DIAGENESIS AND POROSITY DEVELOPMENT OF MISSION CANYON RESERVOIR INTERVAL IN 07 43B POOL, PIERSON FIELD, MANITOBA

A Thesis

Submitted to

The Faculty of Graduate Studies

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

© Mushfique Ahmed

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ABSTRACT

The 07 43B pool is in the northeastern part of the Pierson field located in southwestern Manitoba. This pool is situated within the subcrop of Mississippian MC-3a beds which constitute the producing zone. The MC-3a beds can be correlated with beds in the adjacent Waskada area of southwestern Manitoba.

In the study area, the MC-3a beds represent a carbonate tidal flat complex. Four lithofacies have been identified. These are: algal, vadolite, bioclastic grainstone and peloidal grainstone facies. Except for the vadolite facies, all other facies refer to depositional environments. The vadolite is likely to have formed from subaerial exposure in a strandline environment during early diagenesis.

Diagenetic alteration has been broadly divided into early and late. The early diagenesis is characterized principally by biological diagenesis, formation of vadolite, and calcite cementation. The late stage of diagenesis includes dolomitization, anhydritization, the formation of other authigenic minerals, compaction, pressure solution, fracturing, and leaching. A relative chronology of these events has been reconstructed which, in general, shows considerable overlap of the diagenetic processes.

The development of porosity is not true facies selective. Late diagenetic processes have been inferred to control the preservation of primary porosity as well as the

development of leached porosity and minor intercrystalline porosity. However, facies with higher primary porosity (e.g, vadolite) are more likely to show higher porosity development, and consequently represent the principal reservoir facies. Oil has been found in the traps of primarily structural origin; this is true with the limitation of updip and/or lateral facies change involving porosity development.

TABLE OF CONTENTS

			PAGE
ABSTRACT			i
LIST OF FIGURES			vii
LIST OF TABLES			ix
LIST OF PLATES			x
ACKNOWLEDGEMENTS			xi
CHAPTER			
1	INTRODUCTION		
	1.1	Location	1
	1.2	Purpose of Study	1
	1.3	Methods of Study	6
	1.4	Previous Work	7
	1.5	Regional Geology	8
	1.6	Stratigraphy of the Study Area	16
	1.7	Hydrocarbon Traps of the Study Area	17
	1.7.1	Structural-Topographic Traps	17
	1.7.2	Truncation Traps	22
	1.7.3	Facies Traps	22
2	DEPOSITIONAL ENVIRONMENT		
	2.1	Description of Lithofacies	25
	2.1.1	Stromatolite/Cryptalgal Laminite/ Pseudostromata Facies	25
	2.1.1.1	Stromatolite Subfacies	26
	2.1.1.2	Cryptalgal Laminite Subfacies	27

CHAPTER		PAGE
	2.1.1.3 Pseudostromata Subfacies	27
	2.1.2 Vadolite Facies	28
	2.1.3 Bioclastic Grainstone Facies	29
	2.1.4 Peloidal Grainstone Facies	30
	2.2 Interpretation of Lithofacies	30
	2.2.1 Stromatolite/Cryptalgal Laminite/ Pseudostromata Facies	30
	2.2.1.1 Stromatolite Subfacies	30
	2.2.1.2 Cryptalgal Laminite Subfacies	32
	2.2.1.3 Pseudostromata Subfacies	32
	2.2.2 Vadolite Facies	33
	2.2.3 Bioclastic Grainstone Facies	36
	2.2.4 Peloidal Grainstone Facies	37
	2.3 Summary of Depositional Environment	37
3	DIAGENESIS	
	3.1 Introduction	40
	3.2 Biological Diagenesis	40
	3.2.1 Micritization	40
	3.2.2 Sparmicritization	42
	3.2.3 Burrowing	43
	3.3 Chemical Diagenesis	43
	3.3.1 Calcite Cementation	43
	3.3.1.1 Marine Cement	44
	3.3.1.1.1 Marine Phreatic Cement	45
	3.3.1.1.2 Vadose Marine Cement	45

