

# **Lower Paleozoic Sequence, Southwestern Manitoba - An Overview**

By C.D. Martiniuk

---

**Manitoba  
Energy and Mines  
Petroleum**



---

1992



---

Petroleum Open File POF 13-92

# **Lower Paleozoic Sequence, Southwestern Manitoba - An Overview**

By C.D. Martiniuk  
Winnipeg, 1992

---

Energy and Mines

Hon. James E. Downey  
Minister

Ian Haugh  
Deputy Minister

Petroleum Branch

B. Dubreuil  
Director

This publication is available in large print, audiotape or braille on request

## TABLE OF CONTENTS

|  | Page |
|--|------|
| Introduction . . . . .   | 1    |
| Previous work . . . . .  | 1    |
| Geological Setting . . . . .   | 3    |
| Stratigraphy . . . . .   | 5    |
| Cambrian . . . . .   | 5    |
| Deadwood Formation . . . . .   | 5    |
| Ordovician . . . . .   | 5    |
| Winnipeg Formation . . . . .   | 5    |
| Red River Formation . . . . .  | 5    |
| Stony Mountain Formation . . . . .   | 9    |
| Stonewall Formation . . . . .  | 9    |
| Silurian . . . . .   | 13   |
| Interlake Group . . . . .  | 13   |
| Devonian . . . . .   | 13   |
| Elk Point Group . . . . .  | 13   |
| Ashern Formation . . . . .   | 13   |
| Elm Point Formation . . . . .  | 13   |
| Winnipegosis Formation . . . . .   | 13   |
| Prairie Evaporite . . . . .  | 17   |
| Manitoba Group . . . . .   | 17   |
| Dawson Bay Formation . . . . .   | 17   |
| Souris River Formation . . . . .   | 17   |
| Saskatchewan Group . . . . .   | 21   |
| Duperow Formation . . . . .  | 21   |
| Birdbear(Nisku) Formation . . . . .  | 21   |
| Qu'Appelle Group . . . . .   | 21   |
| Three Forks(Lyleton) Formation . . . . .   | 21   |
| Drilling History . . . . .   | 24   |
| Petroleum Potential . . . . .  | 25   |
| Pre-Mississippian exploration (Saskatchewan and North Dakota) . . . . .                | 25   |
| Pre-Mississippian prospects in Manitoba . . . . .                                      | 25   |
| Summary . . . . .  | 25   |
| References . . . . .   | 27   |
| Appendix I: Index of Lower Paleozoic core and samples, southwestern Manitoba . . . . . | 30   |

## FIGURES

|  |           |
|--|-----------|
| Figure 1: Map of Williston Basin . . . . .   | 2         |
| Figure 2: Schematic cross-section of Manitoba sedimentary wedge . . . . .                          | 2         |
| Figure 3: Manitoba Stratigraphic Column, Lower Paleozoic Sequence . . . . .                        | 4         |
| Figure 4: Composite reference log of the Lower Paleozoic Sequence, southwestern Manitoba . . . . . | in pocket |
| Figure 5: Precambrian Erosion Surface - Structure Contour Map . . . . .                            | 6         |
| Figure 6: Map showing major gravity and magnetic anomalies, southwestern Manitoba . . . . .        | 7         |
| Figure 7: Winnipeg Formation Structure-Isopach map . . . . .                                       | 8         |
| Figure 8: Red River Formation Structure-Isopach map . . . . .                                      | 10        |
| Figure 9: Stony Mountain Formation Structure-Isopach map . . . . .                                 | 11        |
| Figure 10: Stonewall Formation Structure-Isopach map . . . . .                                     | 12        |
| Figure 11: Interlake Group Structure-Isopach map . . . . .   | 14        |
| Figure 12: Ashern Formation Structure-Isopach map . . . . .  | 15        |
| Figure 13: Winnipegosis Formation Structure-Isopach map . . . . .                                  | 16        |
| Figure 14: Prairie Evaporite Structure-Isopach map . . . . .                                       | 18        |

|   | Page      |
|---|-----------|
| Figure 15: Dawson Bay Formation Structure-Isopach map . . . . .   | 19        |
| Figure 16: Souris River Formation Structure-Isopach map . . . . .   | 20        |
| Figure 17: Duperow Formation Structure-Isopach map . . . . .  | 22        |
| Figure 18: Birdbear(Nisku) Formation Structure-Isopach map . . . . .  | 23        |
| Figure 19: Map of the Williston Basin showing major fields and areas of<br>pre-Mississippian production . . . . . | 26        |
| Figure 20: Map of the Elk Point Basin . . . . .   | 26        |
| Figure 21: Oil Show Map: Silurian-Ordovician-Cambrian Sequence . . . . .  | in pocket |
| Figure 22: Oil Show Map: Devonian Sequence . . . . .  | in pocket |



## INTRODUCTION

The purpose of this report is to present currently available data regarding the Lower Paleozoic formations within the subsurface of Manitoba and to provide a brief introduction to that data. The information presented is a compilation of data from approximately 600 wells drilled in Townships 1 to 45; and Ranges 1 to 29 WPM, in addition to information derived from maps and reports generated through Energy and Mines. Well information, available to December 31, 1991, has been incorporated. Maps presented in this report are derived from the Manitoba Stratigraphic Map Series and have been revised and simplified for publication. Full-scale versions of these maps are available through Manitoba Energy and Mines, Petroleum Branch. The report includes a brief discussion of the geological setting, regional stratigraphy, drilling history, and petroleum potential of formations within the Lower Paleozoic sequence of southwestern Manitoba. Paleozoic formations in the Williston Basin that are oil producing outside of Manitoba, but as yet nonproductive within Manitoba, are identified.

The outcrop belt of Paleozoic sediments in southwestern Manitoba provides the only exposure of these strata in the Canadian portion of the Williston and Elk Point basins. Over 420 core holes have been drilled by Manitoba Energy and Mines under the Manitoba Stratigraphic Core Hole Program to obtain stratigraphic data in the Manitoba Paleozoic outcrop. Much of this data (pre-1980) has been recorded in the Manitoba Stratigraphic Map Series and is referenced in this report. Information from these core holes is available in digital form through Manitoba Energy and Mines, Geological Services Branch.

Detailed information regarding Lower Paleozoic drill stem tests and recoveries, cores and formation tops are

provided in the following listings offered through Manitoba Energy and Mines, Petroleum Branch:

1. Lower Paleozoic Formation Tops, Bakken to Precambrian;\*
2. Lower Paleozoic Drill Stem Tests and Oil & Gas Shows, Bakken to Precambrian;\*
3. Lower Paleozoic Formation Water Analyses, Bakken to Precambrian;
4. Index of Core and Sample Storage (1984). Includes all cores and samples taken in southwestern Manitoba. An exclusive listing of all Manitoba Lower Paleozoic core and samples is included in Appendix I of this report.\*

## PREVIOUS WORK

Regional stratigraphic studies in the Manitoba portion of the Williston Basin have been conducted and reported on by Baillie (1951, 1952, 1953), McCabe (1959, 1966, 1971, 1978, 1980), McCabe and Bannatyne (1970, 1970a), Norris *et al.* (1982), McCabe and Bezys (contributions to the Atlas of Western Canada, *in prep.*; Lexicon of Canadian Stratigraphy, Canadian Society of Petroleum Geologists, 1990), and LeFever, *et al.* (1991).

Subsurface studies on the Ordovician and Silurian have been conducted by Foerste (1929a, 1929b), Okulitch (1943), Genik (1954), Stearn (1956), Sinclair and Leith (1958), Andrichuk (1959), Sinclair (1959), Kent (1960), Smith (1963, 1964), King (1964), Roehl (1967), Kendall (1976), Cowan (1971), Vigrass (1971), Jamieson (1979), Longman, *et al.* (1983), Haidl (1987), and Elias, *et al.* (1988). Similar work has been carried out in the Devonian by Martindale, *et al.* (1991). Study of the Lower Paleozoic sequence has been conducted by Porter and Fuller (1959).

The contributions of the above workers have provided a valuable data source for this report.

---

\* These listings have been updated for this report and are current to December 31, 1991



Figure 1.: Map of Williston Basin.

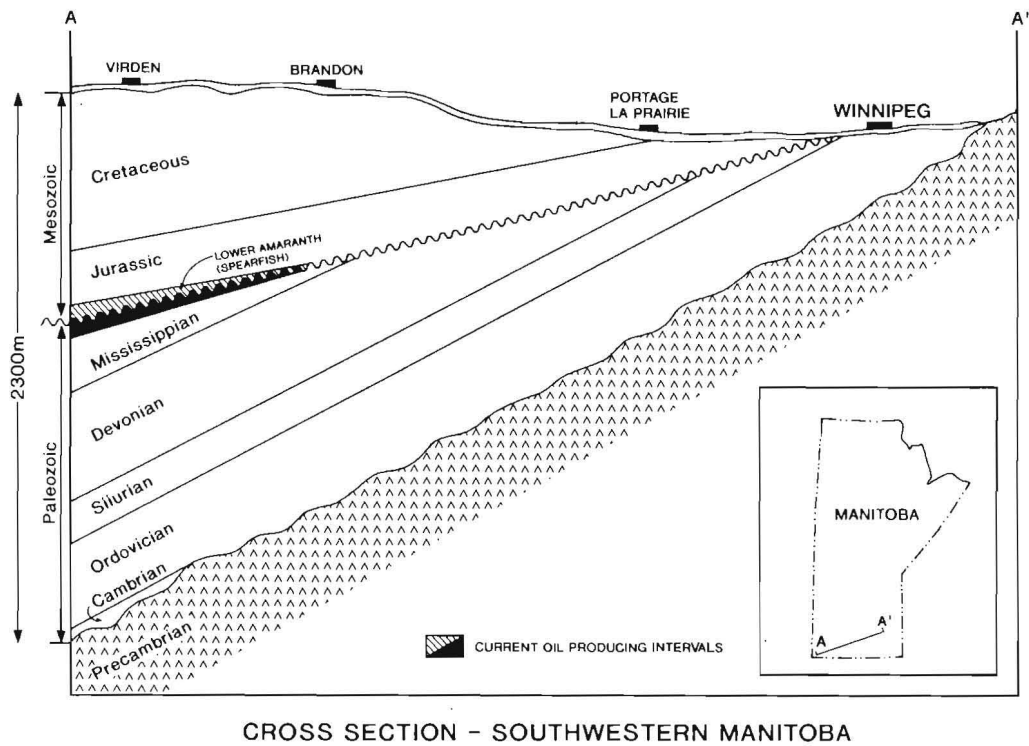


Figure 2.: Schematic cross-section of Manitoba sedimentary wedge.

## GEOLOGICAL SETTING

The Williston Basin is an intracratonic, structural and sedimentary basin located at the western edge of the Canadian Shield. It occupies portions of North Dakota, South Dakota, Montana, Saskatchewan and Manitoba (Fig. 1).

In southwestern Manitoba, Paleozoic, Mesozoic and Cenozoic sedimentary strata form a basinward-thickening wedge that reaches a total thickness of 2300 m (7546 ft) in the extreme southwest corner of the province (Fig. 2). The Mesozoic and Cenozoic sequence comprises shales and sandstones, the Paleozoic sequence comprises predominantly limestones and dolostones with minor sandstones and shales.

A major angular unconformity separates Paleozoic from Mesozoic strata and probably represents one or more periods of erosion that occurred from Late Mississippian to Early Jurassic time. During this interval, Paleozoic strata in the northeastern part of the basin were uplifted and differentially eroded, whereas strata in the southern portion of the basin were relatively unaffected (McCabe, 1959). Successively older Paleozoic strata were progressively truncated toward the basin margin. Deposition resumed during Mesozoic time, when a thick sequence of Jurassic and Cre-

taceous strata was deposited on the eroded Paleozoic surface.

Within the Paleozoic, Devonian and Mississippian strata are separated by an unconformity that represents a period of uplift and erosion that occurred from Late Devonian to Early Mississippian time. During that interval, Devonian strata were uplifted and exposed along the basin margins, while deposition continued in the deeper portions of the basin. Mississippian sediments were later deposited on the eroded Devonian surface (Sandberg, 1964).

The Williston Basin was the principal feature controlling sedimentation in southwestern Manitoba from Ordovician to Cretaceous time. The depocenter of the Williston Basin at that time was centred in northwestern North Dakota. Basin sedimentation was characterized by cyclical transgressions and regressions with repeated deposition of carbonate and clastic sedimentary rocks.

During the Devonian period, the Elk Point Basin was the tectonic feature that controlled sedimentation. The depocenter of the Elk Point Basin was centred in south-central Saskatchewan.

# MANITOBA STRATIGRAPHIC COLUMN

| ERA       | PERIOD  |  |  | BASIC LITHOLOGY  | MAXIMUM THICKNESS (m)  |    |
|-----------|---|--|--|--|--|----|
| PALEOZOIC | Mississippian (part)                            | MADISON GROUP •  |  | Limestone and argillaceous limestone; light brown and red mottled, shaly, oolitic, crinoidal and cherty zones. OIL PRODUCING   |  |    |
|           |   | BAKKEN FORMATION •   |  | Two black shale zones separated by siltstone. OIL PRODUCING  | 20   |    |
|           | Devonian  | Ogishkem Group   | THREE FORKS (LYLETON) FORMATION                        | Red siltstone and shale; dolomitic.  | 55   |    |
|           |   |  | BIRDBEAR (NISKU) * FORMATION                           | Limestone and dolomite; yellow-grey, fossiliferous, porous, minor anhydrite.   | 43   |    |
|           |   | SASKATCHEWAN GROUP   | DUPEROW * FORMATION                                    | Limestone and dolomite; argillaceous and anhydritic in places.   | 195  |    |
|           |   |  | MANITOBA GROUP   | SOURIS RIVER * FORMATION<br>-----<br>First Red Beds  | Interbedded cycles of shale, limestone and dolomite; anhydritic. | 96 |
|           | DAWSON BAY FORMATION *<br>Second Red Bed Member | Limestone and dolomite; porous anhydritic, local red and green shales. |  | 73   |  |    |
|           | ELK POINT GROUP                                 | WINNIPEGOSIS FORMATION *   | Upper Member (Reef)                                    | Holite, sylvite and carnallite (potash); with seams of dolomitic mudstone, dolomite and anhydrite.   | 130  |    |
|           |   |  | (Inter-reef)   | Fossiliferous; yellow-grey dolomite banks (reefs) resting upon platform carbonates (mottled dolomite, bituminous and laminated in places).   | 107  |    |
|           |   |  | Lower Member (Platform)                                | ELM POINT FORMATION  | Limestone; fossiliferous, high calcium content.                  |    |
|           |   |  | ASHERN FORMATION                                       | Dolomite and shale; brick red.   | 18   |    |
|           | Silurian  | INTERLAKE GROUP *  |  | Dolomite; yellow-orange to grey, fossiliferous, oolitic, stromatolitic, interrupted by argillaceous marker beds.   | 120  |    |
|           |   | STONEWALL * FORMATION  | t-marker   | Dolomite; yellow-grey, sparsely fossiliferous, interrupted by argillaceous zones and marker beds.  | 24   |    |
|           | ORDOVICIAN                                      | STONY MOUNTAIN FORMATION   | Guntion Member *<br>Gunn Member<br>Penitentiary Member | Dolomite; yellow-brown, slightly nodular (Guntion). Dolomite; yellow to red-grey, fossiliferous, argillaceous (Penitentiary). Shale; red-green, burrow-mottled, fossiliferous, calcareous, minor limestone (Gunn). | 49   |    |
|           |   | RED * RIVER FORMATION  | Fort Garry Member                                      | Dolomite and limestone; mottled, fossiliferous, cherty, overlain by argillaceous dolomite with breccia beds (Fort Garry).  | 175  |    |
|           |   |  | Selkirk Member   |  |  |    |
|           |   |  | Cat Head Member  |  |  |    |
|           |   | WNNIPEG * FORMATION  | upper<br>lower   | Quartzose sandstone overlain by green, waxy shale with sand and silt interbeds.  | 69   |    |
|           | Cambrian  | DEADWOOD FORMATION *   |  | Sandstone; black to green-grey, waxy. Sandstone; glauconitic. Shale; grey to black.  | 60   |    |
|           | PRECAMBRIAN                                     |  |  |  |  |    |

• productive interval in Manitoba

\* intervals productive in other areas of the Williston Basin

Figure 3: Manitoba Stratigraphic Column, Lower Paleozoic Sequence. Shows basic lithology and maximum thickness (in metres).

## STRATIGRAPHY

The following is a brief overview of the geology of the formations within the Lower Paleozoic sequence of southwestern Manitoba. The information discussed is intended to provide a regional review of the lithologic, structural and isopach features of that sequence.

The Lower Paleozoic sequence of the Manitoba portions of the Williston and Elk Point basins comprises fourteen(14) formations and five(5) groups in Cambrian, Ordovician, Silurian and Devonian strata (Fig. 3). The wireline expression of these strata is shown in Figure 4 (in pocket).

Initial sedimentation of the Paleozoic sedimentary sequence occurred on the eroded, generally uniform, Precambrian surface (Fig. 5). The most prominent features are Lake St. Martin and the Hartney structure (McCabe, 1971; McCabe and Bannatyne, 1970a). The Lake St. Martin feature (Fig. 5), is an area of over 308 m (1000 ft) of Precambrian structural relief. At Lake St. Martin, a brecciated and faulted sequence of carbonate and volcanic rocks, surround a central uplifted core of highly metamorphosed Precambrian gneiss. The feature has been interpreted to be a Permian crypto-explosion crater, or a meteorite impact crater.

The Hartney structure, located in southwestern Manitoba (Township 5; Range 24 WPM), is an area characterized by complex faulting of basal Devonian to Mississippian strata. The Paleozoic surface in the centre of the feature is 183 m (600 ft) below regional elevation. The structure has been interpreted to be post-Mississippian to pre-Jurassic in age. Its origin is uncertain; however, a crypto-explosive origin, or a major northwest-trending transcurrent fault has been suggested (Haïtes and van Hees, 1962).

