The Oil and Gas Prospects of the Pre-Mississippian Sedimentary Rocks of Southern Manitoba

By: J. C. Sproule & Associates

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THE OIL AND GAS PROSPECTS

OF THE

PRE-MISSISSIPPIAN SEDIMENTARY ROCKS

OF

SOUTHERN MANITOBA

Prepared by

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for the

Department of Mines and Natural Resources

Manitoba

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THE COMPLETE SET OF 52 MAPS AND CROSS-SECTIONS LISTED ON PAGES ii AND iii MAY BE OBTAINED FROM THE GEOLOGICAL DIVISION, MINES BRANCH, 900 NORQUAY BLDG., 401 YORK AVE., WINNIPEG 1. THE PRICE IS $40.00 PER SET.

LIST OF ILLUSTRATIONS

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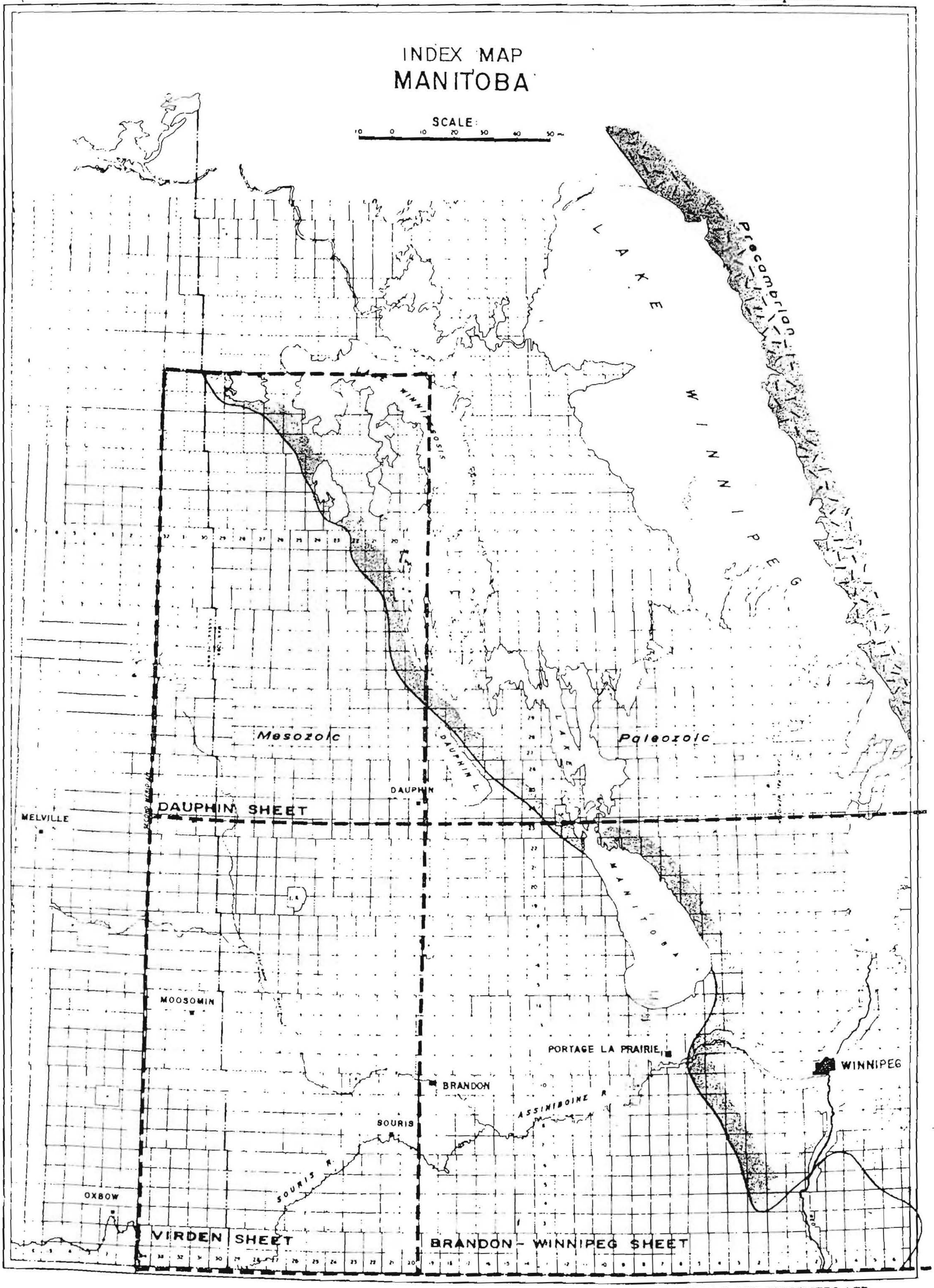
MAP FOLIO NO. II



J.C. SPROULE AND ASSOCIATES LTD.

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INTRODUCTION

This report is based on a study of the oil and gas prospects of the pre-Mississippian Paleozoic rocks of southern Manitoba, authorized by Mr. S. Anderson, Deputy Minister of Mines and Natural Resources for the Province of Manitoba, in a letter dated November 26, 1963.

The Schedule summarizing the scope of the requested study and which accompanied Mr. Anderson's letter is reproduced, in part, below.

Schedule

Study of Lower Palaeozoic Formations in Manitoba

Formations

The study is to cover the recognized formations of the Ordovician, Silurian, and Devonian systems. Nomenclature is to correspond as closely as possible with that of the Manitoba Mines Branch.

Area

All that area of Manitoba and relevant adjacent parts of Saskatchewan for which well data within the above systems are available.

Studies

(a) Isopach maps of all formations
(b) Structure contour maps of all formations
(c) Cross-sections
(d) Porosity distribution
(e) Helium prospects
(f) Discussion and interpretation

Specifications

(a) Scale of maps to be four miles to one inch or more detailed where necessary.
(b) Cross-sections and maps to be based on electric logs.
(c) Porosity distribution to be based on drill stem tests supplemented by study of electric logs.

In later correspondence it was mutually agreed that the schedule was to be taken as a generalized statement and that we were free to proceed at our own discretion, making such maps as we considered necessary.

The maps finally prepared to accompany this report are listed below. Where there is sufficient data to allow us to make interpretations we have shown the distribution of certain porous or potentially porous zones on the maps. In other cases, porosity distribution has been discussed in the text of the report.

Contour Map - Top of the Paleozoic
Structure Contour Map - Top of the Nisku Formation
Isopach Map - Nisku Formation
Isopach Map - Duperow Formation
Isopach Map - Souris River Formation
Structure Contour Map - Dawson Bay Formation
Isopach Map - Prairie Evaporite Formation (Showing structure contours in part of the map-area)
Combined Isopach and Structure Contour Map - Winnipegosis Formation
Structure Contour Map - Interlake Group
Isopach Map - Interlake Group
Isopach Map - Stonewall Formation
Isopach Map - Gunton Member
Structure Contour Map - Red River Formation (Showing distribution of Certain Prospective Zones)
Isopach Map - Red River Formation
Structure Contour Map - Winnipeg Formation (Showing distribution of Certain Prospective Zones)
Isopach Map - Winnipeg Formation
Four Cross-Sections

Only a limited number of wells have been drilled to test the Devonian and older beds in Manitoba, and in the last few years exploration of these beds has virtually ceased. Apparently the decrease in activity has been caused partly by lack of discoveries in Manitoba and partly by the doubtful economics of certain of the smaller pools discovered in those beds in Saskatchewan and Montana; although the large area in which these older beds occur can certainly not be considered to have been adequately explored.

The purpose of the study was to review available data on the pre-Mississippian Paleozoic rocks in an attempt to make recommendations regarding the exploration of these beds for gas and oil. We have tried to avoid duplication of published work and to approach the problem from an unbiased exploration viewpoint. Our approach is discussed more fully in the section of this report entitled "Approach to the Problem."

This report is divided into chapters entitled "Introduction," "Approach to the Problem," "Stratigraphy," "Exploration to Date," "Structural Geology," "Oil and Gas Prospects," "Helium Prospects," "Other Exploration Considerations," and "Summary and Recommendations," and is illustrated by the four cross-sections and the sixteen isopach and structure contour maps referred to above.

APPROACH TO THE PROBLEM

Any study of the prospects of the pre-Mississippian rocks of southern Manitoba is hampered by the fact that very few wells have been drilled to these strata and control is widely scattered. The number of wells drilled to date is discussed in the section of this report headed "Exploration to Date" and it is enough to state here that, except in a very few cases, the control permits only general interpretations of the stratigraphy and structure.

Basic work on stratigraphic correlation has been carried on for many years by various workers and, considering the control available, this necessary preliminary phase to exploration can be considered to have reached a point where the value of additional work at this time is doubtful. Of course there are some differences of opinion on correlation, but these are relatively minor. Additional drilling will, no doubt, result in revisions in correlation and nomenclature, but these cannot be predicted at this time. Some of the more important recent stratigraphic works are cited in the chapter of this report entitled "Stratigraphy." For the present study we have prepared cross-sections showing the stratigraphic correlations, pinchouts, etc. We have also examined all well logs for the purpose of determining elevations and thicknesses of stratigraphic units.

Once the basic correlations in an area have been established, proper exploration requires that both lithofacies relationships and structural features and trends be studied.

There are a number of published works dealing with lithofacies variations within the area under study and adjacent areas, notably those of Baillie (1951a), (1951b), (1952), (1953), Porter and Fuller (1959), Andrichuk (1959), Evans (1960), Kent (1960), Lane (1959), and Edie (1959). In most cases, these workers have established the presence of variations in lithology conducive to the formation of stratigraphic traps. More detailed lithofacies studies than those already published would require a great deal of time and detailed examinations of all samples and cores. In view of the previous published work, the long distance between control wells, the regional nature of the present study, and the time allocated to the study, this does not seem practical at this time.