CHAPTER PAGE

3.3.1.2 Freshwater Cement 46

3.3.1.2.1 Freshwater Vadose Cement 46

3.3.1.2.2 Syntaxial Overgrowth 47

3.3.1.2.3 Equant Cement 47

3.3.1.3 Timing of Cementation 47

3.3.2 Neomorphism 48

3.3.3 Formation of Dolomite and Anhydrite 50

3.3.3.1 Formation of Altered Zone 50

3.3.3.2 Types of Dolomite 54

3.3.3.3 Formation of Dolomite 56

3.3.3.4 Types of Anhydrite 60

3.3.3.5 Formation of Anhydrite 63

3.3.3.6 Gypsification 65

3.3.4 Dedolomitization 66

3.3.5 Other Authigenic Minerals 67

3.3.5.1 Hematite 67

3.3.5.2 Pyrite 68

3.3.5.3 Limonite 68

3.3.5.4 Silica 69

3.3.6 Leaching 70

3.3.7 Pressure Solution 70

3.4 Compaction 72

3.5 Fracturing 73

3.6 Summary of Diagenesis 74

CHAPTER PAGE

4 DEVELOPMENT OF POROSITY

4.1 Introduction 81

4.2 Pore Types 81

4.3 Porosity as a Function of Dolomitization 83

4.4 Porosity as a Function of Anhydritization 87

4.5 Summary of Porosity Development 88

5 SUMMARY 89

REFERENCES 91

PLATES 98

APPENDIX

A Description of Core Slabs 207

B Core Analyses Data 230

C Statistical Data 235

LIST OF FIGURES

FIGURE		PAGE
1	Location map of the study area.	3
2	Mission Canyon Subcrop-southwestern Manitoba.	5
3	Outline map of the Williston Basin.	10
4	Cross-section - southwestern Manitoba.	13
5	Mississippian correlation and nomenclature chart.	15
6	Structural cross-section depicting correlation of Mission Canyon Members between Pierson and Waskada areas.	Back Pocket
7	Structure contour map (in meters) on Mississippian erosion surface.	19
8	Isopach map (in meters) of Lower Amaranth Formation.	21
9	Structure contour map (in meters) on top of MC-2 marker.	24
10	Structural cross-section showing absence of oil accumulation in: (a) updip direction due to facies change, and (b) downdip due to water encroachment.	Back Pocket
11	Structural cross-section depicting control of lateral facies change on oil accumulation.	Back Pocket
12	Lithologic logs of the studied drill cores. Associated porosity (all wells) and permeabilities (two wells) are also shown.	Back Pocket

FIGURE		PAGE
13	Panel diagram constructed from the present study showing lithofacies changes.	35
14	Diagramatic north-south sections through southeastern Saskatchewan illustrating various hypotheses suggested for the origin of the altered zone.	52
15	Stability fields of gypsum and anhydrite at 101.3 KPa total pressure.	52
16	Stability fields of gypsum (G) and anhydrite (A) as a function of temperature and pressure.	52

LIST OF TABLES

TABLES		PAGE
1	Relative chronology of the important diagenetic events in the sediments of the study area.	76
2	Interrelationship of parameters responsible for porosity development.	86

LIST OF PLATES

PLATES		PAGES
1 - 26	Textural Rock Types	99 - 149
27 - 51	Diagenesis	151 - 199
52 - 54	Porosity	201 - 205

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CHAPTER 1

INTRODUCTION

1.1 Location

The Pierson oil field is situated in the extreme southwest corner of the Province of Manitoba lying about 23 km north of the Canadian - United States border, and about 9 km east of Manitoba - Saskatchewan border (Fig. 1). It is located within Townships 2 and 3, Ranges 28 and 29 WPM.

The 07 43B pool (also known as MC-3aB pool), is the largest of the Pierson field pools, and is located in the northeastern part of the field. This pool, confined to Township 3 and Ranges 28 and 29 WPM, is within the Mississippian MC-3a subcrop (Fig. 2). The discovery well of this pool at 13-17-3-28 W1 was drilled by King Resources Ltd. and Partners in 1965.

1.2 Purpose of Study

The purpose of this study is to provide a geologic assessment of the producing interval MC-3a beds, in the 07 43B pool, Pierson field. The objectives were to:

1. Illustrate the stratigraphic relationships of the MC-3a beds.
2. Describe the trapping mechanisms of hydrocarbon.
3. Identify the depositional facies.
4. Document the sequence of diagenetic events.
5. Explain the development of porosity.

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PAGE(S) *Fig. 1* IS/ARE EST/SONT *filmed IN SECTIONS*

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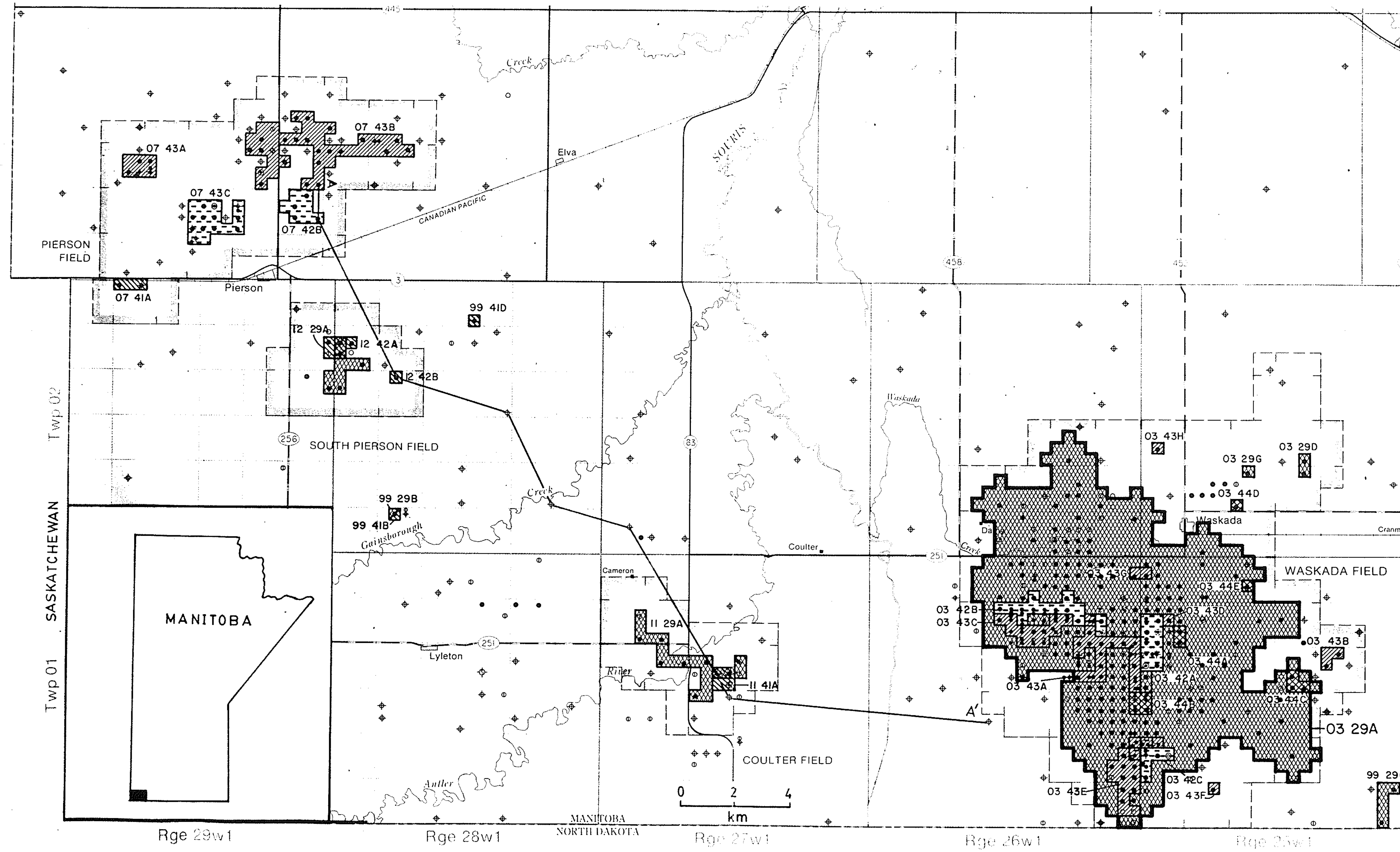
Fig. 1 Location map of the study area. (After Pool Location Map, Petroleum Branch, Department of Energy and Mines, Manitoba, 1983).