The Birdtail-Waskada Axis (McCabe, 1966), is a north-trending anomalous zone approximately 32 km (20 mi) east of the Saskatchewan border, that extends from Township 23, south to the United States border. It is an area characterized by numerous structural and isopach anomalies, and along which minor tectonic movement has occurred since Precambrian time. Although not evident on the Precambrian surface map (Fig. 5), the gravity and magnetic expressions along the axis apparently represent the boundary zone between the Churchill and Superior Precambrian crustal provinces (Fig. 6).

### CAMBRIAN

#### Deadwood Formation

The Deadwood Formation (Fig. 3) unconformably overlies the eroded Precambrian basement and unconformably underlies the Middle or Upper Ordovician Winnipeg Formation.

In Manitoba, the Deadwood Formation reaches a maximum thickness of approximately 60 m (197 ft) in the extreme southwest corner of the province (McCabe, 1978). The Deadwood Formation thins northeastward, where it is regionally truncated at the pre-Winnipeg Formation unconformity.

### ORDOVICIAN

#### Winnipeg Formation

The Winnipeg Formation (Fig. 3) reaches a maximum thickness of 69 m (225 ft) in Manitoba. It unconformably overlies weathered Precambrian basement, except in the extreme southwestern corner of Manitoba, where it unconformably overlies the Deadwood Formation. It is conformably overlain by the Upper Ordovician Red River Formation limestone.

Baillie (1952), Genik (1954) and Vigrass (1971) attempted to subdivide the Winnipeg Formation into distinct stratigraphic units. These units generally consist of a lower, basal sandstone unit, and one, or two, overlying sandstone and shale units. A formal subdivision of the Winnipeg Formation has not been accepted in Manitoba.

During deposition of the Winnipeg Formation, the depocentre of the Williston Basin was centred in northwestern North Dakota. The regional isopach pattern of the Winnipeg Formation reflects basin subsidence and is generally concentric to the Williston Basin. In Manitoba, however, the isopach of the Winnipeg Formation is east-trending (Fig. 7). Deposition of the strata appears to have been related to a greater amount of subsidence in the Manitoba portion of the Williston Basin than that in deeper portions of the basin (McCabe, 1971).

The most significant feature shown on the structure-isopach map of the Winnipeg Formation (Fig. 7) is the isopach anomaly created by the Carman sand body located south of Winnipeg. The Carman sand body is a large, bar-like sand, that consists of very-fine to medium-grained sandstone (Andrichuk, 1959). It reaches a maximum thickness of 30 m (100 ft).

The Winnipeg Formation represents the initial deposits of a marine transgressional cycle that began during Middle to Late Ordovician time, and continued until Late Silurian time. Winnipeg Formation strata consist of terrigenous clastics. The strata deposited later in the transgressional cycle consist almost entirely of carbonates and evaporites (Vigrass, 1971; Porter and Fuller, 1959).

#### Red River Formation

Red River Formation strata conformably overlie the Winnipeg Formation. In northern Manitoba, the strata overlap the Winnipeg Formation to rest unconformably on the Precambrian.

The Red River Formation ranges in thickness from 45 to 175 m (148 to 574 ft). It is subdivided into four members (Fig. 3) that are recognizable in the Manitoba Paleozoic outcrop belt. Subsurface equivalents of the Dog Head, Cat Head and Selkirk members correlate approximately to the Yeoman Formation in Saskatchewan. The Fort Garry Member is equivalent to the Herald Formation in Saskatchewan (Kendall, 1976).

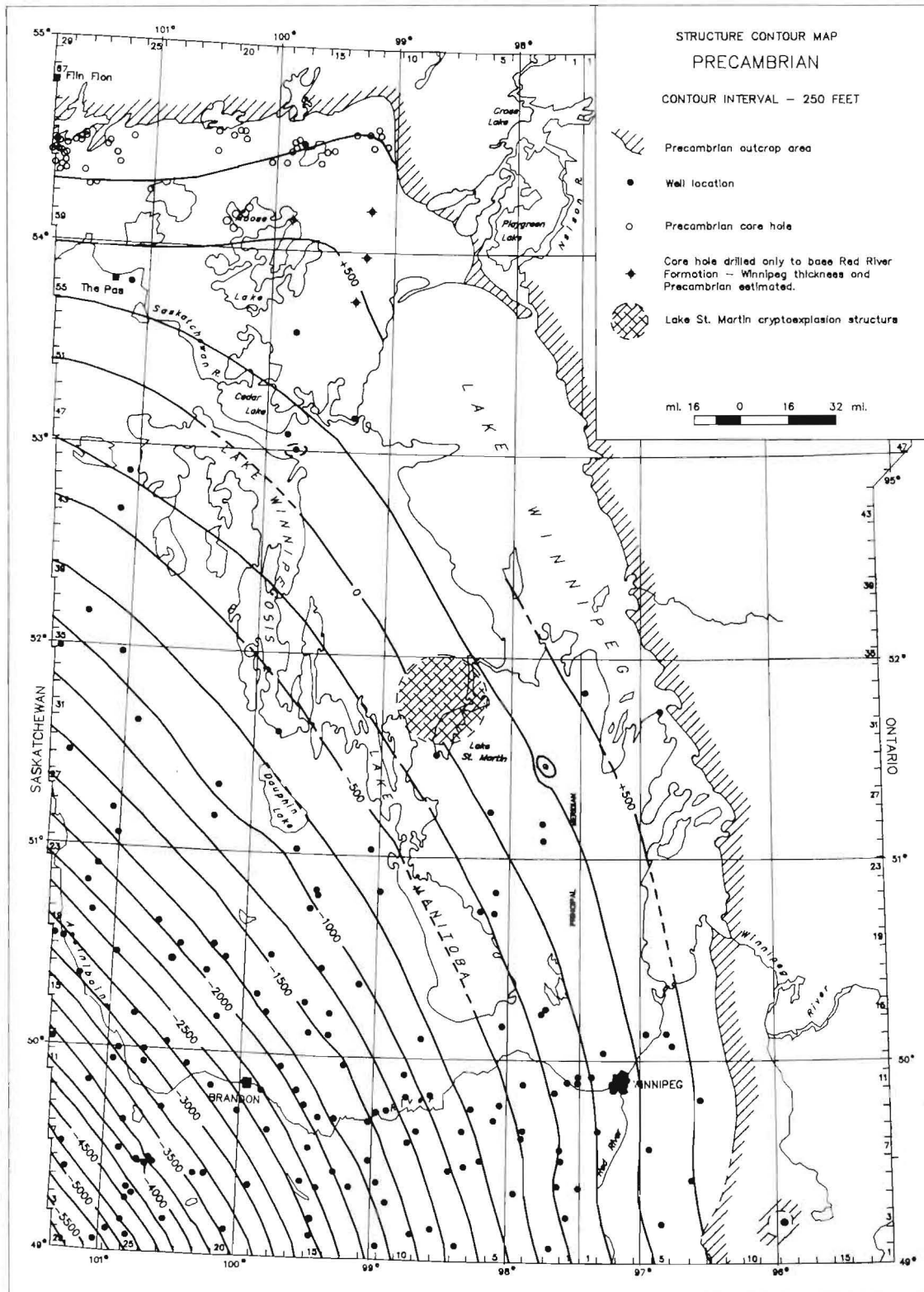


Figure 5: Precambrian Erosion Surface - Structure Contour Map (modified from McCabe, 1980; Martiniuk, 1991). Structure values are given in feet.

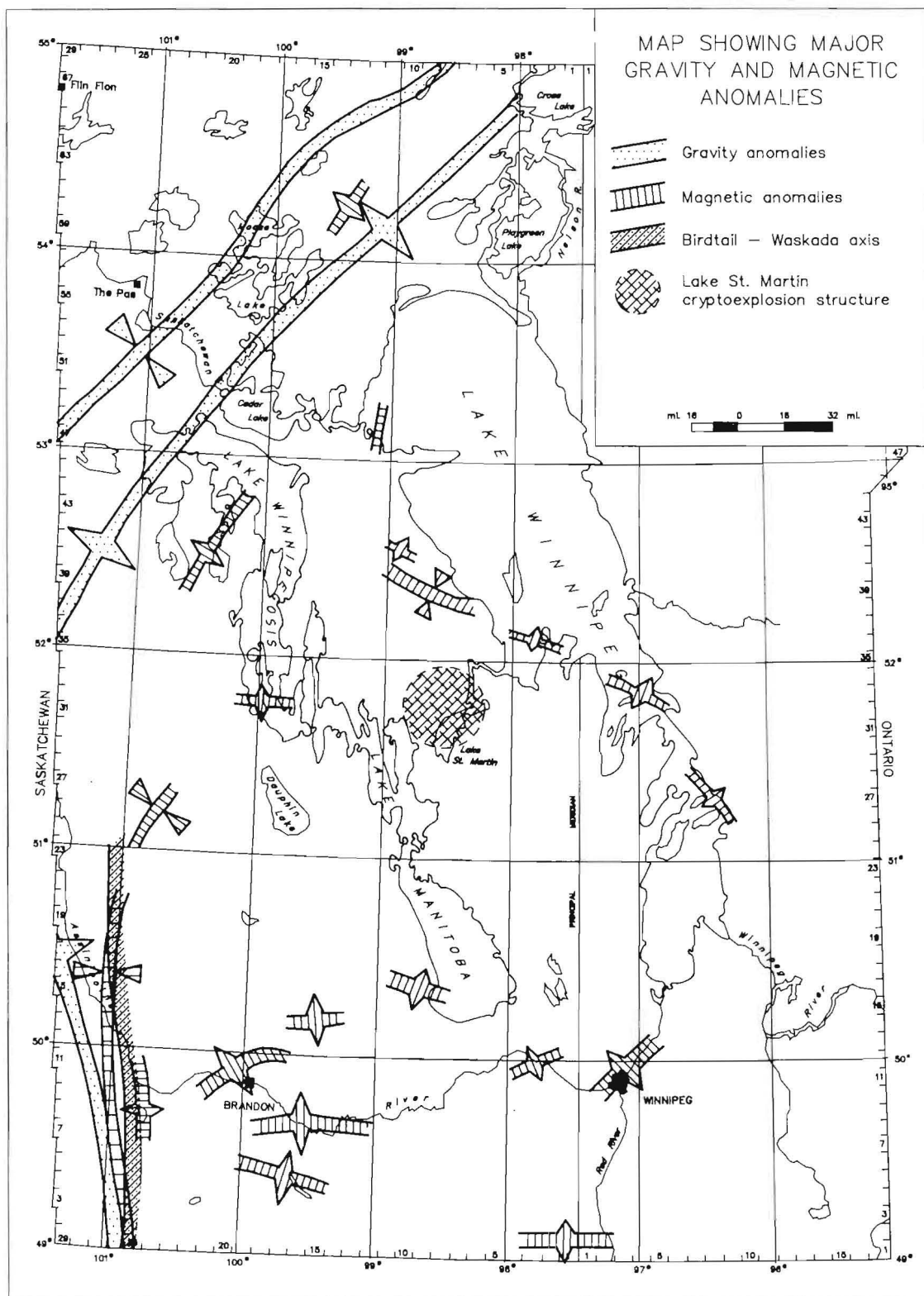


Figure 6: Map showing major gravity and magnetic anomalies, southwestern Manitoba.



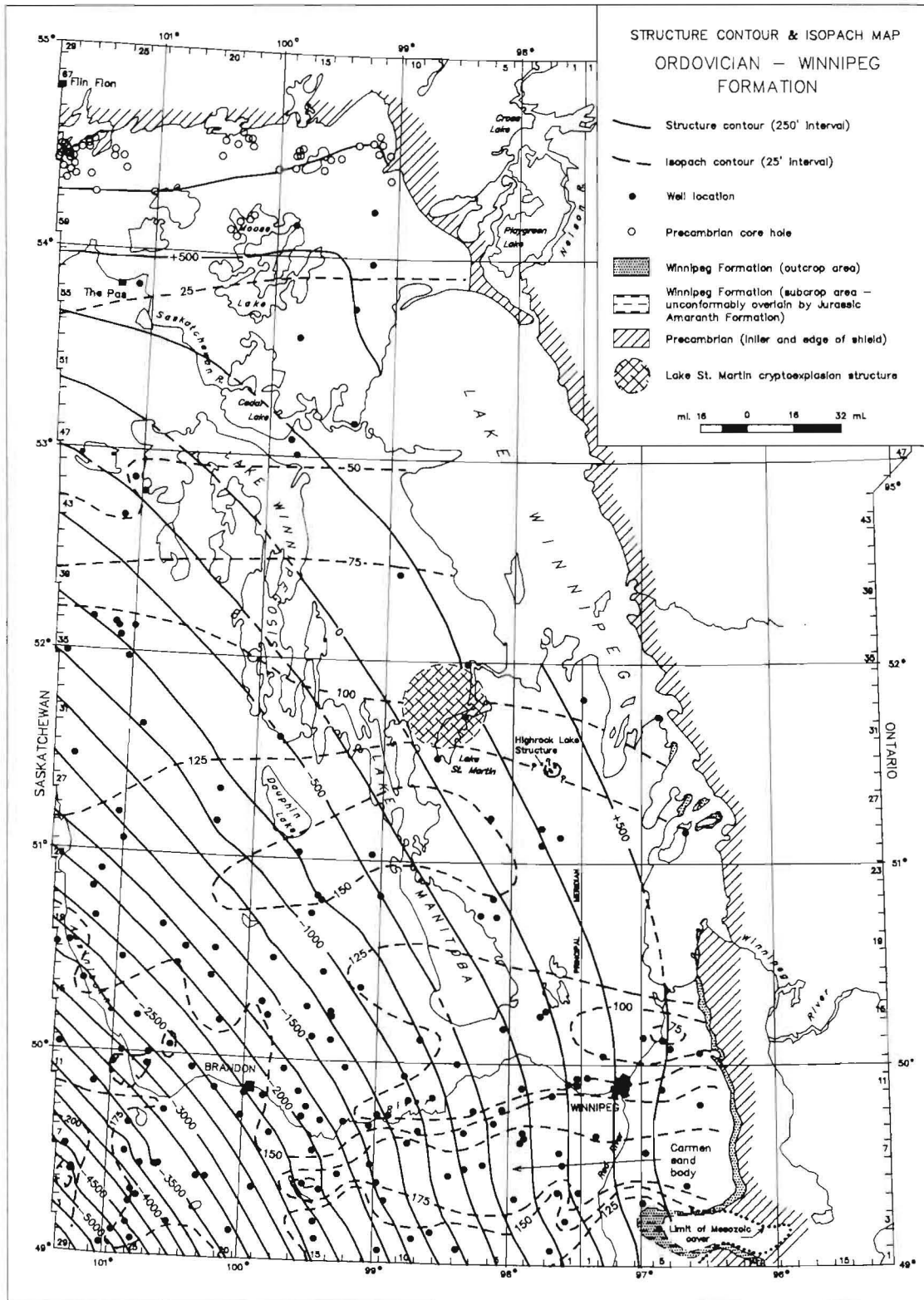


Figure 7: Winnipeg Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.



The Dog Head Member conformably overlies the Winnipeg Formation throughout most of the Manitoba Paleozoic outcrop belt, but north of the depositional limit of the Winnipeg Formation, it unconformably overlies Precambrian basement. The contact with the overlying Cat Head Member is transitional and conformable (Foerste, 1929a, 1929b; Kendall, 1976; LeFever *et al.*, 1991; Porter and Fuller, 1959).

The Cat Head Member is recognized only in the central portion of the Manitoba Paleozoic outcrop belt where it consists of faintly mottled dolomite with scattered to abundant chert nodules. To the north, the overlying Selkirk and underlying Dog Head members both change facies to dolomite, similar to the Cat Head Member. To the south, the Cat Head becomes increasingly calcareous and is indistinguishable from the overlying and underlying units (Foerste, 1929a, 1929b; Kendall, 1976; LeFever *et al.*, 1991; Porter and Fuller, 1959; Sinclair, 1959).

Contacts between the Selkirk Member and the underlying Cat Head and overlying Fort Garry members are transitional and conformable (Foerste, 1929a, 1929b).

The Fort Garry Member differs from the other members of the formation in that it contains a medial zone of shaly dolomite breccia that is believed to be the result of evaporite dissolution. It is overlain sharply and slightly disconformably by the Stony Mountain Formation (Baillie, 1952; Kendall, 1976; LeFever *et al.*, 1991; McCabe and Bannatyne, 1970; Sanford *et al.*, 1968).

The regional east-trending isopach pattern of the Red River Formation (Fig. 8) appears to be the result of greater differential subsidence in the Manitoba portion of the Williston Basin during deposition of Red River Formation strata (Porter and Fuller, 1959); the formation thins northward. An anomalous east-trending thin coincident with the area of the Carman sand occurs south of Winnipeg (Fig. 8). The presence of this feature is attributed to the differential compaction of Winnipeg Formation shale on the flanks of the Carman sand during Winnipeg Formation deposition (McCabe, 1971).

The Red River Formation was deposited in subtidal, upward brining sequences. Sedimentation during each cycle was mainly controlled by increase in salinity (Elias *et al.*, 1988; Longman *et al.*, 1983).

### **Stony Mountain Formation**

The Stony Mountain Formation has previously been subdivided into four members, which in ascending order include; the Gunn, Penitentiary, Gunton and Williams members. Recent standardized correlations established by McCabe and Bezys (*pers. comm.*) for the latest edition of the Atlas of Western Canada (*in prep.*) and the Lexicon of Canadian Stratigraphy (Canadian Society of Petroleum Geologists, 1990), place the top of the Stony Mountain Formation at the base of the Williams Member. It has been proposed that the Williams Member be included in the overlying Stonewall Formation, rather than in the Stony Mountain Formation, as originally defined by Smith (1963, 1964).

For the purpose of this report, all data and mapping of the Stony Mountain and Stonewall formations, as originally defined, has been retained. The treatment of the Stony Mountain and Stonewall formations in following discussions adheres to the newly proposed definition. This definition will be adopted by Manitoba Energy and Mines in future studies.

The Stony Mountain Formation sharply and slightly disconformably overlies the Red River Formation. Thickness of the formation ranges from 30 to 49 m (100 to 160 ft) and the members are lithologically diverse (Fig. 3).