On the other hand, published structure and isopach maps of the area have all been on a small scale and have not shown those details of structure that we feel can be interpreted even from the limited data available at this time. One of our main approaches has, therefore, been to carefully contour and isopach a number of stratigraphic units in an attempt to locate structural or tectonic trends that may be favourable for the formation of both structural and stratigraphic traps. We have determined the thicknesses of all commonly recognized formations but have only prepared final isopach maps of those which, in our opinion, show sufficient variation in thickness to warrant mapping. We have prepared structure maps of enough units to determine trends but have not mapped all units since, in many cases, there is not sufficient variation from overlying or underlying units to justify separate maps.

Some of the accompanying structure maps might be critized as being too interpretative. It is quite true that some of the units could have been mapped more smoothly than has been done, but we have felt that only by using a certain amount of intelligent and educated imagination is it possible to locate possible important trends. Several geologists have worked on the maps and several independent interpretations have arisen. We could have eliminated some of the differences in interpretation but have not always done so on the grounds that, considering the limited control, any one of several interpretations could be correct and that the client should be given the benefit of several interpretations. That being the case, we have not in all cases forced one structure contour or isopach pattern to "fit" all the others involved. As additional control becomes available, one might expect patterns at all or most horizons to be related to a greater or lesser extent, at least in cases of conformable strata.

Our approach has not been that of a detailed exploration study such as might be conducted by a major oil company wishing to evaluate a specific block of acreage. We have rather attempted, within the time available and making use of already published data, as well as our own studies, to determine whether areas favourable for detailed exploration exist and, where possible, to outline such areas in a general way.

The very detailed work that many major companies consider a prerequisite to the planning of exploration programs, selection of drill sites, etc., is not only very time consuming and expensive but must be done with the exploration philosophy and concepts of the particular organization in mind. Seismic or other geophysical data is also usually considered essential. In a general study of the type herein presented such work is impossible.

As well as our regional geological considerations, we have given considerable thought to several non-technical matters that could affect exploration in the Province of Manitoba. Some of our suggestions in this matter are given in the chapter of this report entitled "Other Exploration Considerations."

EXPLORATION TO DATE

Since the discovery of commercial oil in the Mississippian rocks of Manitoba in 1951, there has been considerable exploration of these beds. A number of primarily Mississippian tests have also been drilled deep enough to test the uppermost Devonian prospective beds of the Nisku and Duperow where these are overlain by Mississippian. Below the Duperow, and in those parts of southern Manitoba where Mississippian beds are not present, there have been very few wells drilled. This is probably partly because no discoveries or really encouraging shows have been obtained from the pre-Mississippian in Manitoba. It is our firm belief that one well located discovery could cause a vast increase in exploration activity.

We believe also that it is not commonly realized how few tests have been made of the pre-Mississippian and what large areas are, as yet, totally unexplored. We have, therefore, summarized the approximate number of wells drilled to and through each of the major prospective units. To do this, it has been necessary to determine in some way the prospective area for each stratigraphic unit. We have rather arbitrarily defined the prospective area as that area where the top of the unit is at least 1,000 feet deep and where it does not form the subcrop immediately below the glacial drift. Because of the variation in surface topography and geological structure, an accurate outline of the area covered by these self-imposed terms of reference would involve considerable detailed work. We have, therefore, approximated the area in each case but we feel that all such approximations have been conservative. The actual prospective areas for each unit are probably larger than those given in the table. This applies particularly to the deeper beds. The depth figure of 1,000 feet is arbitrarily chosen and there is no reason why commercial pools could not occur somewhat higher than this, although any such pools would probably have relatively small reserves because of low pressures and limitations relating to cover.

Our summary of wells drilled to and through prospective units follows as Table I.

Table I

Approximate Number of Square Miles Per Well

Drilled to Prospective Zones in Prospective Area

	No. of Square Miles of Prospective Area (1)	Drilled To or Through Unit		Drilled Through Unit	
		No. of Wells	No. of Square Miles Per Well	No. of Wells	No. of Square Miles Per Well
Nisku	7,000 (2)	183 (2)	37 (2)	70 (2)	98 (2)
Duperow	14,500	125	116	91	160
Souris River	15,800	105	151	83	191
Dawson Bay	16,800	86	195	83	202
Winnipegosis	19,100	76	251	71	269
Interlake	20,600	75	275	61	338
Red River	24,800	65	381	59	420
Winnipeg	27,000	67	403	64	422

(1) Prospective area is considered to be the area where the prospective zone is over 1,000 feet deep.
(2) All figures shown are approximations.

It will be noted that even in the case of the Nisku only approximately one well per township has reached the top of the unit and approximately one well per three townships has drilled through the unit. Very few of these wells have been drilled in the most prospective part of the Nisku, where it forms the Paleozoic subcrop. Figures for other units indicate progressively fewer tests per unit area with increasing age of prospective units, until the widespread and very frequently porous sand of the Winnipeg shows over eleven townships per test. It is obvious that none of these formations can be considered to have been adequately tested.

Not only have very few wells been drilled to the prospective units, but few drill stem tests have been run in these wells which did penetrate the units in question.

We have approximated the number of drill stem tests run on various prospective units in the area of interest. Because of the overlapping of several units by some tests and because of the difficulties mentioned above in accurately outlining the prospective areas, our summary is subject to some error.

A table showing the approximate number of drill stem tests of various units follows.

Table II

Drill Stem Tests In Prospective Area

	No. of D.S.T.'s	No. of Wells Tested
Nisku	115(1)	112(1)
Duperow	84	51
Souris River	40	32
Dawson Bay	24	23
Winnipegosis	30	30
Interlake	23	20
Stonewall	3	3
Stony Mountain	2	2
Red River	23	20
Winnipeg	32	26

(1) All figures shown are approximations.

When it is considered that there are seldom any indications of the presence of gas in samples and cores and that light oil stains are frequently not seen, it will be apparent that the pre-Mississippian rocks of southern Manitoba have been tested in only the most cursory manner.

Another very striking point is obvious from an examination of the maps accompanying this report. This is the very small number of deep tests drilled in or near the Mississippian productive trend. Considering that experience in various parts of the world has shown that many oil and gas pools overlie other pools in deeper beds, this lack of deep tests in an established shallower productive area is very surprising.

It may be argued that the location of many of the oil fields in the Mississippian in Manitoba is primarily controlled by the erosional edge of units of the Lodgepole Formation and that deeper beds are not affected. The close proximity of the Lodgepole erosional edge to an apparent major tectonic hinge-line is discussed in the section of this report dealing with structural geology. We feel that this deep-seated feature may well have been an important controlling factor in Mississippian sedimentation and erosion as well as in that of lower units. We feel strongly that some of the best prospects for deeper production in Manitoba are in the general area of present Mississippian production. There are very good chances for the occurrence of stratigraphic and structural anomalies along this hinge-line.

Another striking feature is the lack of concentrated exploration activity in any specific area. With a few exceptions, such as the Hartney area where a number of deep wells have been drilled, there has apparently been little attempt to fully explore any individual features. That is to say, when a porous bed has been encountered there has seldom been any attempt to drill another well structurally higher or closer to the updip limits in the case of stratigraphic traps. Plays have apparently usually been "one-shot" efforts, with little attempt at follow-up. This may be due in part to the difficulty in putting together sufficiently large land blocks for concerted exploration efforts.

STRATIGRAPHY

Detailed stratigraphic discussions would serve no particular purpose in this report. A number of workers, particularly Baillie (1951a), (1951b), (1952), (1953), Porter, and Fuller (1959), and Andrichuk (1959), have provided discussions of the stratigraphy of the area. These have been based on their own studies as well as those of earlier workers and taken together they provide a large amount of information on details of correlation, age relationships, etc. We have not made any detailed studies of this nature other than to satisfy ourselves, as far as present knowledge permits, as to the accuracy of the correlations in common use. Repetition of previous work would be superfluous. This section of our report, therefore, contains only a Table of Formations showing generalized stratigraphy. Some further comments on the stratigraphy of various units are given under the heading of "Oil and Gas Prospects." Persons interested in further details of stratigraphy are referred to the published works listed in the accompanying Selected Bibliography.

Table of Formations(1)

Systems and Series	Group, Formation and Members	Lithology	Approximate Thickness(2) Feet
MESOZOIC			
Lower Cretaceous	Swan River	Sandstone, siltstone, shale and clay. Impervious beds could form caprocks in that part of study area where Jurassic beds are absent.	400?
		- UNCONFORMITY -	
Jurassic	Amaranth	Predominantly red dolomitic shales and siltstones overlain by anhydrite and evaporitic dolomite. Should act as an effective seal. Overlies Paleozoic surface throughout most of study area.	100-250
		- UNCONFORMITY -	
PALEOZOIC			
Mississippian	Lodgepole	Highly variable, predominantly carbonate rocks, generally hard, protected pre-Mississippian beds from erosion in southeastern Manitoba. Locally contains the softer Routledge shale member that has eroded and formed reentrants in the Mississippian scarp.	

(1) Limited to pre-Mississippian beds and directly overlying beds.)
(2) Where not eroded.