PIERSON FIELD
07 43A
07 43B
07 43C
07 42B
07 41A
Pierson
Elva
CANADIAN PACIFIC
SOURIS
Creek
12 29A
12 42A
12 42B
99 41D
SOUTH PIERSON FIELD
99 29B
99 41B
Gainsborough
Creek
Twp 02
Twp 01
SASKATCHEWAN
MANITOBA
Lyleton
Antler
River
Cameron
Coulter
11 29A
11 41A
COULTER FIELD
0
2
4
km
MANITOBA
NORTH DAKOTA
Waskada
Waskada
Cranmer
WASKADA FIELD
03 43H
03 29G
03 29D
03 44D
03 43G
03 44E
03 42B
03 43C
03 43D
03 43B
03 44A
03 42A
03 43A
03 41
03 44C
03 29A
A'
03 42C
03 43E
03 43F
99 29C
Rge 29w1
Rge 28w1
Rge 27w1
Rge 26w1
Rge 25w1

Fig. 1

Fig. 2 Mission Canyon subcrop-southwestern Manitoba

(After Halabura, 1984)

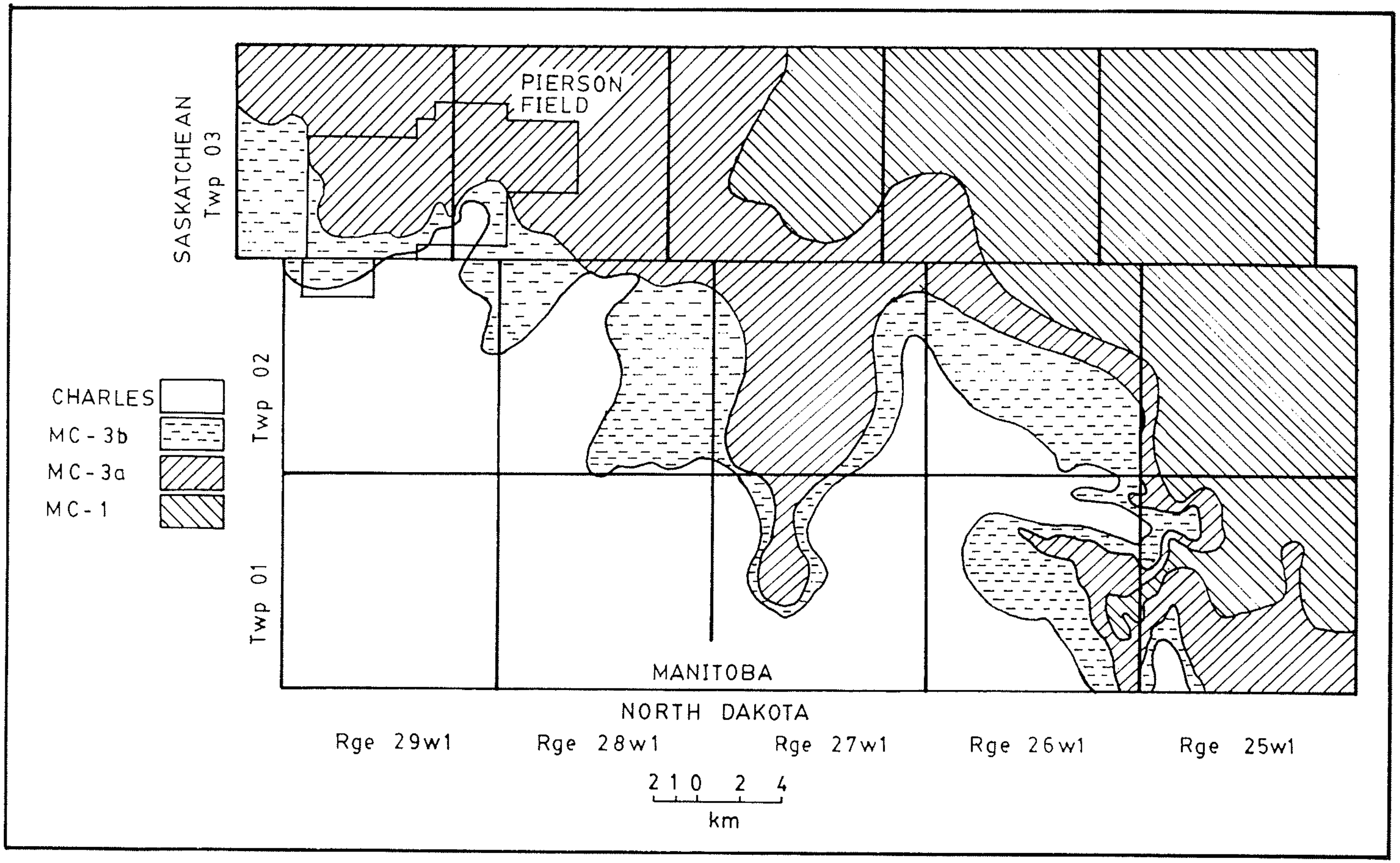

PIERSON
FIELD
SASKATCHEAN
Twp 03
Twp 02
Twp 01
CHARLES
MC - 3b
MC - 3a
MC - 1
MANITOBA
NORTH DAKOTA
Rge 29w1
Rge 28w1
Rge 27w1
Rge 26w1
Rge 25w1
2 1 0 2 4
km

Fig. 2

1.3 Methods of Study

All available cores of studied pool were examined and sampled. These are: 1-18-3-28 W1 (17.98 m), 3-20-2-28 W1 (10.67 m), 2-13-3-29 W1 (7.67 m), 14-13-3-29 W1 (8.13 m) and 15-13-3-29 W1 (7.92 m). Geophysical logs from the wells were also examined.

Stratigraphic and structural data were presented in the form of cross-sections, structure contour maps and isopach map.

To study the sedimentary petrography polished representative slabs from the drill cores were examined both parallel and perpendicular to the stratification under a binocular microscope. A total of 144 thin sections were prepared from the rock plaquettes cut both parallel and perpendicular to stratification from the slabs, and stained with Alazarin Red S. The thin sections were studied under a Leitz Wetzlar SM-LUX-POL microscope and lithologic logs were prepared from the obtained data. Photomicrographs of prepared thin sections and polished core slabs as well as photographs of polished core slabs were taken to document the data.

Porosity and permeability data from core analysis were available for two studied drilled cores. For the rest of the cores estimation of porosity was carried out microscopically.

To show the interrelationships of various parameters responsible for the development of porosity a correlation matrix was prepared using data from the section below the altered zone in 1-18-3-28 W1 well. The determinations of amount of dolomite rhombs and anhydrite as well as dolomite rhomb size was carried out microscopically. The mean and the standard deviation of dolomite rhomb size were calculated on the basis of measurements of twenty randomly selected dolomite crystals along the long diagonals of the rhombs.