The Gunn Member, together with the Penitentiary Member, form the lower Stony Mountain (equivalent to the Stoughton Member of Saskatchewan) and are complete lateral facies equivalents. The Gunn Member represents the southern, deeper basinal limestone-shale facies, and the Penitentiary Member represents the northern, more shelfward, dolomitized facies. These members cannot be differentiated in the subsurface.

The Gunton Member conformably and transitionally overlies the Gunn or Penitentiary members.

The Gunton represents deposition under shallow marine to supratidal conditions (Roehl, 1976; Cowan, 1971). These conditions continued throughout Stonewall and Interlake time and probably represents the regressive or offlap phase of the Ordovician-Silurian depositional cycle (McCabe, 1971; Sloss, 1963).

The isopachs of the Stony Mountain Formation (Fig. 9) indicate a general south to southeast thickening with minor thickening to the west. The isopachs reflect a decrease in the rate of differential subsidence and a change in tectonic framework (McCabe, 1971).

### **Stonewall Formation**

The Stonewall Formation sharply, but with possible slight disconformity, overlies the Stony Mountain Formation. The Stonewall Formation ranges in thickness from 9 to 24 m (31 to 79 ft), and is generally a dolomite (Fig. 3).

A sandy argillaceous marker (t-marker of Porter and Fuller, 1959) that separates beds in the lower part of the Stonewall Formation from beds in the upper part of the formation has been inferred as the Ordovician/Silurian boundary (Smith, 1963; Kendall, 1976; Porter and Fuller, 1959).

The Williams Member (previously assigned to the Stony Mountain Formation; Smith, 1963; 1964), consists of red, argillaceous and sandy dolomite and forms the basal unit of the Stonewall (Fig. 4; in pocket).

The isopach of the Stonewall Formation trends westward (Fig. 10) and reflects a change in the deposition initiated in Stony Mountain time and a return to a more normal rate of sedimentation in Stonewall time. The gradual westward thickening of the Stonewall Formation suggests a slow rate of sedimentation in an equally slowly subsiding and shallow basin (Roehl, 1967; Cowan, 1971).

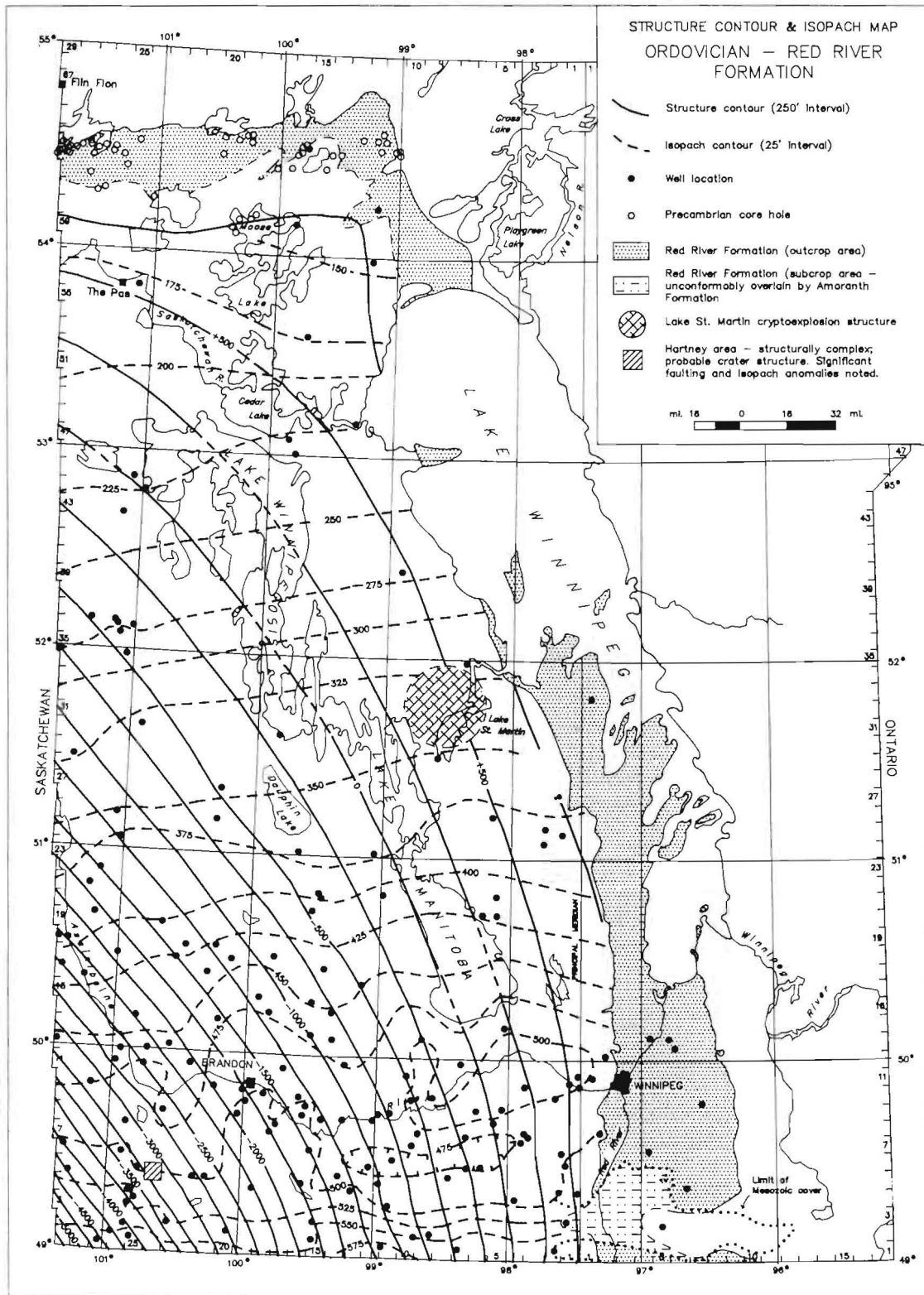


Figure 8: Red River Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

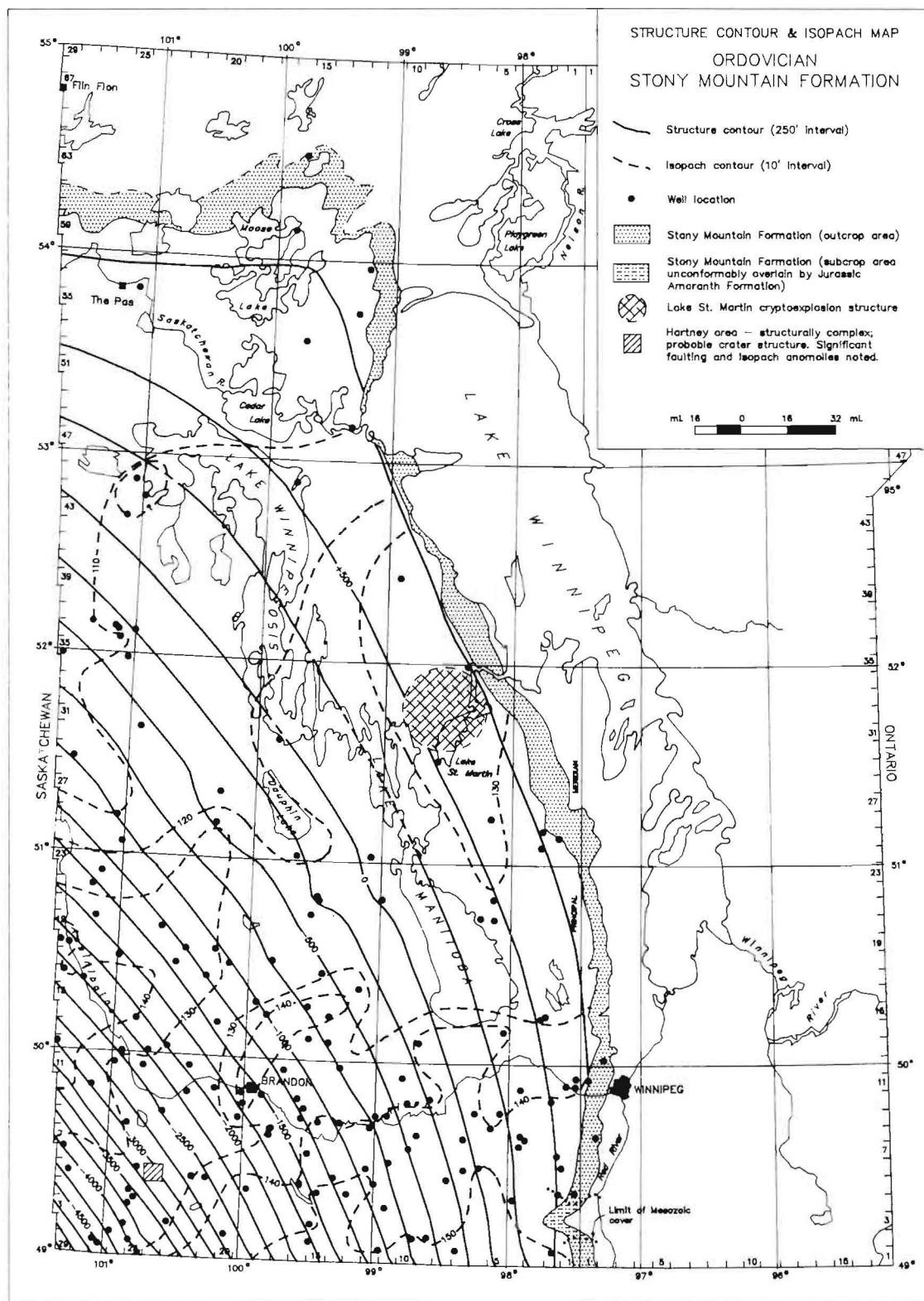


Figure 9: Stony Mountain Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

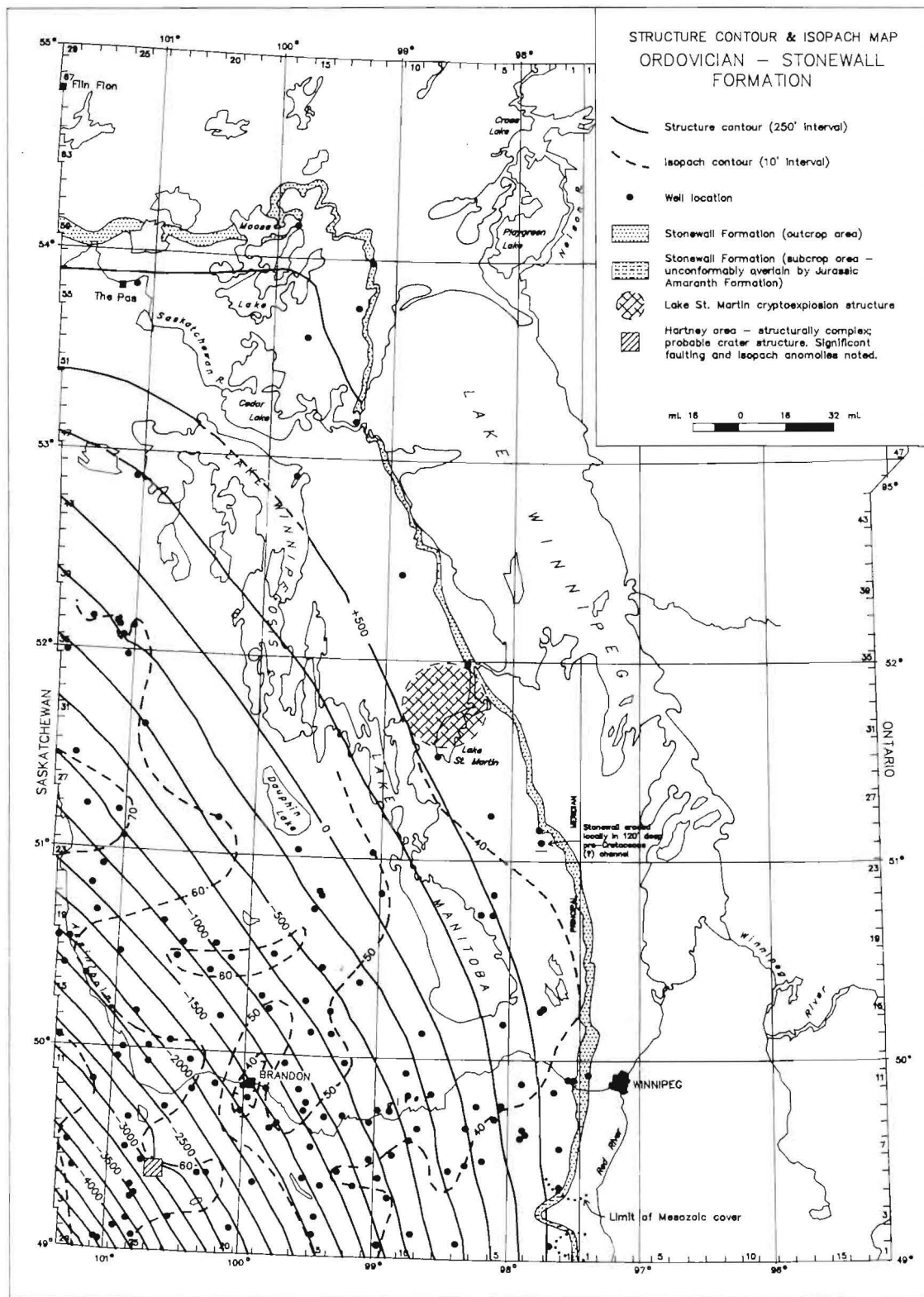


Figure 10: Stonewall Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

## SILURIAN

### Interlake Group

The Interlake Group overlies the Stonewall Formation with slight unconformity. Subdivision of the Interlake Group in the subsurface is difficult, but alternative subdivisions, not discussed here, have been proposed by other workers (Baillie, 1951; Haidl, 1987; Jamieson, 1979; King, 1964; Porter and Fuller, 1959; Saskatchewan Geological Society, 1958; Stearn, 1956). Thickness of the Interlake Group ranges from 49 to 120 m (161 to 394 ft) and it is composed of fossiliferous dolomite (Fig. 3).

Much of the Interlake Group in Manitoba has been eroded. The entire Upper Interlake, present in deeper parts of the basin, has been removed in Manitoba; only the upper part of the Middle Interlake has been preserved in the Manitoba portion of the basin. The top of the Interlake Group marks a major pre-Devonian unconformity. The irregular pattern of the Interlake Group isopachs (Fig. 11), reflect the effects of differential erosion and karst development (McCabe, 1971).

## DEVONIAN

The period of erosion that occurred from Late Silurian to Early Devonian time was followed by a major depositional cycle that began in Early or Middle Devonian time. Deposition of the Devonian sequence also marked a major change in the tectonic framework. During Devonian time, the tectonic feature that controlled sedimentation shifted from the Williston Basin to the Elk Point Basin.

The Devonian system, in Manitoba, is divided into four major lithologic units. These are, in ascending order, the Elk Point, Manitoba, Saskatchewan and Qu'Appelle groups.

### Elk Point Group

The Elk Point Group is subdivided into the Ashern, Elm Point, Winnipegosis and Prairie formations.

#### Ashern Formation

The Ashern Formation ranges in thickness from approximately 3 to 18 m (10 to 60 ft). It unconformably overlies the Interlake Group and is overlain with slight unconformity by the Winnipegosis Formation, or the Elm Point Formation where it is developed.

Deposition of the Ashern Formation dolomite and shale (Fig. 3) marked the beginning of the Devonian sedimentary cycle. The sedimentary rocks represent, in part, the reworking of residual soil formed during the later Silurian to early Devonian erosional interval (Norris *et al.*, 1982).

Deposition of the Ashern Formation on the Silurian erosional surface during the initial stages of the Devonian transgression is reflected by the irregular isopach pattern of the Ashern Formation (Fig. 12)(McCabe, 1971). The effects of post-Ashern Formation erosion is also reflected by the irregular pattern of the Ashern Formation isopach.

### Elm Point Formation

The Elm Point Formation, identified only in Manitoba, overlies the Ashern Formation with possible unconformity and ranges in thickness from approximately 5 to 20 m (16 to 66 ft). The Elm Point Formation grades laterally in the subsurface from variably dolomitized, mottled high-calcium limestone to dolostone that is generally indistinguishable from the overlying Winnipegosis Formation. It is essentially equivalent to the Lower Member, platform carbonate facies of the Winnipegosis Formation (Norris *et al.*, 1982).

### Winnipegosis Formation

The Winnipegosis Formation disconformably overlies the Ashern Formation. It is conformably overlain by the Prairie Evaporite, where it is present. In areas where the Prairie Evaporite is absent, the Winnipegosis Formation is overlain by the basal Second Red Bed Member of the Dawson Bay Formation.

The Winnipegosis Formation attains a maximum thickness of 105 m (344 ft). It is subdivided into a lower member, platform facies, consisting generally of a mottled dolomite; and, an upper member, carbonate mound, reef, or inter-reef facies (Norris *et al.*, 1982). The units are separated by argillaceous-bituminous or laminated beds. A transition zone consisting generally of limestone-shale breccias and coarsely crystalline limestone, occurs locally at the top of the upper member.

The reef, inter-reef and fringing bank complex of the Winnipegosis Formation is represented by the isopach map (Fig. 13). The Winnipegosis Formation thickens gradually to the northwest, from about 12 m (40 ft) to maximum of about 49 to 55 m (160 to 180 ft), towards an area immediately east of the Birdtail-Waskada Axis. This area is believed to represent the fringing bank deposit of the Winnipegosis Formation, which formed on the southeastern edge of the Elk Point Basin.

The fringing bank edge is defined along a north-south trend in the southwestern portion of Manitoba. Its location and coincidence with the Birdtail-Waskada Axis and the salt edge of the overlying Prairie Evaporite, has been attributed to minor recurrent structural movement along the Birdtail-Waskada Axis. Reef development may have also been localized along this axis. This is evident north of Township 24, where patch reefs have been identified along the northward extension of the Birdtail-Waskada Axis (McCabe, 1971).