Table of Formations - Continued

Systems and Series	Group, Formation and Members	Lithology	Approximate Thickness(2) Feet
	Bakken	Black, bituminous shale, generally with a sandy or silty layer. Could form source beds for oil and gas. Distribution similar to that of Lodgepole. Sand is potential reservoir.	50±
		- Minor Unconformity -	
Devonian	Lyleton	Red and brownish red shale and dolomitic shale, argillaceous siltstone and dolomite. Forms caprock seal over Nisku where present. Distribution similar to that of Mississippian.	50±
	Nisku	Dolomite and limestone, frequently very fossiliferous, usually porous; truncated by erosion in southwestern Manitoba.	125
	Souris River	Dolomite, mostly finely crystalline, variable porosity, limestone, some argillaceous bands, evaporitic bands common, some porous beds. Includes 50' thick red shale section of "First Red Bed" at base. This forms seal over Dawson Bay.	200
	Dawson Bay	Limestone and dolomite, frequently very fossiliferous and reefoid in nature; may contain evaporitic section at top, frequently porous, but in the salt basin the porosity is usually salt filled. Includes 30' thick red shale "Second Red Bed" at base.	200
	Prairie Evaporite	Salt, anhydrite and evaporitic dolomite. Salt section present only in southwestern Manitoba although a thin anhydrite section has a wider distribution. Forms seal over underlying Winnipegosis, but where salt beds are present the Winnipegosis porosity is frequently salt filled.	0-400

Table of Formations - Continued

Systems and Series	Group, Formation and Members	Lithology	Approximate Thickness(2) Feet
	Winnipegosis	Reef and inter-reef dolomites, usually porous except in the salt basin where the porosity is frequently salt filled.	50-150
	Ashern	Red dolomitic shale. Forms a base seal for the Winnipegosis and a top seal for the underlying Silurian.	10-50
		- UNCONFORMITY -	
Silurian	Interlake	Dolomites ranging from very fine-grained to relatively coarse bioclastics, bands of good porosity that could form stratigraphic traps. Progressively truncated northeastward due to post-Silurian erosion.	160-450
Ordovician(?)	Stonewall	(Considered by some workers to be part of the Interlake.) Dolomites and evaporites with some limestone bands, cyclically deposited, at least locally porous.	40-80
Ordovician	Stony Mountain		150
	Gunton Member	Dolomites, usually fine-grained with porous interbeds of finely crystalline dolomite.	
	Stony Mountain Shale Member	Argillaceous limestone and dolomite and calcareous shale. May act as source beds or as seals for underlying beds.	
	Red River	Dolomites with limestone and anhydrite beds. Porous beds interbedded with non-porous beds.	250-550
	Winnipeg	Highly porous sandstones interbedded with green, fossiliferous shales. Stratigraphic traps may be expected in the sands and the shales could act as source beds.	100-300

Table of Formations - Continued

Systems and Series	Group, Formation and Members	Lithology	Approximate Thickness(2) Feet
Unknown	Granite Wash	Although the presence of significant thicknesses of Granite Wash has not been established in the area, it may occur, especially along Precambrian topographic or structural features.	?

STRUCTURAL GEOLOGY

The area under discussion lies on the northeast flank of the Williston Basin. The southwestern corner of the province is located on the basin proper while the remainder of the sedimentary area is on the broad, relatively stable platform known as the Manitoba shelf. The hinge-line between the deep part of the basin and the shelf is one of the most prominent structural features of the area.

The structure and the stratigraphy of the area are related not only to basin subsidence but to the Precambrian surface and to tectonic features of the Precambrian, which have apparently continued to influence deposition throughout most of geologic time. The principal trends of this nature appear to have been in a northeast direction. Some of these trends will be discussed in more detail below.

Much of our effort in the present study has been devoted to the preparation of structure and isopach maps. Although, as previously noted, control is sparse over most of the area and it is possible to contour most horizons relatively smoothly, we believe that considerably more useful interpretation is possible than has been shown on published maps. Although many of our interpretations may well be shown to be incorrect by later drilling, interpretative contouring is probably the best method of detecting tectonic trends and structural plays.

Our structure maps have been prepared by several different geologists and, in some cases, there are differences in interpretation. It might have been possible to adjust all maps to similar interpretations but this has not always been done because the sparse control could allow any one of several interpretations to be correct and we have felt that the client should have the benefit of these different interpretations.

Figure I is a contour map on the top of the Paleozoic in the area where Mississippian beds have been eroded. This map has been prepared by a mechanical method. We first prepared an isopach map of the interval between the Ashville Formation and the top of the Paleozoic. This map approaches a mirror image of the top of the Paleozoic with the effect of regional dip minimized. Because of the reduced regional dip effect, it should be possible to contour a more realistic drainage pattern on this map than can be done directly on the Paleozoic surface. A structure map of the top of the Ashville was also prepared. The two maps were then combined mechanically to obtain the Paleozoic surface contour map, an interpreted drainage pattern with superimposed regional dip.

The top of the Paleozoic map was originally contoured using a 25-foot contour interval over most of the area, but, for the sake of clarity, a 100-foot contour interval has been used on the drafted version.

For the most part, the formational boundaries shown on the Paleozoic map (Figure I) have been obtained by contour intersection methods using the appropriate structure contour maps in conjunction with the map of the top of the Paleozoic. This has resulted in irregular subcrop patterns such as might be expected on an erosional surface. There is no doubt that the contours and formational boundaries shown on the map of the top of the Paleozoic will be subject to considerable change as more information becomes available from drilling. We believe, however, it is only by attempting to interpret details of structure and resultant lobes or outliers of subcropping formations that plays can be developed.

The structure contour map on the top of the Nisku (Figure II) has been prepared with the aid of a structure map of the Bakken for which more control is available. Although there may be a disconformity between the Devonian and the Mississippian, there appears to be very little angular unconformity between the two systems and the use of the additional Bakken control seems justified. We have carried down into the Nisku several features that appear on our Bakken map but for which there is limited Nisku control. This map was prepared using a 50-foot contour interval but only 100-foot contours are shown on the drafted version.

There are a number of structural noses shown on the Nisku map. The only closure shown on this map is in the Daly area, but other closures could exist along the noses shown, or elsewhere, and could form traps. Inert gas has been obtained from the Duperow and Souris River formations in a well drilled on the feature in the Daly area.

In the northern part of the Virden sheet in the vicinity of Townships 18 to 20, Ranges 25 to 30, W. 1 M., there is evidence of strong structural irregularities. This map has been contoured to suggest the presence of faults, although there is not enough control to enable us to map individual faults. The isopach maps of the Nisku, Duperow and Souris River (Figures III, IV and V) also show the suggestion of faulting in this area. There is a Winnipegosis thick in the same area overlain by a Prairie Evaporite thin. A depositional thinning of the salt is indicated, but it is also quite likely that local thinning by salt solution has taken place. The Winnipegosis thick may well lie on a tectonically active area that has controlled reef growth and along which later movement has also taken place. The area is worthy of considerable further study.

In the Hartney area (Township 5, Range 24, W. 1 M.), there is evidence of faulting. Our map of the top of the Nisku shows one possible interpretation. It has been suggested (Haites, 1962) that transcurrent faulting may have been responsible, in part at least, for this feature. Lineaments of the Souris River and its tributaries may be taken as evidence for this concept. A crypto-volcanic origin has also been suggested, similar to that postulated for the Elbow (Saskatchewan) structure by de Mille (1960). Crypto-volcanoes might be expected along tectonically active trends, and again the lineaments of the Souris River and its tributaries may be cited as evidence for such a trend. Our isopach maps of the Nisku and Duperow (Figures III and IV) provide some evidence for the presence of a northwest-trending feature passing through the Hartney area. Control for these maps in this area is very limited and other interpretations are possible. The lead does, however, appear worthy of further study. A detailed photogeological study of the area could be most revealing.

The structure contour map on the Dawson Bay (Figure VI) shows the pronounced effect of the Prairie Evaporite salt basin. Steeper dips to the southwest are encountered in the area of present salt occurrence than in the area to the north and east. (For convenience, Prairie Evaporite isopachs in the vicinity of the salt edge are shown on this map. For the complete isopach of the Prairie Evaporite see Figure VII.) The change in strike of the contour lines at the edge of the salt basin is quite evident on the Dawson Bay structure map (Figure VI) as well as on the Prairie Evaporite and Winnipegosis structure maps (Figures VII and VIII). This is interpreted as indicating the presence of a hinge-line along which an increase in rate of subsidence took place.

The Dawson Bay structure map also shows some indications of a minor nosing feature extending from the vicinity of Altamont to the south end of Pelican Lake. This feature is close to an Ordovician feature that will be discussed later and that may represent a persistent tectonic trend.

Some irregularities are indicated in the vicinity of Townships 18 to 20, Ranges 25 to 30, W. 1 M., where the Nisku and Duperow maps suggest faulting. The irregularities are not shown as strongly on the Dawson Bay map as on higher maps, perhaps because there is less control for the deeper horizons.

The isopach maps of the Duperow and Souris River (Figures IV and V) show thicks in the vicinity of Township 14, Range 29, W. 1 M. These may be the result of the presence of a small sub-basin in this area during the time these units were deposited.

Several of the features referred to above in connection with the Dawson Bay are also shown on the Prairie Evaporite map (Figure VII). On this map we have only shown structure contours on the Virden sheet since over the remainder of the area the Prairie Evaporite is very thin and the structure map on the top of the Winnipegosis (Figure VIII) is a close approximation of Prairie Evaporite structure. In particular, the relatively sharp drop into the salt basin is shown by the Prairie Evaporite map. This is most pronounced in the area south of Virden. This relatively sharp drop into the basin is regarded as strong evidence that the present salt edge is very close to the depositional edge. If the edge were a solution edge, we might expect to find a structural drop away from the salt rather than towards it. Of course, it is quite possible that local solution may have taken place close to the salt edge with resultant structural irregularities, but present control is not good enough to show whether or not this is the case. The salt thin in the vicinity of Township 18 is shown by the Prairie Evaporite map and, again, there is some evidence of structural irregularity in this area.

The combined structure and isopach map of the Winnipegosis (Figure VIII) should be compared with the Prairie Evaporite map (Figure VII). The steepening of dip into the salt basin is again evident. The Winnipegosis isopachs indicate a pronounced thickening at the salt edge. This is taken as further evidence that the present salt edge is close to the depositional edge, since the Winnipegosis thicks may represent the type of barrier reef expected close to a deeper basin. Closed Winnipegosis thicks are shown close to the salt edge. These may be thicker and more common than indicated by present control. It is interesting to note that small, closed Interlake thicks are shown between Lizard Point and Oak River Indian Reserves in the same general area as the Winnipegosis thick.

The structure contours show highs in the area of most of the thicks. No closures are shown but there is no reason why such could not be expected. A thick and a structural high are indicated in the vicinity of Township 18 in the area where possible faulting has already been discussed.

A relatively minor Winnipegosis thick, with some indication of a structural high, is also shown near the south end of Pelican Lake (Township 3, Range 15, W. 1 M.). This may well be related to the feature already discussed in this area and which apparently extends from Pelican Lake to near St. Agathe.

A very strong Winnipegosis thick with a related high is shown on the Dauphin sheet. This feature probably actually consists of a number of smaller individual thicks, but again there is not enough well control to determine whether or not this is the case.