1.4 Previous Work

McCabe (1959) in his regional stratigraphic study first covered the Pierson area. Later McCabe (1963) discussed the stratigraphic and structural factors responsible for the oil accumulation in the MC-3a beds in the Pierson field. These works were published before the discovery of the 07 43B pool. Ghazar (1978) undertook a reconnaissance study to evaluate the hydrocarbon potential in the Pierson area. The only other work is a detailed stratigraphic and sedimentological study of the MC-3 Member in this area by Halabura (1984). These studies provided specific information relevant to the present study.

Previous studies of the Mission Canyon sequence in adjoining areas gave rise to a number of different predictions regarding the porosity development. Gerhard et al. (1978) suggested that permeability of the Frobisher-Alida beds producing in the Glenburn field (northeastern Williston Basin), North Dakota is associated with early diagenetic strandline vadose pisolite. This coated-grain facies was previously regarded as oolite formed in agitated water of submarine shoals on a platform edge far away basinward from the shoreline. Elliot (1982) and McCulloch-Smith (1984) working on the Haas field (northeastern Williston Basin), North Dakota and the Woodnorth field, southwestern Manitoba respectively concluded that most porosity was secondary or secondarily enlarged and resulted from leaching of calcite during later diagenesis. Lindsay (1982), Lindsay and Roth (1982), and Lindsay and Kendall (1984, quoted by Elliot, 1982), in their study on Little Knife field (central Williston Basin), North Dakota related the development of porosity to early diagenetic anhydrite replacement of skeletal fragments followed by dolomitization of the muddy matrix, and late diagenetic anhydrite leaching. These contrasting scenarios may reflect either regional differences or different interpretations of similar processes due to lack of sufficient data.

1.5 Regional Geology

Southwestern Manitoba constitutes the northeastern corner of the Williston Basin (Fig. 3). The Williston Basin encompasses an area of about 160,934 sq. km with its centre in northwestern North Dakota (McCabe, 1959).

The Williston Basin may be defined as an autogeosyncline of Kay (1951) or an intracratonic basin of Krumbein and Sloss (1951) (Laird, 1956).

It had been tectonically active from Ordovician to

Fig. 3 Outline map of the Williston Basin (After McCabe 1959).