North and west of the area of maximum fringing bank build-up, the Winnipegosis Formation thins rapidly to about 12 m (40 ft) in a area interpreted to be basinal inter-reef. The inter-reef area is interrupted periodically by locally, sharply defined areas where the Winnipegosis Formation thickens from 61 to 107 m (200 to 350 ft). These areas have been interpreted to represent patch or pinnacle type reefs that developed in favourable areas where reef growth was able to keep pace with basin subsidence (McCabe, 1971).



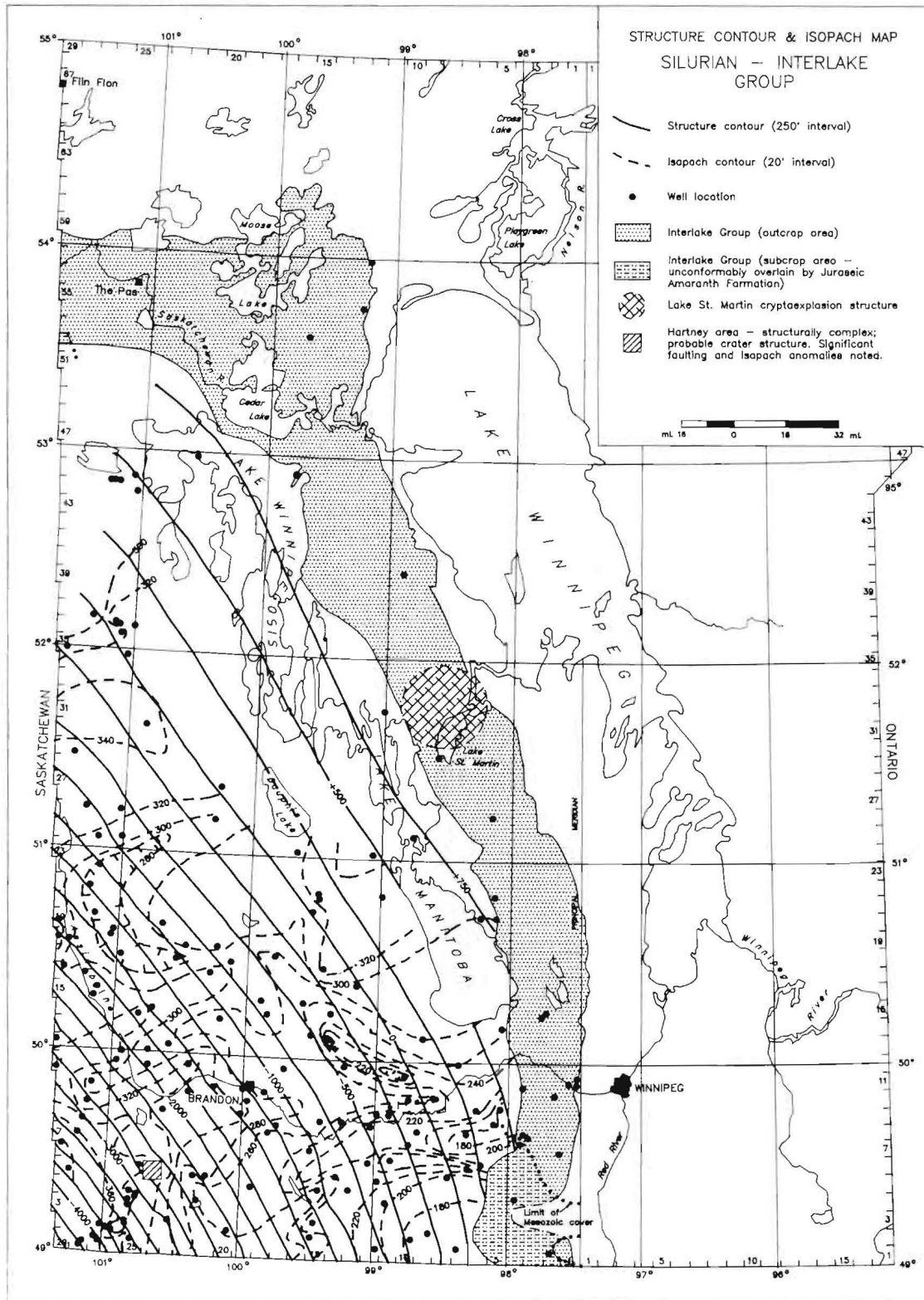


Figure 11: Interlake Group Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

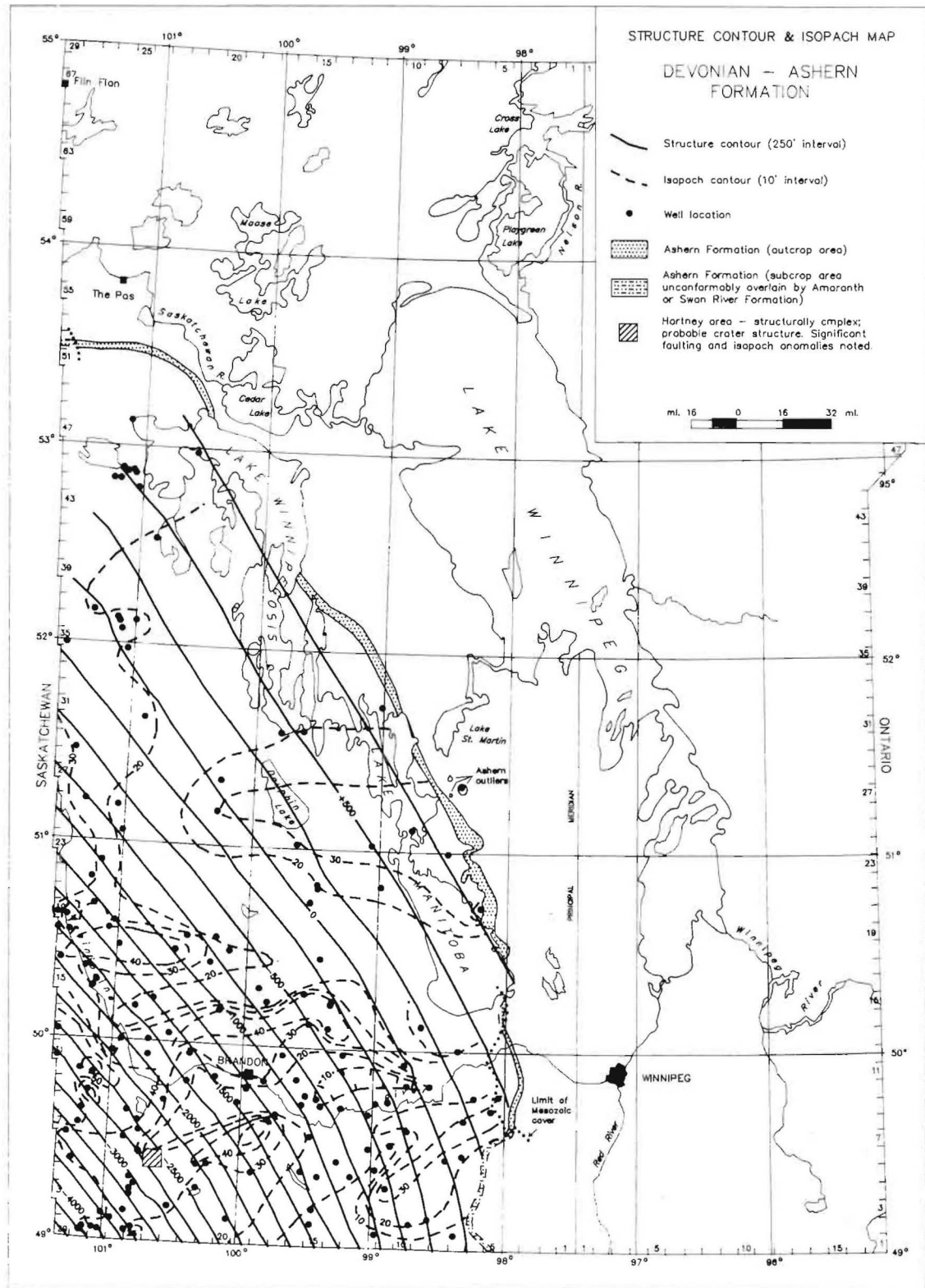


Figure 12: Ashern Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

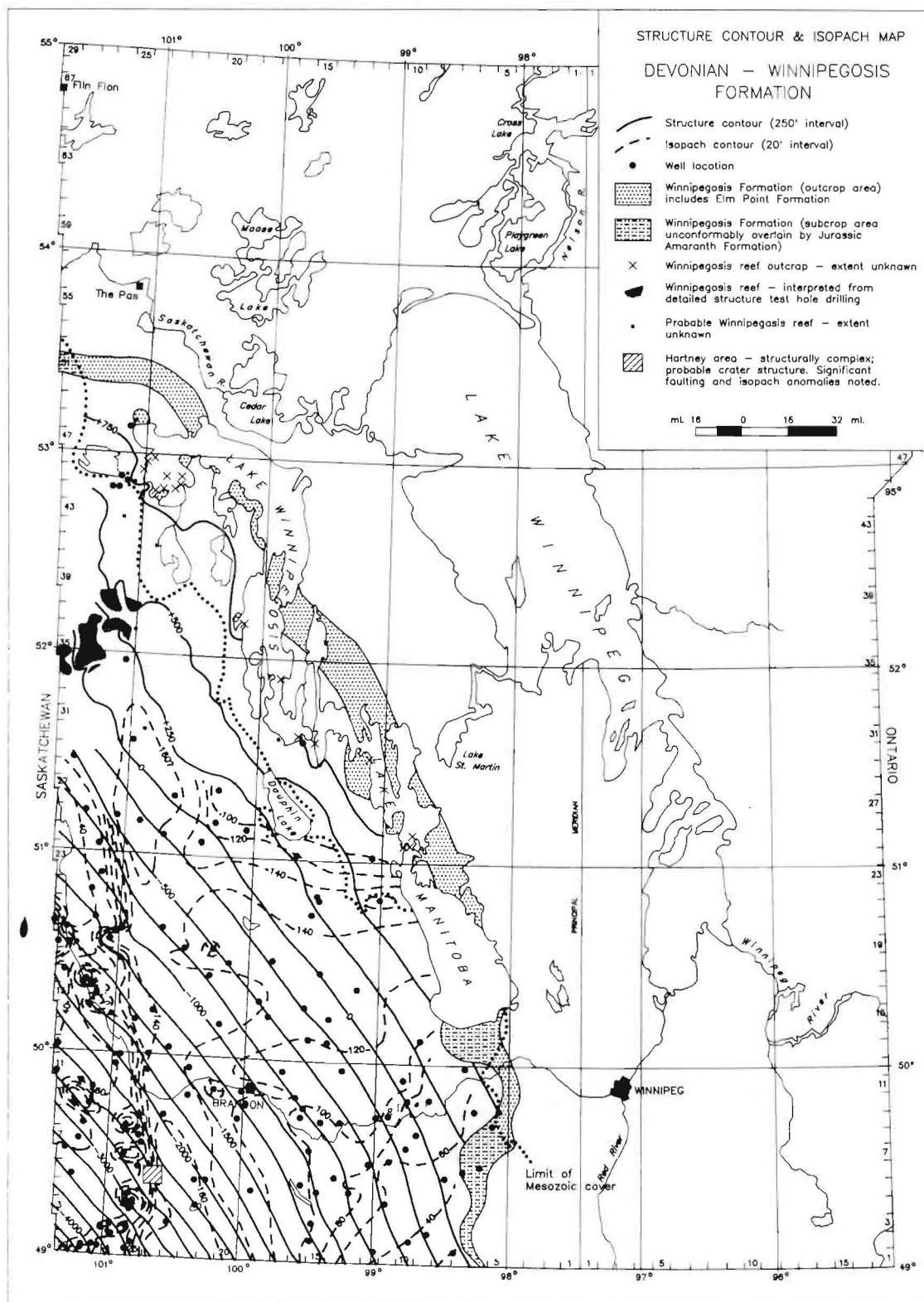


Figure 13: Winnipegosis Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.



### Prairie Evaporite

The Prairie Evaporite is the uppermost formation in the Elk Point Group. It comprises a sequence of halite beds with minor anhydrite. A potash-rich interval occurs near the top of the unit. Contact with the underlying Winnipegosis Formation appears to be conformable. However, some workers have suggested that there was a period of emergence and weathering prior to and during evaporite deposition. There is also some debate as to whether a basal anhydrite should be included as part of the Winnipegosis Formation or the Prairie Evaporite. These interpretations remain under discussion.

The Prairie Evaporite thickens from a zero edge, due to dissolution, to a maximum of 130 m (425 ft). The formation originally extended north and east of the present area of evaporites (Fig. 14). The salt edge of the Prairie Evaporite represents a dissolution, rather than a depositional edge. The main body of the Prairie Evaporite is restricted to an area west of the Winnipegosis Formation fringing bank, along, or near the Manitoba/Saskatchewan border, where it comprises a sequence of halite, minor anhydrite and potash beds. A tongue of anhydrite extends eastward from this main body, over part of the Winnipegosis Formation fringing bank.

### Manitoba Group

The Manitoba Group is divided into the Dawson Bay and Souris River formations.

#### Dawson Bay Formation

The Dawson Bay Formation disconformably overlies the Prairie Evaporite and is the lowermost formation in the Manitoba Group. It ranges in thickness from 43 to 73 m (141 to 240 ft).

The Dawson Bay Formation is subdivided in ascending order, into a basal unit termed the Second Red Bed Member, and three upper units. The Second Red Bed Member (Mafeking Member; Norris *et al.*, 1982) consists of red to green, noncalcareous, fissile shale that grades upward to argillaceous and dolomitic limestone and argillaceous dolomite. These beds are recognizable in the subsurface and in outcrop.

The upper part of the Dawson Bay Formation consists of three rock units that are recognizable in outcrop. The unit overlying the Second Red Bed Member comprises argillaceous dolomites and fossiliferous biomicritic limestones (Member B; Norris *et al.*, 1982). The second unit consists of calcareous shales and argillaceous limestones (Member C; Norris *et al.*, 1982) and the uppermost unit comprises saccharoidal dolomites and fragmental limestones that commonly contain stromatoporoids (Member D; Norris *et al.*, 1982; Baillie, 1953).

The isopach pattern of the Dawson Bay Formation is fairly irregular (Fig. 15). Local thickening of the Second Red Bed Member (Townships 1 to 5; Ranges 24 to 26 WPM) is related to salt dissolution along the edge of the Winnipegosis fringing bank (McCabe, 1971). The Dawson Bay Formation thins northward along an area which is coincident with

the Birdtail-Waskada Axis. The formation thickens east of the Birdtail-Waskada Axis, towards the Manitoba Paleozoic outcrop belt (Fig. 15). McCabe (1971) suggests that eastward thickening of the Dawson Bay Formation related to pre-Dawson Bay salt dissolution of the underlying Prairie Evaporite and to differential subsidence.

The deposition of the Second Red Bed Member is believed to have occurred under continental, or very shallow water, intertidal conditions. The Second Red Bed Member may represent the insoluble residue as a result of pre-Dawson Bay salt dissolution and removal of the underlying Prairie Evaporite over much of southwestern Manitoba. Deposition of the argillaceous dolomites, fossiliferous limestones and argillaceous limestones of the upper units of the Dawson Bay Formation represent an increase in water depth and transgression of the Dawson Bay sea (Norris *et al.*, 1982).

#### Souris River Formation

The Souris River Formation transitionally overlies the Dawson Bay Formation. It ranges in thickness from 67 to 96 m (220 to 315 ft).

The Souris River Formation, as defined by Norris *et al.* (1982), comprises a lower unit, the Point Wilkins Member, and an upper unit, the Sagamece Member (these members are not shown in Fig. 3). Both members are recognized in the Manitoba Paleozoic outcrop belt. The Point Wilkins Member is subdivided, in ascending sequence, into four units, the First Red Beds (the only unit recognized in the subsurface; Fig. 3), a red and green, calcareous shale; a fossiliferous, argillaceous limestone; a dense, micritic and fragmented limestone (original point Wilkins Member of Baillie, 1951); and a yellowish-brown, finely crystalline dolomite and dolomitic limestone. The Sagamece Member consists of variably fossiliferous, micritic limestone grading, in part, to laminated and pelletal limestone and saccharoidal dolomite (LeFever, *et al.*, 1991).

The lowermost portions of the Souris River Formation extend to the Manitoba Paleozoic outcrop belt, whereas the upper portions of the formation are overlain by onlapping Mesozoic strata.

Recent standardized correlations established by McCabe and Bezys (*pers comm.*) for the latest edition of the Atlas of Western Canada (*in prep.*) and the Lexicon of Canadian Stratigraphy (Canadian Society of Petroleum Geologists, 1990), have redefined the top of the Souris River Formation to correspond with its type section. The previous top of the Souris River Formation in Manitoba was defined as the top of a shale break approximately 15 m (50 ft) below the established top of the Souris River Formation. This pick has been retained in Manitoba as the "Souris River marker". The picks are identified on the wireline log (Fig. 4; in pocket).

For the purpose of this report, all data and mapping of the Souris River Formation and overlying Duperow Formation, as originally defined, has been retained. The definition proposed will be adopted by Energy and Mines in future studies.