Below the Devonian, control becomes even more sparse. The structure map on the Interlake Group (Figure IX) shows the increase in dip into the present salt basin, although there are only a very few wells in this part of the map-area. There is some evidence of structural nosing in the area between Carman and Pelican Lake, and also north of Neepawa. An Interlake thick (Figure X), centred near Township 5, Range 10, W. 1 M., appears to be reflected on the structure map and the nose already referred to north of Neepawa also appears to overlie a thick.

Except for thickening into the deeper part of the basin to the southwest, the isopach maps of the Stonewall Formation and the Gunton Member (Figures XI and XII) provide little information on the structural history of the area.

The structure contour map of the top of the Red River Formation (Figure XIII) also shows the steepening of dip into the present salt basin, although, because of the sparse control, the actual position of the hinge-line is not so clearly shown as on maps of higher horizons. Structural flexures between Carman and the area of Pelican Lake are again noted, as is the nosing feature north of Neepawa referred to previously. There are indications of the presence of a southeast-trending nose through Portage La Prairie. Another nose has been contoured in the vicinity of Township 35, Range 25, W. 1 M. The distribution of the 'B' prospective zone, discussed in the section of this report dealing with oil and gas prospects, appears to be partly controlled by the Carman-Pelican Lake and Neepawa features.

The isopach map of the Red River (Figure XIV) shows a pronounced thin in the area of the Carman-Pelican Lake structural feature. A less clearly defined thin is also shown north of Neepawa. On the Virden sheet, a thick trend is aligned close to the hinge-line between the shelf to the east and the deeper part of the basin to the west.

Most of the features shown by the Red River structure map are also shown on the Winnipeg Formation structure map (Figure XV). The structural flexures in the Carman-Pelican Lake trend are perhaps a little more pronounced on this lower map and an eastward extension of this trend can be seen. The nose through Portage La Prairie shown on the Red River map is very faint on the Winnipeg Formation. The nose north of Neepawa is quite pronounced and the nose in Township 35, Range 25, W. 1 M., is again apparent. The change in dip at or near the hinge-line is present but is very poorly controlled.

On the isopach of the Winnipeg (Figure XVI) the Carman-Pelican Lake feature appears as a pronounced thick. The Neepawa feature is also thick, as is the feature in Township 35, Range 25, W. 1 M., but these are less pronounced than the Carman trend.

The distribution of the Upper Sand zone of the Winnipeg appears to bear a strong relationship to the Carman-Pelican Lake trend.

In summary, several pronounced structural trends and features occur in the map-area.

Perhaps the most important of these is the hinge-line separating the deeper portion of the basin to the southwest from the shelf area to the north and east. Local closed features may well occur along this hinge-ling. It has apparently been a favourable area for reef growth. It separates the area of salt occurrence from the generally salt-free area. Hydrodynamic and stratigraphic traps may well occur at the change in dip between basin and shelf. This hinge-line appears to be a very favourable prospecting area.

A tectonic trend is indicated running from the vicinity of St. Agathe through Carman to Pelican Lake. The greatest effect of this trend has probably been in controlling deposition of Ordovician sediments. It is also noted in later beds and there is some indication of Winnipegosis reef development along part of the trend. This trend may well represent an extension of a faulted zone mapped in the Canadian Shield in Ontario and Manitoba. Sproule (1962) has discussed the importance of such trends in controlling hydrocarbon accumulations. This trend is regarded as another important prospecting area, especially for the Ordovician beds.

North of Neepawa there is evidence of the presence of a nosing feature. This again appears to have been most important in its effects on Lower Paleozoic rocks.

Faulting is present in the Hartney area and has also been shown further to the west in Saskatchewan. Topographic and other evidence indicates that the Hartney faulting may be part of a northeast-trending structural system. This appears to be another very favourable prospecting area. To the southwest of Hartney the Winnipegosis and Dawson Bay porosity are usually salt-filled, but there should be good prospects for the occurrence of local salt-free areas, such as occur at Outlook, Montana, along this trend.

Although we have found little evidence of local salt solution in the main salt basin, such solution is almost certain to be present, giving rise to as yet unmapped structural features.

Our contour map of the top of the Paleozoic shows a very irregular surface. Closed erosional highs capable of forming traps that may be sealed by overlying Mesozoic beds may occur anywhere on this surface.

The proximity of the erosional edge of the Mississippian to the hinge-line over much of the study area north of Oak Lake is most striking as is the fact that most of the known Mississippian oil pools are close to this line. This probably indicates that the hinge-line had a strong controlling influence on Mississippian sedimentation and erosion as well as on older beds.

OIL AND GAS PROSPECTS

GENERAL

Although no commercial oil and/or gas discoveries have been made in the pre-Mississippian rocks of Manitoba and no particularly encouraging shows have been obtained, this must in no way be considered to have condemned the prospects of the area. On the contrary, it is our view that the results obtained to date must be regarded as encouraging from the long-range point of view. One would think that if Industry shared this view they would not have ceased operations in the area. That cessation of interest, however, we would attribute largely to the difficult land situation, the limited budgets even of major companies, and the apparently more fruitful "hunting ground" elsewhere in Western Canada, as well as, to some extent, to the lack of appreciation of the prospects in this area.

Commercial production and good shows have been obtained from equivalent beds in adjacent areas in Saskatchewan, Montana, and North Dakota. There are indications of significant tectonic trends passing through the province and there is evidence of the presence of facies variations conducive to the formation of stratigraphic traps. Certain porous beds are truncated erosionally, forming traps. A number of shows have been reported in Manitoba, although most of these have been relatively minor, consisting only of oil staining in samples and cores or oil-cut mud in drill stem test recoveries.

A number of reasons have been suggested for the lack of discoveries to date in the Pre-Mississippian rocks of Manitoba. It has, for instance, been suggested that the fact that certain formations outcrop a relatively short distance to the northeast may have permitted all oil and gas to escape. This is, of course, not necessarily true. Structural and stratigraphic traps may form within short distances of the outcrop. The trap at Norman Wells, Northwest Territories, where the producing formation outcrops a few miles from the field, is a well known example.

It has also been suggested that water entering from the outcrop areas may have flushed all oil from the potential beds. This may have happened in some cases, but there is also the possibility that any such water entry may have resulted in the formation of hydrodynamic traps. For discussions of the role of downdip hydrodynamic movement in forming traps, the reader is referred to Levorson (1964), Hill (1961) and Hubbard (1953).

The depositional position on the flank of the Williston Basin has been suggested as another detracting factor in that euxinic conditions resulting in the formation of oil or gas were not present. It is here suggested that there is as yet insufficient knowledge regarding origin and migration to accept this hypothesis. There appears to be considerable conflict between opinions, on the one hand, that oil and gas could have migrated as far as to be dispersed at the outcrop and, on the other hand, that the oil could not have migrated from deeper parts of the basin, a relatively short distance to the southwest.

Knebel (1956), in an excellent review, has pointed out that the greater portion of the free world's oil reserves, especially outside of the Middle East, lies on the basin shelves or hinge-lines of the depositional and structural basins. According to Knebel, who considered only major fields forming about 82 percent of the free world's reserves, almost 25 percent of these reserves lie on the shelves of the depositional basins and about 54 percent on the hinge-lines. If the Middle East is excluded, the comparative figures are 71 and 23 percent. Considering present structural basins as opposed to the original depositional basins, 50 percent of the free world's reserves is on the hinge-lines and 13 percent on the shelves. If the Middle East is excluded, the comparative figures are 13 percent on the hinge-lines and 38 percent on the shelves. Knebel also shows that stable areas have much greater known reserves than mobile areas. Although many other factors must be considered, these figures clearly show that the prospects of the Manitoba shelf cannot be discredited merely because of its stable structural and depositional history.

Knebel also shows that most of the oil reserves known at the time his paper was written lie at a depth of less than 5,000 feet and that at that time 26 percent of the free world's major oil reserves lay at depths between 3,000 and 4,000 feet.

Weeks (1958), in a paper that discusses many problems of hydrocarbon origin and accumulation, points out that an abundance of the type of sediments frequently thought of as source beds is not necessary for oil accumulation and he quotes a number of examples of prolific productive areas where such beds are not common. Weeks' paper and others in the same volume are recommended to those who have fixed ideas on hydrocarbon origin, migration, and trapping, and who may be inclined to condemn an area on the basis of one or two apparently unfavourable characteristics.

A recent paper by Levorsen (1964) indicates the need for finding large additional oil reserves in the next 40 years. Levorsen emphasizes the potential of unconformable surfaces and wedge edges as petroleum traps. He points out that with the exploration practices now in use by many companies (a structural feature is considered to be an essential prerequisite to drilling) it is very doubtful if some of the world's major oil reserves would be discovered. He gives the East Texas pool, with ultimate recoverable reserves of 5.5 billion or more barrels, and the huge Bolivar Coastal field in Venezuela, among others, as examples.

Levorsen emphasizes the importance of hydrodynamics at unconformities and wedge edges in controlling trapping and the importance of co-ordinated efforts by specialists in structure, stratigraphy, and reservoir fluids.

To quote Levorsen, "The geometric pattern that we are concerned with is found repeatedly in a number of oil pools and oil provinces. It consists of a low-dipping, truncated sequence of sediments, one or more of which is the reservoir rock, and capped by a less pervious overlapping formation to form an updip wedge of permeability. Such a cross section reflects an episode in the geologic history of the area, the episode being the tilting of the strata, subsequent erosion and probable base levelling, followed by the deposition of a transgressive, overlapping formation across the truncated edges of the older formations."

The post-Silurian and post-Paleozoic unconformities in Manitoba fit Levorsen's requirements very well.

Levorsen's conclusions are well worth quoting in part, as follows:

"Before we can say that we are running short of petroleum, every one of these wedge-edges should be examined, mile by mile, by experienced and coordinated teams of experts in structure, stratigraphy, and hydrodynamics. The gentle type trap that is searched for may require that more wells be drilled merely to learn the underground conditions of structure, geologic history, hydrodynamics, and stratigraphy, than does exploration for the structural-type trap. As the ingredients develop, however, they gradually become integrated into the recipe and discovery results. Each area and each pool is unique and it will require more than ever a wider understanding and application of geology and an integration of principles rather than a search for some single structural, stratigraphic, or hydrodynamic anomaly."