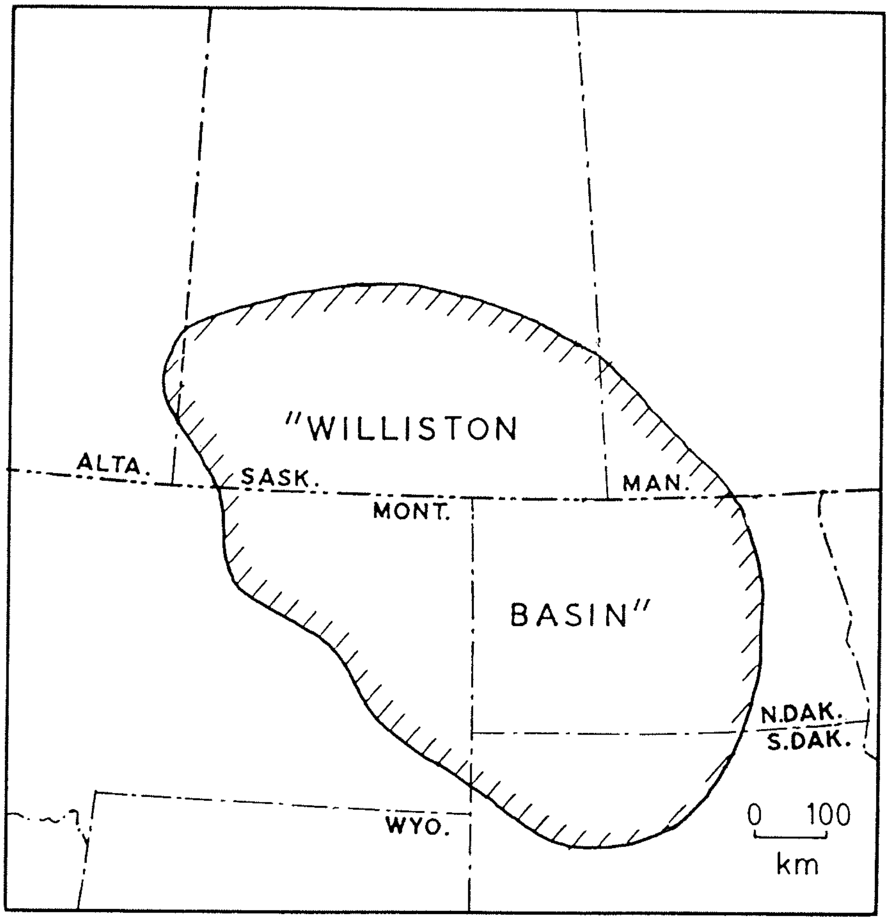


Fig. 3

Cretaceous time and, hence, was the principal feature governing the pattern of sedimentation in this region during this time (McCabe, 1971).

Two gross lithologic sequences are present in southwestern Manitoba:

1. The lower Paleozoic sequences composed almost entirely of carbonate rocks.
2. The upper Mesozoic and Cenozoic sequences consisting mainly of shale and sandstone.

These two sequences are separated by a pronounced angular unconformity (Fig. 4) which results in the burial of the entire Mississippian system as well as the upper part of the Devonian beneath the overlapping Mesozoic strata. Consequently, an irregular series of northwest trending subcrop belts developed beneath the Jurassic strata.

The Mississippian system in southwestern Manitoba consists of four formations. These are, from bottom to top: Bakken, Lodgepole, Mission Canyon, and Charles Formations (Fig. 5).

The Bakken Formation consists of two highly radioactive black shales separated by grey variegated calcareous sandstones, siltstones or dolomites, and conformably overlies upper Devonian strata (Ghazar, 1978). This formation is one of the three significant source rocks for hydrocarbon in the Williston Basin (Williams, 1974).

The Lodgepole Formation rests conformably on the Bakken Formation, and is composed of argillaceous, cherty,

Fig. 4 Cross-section - southwestern Manitoba. (After McCabe, 1963).