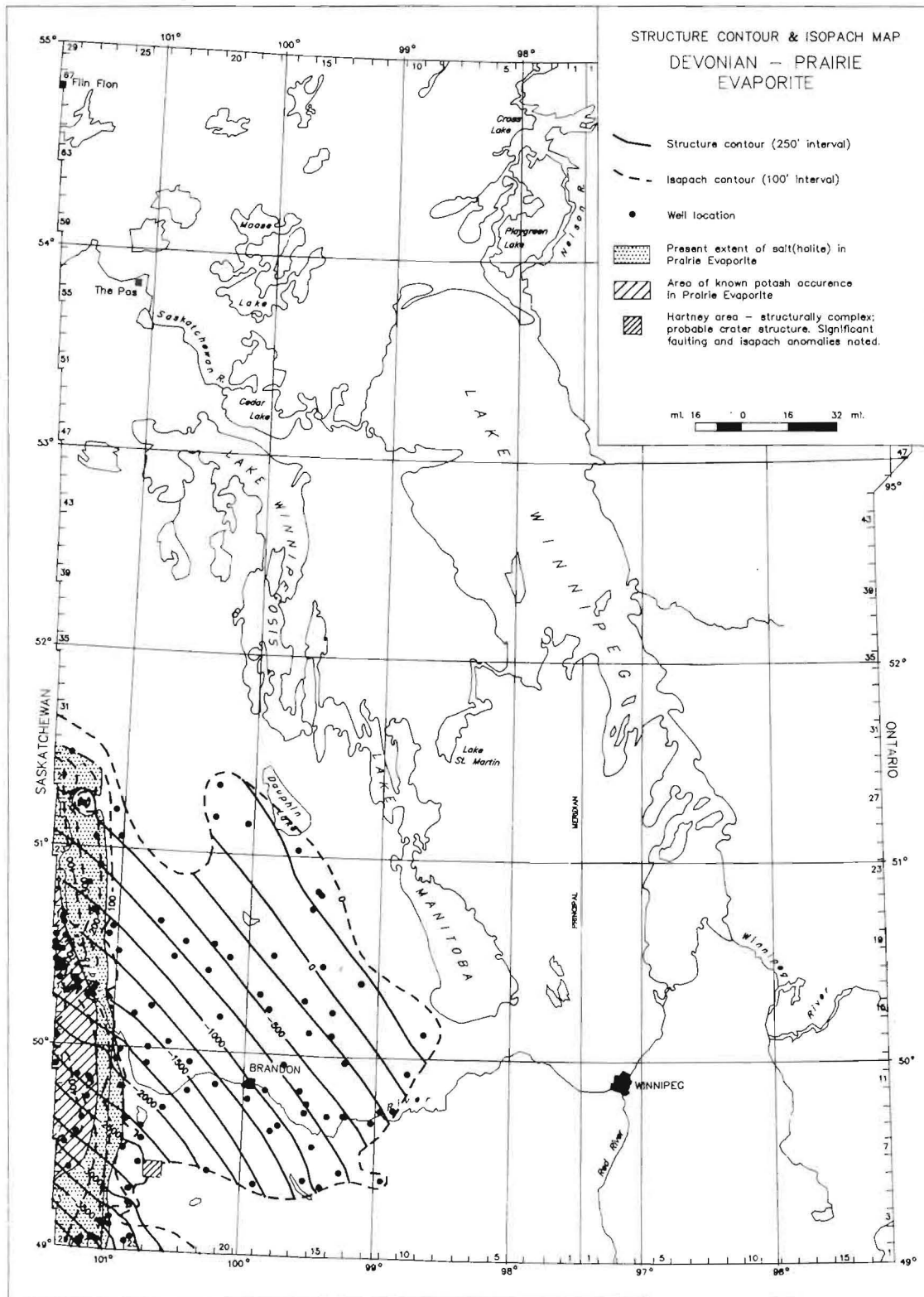


Figure 14: Prairie Evaporite Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

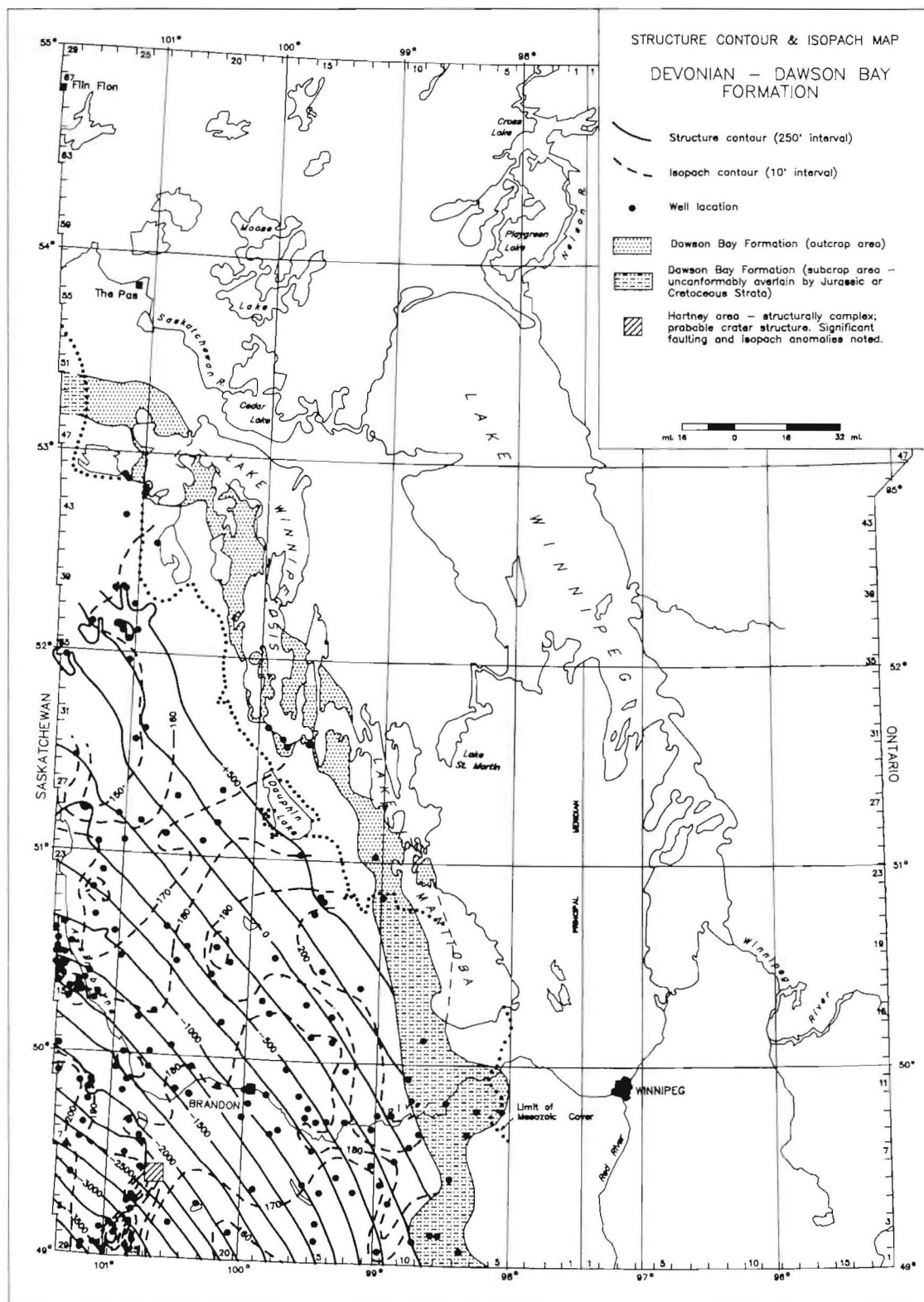


Figure 15: Dawson Bay Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

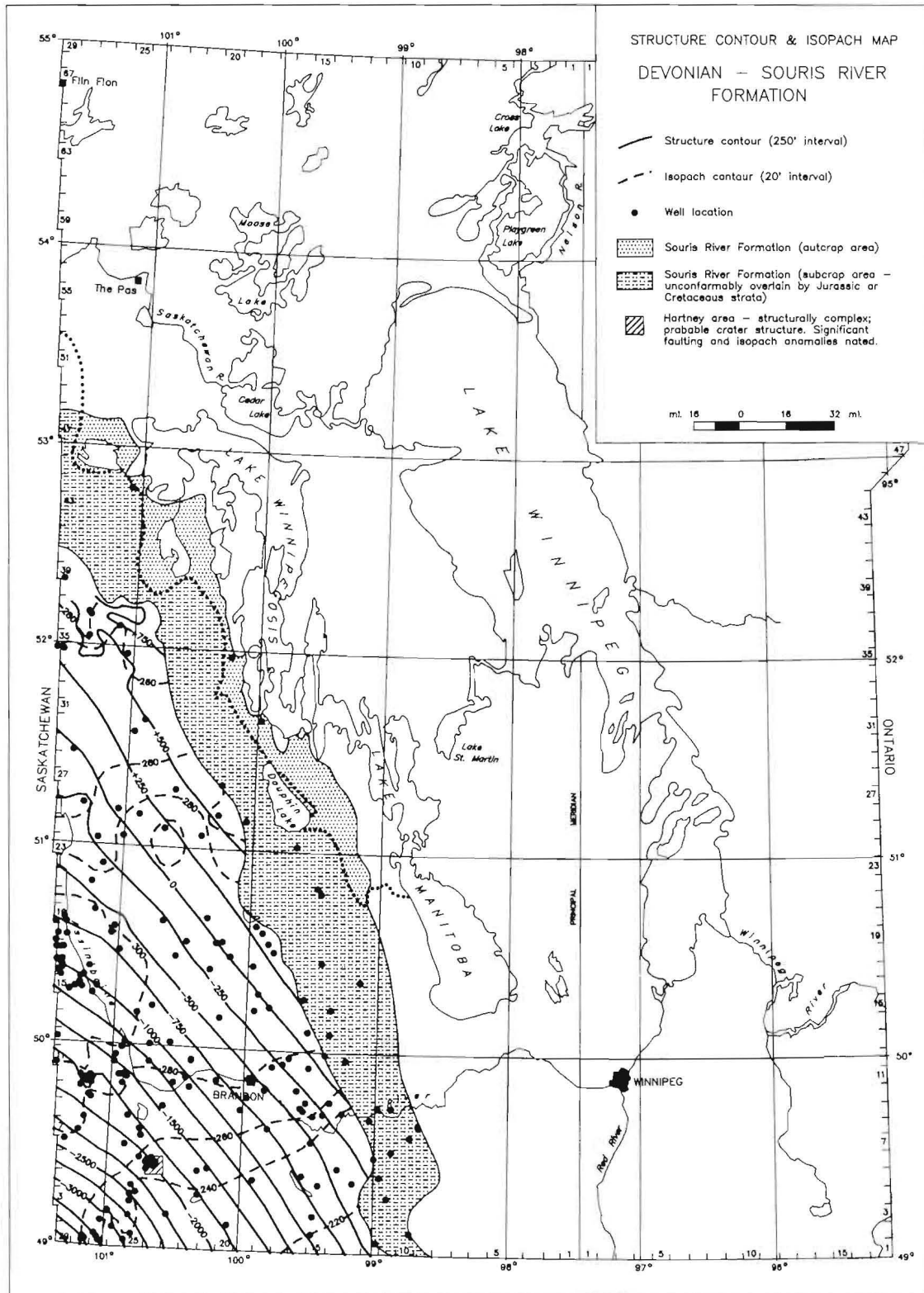


Figure 16: Souris River Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

The isopach of the Souris River Formation (Fig. 16) reflects a relatively normal tectonic framework with uniform thickening towards an east-trending area of maximum subsidence. This may represent the eastern edge of the Elk Point Basin (McCabe, 1966).

The Souris River Formation represents an alternating cycle of marine transgression and regression. The First Red Beds and argillaceous and micritic limestones of the Point Wilkins Member represent the initial part of a regressive phase. The Sagemace Member represents the transgressive phase of a second cycle (Norris *et al.*, 1982).

#### **Saskatchewan Group**

The Saskatchewan Group is divided into the Duperow and Birdbear(Nisku) formations.

##### **Duperow Formation**

The Duperow Formation conformably overlies the Souris River Formation. It ranges in thickness from 122 to 195 m (400 to 640 ft). The formation is characterized by a cyclical sequence of strata similar to that of the underlying Souris River Formation. The lowermost cycle consists mainly of fragmented, saccharoidal dolomite and lesser amounts of limestone. Corals, stromatoporoids, bryozoa and algal material are commonly present. The third and final phase comprises massive anhydrite (LeFever *et al.*, 1991).

The Duperow Formation is confined to the subsurface in Manitoba. It is completely overlapped by Jurassic and/or Cretaceous strata.

The regional isopach pattern of the Duperow Formation is similar to that of the underlying Souris River Formation (Fig. 17). The most significant isopach features occur in the Napinka area (Townships 3 to 6; Range 25 WPM), and in the St. Lazare area (Townships 15 to 17; Ranges 27 to 29 WPM), where the Duperow Formation locally thickens. Napinka coincides with an area of thin Prairie Evaporite, and is structurally high on the Duperow Formation. St. Lazare is an area of thickening in the Souris River and Duperow formations and is structurally low on the Prairie Evaporite. The features in both of these areas are related to salt dissolution. The feature at Napinka is the result of salt dissolution during Duperow time. The feature at St. Lazare resulted from limited, or partial salt dissolution during Souris River-Duperow time (McCabe, 1971).

##### **Birdbear(Nisku) Formation**

The Birdbear Formation conformably overlies the Duperow Formation and ranges in thickness from 13 to 43 m (42 to 141 ft). It is confined to the subsurface and is completely overlapped by Jurassic and/or Cretaceous strata. The Birdbear Formation comprises a sequence of fragmental, fossiliferous limestones and dolomites; corals, bryozoa, stromatoporoids and algal material are common and abundant.

The isopach pattern of the Birdbear Formation (Fig. 18) is fairly irregular, reflecting the biostromal nature of the formation. There are no noticeable regional isopach trends, suggesting the relative stabilization of the tectonic framework toward the end of the Devonian depositional cycle (Baillie, 1953; McCabe, 1966).

A series of structural lows on the Birdbear Formation occur along the Birdtail-Waskada Axis (Fig. 18). These small, structural lows are similar to those noted previously in the underlying Duperow Formation and are related to salt dissolution. However, the lack of any thickening associated with these features, seems to indicate that these structures were not created during Birdbear time.

#### **Qu'Appelle Group**

##### **Three Forks(Lyleton) Formation**

The Qu'Appelle Group, as proposed by Baillie (1953), comprises the Three Forks Formation. The Three Forks Formation conformably overlies the Birdbear Formation and is unconformably overlain by the Mississippian Bakken Formation. It consists predominantly of red, dolomitic siltstones and silty shales, and argillaceous dolomites. Local interbeds of intraformational breccia are common and suggest several minor periods of erosion during Three Forks time.

The Three Forks Formation has not been represented by any mapping in this report due to the difficulty in distinguishing between the Bakken-Three Forks boundary. Previous studies reveal the effects of salt dissolution during Bakken-Three Forks time, which is evident in mapping of the Bakken-Three Forks interval (Martiniuk, 1988; McCabe, 1971).

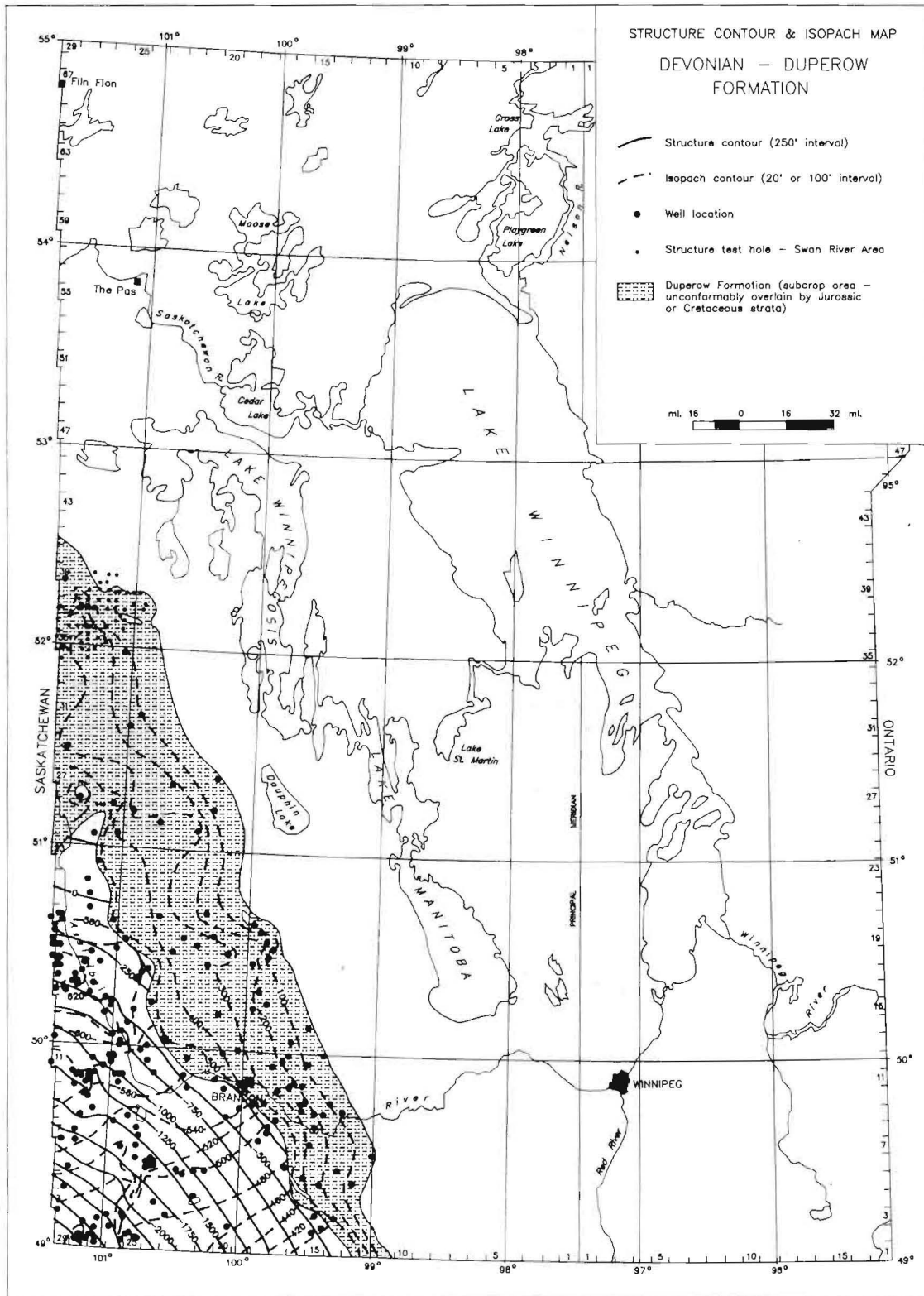


Figure 17: Duperow Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.