We suggest that the main reason for the lack of discoveries in Manitoba is probably the lack of drilling and a sustained exploration effort.

Discussions of prospects of individual stratigraphic units follow. The subcrop edges of most of the units (Figure I) are considered prospective wherever sufficient cover is present. To avoid repetition, these subcrop edges are not always specifically mentioned.

DISCUSSION OF OIL AND GAS PROSPECTS BY FORMATIONS

Granite Wash

The presence or absence in Manitoba of Granite Wash type potential reservoirs has not been established although there does not appear to be any reason why these should not occur, particularly along Precambrian tectonic features. Due to lack of Precambrian control, it is impossible at this time to establish accurately areas where such features occur, but prospects should exist along the interpreted hinge-line between the deeper part of the basin in the southwestern part of the province and the more flat-lying shelf-type deposits to the east and north. Another possible prospecting area is along the Winnipeg Formation thick that extends from the vicinity of St. Agathe through Carman to Pelican Lake. This trend, or parts of it, is seen on several maps. It shows as a Winnipeg Formation thick and as a Red River Formation thin. There appears to be a weak Winnipegosis thick related to the feature which may well represent an ancient tectonic trend.

Where the basal part of the overlying Winnipeg consists of green shale, it could form an effective seal over any Granite Wash type deposits that may lie directly upon the Precambrian surface.

Winnipeg Formation

The Winnipeg Formation, which may include some beds equivalent to the Granite Wash, is the most widespread sedimentary formation in Manitoba. It consists of sandstones, which are commonly porous, interbedded with grey and green shales. The sandstone bodies pinch out laterally, and the surrounding shales should form excellent seals and may also act as source rocks. Oil staining has been reported in the Winnipeg sand in at least two wells in Manitoba, Souris Valley Warnez 13-5 (Lsd. 5-13-5-22 W. 1 M.) and Dome Strathclair 8-34 (Lsd. 8-34-16-21 W. 1 M.). No production or oil or gas recoveries on drill stem tests are reported. A good show is reported from a well in South Dakota, and one well on the Nesson Anticline is reported to have been completed in the Winnipeg after having had a good gas recovery with some oil on drill stem test, but this well was apparently never put on commercial production.

Several distinct sand beds may be mapped in the Winnipeg Formation, although, due to lack of control, this mapping must be of a generalized nature only. In the cross-sections and maps that accompany this report, we have designated three separate sand zones that we recognize in the Winnipeg Formation over the southern part of the province. Towards the north, in about Township 19, the upper units, Nos. 1 and 2, may well merge; and in about Township 24, all three units have apparently merged or are so close that effective separation is probably not present.

The uppermost sand unit, No. 1, which is essentially equivalent to the Carman sand of Andrichuk (1959), reaches its maximum development in the southern part of the province, in a belt some 15 to 40 miles wide extending eastward from the vicinity of Pelican Lake, past Carman, to the area of St. Agathe, and probably to the erosional limits of the formation where it is overlain by Pleistocene deposits. This sand body reaches 50 to 80 feet in thickness over most of this belt. There may be communication between this large sand body and the outcrops, therefore any occurrences of oil or gas would depend on local variations of structure or sedimentation. There are some indications from present well control that shale re-entrants along the flanks of the sand body may be strong enough to form local traps. In the vicinity of Township 8, Range 2, W. 1 M., we have interpreted a northerly extending lobe of this main sand body in which it would be possible for trapping to occur. Another small lobe has been interpreted in Township 8, Range 10, W. 1 M. Control is not, of course, sufficient to firmly establish the presence of any such traps at this time, but we see no reason why they should not exist.

If water should be entering the sand at its outcrop area and moving downdip, such movement could easily form hydrodynamic traps.

A somewhat less spectacular development of the No. 1 sand is present in the area northwest of Brandon, extending west into Saskatchewan and northward to where it merges with the lower zones. The distribution of this sand appears to offer a number of possibilities for pinchout traps along its northeastern limits, for example, near Brandon and in the vicinity of Township 16, Range 18, W. 1 M.

The middle or No. 2 zone shows development in excess of 20 feet of effective sand in the area northeast of Virden. This sand pinches out to the east and would seem to have numerous possibilities for stratigraphic traps, especially in the area near Minnedosa.

The No. 3 or lower zone, which forms the basal unit of the Winnipeg Formation over much of Manitoba, is the most widespread. This sand was deposited irregularly over the Precambrian surface and varies in effective sand thickness from zero to over forty feet. The variation in sand development offers numerous possibilities for stratigraphic traps in this zone.

Structure contours on the top of the Winnipeg Formation are shown on Figure XV. It will be noted that there are indications of structural flexures, particularly in the area south of Township 11, and that there are some indications of nosing in the area of the development of the No. 1 sand between St. Agathe and Pelican Lake. To the north of this, the contours are much more uniform, except for some small nosing features shown just north of Neepawa. The more pronounced features south of Township 11 may be due to a slight additional amount of control in this area. Additional control would probably show these to be much more pronounced than indicated on our maps. The steeper dips into the central part of the basin southwest of the Virden area are evident on this map. We have not concentrated on the area where the Winnipeg forms the Paleozoic outcrop, since this is not regarded as an important prospective area. It is possible, of course, that minor trapping might occur below weathering seals at the unconformity but, at this shallow depth, the formation of large traps is unlikely.

The lack of tests to the Winnipeg in the deeper southwesternmost part of the basin and at the hinge-line where the main change in regional dip occurs is most striking.

Red River Formation

The carbonates of the Red River show considerable variation in porosity, from good to non-porous. Oil staining has been reported in a number of parts of Manitoba and production is obtained from these beds in North Dakota, Montana, and Saskatchewan, although sufficient details of Saskatchewan production are not yet available to determine whether or not production will prove to be commercial. Facies changes are common and should provide effective barriers to migration. A number of fields along the Cedar Creek Anticline in Montana produce from the Red River. In Saskatchewan, Imperial Hummingbird 6-13 (Lsd. 6-13-2-19 W. 2 M.) produced oil from the Red River but was abandoned because of water problems. In 1963, Central Del Rio Scurry South Lake Alma 1-14 (Lsd. 1-14-1-17 W. 2 M.) was reported to have been a Red River discovery. It is reported that, after perforating the well and swabbing, fairly good oil returns were obtained but that drill stem tests prior to running the casing showed no conclusive results. A well drilled in Montana (Township 25 North, Range 54 East) in 1962 is reported to be capable of producing 314 barrels per day from the Red River.

Four zones in which porosity is commonly developed can be traced over much of Manitoba. These are referred to here as the upper porous zone and the 'A', 'B', and 'C' zones. They are indicated on the accompanying cross-sections. It is emphasized that these zones are not continuously porous but are, rather, persistent zones in which porosity may be developed and should be considered as prospective. Detailed sample studies, especially as more information becomes available, should be able to locate prospective areas in the individual units. The upper porous zone is the most widespread and has been tested in about 15 wells in Manitoba, resulting in most cases in considerable recoveries of salt water. Although this zone is porous in most areas, there are local variations which may form stratigraphic traps.

The 'A' zone is widespread over most of southwestern Manitoba but loses its identity to the north and probably does not extend to the outcrop area except in the southeast. This zone has been tested in about seven wells, with salt water recoveries in each case. Porosity is quite variable; in some wells two distinctive porous sections are observed. Porosity pinchout traps would appear to be probable in this zone.

The 'B' zone is highly variable and its distribution is mainly confined to the southern part of the province. Its irregular distribution offers many possibilities for porosity pinchout traps, especially to the south and west of Portage La Prairie. Only about five wells in Manitoba have tested this zone. One test was negative; the other tests recovered salt water.

The 'C' zone is somewhat nebulous and porosity does not appear to be consistently developed. Some porosity is reported in sample descriptions of various wells and mechanical logs indicate porosity and permeability in a number of other wells. The zone is recognizable over most of southern Manitoba. Only one test is reported in this zone. Calstan Woodlands Core Hole No. 1 (Lsd. 4-6-15-2 W. 1 M.), which tested the interval from 755 to 800 feet, recovered 120 feet of fresh muddy water.

Our isopach map of the total Red River (Figure XIV) shows a pronounced thin in the area between Carman and Pelican Lake, which approximately coincides with a Winnipeg sand thick. This feature may indicate a tectonic trend that may have caused important facies changes which are not yet apparent from the other information available. There is approximately 100 feet of thinning from the southern border of Manitoba to the Carman-Pelican Lake thin and this, together with the decrease of dolomitization northwards in the lower part of the Red River mentioned by Andrichuk (1959), may be conducive to the formation of stratigraphic traps.

In the southwestern part of the province, the tendency to regional thickening into the deep part of the Williston Basin is evident. The structure map of the top of the Red River (Figure XIII) fails to show any closures but, as in the case of the map of the top of the Winnipeg, there are a number of flexures in contours, particularly south of Township 10. Additional control will probably show the structure to be much more complicated than indicated by the present maps.

The four potentially productive zones in the Red River referred to above are shown on the cross-sections, but there is not yet sufficient well control to permit mapping these with any reasonable accuracy, so we have not attempted to show them on our maps except as generalized outlines for the 'A', 'B', and 'C' zones.

Stonewall Formation

Porous beds are present in the Stonewall Formation and should form adequate reservoirs under suitable structural conditions. Stratigraphic traps may be caused by local porosity variations. The cyclic nature of parts of the Stonewall could also aid in the formation of stratigraphic traps. Drill stem tests of the unit have been extremely rare in Manitoba and we have only been able to locate reference to three tests of this unit. Some slight oil shows have been reported in the general area, especially in the central part of the basin. There are not enough data to enable us to map porosity in detail.

Stony Mountain Formation

The Stony Mountain Formation consists of two members, the Gunton and the Stony Mountain shale.