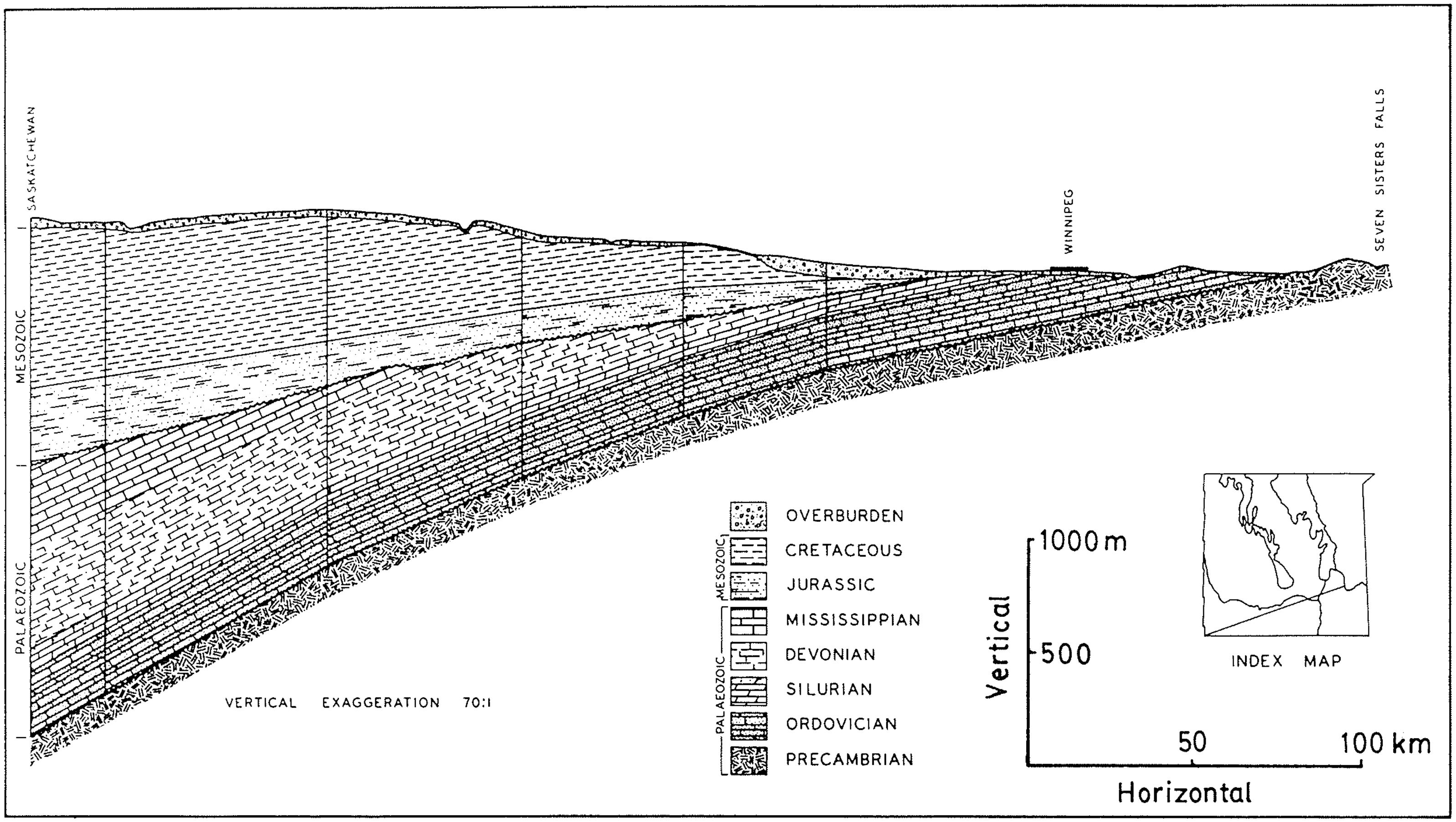

SASKATCHEWAN
WINNIPEG
SEVEN SISTERS FALLS
MESOZOIC
PALAEOZOIC
VERTICAL EXAGGERATION 70:1
OVERBURDEN
CRETACEOUS
JURASSIC
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
PRECAMBRIAN
Vertical
1000 m
500
50
100 km
Horizontal
INDEX MAP

Fig. 4

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Fig. 5 Mississippian Correlation and Nomenclature Chart. (After McCabe, 1959).