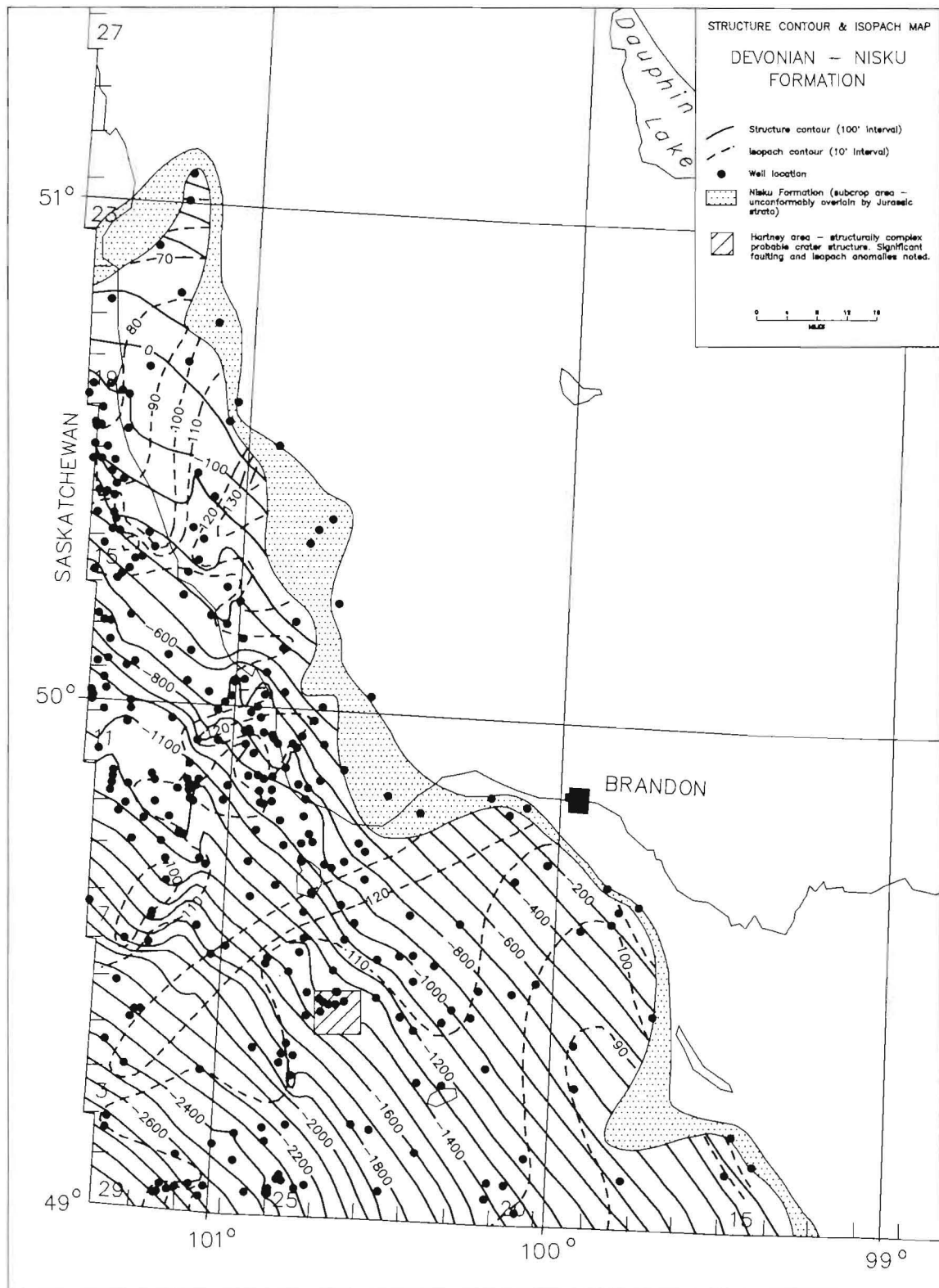


Figure 18: Birdbear(Nisku) Formation Structure-Isopach Map (modified from McCabe, 1980; Martiniuk, 1991). Structure and isopach values are given in feet.

## DRILLING HISTORY

The pre-Mississippian formations have remained largely undrilled and essentially untested in Manitoba. Since 1947, there has been approximately 600 wells drilled in southwestern Manitoba (Townships 1 to 45; Ranges 1 to 29 WPM).

Major deep drilling programs have been conducted over the past twenty years in Manitoba. The first of these programs was conducted in the early 1970's by Asamera Oil Corporation Ltd. It was designed to explore for pre-Mississippian formations and included twenty-five Precambrian test wells that were drilled throughout Manitoba; from Townships 1 to 29 and Ranges 1 to 29 WPM.

In the early 1980's, Clarion drilled several deep tests in the area covering Townships 1 to 3; and Ranges 20 to 22 WPM. The program lead to the discovery of the Whitewater Field area; a field that produces from the Mississippian Lodgepole Formation.

During the mid-1980's there were no major deep drilling programs. The majority of wells were drilled to define the Mississippian Bakken Formation in the Daly Field (Townships 9 to 11; Ranges 27 to 29 WPM). Only 18 wells have been drilled since 1984 that either reach, or penetrate the Birdbear Formation or deeper.

The most notable wells drilled in the past seven(7) years include the following; two wells drilled to the Precambrian in 1984 and 1985; the first one by KLM Ventures Ltd., at 3-24-10-21 WPM; and, the second one by Chevron Canada Resources, at 1-18-8-25 WPM. In 1986, Tundra Oil & Gas drilled a well to the Duperow Formation at 2-8-8-17 WPM. Tundra drilled another deep test in the Daly Field in 1987 at 13-21-10-28 WPM, which penetrated the Interlake Group. The most recent pre-Mississippian well was drilled in the Pierson area in 1989, by Petro-Canada Ltd. The well, at 10-9-1-28 WPM, was drilled into the Interlake Group.



## PETROLEUM POTENTIAL

### Pre-Mississippian exploration (Saskatchewan and North Dakota)

Recent exploration and development of Lower Paleozoic strata in neighbouring Saskatchewan and North Dakota has revealed the tremendous petroleum potential of that sequence (Fig. 19). This is particularly evident by the oil plays at Minton in south-central Saskatchewan, and at Tableland and Hitchcock in southeastern Saskatchewan. The Minton pool produces from the Ordovician Red River and Devonian Winnipegosis formations. Hitchcock and Tableland both produce from the Winnipegosis Formation. These areas represent extensions along major production fairways within the Williston Basin.

The Minton pool is the most northern accumulation of oil in Red River dolomites along the production fairway that extends 200 km south into Richland County, Montana. The Tableland and Hitchcock areas both occupy positions in the southwestern corner of the Devonian Elk Point Basin. This basin extended from the Northwest Territories to the southern part of North Dakota and, from the West Alberta Ridge to the subcrop edge; trending northwest through Saskatchewan and Manitoba (Fig. 20). Tableland and Hitchcock are productive within reef buildups in the Winnipegosis. Similar dolomitized buildups occur throughout the Elk Point Basin in Alberta, Saskatchewan, Manitoba and North Dakota.

Since the first commercial discovery of Winnipegosis oil at Tableland in 1986 by Home Oil and Canadian Hunter, more than 60 Winnipegosis wells have been drilled in southeastern Saskatchewan, with a cumulative production to January 1, 1991, of over 2.5 million barrels (Martindale, *et al*, 1991).

In North Dakota, the majority of pre-Mississippian production occurs along the Nesson Anticline. Major fields at Elkhorn Ranch, Antelope and Tioga produce from the Red River and Stonewall formations, the Silurian, and the Winnipegosis, Duperow and Birdbear formations (Fig. 19). In 1990, pre-Mississippian production accounted for 31% of the State's total oil production. To February, 1991, cumulative production for the pre-Mississippian in North Dakota was 248 709 214 m<sup>3</sup> (1,043,804,712 barrels) (North Dakota Geological Survey).

### Pre-Mississippian prospects in Manitoba

The Mississippian has traditionally been the primary target for exploration in southwestern Manitoba. The success of the Mississippian Bakken Formation in the Daly Field and more recent successes in deeper formations at

Tableland and Minton in Saskatchewan, demonstrates that the discovery of "nontraditional" reservoirs is possible.

Limited deep drilling in southwestern Manitoba has revealed the presence of potential reservoir horizons below the traditional Mississippian targets (Figs. 21 and 22; in pocket). Potential exists within reservoir beds found in deeper Ordovician formations (Winnipeg and Red River formations) and Devonian formations (Winnipegosis, Dawson Bay, Duperow and Birdbear formations).

Potential Manitoba Lower Paleozoic oil plays to consider are those that fall within the Paleozoic subcrop edge, and along the margins of the Elk Point Basin. The Birdtail-Waskada Axis, along which many coincident structural and isopach anomalies have been documented, must also be considered. Basement structures and salt dissolution features are also important to oil accumulation in the Lower Paleozoic.

The Ordovician Winnipeg Formation, offers potential in Manitoba where porous reservoir sandstone beds are trapped stratigraphically within interbedded shales.

In Manitoba, Red River Formation oil may be found along the flanks of the Williston Basin, in areas where dense carbonates and anhydrites are cyclically alternated with porous reservoir beds. The Red River Formation may be stratigraphically trapped in these areas and where structural closure is developed.

Fringing bank deposits and pinnacle reefs of the Winnipegosis Formation occur along the entire edge of the Elk Point Basin. Potential exists in Manitoba along the eastern edge of the Elk Point Basin, in areas where reef and bank deposits are developed (Fig. 20).

Dawson Bay, Duperow and Birdbear formations carbonates may form trap settings similar to those found along the subcrop trends of the Mississippian. Potential traps may exist where these formations are truncated at the Paleozoic erosion surface.

Numerous isopach and structural anomalies are associated with areas of Devonian Prairie Evaporite salt removal. Favourable structural traps created by salt dissolution may offer potential for deep prospects. These prospects may occur in an area immediately east of Range 27 WPM, along the salt edge of the Prairie Evaporite; an area coincident with the Birdtail-Waskada Axis.

Basement structures have played an important role in the accumulation of Ordovician and Devonian oil in Saskatchewan and North Dakota, and therefore, must be considered in Manitoba.

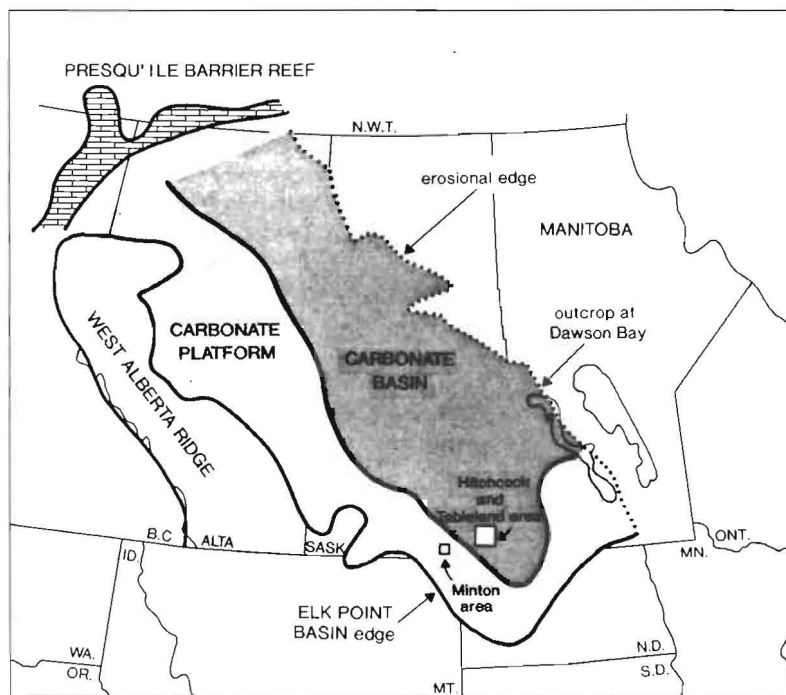
## SUMMARY

The information presented in this report provides a brief introduction to the Lower Paleozoic sequence of southwestern Manitoba. It provides a general discussion of the regional stratigraphy and petroleum potential of that

sequence. Available and recent geologic data regarding the Lower Paleozoic of southwestern Manitoba has been summarized. It is intended that this data will provide the basis for future detailed geologic study.



Figure 19: Map of the Williston Basin showing major fields and areas of pre-Mississippian production.



Simplified map of the Elk Point Basin and Presqu'ile Barrier  
(modified from Martindale *et al.*, 1991)

Figure 20: Map of the Elk Point Basin (modified from Martindale *et al.*, 1991).

## REFERENCES

- Andrichuk, J.M.  
 1959: Ordovician and Silurian stratigraphy and sedimentation in southern Manitoba, Canada: *American Association of Petroleum Geologists Bulletin*, v. 43, p. 2333-2398.
- Baillie, A.D.  
 1951: Silurian geology of the Interlake area: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 50-1, 82 p.  
 1952: Ordovician geology of Lake Winnipeg and adjacent areas: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 51-6, 64 p.  
 1953: Devonian system of the Williston Basin area: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 52-5, 105 p.
- Canadian Society of Petroleum Geologists  
 1990: *Lexicon of Canadian stratigraphy, volume 4, western Canada including eastern British Columbia, Alberta, Saskatchewan and southern Manitoba*: Calgary, Alberta, Canadian Society of Petroleum Geologists, 772 p.
- Cowan, J.R.  
 1971: Ordovician and Silurian stratigraphy in the Interlake area, Manitoba, In Turnock, A.C. (ed.), *Geoscience Studies of Manitoba*: Geological Association of Canada, Special Paper No. 9, p. 235-241.
- Elias, R.J., Nowlan, G.S., and Bolton, T.E.  
 1988: Paleontology of the type section, Fort Garry Member, Red River Formation (Upper Ordovician), southern Manitoba: Socorro, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Memoir 44, p. 341-359.
- Foerste, A.F.  
 1929a: The Ordovician and Silurian of the American arctic and sub-arctic regions: *Denison University Science Lab Journal*, v. 24, p. 27-79.  
 1929b: The cephalopods of the Red River Formation of southern Manitoba: *Denison University Science Lab Journal*, v. 24, p. 129-235.
- Genik, G.J.  
 1954: A regional study of the Winnipeg Formation: *Journal of the Alberta Society of Petroleum Geologists*, v. 2, p. 1-5.
- Haidl, F.M.  
 1987: Stratigraphic and lithologic relationships, Interlake Formation (Silurian), southern Saskatchewan, In *Summary of Investigations: Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 87-4*, p. 187-193.
- Haite, T.B., and van Hees, H.  
 1962: The origin of some anomalies in the plains of Western Canada: *Journal of the Alberta Society of Petroleum Geologist*, v. 10, No. 9, p. 511-533.
- Jamieson, E.R.  
 1979: Well data and lithologic descriptions of the Interlake Group (Silurian) in southern Saskatchewan: Regina, Saskatchewan, Saskatchewan Department of Mineral Resources, Report No. 139, 67 p.
- Kendall, A.C.  
 1976: The Ordovician carbonate succession (Big-horn Group) of southeastern Saskatchewan: Regina, Saskatchewan, Saskatchewan Department of Mineral Resources, Report No. 180, 186 p.
- Kent, D.M.  
 1960: The evaporites of the Upper Ordovician strata in the northern part of the Williston Basin: Regina, Saskatchewan, Saskatchewan Department of Mineral Resources, Report No. 46, 46 p.
- King, K.R.  
 1964: The Silurian Interlake Group in Manitoba, In Leskela, W., Brindle, J., and Harris, S.H. (eds.), *Third International Williston Basin Symposium*: Regina, Saskatchewan, Saskatchewan, North Dakota and Billings Geological Societies, p. 51-55.
- LeFever, J.A., Martiniuk, C.D., and Anderson, S.B.  
 1991: Correlation cross-sections along the United States-Canada International Border (North Dakota-Manitoba): Winnipeg, Manitoba, Manitoba Energy and Mines, Petroleum Branch, Petroleum Open-File Report POF 12-91, 5 sheets.
- Longman, M.W., Fertil, T.G., and Glennie, J.S.  
 1983: Origin and geometry of Red River dolomite reservoirs, western Williston Basin: *American Association of Petroleum Geologists Bulletin*, v. 67, p. 744-771.