The Stony Mountain shale is primarily argillaceous and tight, although it could form source beds.

Porosity is developed in the Gunton Member in many wells. This unit would be an important prospect wherever structural closure is present and at its subcrop edge. Local variation in porosity may also form stratigraphic traps. This member has been tested only in one or two wells in Manitoba, although slight oil staining has been reported from some wells. Because of its relatively uniform thickness, the structure of the Gunton is very similar to that of the Silurian, and a separate structure map of it has not been made.

The Gunton Member produces oil along the Cedar Creek Anticline in Montana and shows have been obtained in North Dakota, as at the Iverson Nelson Unit No. 1 well (Township 155 North, Range 96 West) in the Beaverlodge field.

Interlake Group

Porous beds are present in the Interlake through much of the area under study and these should form adequate reservoirs under favourable structural conditions. Present well control is not sufficient to permit tracing of individual porous units with any degree of confidence, but it is probable that regional variations in the porosity may form stratigraphic traps.

The major prospect is probably at the unconformity at the top of the Interlake. The top of the Interlake was subject to a long period of erosion previous to the deposition of the overlying Ashern. Regional bevelling took place in an easterly direction, essentially updip, so that progressively older beds reached the unconformity to the north and east. This condition is most apparent in the southwestern part of the province, where dips are steeper. As individual porous beds reach the unconformity, stratigraphic or hydrodynamic traps may result. The overlying Ashern should form an adequate caprock. A floor seal would also be necessary to prevent escape of hydrocarbons along the unconformity. This might be provided by impermeable beds underlying the individual porous zones. Unfortunately, over much of the province, dips in the Silurian are only slightly greater than the dip at the unconformity. This normally results in subcrop bands in the porous zones being comparatively wide and, in the case of strictly stratigraphic traps, intensifies the need for an adequate floor seal. Of course, local closed erosional highs on the unconformity could still form traps in the absence of any floor seal. Andrichuk (1959) notes that in some places the beds near the unconformity are impermeable due to secondary infilling of porous spaces by calcite and clay. This condition may, in some places, form a seal that would cause stratigraphic traps.

The isopach map of the Interlake (Figure X) shows considerable local variation in thickness and, although control is limited, there is some suggestion that a well-developed drainage pattern may have existed on the Interlake surface prior to deposition of the Ashern. There appears to be a good possibility that erosional scarps of sufficient magnitude to serve as traps for oil and gas may be present, although the control is not sufficient to establish this.

A thick section of Interlake is present in the Hartney area, especially in California Standard Hartney 16-33 (Lsd. 16-33-5-24 W. 1 M.). This is probably due to the structural deformation which has occurred in this locality, resulting in preservation of the upper beds from erosion. It is also possible that there may be some repetition of Interlake beds in this well, due to thrust faulting. There is a possibility of a stratigraphic trap updip from this well.

A thick trend is present along a line from Township 11, Range 22, to Township 18, Range 29, W. 1 M. Control is sparse, but it is noted that there is thinning of some 60 feet between the wells along this line and the nearest updip wells. If this thinning proves to be abrupt rather than gradual there would be a good possibility of traps at the top of the group. Small closed thicks have been mapped along this trend. These could represent local reef type growths in which traps could form.

Small reefs, referred to as patch reefs, biostromes, etc., have been observed at the surface outcrop of the Interlake. Reefoid rocks have been encountered in some wells, notably Sweetgrass Altamont No. 1 (Lsd. 2-35-5-8 W. 1 M.) and Sweetgrass Pilot Mound No. 1 (Lsd. 3-9-4-11 W. 1 M.). Good porosity and permeability are present in these rocks and they should make good reservoirs if their updip limits can be located.

Of particular interest is a thick in the Interlake extending from approximately Pelican Lake to the vicinity of Carman. This thick is very close to the position of the features noted in the Winnipeg and Red River, and may again be indicative of the presence of a tectonic trend in this area. The Altamont and Pilot Mound wells referred to above lie on this thick.

Silurian production is obtained from the Interlake at the Outlook field in Montana, and oil and gas have been obtained from the Cedar Creek Anticline in Montana and the Nesson Anticline in North Dakota. This production is associated with structural features.

At Mobil Oil Woodley Sinclair North Redvers No. X-14-19 (Lsd. 14-19-8-32 W. 1 M.), a drill stem test of the Silurian is reported to have given up 90 feet of muddy oil with 120 feet of salt water. This show has not been followed up by additional drilling.

Winnipegosis

The reefoid carbonates of the Winnipegosis form one of the most interesting prospective zones in the area. Pronounced reefoid masses in the Winnipegosis have been mapped in the outcrop area by Baillie and have been demonstrated to the west in Saskatchewan by Edie (1959). Relatively strong thickness variations are shown by the Winnipegosis within the southern part of Manitoba. The Winnipegosis is porous almost everywhere it occurs except in the present salt basin.

Winnipegosis production is obtained from the Outlook, South Outlook and Redstone fields in Montana. These fields lie a short distance from the International Border, approximately south of Range 22, W. 2 M. They occur within the area where the Winnipegosis is generally salt filled, and apparently fracturing and associated salt removal is an important factor.

In Saskatchewan, Edie (1959) refers to heavy black oil or pyrobitumen in the samples near the top of the Winnipegosis in Socony Briercrest 11-14 (Lsd. 14-11-14-24 W. 2 M.) and Sohio Standard Pense No. 1 (Lsd. 14-10-17-22 W. 2 M.). Slightly oil-cut mud was obtained on a drill stem test of the Winnipegosis in Hudson's Bay Gronlid No. 1 (Lsd. 15-32-44-17 W. 2 M.). All of the above wells in Saskatchewan are outside the presently known limits of the Prairie Evaporite salt. Edie points out the fact that, where light gravity oil occurs in reef dolomite, the evidence in the form of staining is commonly difficult to recognize.

Favourable features of the Winnipegosis are, of course, its reefoid nature and common porosity and permeability, the bottom seal formed by the red shale of the Ashern, and the top seal formed by the Prairie Evaporites of the Second Red Beds. It is unfortunate that over most of the area where the Prairie Evaporite salt is present, the porosity of the Winnipegosis is salt filled. Local salt removal could result in porous developments.

The relationship between the occurrence of Prairie Evaporite salt and the thickness of the Winnipegosis is remarkable (Figures VII and VIII). A thickening of the Winnipegosis almost invariably coincides with a thinning of the Prairie Evaporite section. Figure VIII, a combined structure and isopach map of the Winnipegosis, shows it to be regionally thin in the area of thick salt deposits, thickening rapidly at the salt edge. It is also very significant that there are indications of closed thicks in the Winnipegosis along the edge of the salt. For instance, we have interpreted individual closed thicks in the vicinity of Township 5, Range 24, W. 1 M., Township 11, Range 24, W. 1 M., and Township 14, Range 26, W. 1 M. It would, of course, be possible, from the control available, to connect all of these thicks into one elongate feature. The thicks shown on the map give the impression of a barrier type reef at the edge of the salt basin, and it would be only reasonable to assume the presence of individual highs separated by channels, etc., along such a reefal trend. The closed features shown are outside the actual salt area, or the area of salt filling of the Winnipegosis, and almost all have given up relatively large quantities of water where tested.

One of the most interesting features of the map is the west-trending thick from the area of Township 18, approximately Range 26, to the westernmost edge of the map-area. This is an area where the Prairie Evaporite salt section is thin and probably locally absent. Oil staining is reported in some samples in this area and traces of gas were obtained on drill stem tests. From the very few wells tested, porosity did not appear to be good and is probably partly salt filled, but within this band there are probably salt-free localities where excellent porosity and permeability could be developed in the Winnipegosis. The maps of shallow horizons in the Devonian, where more control is available, provide indications of possible faulting in this area, and conditions similar to those in the Outlook area of Montana, where oil has been produced from the Winnipegosis, could prevail.

Outside the main salt area, the Winnipegosis is normally overlain by a thin anhydrite section that we have correlated with the Prairie Evaporite but which could actually be part of the Winnipegosis itself. In any case, this anhydrite should form an effective seal over the Winnipegosis throughout much of the area.

There is some evidence of a minor thickening of the Winnipegosis in a northeast-trending band, passing between Pelican Lake and Rock Lake, about Township 3, Range 15, W. 1 M. This could be the result of reef growth along the tectonic features through Pelican Lake and Carman suggested by the Ordovician maps.

As previously mentioned, pronounced thicks occur in the outcrop area to the north, and we see no reason why such thick reefoid developments could not occur anywhere on the Manitoba shelf, outside of the present salt area. A pronounced thick has been mapped on the Dauphin Sheet, and present interpretation shows this to be of large areal extent. This is perhaps overly simplified, due to lack of control in this area and it could actually be formed of a number of individual thicks.

Returning to the thick developments along the flank of the salt basin, it is interesting to note that these show as highs on the contour map. Although control is not sufficient to permit us to show structural closures, it is probable that such closures exist.

The Winnipegosis along the flank of the salt basin is regarded as one of the most promising exploration targets in Manitoba.

As mentioned in an earlier section of this report, there is a common tendency of older pools to underlie younger pools or to lie close to them. In view of this and in view of the proximity of the Mississippian fields of the Routledge-Virden area to the salt edge and the Winnipegosis thicks, it is most surprising that so few Winnipegosis tests have been drilled in this area.

Prairie Evaporite Formation

The Prairie Evaporite Formation, consisting of salt and anhydrite with some evaporitic dolomite, is not in itself a prospective reservoir, but it has a very important bearing on the oil and gas prospects of the area. Where salt is present, there is a tendency for porosity in the underlying Winnipegosis and the overlying Dawson Bay to be salt filled.

Over a large part of Manitoba where no salt is present but where anhydrite, which we have equated with the Prairie Evaporites, is present, this anhydrite can form a seal over the underlying Winnipegosis.

In addition to its effects as a caprock and filling porosity, the distribution of the salt is a very good indication of the configuration of the basin during Devonian sedimentation. The salt edge over much of the Williston Basin has been modified by solution and does not, therefore, reflect original conditions of deposition. In most of southwestern Manitoba, however, there is evidence that the edge of the Prairie Evaporites is either the original depositional edge or very close to the depositional edge.