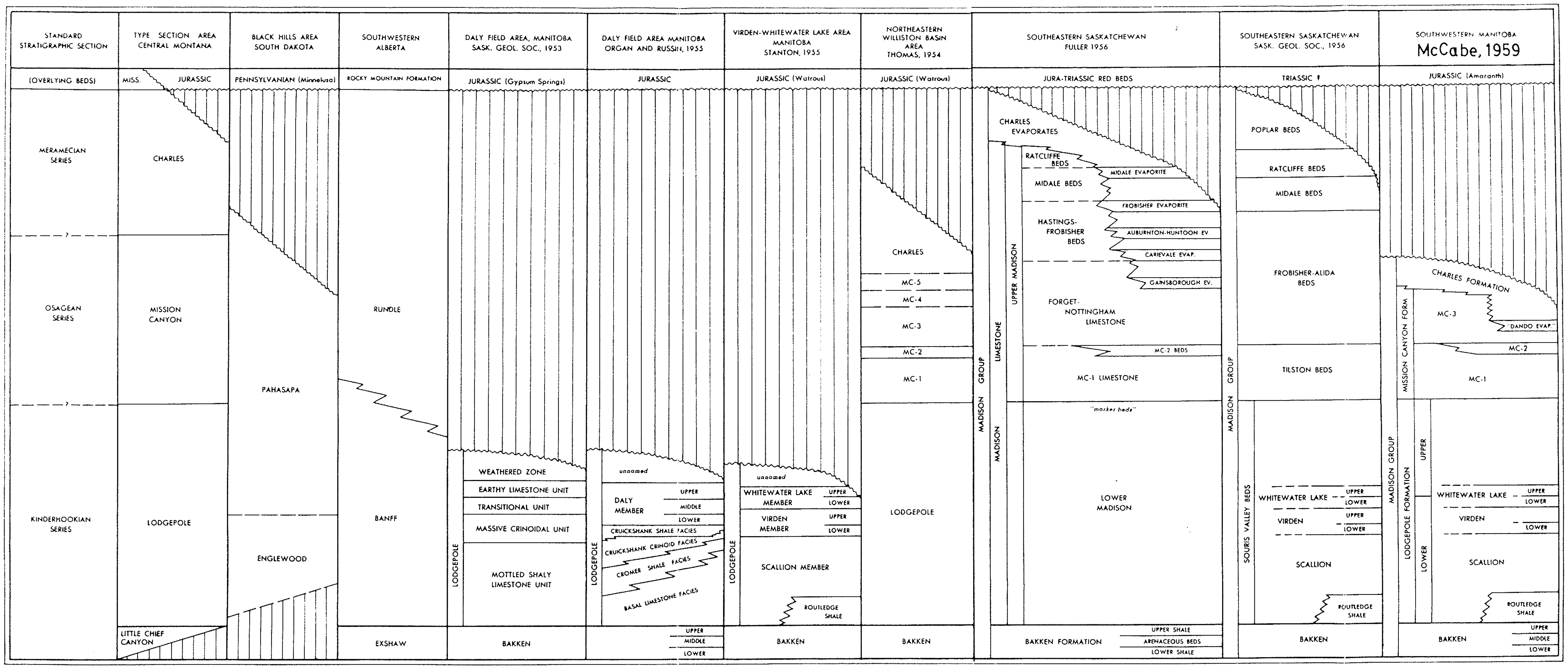

STANDARD STRATIGRAPHIC SECTION
(OVERLYING BEDS)
MERAMECIAN SERIES
OSAGEAN SERIES
KINDERHOOKIAN SERIES
TYPE SECTION AREA CENTRAL MONTANA
MISS.
JURASSIC
CHARLES
MISSION CANYON
LODGEPOLE
LITTLE CHIEF CANYON
BLACK HILLS AREA SOUTH DAKOTA
PENNSYLVANIAN (Minnelusa)
PAHASAPA
ENGLEWOOD
SOUTHWESTERN ALBERTA
ROCKY MOUNTAIN FORMATION
RUNDLE
BANFF
EXSHAW
DALY FIELD AREA, MANITOBA SASK. GEOL. SOC., 1953
JURASSIC (Gypsum Springs)
WEATHERED ZONE
EARTHY LIMESTONE UNIT
TRANSITIONAL UNIT
MASSIVE CRINOIDAL UNIT
MOTTLED SHALY LIMESTONE UNIT
LODGEPOLE
BAKKEN
DALY FIELD AREA MANITOBA ORGAN AND RUSSIN, 1955
JURASSIC
unnamed
DALY MEMBER
UPPER
MIDDLE
LOWER
CRUICKSHANK SHALE FACIES
CRUICKSHANK CRINOID FACIES
CROMER SHALE FACIES
BASAL LIMESTONE FACIES
LODGEPOLE
UPPER
MIDDLE
LOWER
VIRDEN-WHITEWATER LAKE AREA MANITOBA STANTON, 1955
JURASSIC (Watrous)
unnamed
WHITEWATER LAKE MEMBER
UPPER
LOWER
VIRDEN MEMBER
UPPER
LOWER
SCALLION MEMBER
ROUTLEDGE SHALE
LODGEPOLE
BAKKEN
NORTHEASTERN WILLISTON BASIN AREA THOMAS, 1954
JURASSIC (Watrous)
CHARLES
MC-5
MC-4
MC-3
MC-2
MC-1
LODGEPOLE
BAKKEN
SOUTHEASTERN SASKATCHEWAN FULLER 1956
JURA-TRIASSIC RED BEDS
CHARLES EVAPORATES
RATCLIFFE BEDS
MIDALE EVAPORITE
MIDALE BEDS
FROBISHER EVAPORITE
HASTINGS-FROBISHER BEDS
AUBURNTON-HUNTOON EV.
CARIEVALE EVAP.
GAINSBOROUGH EV.
FORGET-NOTTINGHAM LIMESTONE
MC-2 BEDS
MC-1 LIMESTONE
"marker beds"
LOWER MADISON
UPPER MADISON
MADISON LIMESTONE
MADISON GROUP
BAKKEN FORMATION
UPPER SHALE
ARENACEOUS BEDS
LOWER SHALE
SOUTHEASTERN SASKATCHEWAN SASK. GEOL. SOC., 1956
TRIASSIC ?
POPLAR BEDS
RATCLIFFE BEDS
MIDALE BEDS
FROBISHER-ALIDA BEDS
TILSTON BEDS
WHITEWATER LAKE
UPPER
LOWER
VIRDEN
UPPER
LOWER
SCALLION
ROUTLEDGE SHALE
SOURIS VALLEY BEDS
MADISON GROUP
BAKKEN
SOUTHWESTERN MANITOBA
McCabe, 1959
JURASSIC (Amaranth)
CHARLES FORMATION
MC-3
DANDO EVAP.
MC-2
MC-1
MISSION CANYON FORM.
WHITEWATER LAKE
UPPER
LOWER
VIRDEN
LOWER
SCALLION
ROUTLEDGE SHALE
UPPER
LOWER
LODGEPOLE FORMATION
MADISON GROUP
BAKKEN
UPPER
MIDDLE
LOWER

Fig. 5

bioclastic limestone with interbedded silty shales (Ghazar, 1978).

The Mission Canyon Formation overlies the Lodgepole Formation conformably. It is composed of bioclastic, oolitic, and algal limestones with intercalations of thin but fairly persistent silty dolomites (Ghazar, 1978).

Conformably resting on the Mission Canyon Formation is a sequence of anhydrite, dolomite, and red and green shales of Charles Formation (Ghazar, 1978).

These Mississippian strata are unconformably overlain by Jurassic Amaranth red beds.

1.6 Stratigraphy of the Study Area

The Mission Canyon Formation has been divided into three members (McCabe, 1959). These are, in the ascending order, MC-1, MC-2, and MC-3 Members.