- Martindale, W., Erkmen, D., Metcalfe, D., and Potts, E.  
 1991: Winnipegosis buildups in the Hitchcock area, southeastern Saskatchewan - a case study, In Christopher, J.E., and Haidl, F. (eds.), Sixth International Williston Basin Symposium: Regina, Saskatchewan, Saskatchewan, North Dakota and Montana Geological Societies, Special Publication No. 11, p. 47-63.
- Martiniuk, C.D.  
 1988: Regional geology and petroleum potential of the Bakken Formation, southwestern Manitoba: Winnipeg, Manitoba, Manitoba Energy and Mines, Petroleum Branch, Petroleum Open-File Report POF 8-88, 34 p.  
 1991: Manitoba Stratigraphic Map Series.
- McCabe, H.R.  
 1959: Mississippian Stratigraphy of Manitoba: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 58-1, 99 p.  
 1966: Tectonic framework of Paleozoic formations in Manitoba: Annual Western Meeting, CIM, Calgary, Alberta, Transactions, v. LXX, p. 180-189.  
 1971: Stratigraphy of Manitoba, an introduction and review, In Turnock, A.C. (ed.), Geoscience studies in Manitoba: Geological Association of Canada, Special Paper No. 9, p. 167-187.  
 1978: Reservoir potential of the Deadwood and Winnipeg formations, southwestern Manitoba: Winnipeg, Manitoba, Manitoba Mines, Natural Resources and Environment, Mineral Resources Division, Geological Paper GP 78-3, 54 p.  
 1980: Manitoba Stratigraphic Map Series.
- McCabe, H.R., and Bannatyne, B.B.  
 1970: Lake St. Martin crypto-explosion crater and geology of the surrounding area: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Geological Paper GP 70-3, 79 p.  
 1970a: Paleozoic and Mesozoic of the Dawson Bay area and the Manitoba Escarpment, Manitoba: Winnipeg, Manitoba, Geological Association of Canada - Mineralogical Association of Canada, Joint Annual Meeting, Guidebook for Field Trip No. 6.
- Norris, A.W., Uyeno, T.T., and McCabe, H.R.  
 1982: Devonian rocks of the Lake Winnipegosis - Lake Manitoba outcrop belt, Manitoba: Winnipeg, Manitoba, Manitoba Energy and Mines, Mines Branch, Publication 77-1, 280 p.
- Okulitch, V.J.  
 1943: The Stony Mountain Formation of Manitoba: Transactions of the Royal Society of Canada, v. 37, p. 59-74.
- Porter, J.W., and Fuller, J.G.C.M.  
 1959: Lower Paleozoic rocks of northern Williston Basin and adjacent area: American Association of Petroleum Geologists Bulletin, v. 43, p. 124-189.
- Roehl, P.O.  
 1967: Stony Mountain (Ordovician) and Interlake (Silurian) facies analogs of recent low-energy marine and subaerial carbonates, Bahamas: Bulletin of the American Association of Petroleum Geologists, v. 51, No. 10, p. 1979-2032.
- Sandberg, C.A.  
 1964: Precambrian to Mississippian paleotectonics of the southern Williston Basin (abs.), In Leskela, W., Brindle, J., and Harris, S.H. (eds.), Third International Williston Basin Symposium: Regina, Saskatchewan, Billings, North Dakota and Saskatchewan Geological Societies, p. 37-38.
- Sanford, B.V., Norris, A.W., Bostock, H.H., and Bell, R.T.  
 1968: Geology of the Hudson Bay lowlands - Operation Winisk: Geological Survey of Canada, Paper 67-60, p. 1-46.
- Saskatchewan Geological Society  
 1958: Report of the Lower Paleozoic Names and Correlations Committee: Regina, Saskatchewan, Saskatchewan Geological Society Report.
- Sinclair, G.W.  
 1959: Succession of Ordovician rocks in southern Manitoba: Geological Survey of Canada, Paper 59-5.
- Sinclair, G.W., and Leith, E.I.  
 1958: New name for an Ordovician shale in Manitoba: Journal of Paleontology, v. 32, p. 243-244.
- Sloss, L.L.  
 1963: Sequences in the cratonic interior of North America: Bulletin of the Geological Society of America, v. 74, No. 2, p. 93-114.
- Smith, D.L.  
 1963: A lithologic study of the Stony Mountain Formation and Stonewall Formation in southern Manitoba: Master's thesis, University of Manitoba, Winnipeg, Manitoba, 219 p.  
 1964: A lithologic study of the Stony Mountain and Stonewall formations in southern Manitoba (abs.): Canadian Mining Journal, v. 85, p. 114, 117.

Stearn, C.W.

- 1956: Stratigraphy and paleontology of the Interlake Group and Stonewall Formation of southern Manitoba: Geological Survey of Canada, Memoir 281.

Vigrass, L.W.

- 1971: Depositional framework of the Winnipeg Formation in Manitoba and eastern Saskatchewan, In Turnock, A.C. (ed.), Geoscience Studies in Manitoba: Geological Association of Canada, Special Paper No. 9, p. 225-234.

## **APPENDIX I**

### **Index of Lower Paleozoic core and samples, southwestern Manitoba**

The following index provides a complete listing of all available Lower Paleozoic cores and samples taken from southwestern Manitoba wells. These include wells drilled for the purpose of oil and gas exploration and Precambrian tests. The index is current to December 31, 1991. All intervals are recorded in metres (m), or feet (ft), as indicated. Formations are listed with cored intervals only. The following formations appear in the index:

#### **Mississippian:**

Bakken Formation

#### **Devonian:**

Three Forks(Lyleton) Formation

Birdbear(Nisku) Formation

Duperow Formation

Souris River Formation

First Red Beds (1st Red)

Dawson Bay Formation

Second Red Bed Member (2nd Red)

Prairie Evaporite

Winnipegosis Formation

Ashern Formation

#### **Silurian:**

Interlake Group

#### **Ordovician:**

Stonewall Formation

Stony Mountain Formation

Gunton

Stony Mountain Shale

Red River Formation

Winnipeg Formation

#### **Precambrian**

| Well Location                     | Sample Interval | Cored Formation  | Interval                                     |
|-----------------------------------|-----------------|--|--|
| <b>East of Principal Meridian</b> |                 |  |  |
| 13-34-2-5                         |                 | Jurassic-Winnipeg<br>(gypsum test)   | 280-560 ft                                   |
| 10-4-3-5                          |                 | Jurassic-Winnipeg-Precambrian<br>(gypsum test)   | 300-636 ft                                   |
| 1-5-3-5                           |                 | Jurassic-Winnipeg<br>(gypsum test)   | 300-554 ft                                   |
| 4-24-10-2                         |                 | Red River-Winnipeg-Precambrian<br>Red River-Winnipeg-Precambrian<br>(natural gas storage test) | 0-633 ft<br>61-663 ft                        |
| 6-12-11-2                         |                 | Red River (limestone test)   | 66-297 ft                                    |
| NE 14-13-4                        |                 | Red River-Winnipeg<br>(Precambrian test)   | 0-569 ft                                     |
| SW 27-13-4                        |                 | Red River-Winnipeg<br>(Precambrian test)   | 25-450 ft                                    |
| <b>West of Principal Meridian</b> |                 |  |  |
| 6-21-1-19                         |                 | Lodgepole-Bakken-Three Forks   | 3196-3269 ft                                 |
| 4-36-1-21                         | 90-3685 ft      | Bakken-Three Forks-Birdbear  | 3590-3665 ft                                 |
| 6-22-1-25                         |                 | Birdbear   | 1173-1192 m                                  |
| 11-29-1-25                        | 10-6390 ft      | Birdbear<br>Winnipegosis   | 3940-3990 ft<br>4988-5031 ft                 |
|                                   |                 | Winnipeg-Deadwood  | 6264-6324 ft                                 |
| 3-32-1-25                         | 400-3940 ft     | Birdbear   | 3929-3944 ft                                 |
| 9-13-1-26                         | 0-5175 ft       | Birdbear<br>Duperow<br>Winnipegosis  | 3952-3962 ft<br>4300-4310 ft<br>5061-5071 ft |
| 16-13-1-26                        | 0-3895 ft       | Three Forks  | 3897-3937 ft                                 |
| 11-9-1-27                         | 340-4870 ft     | Birdbear<br>Duperow  | 4235-4269 ft<br>4387-4411 ft                 |
| 16-16-1-27                        | 20-6840 ft      | Interlake<br>Winnipeg  | 5544-5573 ft<br>6757-6786 ft                 |
| 5-20-1-27                         | 370-6030 ft     | Birdbear<br>Interlake  | 4170-4205 ft<br>5602-5618 ft                 |
| 10-9-1-28                         |                 | Winnipegosis   | 1724-1742 m                                  |
| 11-13-1-28                        | 350-4480 ft     | Birdbear   | 4224-4284 ft                                 |
| 5-14-1-28                         | 0-5160 ft       | Birdbear<br>Duperow  | 4391-4406 ft<br>4735-4742 ft                 |
| 9-6-2-26                          | 0-1986 m        | Winnipegosis   | 1524-1534 m                                  |
| 5-23-3-24                         | 300-3390 ft     | Birdbear<br>Duperow  | 3366-3386 ft<br>3482-3502 ft                 |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation                              | Interval     |
|---------------|-----------------|--|--------------|
| 16-33-4-13    | 1500-3390 ft    | Duperow                                      | 1688-1703 ft |
|               |                 | Souris River                                 | 1772-1782 ft |
|               |                 | Winnipegosis                                 | 2223-2238 ft |
|               |                 | Interlake                                    | 2350-2410 ft |
|               |                 | Red River                                    | 2964-2979 ft |
| 7-34-4-15     | 500-3740 ft     | Duperow                                      | 1885-1935 ft |
|               |                 | Interlake                                    | 2745-2795 ft |
|               |                 | Red River                                    | 3260-3310 ft |
| 6-7-4-21      | 290-2795 ft     | Bakken-Three Forks                           | 2799-2824 ft |
| 4-4-4-22      |                 | Birdbear                                     | 3020-3060 ft |
| 5-3-4-25      | 370-5853 ft     | Winnipegosis                                 | 4413-4506 ft |
| 8-20-4-25     | 350-3240 ft     | Birdbear                                     | 3317-3335 ft |
| 3-22-4-25     | 1600-3250 ft    | Birdbear                                     | 3262-3312 ft |
| 3-1-5-2       |                 | Interlake-Stonewall-<br>Stony Mtn.-Red River | 210-520? ft  |
| 5-13-5-22     | 390-5030 ft     | Birdbear                                     | 2733-2793 ft |
|               |                 | Winnipegosis                                 | 3770-3805 ft |
|               |                 | Interlake                                    | 4048-4082 ft |
|               |                 | Winnipeg                                     | 5030-5061 ft |
| 1-19-5-24     | 400-3910 ft     | Duperow?                                     | 3424-3434 ft |
|               |                 | "  | 3495-3508 ft |
|               |                 | Dawson Bay                                   | 3915-3925 ft |
| 7-27-5-24     | 810-3990 ft     | Bakken-Three Forks                           | 2480-2500 ft |
|               |                 | Birdbear                                     | 2616-2626 ft |
|               |                 | Winnipegosis                                 | 3695-3705 ft |
|               |                 | Interlake                                    | 3991-4001 ft |
| 1-28-5-24     | 210-1575 m      | Winnipeg                                     | 1521-1531 ft |
| 1-29-5-24     | 540-5500 ft     | Mississippian or Devonian?                   | 2198-2248 ft |
|               |                 | Interlake                                    | 4142-4187 ft |
| 16-33-5-24    | 20-5135 ft      | Birdbear?                                    | 2940-2966 ft |
|               |                 | Souris River?                                | 3367-3394 ft |
|               |                 | "  | 3420-3447 ft |
|               |                 | Winnipegosis                                 | 3675-3700 ft |
|               |                 | Ashern                                       | 3775-3802 ft |
|               |                 | Interlake                                    | 3855-3876 ft |
|               |                 | "  | 3945-3973 ft |
|               |                 | "  | 4095-4116 ft |
|               |                 | Stonewall                                    | 4226-4231 ft |
|               |                 | Gunton                                       | 4326-4341 ft |
|               |                 | Red River                                    | 4425-4452 ft |
|               |                 |  | 4787-4813 ft |
|               |                 | Winnipeg                                     | 4979-4992 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated



| Well Location | Sample Interval | Cored Formation              | Interval     |
|---------------|-----------------|------------------------------|--------------|
| 1-28-5-24     | 210-1575 m      | Winnipeg                     | 1521-1531 m  |
| 8-13-5-29     | 5-2058 m        | Dawson Bay-Winnipegosis      | 1507-1525 m  |
| 13-16-6-12    | 340-3030 ft     | Souris River                 | 1544-1594 ft |
|               |                 | Red River                    | 2424-2474 ft |
| 7-27-6-27     | 10-3280 ft      | Birdbear                     | 3229-3239 ft |
| 11-19-7-18    | 550-2050 ft     | Birdbear                     | 1785-1835 ft |
| 5-26-7-18     | 650-1720 ft     | Lodgepole-Bakken-Three Forks | 1510-1540 ft |
|               |                 | Birdbear                     | 1598-1648 ft |
| 4-12-7-25     |                 | Prairie Evap?-Winnipegosis   | 1193-1211 m  |
| 9-26-7-25     | 800-4050 ft     | Birdbear                     | 2680-2690 ft |
|               |                 | Duperow                      | 3035-3045 ft |
|               |                 | Souris River                 | 3425-3435 ft |
|               |                 | Winnipegosis                 | 3848-3858 ft |
| 2-21-7-28     | 0-4945 ft       | Bakken-Three Forks           | 3078-3088 ft |
|               |                 | Birdbear                     | 3227-3237 ft |
|               |                 | Prairie Evap.-Winnipegosis   | 4719-4749 ft |
| 10-4-8-15     | 220-1520 ft     | Duperow                      | 1347-1357 ft |
| 3-1-8-18      | 0-3815 ft       | Birdbear                     | 1500-1570 ft |
|               |                 | Duperow                      | 1645-1650 ft |
|               |                 | "                            | 1708-1723 ft |
|               |                 | "                            | 1848-1853 ft |
|               |                 | Souris River                 | 2297-2307 ft |
|               |                 | Dawson Bay                   | 2398-2408 ft |
|               |                 | Prairie Evap.-Winnipegosis   | 2568-2578 ft |
|               |                 | Interlake                    | 2814-2824 ft |
|               |                 | Red River                    | 3335-3345 ft |
|               |                 | Precambrian                  | 3816-3826 ft |
| 12-22-8-20    | 420-2100 ft     | Birdbear                     | 1840-1890 ft |
| 2-3-8-26      |                 | Birdbear                     | 2780-2830 ft |
| 9-28-8-27     | 2500-3260 ft    | Birdbear                     | 2851-2902 ft |
|               |                 | Duperow                      | 3236-3275 ft |
| 4-14-8-28     | 10-4815 ft      | Birdbear                     | 3031-3041 ft |
|               |                 | Duperow                      | 3390-3400 ft |
|               |                 | "                            | 3582-3592 ft |
|               |                 | Souris River                 | 3862-3872 ft |
|               |                 | Prairie Evaporite            | 4242-4403 ft |
|               |                 |                              | 4413-4463 ft |
| 8-27-8-28     | 300-2840 ft     | Bakken-Three Forks           | 2807-2827 ft |
| 7-36-8-28     | 1610-2825 ft    | Bakken-Three Forks?          | 2780-2810 ft |
| 1-20-9-14     | 0-1475 ft       | Duperow                      | 1243-1250 ft |
| 10-2-9-16     | 470-3210 ft     | Winnipeg                     | 3220-3250 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation              | Interval     |
|---------------|-----------------|------------------------------|--------------|
| 10-24-9-16    | 500-3175 ft     | Winnipeg-Precambrian         | 3175-3215 ft |
| 3-5-9-19      | 510-3955 ft     | Birdbear                     | 1601-1661 ft |
|               |                 | Interlake                    | 2882-2932 ft |
|               |                 | Red River                    | 3325-3361 ft |
|               |                 | "                            | 3490-3520 ft |
| 16-27-9-19    | 520-3450 ft     | Dawson Bay                   | 2285-2315 ft |
|               |                 | Red River                    | 3100-3150 ft |
| 13-29-9-25    | 0-2425 ft       | Birdbear                     | 2428-2438 ft |
| 7-26-9-26     |                 | Bakken-Three Forks           | 2401-2431 ft |
| 5-18-9-27     | 0-3646 ft       | Three Forks                  | 2662-2672 ft |
|               |                 | Birdbear                     | 2758-2768 ft |
|               |                 | "                            | 2792-2802 ft |
|               |                 | Duperow                      | 2990-3000 ft |
| 13-14-9-28    |                 | Bakken-Three Forks           | 2730-2755 ft |
| 1-30-9-28     | 2480-2995 ft    | Three Forks                  | 2870-2920 ft |
| 1-31-9-28     |                 | Bakken-Three Forks           | 2996-3031 ft |
| 13-12-10-17   |                 | Duperow                      | 1390-1415 ft |
| 14-16-10-19   | 566-3565 ft     | Jurassic-Duperow             | 1565-1660 ft |
|               |                 | Souris River                 | 2027-2070 ft |
|               |                 | "                            | 2102-2141 ft |
|               |                 | Dawson Bay                   | 2251-2311 ft |
| 13-4-10-20    |                 | Duperow                      | 1880-2003 ft |
| 13-4-10-22    | 0-3639 ft       | Interlake                    | 3200-3256 ft |
| 11-29-10-22   | 510-2180 ft     | Duperow-Souris River         | 2180-2252 ft |
| 6-30-10-24    |                 | Birdbear                     | 657-667 m    |
| 14-34-10-24   | 295-770 m       | Jurassic-Bakken?-Three Forks | 583-655 m    |
| 2-8-10-26     | 2300-2590 ft    | Birdbear                     | 2526-2626 ft |
| 2-26-10-26    | 1800-3200 ft    | Birdbear                     | 2395-2435 ft |
|               |                 | Souris River                 | 3200-3250 ft |
| 7-27-10-26    | 1500-3285       | Birdbear                     | 2390-2430 ft |
|               |                 | Duperow                      | 2650-2665 ft |
|               |                 | "                            | 2770-2840 ft |
|               |                 | Souris River                 | 3240-3285 ft |
| 6-28-10-26    | 320-2465 ft     | Birdbear                     | 2470-2499 ft |
| 7-18-10-27    | 620-3630 ft     | Duperow                      | 3000-3120 ft |
|               |                 | Souris River                 | 3472-3592 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation              | Interval     |
|---------------|-----------------|------------------------------|--------------|
| 15-18-10-27   | 0-5375 ft       | Birdbear                     | 2609-2629 ft |
|               |                 | "                            | 2637-2649 ft |
|               |                 | Duperow                      | 3018-3038 ft |
|               |                 | Souris River-1st Red         | 3511-3526 ft |
|               |                 | Ashern                       | 4175-4192 ft |
|               |                 | Winnipeg                     | 5353-5363 ft |
| 11-19-10-27   |                 | Souris River                 | 3489-3609 ft |
| 16-20-10-27   | 320-3230 ft     | Birdbear                     | 2790-2800 ft |
|               |                 | Duperow                      | 2906-2916 ft |
|               |                 | "                            | 2930-2940 ft |
|               |                 | "                            | 3040-3050 ft |
| 1-24-10-27    | 640-2540 ft     | Birdbear                     | 2558-2625 ft |
| 12-4-10-28    |                 | Birdbear                     | 2872-2912 ft |
|               |                 | Duperow                      | 3241-3281 ft |
|               |                 | Souris River                 | 3568-3608 ft |
|               |                 | "                            | 3720-3760 ft |
| 14-4-10-28    | 430-2380 ft     | Lodgepole-Bakken-Three Forks | 2388-2727 ft |
| 10-12-10-28   | 1500-2250 ft    | Jurassic-Lodgepole-          |              |
|               |                 | Bakken-Three Forks           | 2246-2637 ft |
| 8-14-10-28    | 2410-3595 ft    | Bakken-Three Forks           | 2600-2625 ft |
|               |                 | Birdbear                     | 2716-2744 ft |
|               |                 | Duperow                      | 3080-3125 ft |
|               |                 | Souris River                 | 3605-3650 ft |
| 8-29-10-28    | 100-3150 ft     | Three Forks                  | 2658-2668 ft |
|               |                 | Birdbear                     | 2775-2795 ft |
|               |                 | Duperow                      | 3153-3176 ft |
| 14-16-10-29   |                 | Bakken-Three Forks           | 881-899 m    |
| 4-27-11-22    | 550-4570 ft     | Duperow                      | 2115-2165 ft |
|               |                 | Souris River                 | 2472-2522 ft |
|               |                 | Dawson Bay                   | 2580-2630 ft |
|               |                 | Winnipegosis                 | 2788-2838 ft |
| 4-5-11-24     | 110-653 m       | Birdbear                     | 653-672 m    |
| 2-20-11-24    | 410-4570 ft     | Winnipeg                     | 4520-4526 ft |
| 16-7-11-25    |                 | Birdbear                     | 2225-2285 ft |
| 5-11-11-26    | 1800-2225 ft    | Three Forks-Birdbear         | 2279-2334 ft |
| 12-16-11-26   |                 | Lodgepole-Bakken-Three Forks | 1992-2342 ft |
| 15-12-11-27   |                 | Bakken-Three Forks           | 2408-2433 ft |
| 15-16-11-27   | 0-2938 ft       | Birdbear                     | 2502-2542 ft |
| 7-8-11-29     | 160-4710 ft     | Prairie Evaporite            | 4080-4115 ft |
|               |                 | Winnipegosis                 | 4517-4537 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation                           | Interval     |
|---------------|-----------------|---|--------------|
| 3-17-12-24    | 10-4510 ft      | Birdbear                                  | 2035-2045 ft |
|               |                 | Duperow                                   | 2280-2285 ft |
|               |                 | Precambrian                               | 4511-4512 ft |
| 1-10-12-26    | 100-2260 ft     | Bakken-Three Forks                        | 2176-2201 ft |
| 15-11-12-26   | 180-1445 m      | Winnipeg                                  | 1384-1402 m  |
| 4-32-12-26    |                 | Birdbear                                  | 2284-2345 ft |
| 10-33-12-26   | 500-2620 ft     | Birdbear-Duperow                          | 2220-2270 ft |
| 9-22-12-27    | 10-2225 ft      | Bakken-Three Forks                        | 2124-2135 ft |
|               |                 | Birdbear                                  | 2227-2257 ft |
| 9-28-12-28    | 320-2430 ft     | Lodgepole-Bakken-Three Forks              | 2315-2365 ft |
| 13-4-12-29    | 10-2870 ft      | Bakken-Three Forks                        | 2700-2720 ft |
| 1-10-12-29    |                 | Lodgepole-Bakken-<br>Three Forks-Birdbear | 2360-2750 ft |
| 12-19-12-29   | 215-828 m       | Bakken-Three Forks                        | 807-818 m    |
| 16-29-12-29   | 12-5475 ft      | Three Forks                               | 2600-2638 ft |
| 5-29-14-14    |                 | Cretaceous-Souris R.                      | 950-956 m    |
|               |                 | Stony Mountain                            | 1878-1891 ft |
| 15-29-14-14   | 10-2580 ft      | Precambrian                               | 2562-3077 ft |
| 16-26-14-18   | 440-3574 ft     | 1st Red-Dawson Bay                        | 2104-2154 ft |
| 12-10-14-25   | 520-4417 ft     | Birdbear                                  | 1952-2002 ft |
|               |                 | Interlake                                 | 3570-3620 ft |
|               |                 | Red River                                 | 3830-3880 ft |
|               |                 | "   | 3975-4025 ft |
| 6-31-14-27    |                 | Bakken-Three Forks                        | 1795-1835 ft |
| 9-9-14-29     | 320-2315 ft     | Bakken-Three Forks                        | 2191-2245 ft |
| 9-11-14-29    | 240-2265 ft     | Three Forks                               | 2138-2157 ft |
| 3-13-14-29    | 320-2210 ft     | Lodgepole-Bakken-Three Forks              | 2063-2104 ft |
|               |                 | Bakken-Three Forks                        | 2105-2140 ft |
| 4-6-15-2      | 5-1045 ft       | Gunton                                    | 338-363 ft   |
|               |                 | Red River                                 | 458-639 ft   |
|               |                 | "   | 750-800 ft   |
| 4-29-15-26    | 400-1920 ft     | Bakken-Three Forks                        | 1849-1869 ft |
| 10-8-15-27    | 300-3480 ft     | Three Forks-Birdbear                      | 1883-1891 ft |
|               |                 | Birdbear                                  | 1912-1930 ft |
| 3-21-15-27    | 350-1840 ft     | Lodgepole-Bakken-Three Forks              | 1705-1765 ft |
| 9-21-15-27    |                 | Bakken-Three Forks                        | 1712-1717 ft |
| 12-22-15-27   | 320-1820        | Lodgepole-Bakken-Three Forks              | 1685-1750 ft |
| 10-28-15-27   | 470-1815 ft     | Lodgepole-Bakken-Three Forks              | 1660-1705 ft |
| 4-19-15-28    | 1200-2040 ft    | Bakken-Three Forks                        | 1859-1899 ft |
| 12B-20-15-28  |                 | Dawson Bay-Prairie Evap.                  | 972-1008 m   |
| 4B-22-15-28   |                 | Dawson Bay-Prairie Evap.                  | 956-992 m    |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation                           | Interval     |
|---------------|-----------------|---|--------------|
| 16-28-15-28   |                 | Dawson Bay-Prairie Evap.                  | 944-980 m    |
| 4-32-15-28    |                 | Bakken-Three Forks                        | 1807-1860 ft |
|               |                 | Dawson Bay-Prairie Evap.                  | 3138-3258 ft |
|               |                 | " "                                       | 3170-3317 ft |
| 12-2-15-29    | 290-2210 ft     | Three Forks                               | 2110-2121 ft |
| 14D-12-15-29  |                 | Prairie Evaporite                         | 996-1032 m   |
| 4-36-15-29    |                 | Prairie Evaporite                         | 3170-3317 ft |
| 8-34-16-21    | 600-3930 ft     | Interlake                                 | 2863-2913 ft |
|               |                 | Interlake-Stonewall                       | 3145-3195 ft |
|               |                 | Stony Mtn. Shale-Red River                | 3330-3380 ft |
|               |                 | Red River                                 | 3538-3590 ft |
|               |                 | Winnipeg                                  | 3802-3852 ft |
| 3-25-16-25    | 480-3045 ft     | Dawson Bay-Prairie Evap.                  | 3044-3194 ft |
| 8-8-16-27     | 400-1700 ft     | Bakken-Three Forks                        | 1692-1742 ft |
| 9-8-16-27     | 350-1800 ft     | Birdbear                                  | 1805-1844 ft |
| 11-9-16-27    | 320-1799 ft     | Lodgepole-Bakken-Three Forks              | 1680-1730 ft |
| 14-35-16-27   | 420-2235 ft     | Bakken-Three Forks                        | 1809-1828 ft |
|               |                 | Birdbear                                  | 1906-1942 ft |
| 12-4-16-28    |                 | Dawson Bay-Prairie Evap.                  | 937-973 m    |
| 13-6-16-28    | 450-3110 ft     | Dawson Bay-Prairie Evap.                  | 3110-3260 ft |
| 16-18-16-28   |                 | Dawson Bay-Prairie Evap.                  | 3026-3176 ft |
| 13-2-16-29    |                 | Souris River-Dawson Bay-Prairie Evaporite | 2945-3245 ft |
| 13C-4-16-29   |                 | Dawson Bay-Prairie Evap.                  | 974-1010 m   |
| 10-14-16-29   |                 | Dawson Bay-Prairie Evap.                  | 3078-3228 ft |
| 7-15-16-29    | 400-1940 ft     | Lodgepole-Bakken-Three Forks              | 1710-1780 ft |
| 1-21-16-29    |                 | Lodgepole-Bakken-Three Forks              | 527-541 m    |
| 3-25-16-29    | 480-3045 ft     | Prairie Evaporite                         | 3044-3194 ft |
| 4B-20-16-29   | 905-965 m       | Dawson Bay-Prairie Evap.                  | 965-992 m    |
| 4-22-16-29    | 250-887 ft      | Souris River-Dawson Bay-Prairie Evaporite | 887-1050 m   |
| 14-28-16-29   |                 | Prairie Evaporite                         | 3087-3207 ft |
| 1-34-16-29    |                 | Dawson Bay-Prairie Evap.                  | 3026-3176 ft |
| 1-27-17-26    | 0-4256 ft       | Birdbear                                  | 1787-1857 ft |
|               |                 | Duperow                                   | 2254-2264 ft |
|               |                 | "   | 2313-2323 ft |
|               |                 | "   | 2463-2468 ft |
|               |                 | Souris River                              | 2768-2775 ft |
|               |                 | Interlake                                 | 3263-3280 ft |
|               |                 | Winnipeg                                  | 4149-4154 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation                               | Interval     |
|---------------|-----------------|---|--------------|
| 16-17-17-27   | 600-2400 ft     | Bakken-Three Forks                            | 1811-1836 ft |
|               |                 | Birdbear                                      | 1912-1938 ft |
| 2-16-17-28    |                 | Bakken-Three Forks                            | 1621-1671 ft |
| 11-30-17-28   | 430-1730 ft     | Bakken-Three Forks                            | 1576-1624 ft |
| 8-2-17-29     | 470-2980 ft     | Dawson Bay-Prairie Evap.                      | 2975-3101 ft |
| 3-4-17-29     | 460-2960 ft     | Prairie Evaporite                             | 3045-3213 ft |
| 8-6-17-29     | 500-3000 ft     | Dawson Bay-Prairie Evap.                      | 3088-3238 ft |
| 5-10-17-29    | 1310-2518 ft    | Souris River-Dawson Bay-<br>Prairie Evaporite | 2518-2931 ft |
| 13-11-17-29   | 10-2520         | Dawson Bay-Prairie Evap.                      | 2755-2905 ft |
| 15-16-17-29   | 0-2970 ft       | Prairie Evaporite                             | 2960-3112 ft |
| 8-28-17-29    | 600-2930 ft     | Bakken-Three Forks                            | 1636-1671 ft |
|               |                 | Prairie Evaporite                             | 2940-3040 ft |
| 6-29-17-29    | 475-2930 ft     | Prairie Evaporite                             | 2963-3060 ft |
| 6-30-17-29    | 0-2710 ft       | Prairie Evaporite                             | 2722-2842 ft |
| 15-32-17-29   | 0-2970 ft       | Prairie Evaporite                             | 2975-3037 ft |
| SW 25-18-10   |                 | Jurassic-Dawson Bay?                          | 121-201 ft   |
| 2-6-18-29     | 500-2935 ft     | Bakken-Three Forks                            | 1645-1689 ft |
|               |                 | 2nd Red-Prairie Evap.                         | 2940-3065 ft |
| 11-18-18-29   | 0-2596 ft       | Prairie Evaporite                             | 2975-3033 ft |
| 16-18-18-29   | 600-4450 ft     | Duperow                                       | 2047-2055 ft |
|               |                 | Souris River                                  | 2674-2680 ft |
|               |                 | 1st Red                                       | 2715-2746 ft |
|               |                 | Dawson Bay                                    | 2759-2769 ft |
|               |                 | 2nd Red-Prairie Evap.                         | 2905-2935 ft |
|               |                 | Winnipegosis                                  | 3147-3157 ft |
|               |                 | "   | 3295-3297 ft |
|               |                 | Ashern-Interlake                              | 3340-3362 ft |
|               |                 | Winnipeg                                      | 4292-4310 ft |
| 4-32-18-29    | 0-3054 ft       | Dawson Bay-Prairie Evap.                      | 2848-2948 ft |
| 16-32-19-27   | 0-4170 ft       | Birdbear                                      | 1749-1754 ft |
|               |                 | Duperow                                       | 1876-1897 ft |
|               |                 | "   | 1918-1963 ft |
|               |                 | "   | 2354-2379 ft |
|               |                 | Souris River (base)                           | 2656-2661 ft |
|               |                 | Dawson Bay                                    | 2750-2760 ft |
|               |                 | Prairie Evaporite                             | 2880-2890 ft |
|               |                 | "   | 2951-2961 ft |
|               |                 | Interlake                                     | 3256-3276 ft |
|               |                 | Precambrian                                   | 4169-4173 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation               | Interval     |
|---------------|-----------------|-------------------------------|--------------|
| 13-6-19-29    | 310-2850 ft     | Bakken-Three Forks            | 1558-1615 ft |
|               |                 | Prairie Evaporite             | 2850-2962 ft |
| 9-11-19-29    | 3040-3235 ft    | Prairie Evaporite             | 2959-3019 ft |
| 7-15-19-29    |                 | 2nd Red-Prairie Evap.         | 2522-2672 ft |
| 7A-15-19-29   | 310-1455 ft     | Bakken-Three Forks            | 1305-1341 ft |
| 4-17-19-29    | 0-3290 ft       | Bakken-Three Forks            | 1601-1641 ft |
|               |                 | Prairie Evaporite             | 3133-3193 ft |
| 8-23-20-6     |                 | Red River-Winnipeg            | 500-1000 ft  |
| 4-22-20-25    | 155-1588 ft     | Jurassic-Devonian             | 1449-1956 ft |
| 16-20-21-5    | 0-1047 ft       | Winnipeg                      | 950-980 ft   |
| 9-9-21-29     | 350-1285 ft     | Bakken-Three Forks            | 1162-1210 ft |
|               |                 | Three Forks-Birdbear          | 1285-1302 ft |
| 1-21-22-28    |                 | Birdbear                      | 1642-1658 ft |
| 4-33-23-16    | 20-440 ft       | Winnipegosis                  | 678-721 ft   |
| 1-34-25-28    | 350-2930 ft     | Dawson Bay                    | 2308-2367 ft |
| 14-16-23-29   | 330-1502 ft     | Birdbear                      | 1502-1560 ft |
| NE 35-24-2    |                 | Stony Mtn.-Red River-Winnipeg | 10-544 ft    |
| 4-33-23-16    | 20-440 ft       | Winnipegosis                  | 678-721 ft   |
| 13-4-24-27    | 0-2975 ft       | Birdbear                      | 1452-1468 ft |
|               |                 | Duperow                       | 1547-1557 ft |
|               |                 | 2nd Red                       | 2463-2474 ft |
|               |                 | Interlake                     | 2922-2936 ft |
| NE 11-25-3    |                 | Stonewall-Stony Mtn.-Red R.-  |              |
|               |                 | Winnipeg-Precambrian?         | 25-700 ft    |
| 8-30-29-8     | 10-910 ft       | Winnipegosis                  | 810-827 ft   |
| 8-20-32-8     | 10-1042 ft      | Lake St. Martin Breccia       | 431-454 ft   |
|               |                 | Precambrian                   | 1042-1055 ft |
| 3-29-36-25    |                 | Souris River-Winnipeg         | 267-1668 ft  |
| 13-10-36-26   |                 | Souris River-Winnipeg         | 316-1757 ft  |
| 1-28-36-26    |                 | Duperow-Winnipeg              | 304-1727 ft  |
| 15-32-36-26   |                 | Souris River-Winnipeg         | 284-1697 ft  |
| 9-1-37-28     | 0-1035 ft       | Dawson Bay                    | 840-856 ft   |
|               |                 | Winnipegosis                  | 870-890 ft   |
|               |                 | "                             | 1092-1136 ft |
|               |                 | "                             | 1141-1165 ft |
|               |                 | "                             | 1182-1190 ft |
|               |                 | Winnipegosis-Ashern-          |              |
|               |                 | Interlake                     | 1197-1264 ft |
|               |                 | Interlake                     | 1280-1288 ft |
|               |                 | "                             | 1313-1324 ft |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated

| Well Location | Sample Interval | Cored Formation   | Interval     |
|---------------|-----------------|---|--------------|
|               |                 | "   | 1360-1369 ft |
|               |                 | "   | 1419-1429 ft |
|               |                 | "   | 1479-1484 ft |
|               |                 | Stonewall   | 1534-1562 ft |
|               |                 | Gunton  | 1611-1616 ft |
|               |                 | Stony Mtn. Shale  | 1653-1658 ft |
|               |                 | Red River   | 1698-1703 ft |
|               |                 | "   | 1754-1759 ft |
|               |                 | "   | 1802-1807 ft |
|               |                 | "   | 1857-1862 ft |
|               |                 | "   | 1913-1917 ft |
|               |                 | Winnipeg  | 1967-1987 ft |
|               |                 | Precambrian   | 2037-2047 ft |
| 6-16-44-25    |                 | Jurassic/Cretaceous-Souris                              |              |
|               |                 | River-Interlake   | 100-500 ft   |
| 10-31-44-26   |                 | Souris River-Interlake                                  | 125-500 ft   |
| 4-33-44-26    |                 | Dawson Bay-Interlake                                    | 225-500 ft   |
| 14-36-44-27   |                 | Souris River?-Dawson Bay?                               | 251-363 ft   |
| 11-8-45-25    | 0-1122 ft       | Precambrian   | 1122-1138 ft |
| 12-20-47-14   |                 | Interlake (foundation test-<br>Grand Rapids)            | 5-169 ft     |
| 16-21-48-13   |                 | Stony Mtn?-Red River-Winnipeg                           |              |
|               |                 | Precambrian (foundation test-<br>Grand Rapids)          | 250-486 ft   |
| 1-28-48-13    |                 | Interlake-Ordovician (foundation<br>test- Grand Rapids) | 7-299 ft     |
| 3-9-56-25     |                 | Interlake-Ordovician<br>(Precambrian test)              | 94-497 ft    |
| 9-9-64-16     |                 | Red River-Winnipeg<br>(Precambrian test)                | 27-132 ft    |

**Note:** Cores and samples measured in metres (m) or feet (ft), as indicated



