired photographs.

A complete list of all publications, either free or for sale, may be obtained by application to the Department of Mineral Resources, Regina. This list includes a variety of geological data. A comprehensive correlation chart and a recently issued Stratigraphic Correlation Chart printed in colour are among the many items on the list.

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