Evidence for this is provided by the Winnipegosis thick along the present salt edge, which apparently represents a barrier reef of the type that might be found at the edge of the salt basin, by steepening of dips into the basin close to the present edge and by the combination of the structure and isopachs shown on Figure VII. In the case of a solution edge, the strata immediately overlying the salt usually drops structurally away from the salt edge. In the case of the edge in Manitoba, there is usually a rise away from the salt edge, again indicative of the edge of the basin. Undoubtedly, there are local areas of salt solution, and there is some evidence for this in the vicinity of the Daly field for instance, but it is thought that the main north-south edge as shown on our maps is very close to the depositional edge.

Within the area of the salt basin there is not sufficient control to outline areas where solution has taken place, but these probably occur since they are known throughout so many other parts of the basin. One area in Manitoba where solution may well have occurred is in the vicinity of Township 18, Ranges 25 to 33, W. 1 M. As previously mentioned, this is an area where the Winnipegosis is thick. The salt section originally deposited was probably thinner than in areas to the north and south. There is, however, evidence of faulting in the Devonian where more control is available, and it is quite possible that the present salt thin is partly due to solution. If this is the case, salt-free localities could be present where traps could occur in the Winnipegosis and Dawson Bay, and structural features could be formed in beds overlying the salt.

The evidence of the presence of a tectonic hinge-line provided by the main salt edge gives encouragement for the formation of structural and stratigraphic traps in all Lower Paleozoic units along this band.

Dawson Bay Formation

The Dawson Bay is a very widespread dolomite and limestone unit that is of remarkably uniform thickness in Manitoba. Because of its relatively uniform thickness, isopach maps of this unit have not been prepared.

Our structure contour map of the top of the Dawson Bay (Figure VI) shows very little in the way of irregularities, although there is some evidence of a weak high in Township 4, Ranges 8 to 16, W. 1 M. It is interesting to note that oil staining and cuttings are reported from one well, Dome et al Greenway 16-33 (Lsd. 16-33-4-13 W. 1 M.), along this very weak feature. The map does show a rather pronounced drop into the salt basin along the edge of the salt. Some anomalous features are indicated in the vicinity of Township 18, Ranges 25 to 33, W. 1 M., the area where the Winnipegosis is thick, and where some faulting has been suggested by our maps of higher horizons. The Dawson Bay is usually porous except in the area of present occurrence of Prairie Evaporite salt, where the porosity is apparently salt filled. There are undoubtedly areas of local solution within the salt basin where the Dawson Bay is porous but there is not sufficient control to interpret these at present.

Some of the best prospects in the Dawson Bay are thought to lie along the edge of the salt, where structural and stratigraphic anomalies may occur. Further to the west, in Saskatchewan, dark brown staining has been reported from the Dawson Bay. Commercial production is reported from Montana in Shell Oil Company wells in Sections 25 and 33, Township 22 North, Range 48 East, in the Southwest Richey field. Excellent shows are reported in that area. On the Cedar Creek Anticline in eastern Montana, a well is reported to have obtained 390 feet of oil-cut mud on a drill stem test.

Where the salt is absent the Dawson Bay may have closure due to draping over Winnipegosis reefs. Baillie has noted this effect in the outcrop area, and Andrichuk (1959) compares it to the draping of the Nisku over Leduc reefs in Alberta.

Souris River Formation

This formation consists mainly of carbonates. Dolomite is the dominant rock type, with some limestone, frequent argillaceous bands, and, especially in the western part, considerable anhydrite. The basal member is the First Red Bed, an argillaceous unit that forms an effective seal between this formation and the underlying Dawson Bay.

An isopach map (Figure V) was made of the formation, excluding the First Red Bed or, in other words, of the prospective carbonate unit. The isopach shows a slight regional thinning from northwest to southeast, thicknesses ranging from about 285 feet in Township 20, Range 32, W. 1 M., to 200 feet in Township 2, Range 15, W. 1 M.

Anomalous thicknesses are noted at two localities. L-M Imperial Hartney No. 1-29 (Lsd. 1-29-5-24 W. 1 M.) has a thickness of 492 feet compared to nearby wells with thickness as low as 182 feet. This is interpreted as being due to repetition of beds, through thrust faulting. Dome St. Alphonse No. 13-16 (Lsd. 13-16-6-12 W. 1 M.) has a thickness of only 170 feet in an area where normal thickness is over 210 feet. Correlation with the nearest wells suggests that this thinning may be accounted for by minor normal faulting.

A series of northeast-southwest lineaments of alternating thick and thin trends is mapped in the area north of Township 15 near the Saskatchewan boundary. These lineaments also appear on some of the other maps, particularly the Duperow and Nisku. It is suggested that these may have been caused by recurrent faulting during and following deposition.

The formation shows some porosity in most wells and where tested has yielded moderate to large recoveries of salt water in most cases.

California Standard Daly No. 15-18 (Lsd. 15-18-10-27 W. 1 M.) obtained a flow of non-inflammable gas at the rate of 10.6 MMcf. per day. Analysis of the gas showed 96.6 percent nitrogen, 2.4 percent methane, and traces of ethane, propane and other gases, including a questionable trace of helium. It is interesting to note that a test of the Duperow in this well, about 500 feet higher in the hole, also obtained a large flow of gas with a similar analysis.

Souris Valley Robert Moore No. 1 (Lsd. 5-20-1-27 W. 1 M.) was perforated in the Souris River with a result reported as "very definite show of oil with a small amount of gas, followed with large amount of salt water." Landa White 5-14-1-28 was reported to have "oil in the pit" while drilling the Souris River. Oil staining or bituminous material has been reported in cuttings from this formation at a few other wells.

The Souris River Formation would be prospective on any closed structure, local or regional variations in porosity may form pinchout traps, and there appears to be some definite possibilities along the subcrop belt in the area that has Mesozoic cover (Figure I). Hydrodynamic variations may be particularly important in this area.

Duperow Formation

The Duperow Formation directly underlies the Nisku and, considering the relatively little variation in the thickness of the Nisku, it has not been considered necessary to make a separate Duperow structure map. The structure should be very similar to that of the Nisku, where the latter is present, and over the subcrop band of the Duperow its surface structure is shown by the map of the top of the Paleozoic (Figure I).

The Duperow does not normally have as good porosity as the Nisku, but large recoveries of water are common on drill stem tests. Variations in porosity may well form stratigraphic traps. Truncation of porous beds at the subcrop surface where the Jurassic forms an overlying seal may also be expected to form traps. It is not possible to map distribution of porosity from the control available.

A few shows have been reported from the Duperow in Manitoba but these have mostly been rather weak.

One of the very few established pre-Mississippian traps in Manitoba is in the Duperow in the well in Lsd. 15-18-10-27 W. 1 M., where almost five million cubic feet per day of non-inflammable gas are reported to have been obtained on drill stem test. Although only five percent methane is reported in the sample, this clearly demonstrates the occurrence of trapping in this formation. There is not enough control to determine the type of trap, but it is quite possible that a local salt collapse feature is responsible as this is well within the salt basin.

On our isopach map of the Duperow (Figure IV), we have interpreted a southwest-trending thick passing between the Hartney area and the Pierson area. Part of the evidence for this thick is provided by a well in Township 5, Range 25, W. 1 M. Although faulting is known to occur in this area, it is not thought that the extra thickness in this well is due to the repetition of beds. Our map suggests that there may be a tectonically active zone extending from the vicinity of Township 2, Range 30, to at least Township 6, Range 24. As well as the rather meagre well control, evidence for this trend is provided by the lineaments of the stream beds of the Souris River, Stony Creek, Jackson Creek, Graham Creek, and Gainsborough Creek. A more conventional interpretation would have been possible, but again it is felt that the unconventional provides the best prospects of discovering oil and gas.

The Duperow Formation produces in the Beaverlodge field, near the north end of the Nesson Anticline, in North Dakota. Oil shows have also been reported in several wells in western Saskatchewan. It is of interest to note that significant amounts of helium have been obtained from tests of the Duperow in Saskatchewan, and there appears to be no reason why there should not be helium reservoirs in the Duperow in Manitoba.

Nisku

The Nisku, or the Birdbear as it is now known in Saskatchewan, has been shown to be porous in almost every well where it has been tested in Manitoba. The most obvious place to search for traps in the Nisku in Manitoba is at the post-Paleozoic unconformity where it has been truncated and then sealed by overlying Jurassic beds. As will be seen from our Nisku structure map, the map for which we have the most control, there are also indications of a number of structural flexures where traps could occur to the south and west of the erosional edge. This map has been prepared using available Nisku well control and a structure map on the Bakken for which some additional control is available. Some features shown by the Bakken control have been extended down into the Nisku, since there is apparently relatively little disconformity at the top of the Devonian.

The subcrop edge of the Nisku is shown on our Paleozoic contour map (Figure I) as well as on the Nisku isopach map (Figure III). It will be noted that several lobes of Nisku are shown extending to the north and east. Considering the lack of control, it would be presumptuous to suggest that these lobes will be found exactly as shown, but it is almost certain that such lobes do exist along erosional highs and there should be excellent possibilities for trapping in them. Apart from the northeastward-extending lobes of Nisku, there should be excellent possibilities for trapping in those areas in the southern part of the Virden sheet where the subcrop, due to steeper dips, forms a relatively narrow band.

Apart from the subcrop band, the isopach map of the Nisku (Figure II) shows little variation except in the vicinity of Township 18, where our structure map gives indications of faulting. Other evidence, such as the Winnipegosis thick, indicates that this may have been a tectonically active area, at least through much of Devonian time. We have shown a southwest-trending thick approximately between Oak Lake and Pierson. There is very little control for this and it could be contoured in several different ways; however, as is discussed in somewhat more detail in the section dealing with the Duperow, certain topographic evidence indicates that this may also have been an area of tectonic activity and this may be responsible for this change in thickness.

More wells have been drilled to test the Nisku than any other pre-Mississippian zone, and it must be admitted that very few shows have been obtained. It is emphasized, however, that very few of these tests were along the subcrop edge where the best prospects for trapping occur.

In Montana, the Tule Creek and Benrud fields produce from the Nisku. A fairly recent discovery is reported from the Hellegaard No. 1 well (Township 37 North, Range 57 East), located one and one-half miles south of the Saskatchewan-Montana border. This well is reported to have gas to surface and 720 feet of free oil on drill stem test. A well drilled in Montana in 1962, in Section 35-25N-54E, is reported to be capable of producing 428 barrels of oil per day from the Nisku. The Keeler well in Renville County, North Dakota, about 35 miles south of the International Border and almost directly south of Range 30, W. 1 M., is reported to have had shows from the Nisku.

HELIUM PROSPECTS

Because of the lack of gas analyses, there is very little direct information on possible helium reserves in Manitoba. Analyses of inert gas recovered from a drill stem test of the Duperow in a well in Lsd. 15-18-20-27 W. 1 M. indicate the presence of 0.2 percent helium. Gas from the Souris River in the same well showed 0.1 percent. There is a possibility of helium contamination in the apparatus in both cases. It appears that sediments overlying Precambrian granitic features have the best prospects for helium accumulation. The interpreted ancient tectonic feature passing from the area of St. Agathe to Pelican Lake is probably a favourable area for helium accumulation. The porous sand in the overlying Winnipeg Formation in this area could form reservoirs for helium. The nosing feature north of Neepawa could also be a favourable feature.

An analysis of the samples from Precambrian wells drilled in Manitoba to determine the distribution of acidic and basic type rocks could be a valuable aid in the search for helium.

Until more gas samples are obtained and analyzed, no detailed comments on the possible distribution of helium-bearing gases are possible. It can only be stated that, from the evidence available, the best prospects appear to lie close to the Precambrian basement in areas where granitic rocks form the basement.

In Saskatchewan some of the gases with the highest helium content have been obtained from the Duperow. Why this should be the case, considering its separation from the Precambrian by intervening beds, is not clear. It is interesting to note that of the two Manitoba analyses quoted above, although both are suspect, the Duperow analysis shows the higher helium content.

OTHER EXPLORATION CONSIDERATIONS

The geological considerations discussed herein have provided ample evidence that there are many favourable prospecting areas for oil and gas in the province. Despite this fact, interest in the area has fallen drastically over the past several years and there have, therefore, been few discoveries or encouraging shows.

One of the contributing factors to loss of interest in this area has been the concurrent developments relating to oil and gas discoveries elsewhere in Western Canada. Even the larger oil companies have limited budgets and, by the nature of oil company competitive practices, their budgets are controlled to a considerable extent by the operations of their competitors. Many of their activities are, therefore, conducted in part with the idea of "keeping up with the Jones." The net result is that, with numerous substantial reef and sand discoveries being made in Alberta and Northeastern British Columbia, in areas where the land picture is relatively favourable, Industry interest in southwest Manitoba has waned. It is our view that many of the better informed companies are well aware of the potential for large oil and gas reservoirs in the earlier Paleozoic beds in Manitoba, but they are content to confine their attention, temporarily at least, to areas where their presence is rendered desirable by virtue of the competitive struggle for prospective land holdings.

There is an additional factor that is keeping activity away from the province of Manitoba. This is the relatively high proportion of Freehold Mineral Rights in Manitoba as compared with others of the western provinces. Approximately 17 percent of the oil and gas rights are held by the Crown in Manitoba, whereas in Saskatchewan the figure is about 70 percent, and in Alberta it is about 90 percent. In British Columbia, over 95 percent is held by the Crown. This means that it is difficult for a company to assemble a block of land large enough to justify a detailed exploration program, especially one designed to explore the deeper and relatively unknown pre-Mississippian beds. Acquisition and administration costs are higher when a number of holders of Mineral Rights must be dealt with and there is a much greater resultant tendency towards checkerboarding by other companies. It is quite possible that some method of overcoming this obstacle may be an important factor in attracting exploration activity to the province. At the same time, it might be possible to provide the preferential treatment or favourable exploration climate which may begin to attract exploratory activity. Once activity begins in any particular area, there is always a tendency for it to increase, because of the increased competition for potentially prospective lands.

Although this is primarily an administrative problem rather than a technical one, some suggestions are offered.

(1) It might be possible to induce individual Mineral Rights owners in specific areas, such as municipalities, to institute a "pre-discovery pooling" arrangement whereby all would share in royalties on production from any part of the pooled lands. The Mineral Rights owners might also be persuaded to accept lower bonuses and annual rentals for relatively long-term leases in order to encourage exploration activity.

(2) It is our considered opinion that the most effective single incentive would be to grant on all newly developed Crown lands, say, a five-year royalty-free period ending January 1, 1970. That should provide incentive to develop Crown lands on a priority basis. It is true that the Government may forego royalty revenue for a short period but the revenue that would accrue through taxation of related developments, citizen employment, etc., could far outweigh the loss of a royalty revenue on undeveloped lands that is in any event non-existent at this time.

(3) Rentals on Crown lands could be reduced and work obligations increased accordingly to encourage companies to explore and develop such lands rather than hold them as protective acreage.

SUMMARY AND RECOMMENDATIONS

The pre-Mississippian sedimentary rocks of southern Manitoba cover a prospective area of at least 27,000 square miles. Only a very limited number of tests have been drilled to the prospective horizons in these formations. The youngest beds, those of the Nisku Formation, have been tested by less than one well per township. The oldest, those of the Winnipeg Formation, have been reached by less than one well per eleven townships. The relatively few wells that have been drilled are widely scattered. Some of the most interesting prospects, such as formation subcrop edges, are almost untested.

The stratigraphic section below the Mississippian contains a number of porous zones in which traps could form, and there are indications of strong tectonic trends along which closed structural features can be expected. The existence of favourable facies changes in the area has been demonstrated and there are encouraging prospects for the formation of stratigraphic traps.

One of the most striking known structural features in the area is an apparent hinge-line between the deeper portion of the basin to the southwest and the shelf area to the north and east. Winnipegosis reef growth is indicated as having taken place along this hinge-line, and there are evidences of closed thick lenses within the Silurian beds in the same area. The edge of the Prairie Evaporite salt unit is also located along this hinge-line. In the deeper part of the basin to the southwest, salt filling of porosity is common in the Winnipegosis and Dawson Bay formations. On the shelf, these same units are usually porous.

As a result of the above and other considerations, the above-described hinge-line is regarded as one of the most favourable prospecting areas in Manitoba.

Another important feature is the apparent tectonic trend that runs from the vicinity of St. Agathe through Carman to Pelican Lake. The effect of this "Carman" trend, which probably originates as an ancient Precambrian feature, was most pronounced in Ordovician and Silurian time. It had a strong effect on Winnipeg sand distribution. When more control is available, it will probably be found that the effects of this trend are even more pronounced than are presently indicated. The economic significance of this feature could be very great.

The presence of other similar northeast-trending tectonic features is also indicated, but the Carman trend is the most pronounced.

There is evidence of faulting in the Hartney area, but there is not enough well control to permit an interpretation of the details of this faulting.

As mentioned above, there are a number of prospective porous stratigraphic units. From present information, the most important of these appear to be the Winnipeg sands, the Red River beds, the Interlake carbonates, especially at the post-Silurian unconformity, the Winnipegosis and the Nisku formations. Almost all units are also prospective where they have been truncated at the post-Paleozoic unconformity.

Although no production and very few encouraging shows have been obtained in Manitoba, commercial production and excellent shows have been obtained from equivalent beds in adjacent areas of North Dakota, Montana, and Saskatchewan. The Red River Formation has been one of the most important producing zones in eastern Montana.

On the basis of experience in other parts of the world, the shelf and hinge-line position of the area is favourable for oil and gas generation and accumulation.

The area appears particularly favourable for the formation of stratigraphic traps. If a hydrodynamic flow downdip into the basin should exist, this could, under special circumstances, aid in the formation of traps.

Because of the widely spaced control, there is relatively little information upon which to base a search for individual structural traps, although there is evidence of favourable structural trends. It is probable that some of the trends indicated by subsurface data could be further defined by photogeological methods. With that in mind, we recommend that a photogeological study of a limited trial area be undertaken and, if the results are favourable, the study be extended to larger areas. The initial area chosen should include at least part of the Carman-Pelican Lake trend and part of the hinge-line area. We suggest, for example, an area extending from Townships 1 to 8 and from Ranges 10 to 28, W. 1 M.

Although somewhat outside the scope of our study, considerable thought has been given to the possible non-technical business aspects of exploration stimulation. In this connection, it appears that the difficult land situation, due to the large perfentage of freehold mineral rights, is a contributing factor to the reduction in exploration activities. Presently available evidence indicates that large stratigraphic traps have more potential over much of Manitoba than do structural traps. That being the case, the type of exploration that is most likely to meet with success may require the drilling of holes over a relatively large area. Detailed facies studies of the resultant stratigraphic sections can be expected to define the more prospective areas.

In order to promote an exploration program that would of necessity involve oil pools and trends that are difficult to define locally, the availability of large land blocks is essential. The combination in southwestern Manitoba of a closely checkerboarded land picture and reservoirs that are probably large but which will be difficult to identify as to geographic position, is unfortunate. It would, therefore, be advisable for the government to do what it can to correct that situation. As we see it, the problem could be corrected in large measure by:

(a) Encouraging the pooling of freehold mineral rights in municipal or other groupings.

(b) Foregoing royalties on Crown lands for a suggested five-year period, ending January 1, 1970.

(c) Encouraging companies to explore and develop permit areas by reducing rentals and increasing work obligations.

In summary of the prospective nature of the southwestern Manitoba stratigraphic section, our studies indicate that the pre-Mississippian sedimentary rocks there have excellent prospects for oil and gas discoveries, in spite of the disappointing results so far. Any incentives that can, therefore, be given to encourage exploration and development should be considered, so long as the long range interests of the Province and the Taxpayers are protected.

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