Ghazar (1978) described the MC-1 Member as consisting of dense, cherty, crinoidal limestones in the basal part through finely granular chalky limestone to oolitic and algal zones in the upper part.

The overlying MC-2 Member is composed of anhydrite and argillaceous, microcrystalline algal dolomite (Ghazar, 1978).

According to Ghazar (1978), the succeeding MC-3 Member is a dense cherty, crinoidal limestone in the basal part to porous oolitic finely comminuted crinoidal limestone in the upper part. The Pierson field produces from MC-3 Member.

The MC-3 Member has been further subdivided into lower

(MC-3a) and upper (MC-3b) intervals with MC-3 marker bed separating them (Halabura, 1984). The producing horizons of the 07 43B pool have been found in the MC-3a beds.

Fig. 6 (Back Pocket) shows correlation of Mission Canyon Formation between the Pierson and Waskada areas.

1.7 Hydrocarbon Traps of the Study Area

Three styles of hydrocarbon trapping, namely, structural-topographic, truncation and facies traps have been found in the study area, and each of these is described below.

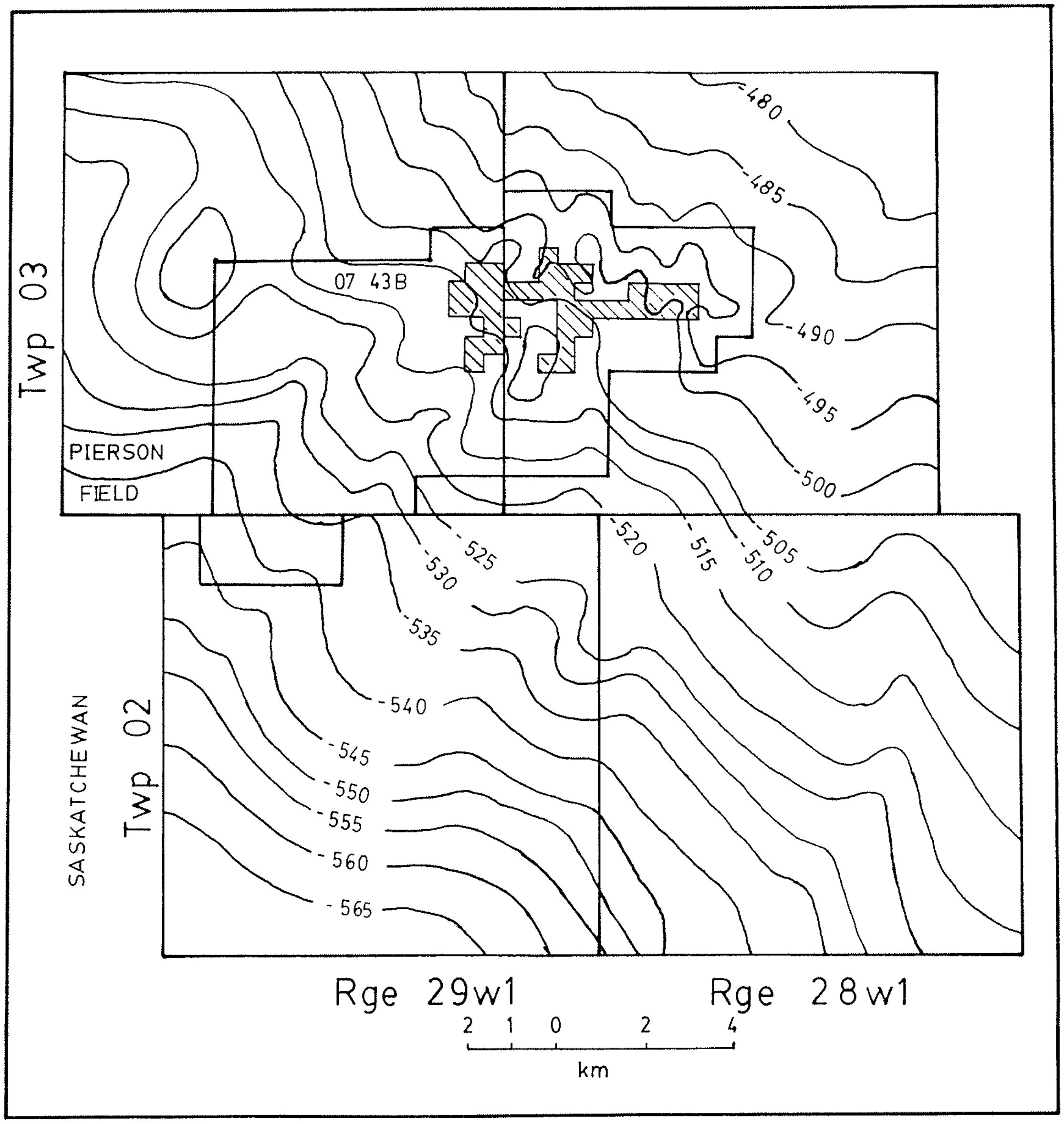
1.7.1 Structural-Topographic Traps

The Mississippian erosion surface is characterized by "highs" or "noses" (Fig. 7 and Fig. 1) representing primarily the sites of oil accumulation.

Local thinning of Jurassic red beds (Fig. 8) depicting topographic "highs" is somewhat coincidental with these structures. However, a remarkable resemblance between structure contours on the Mississippian erosion surface and on the top of MC-2 marker has been observed (Fig. 9).

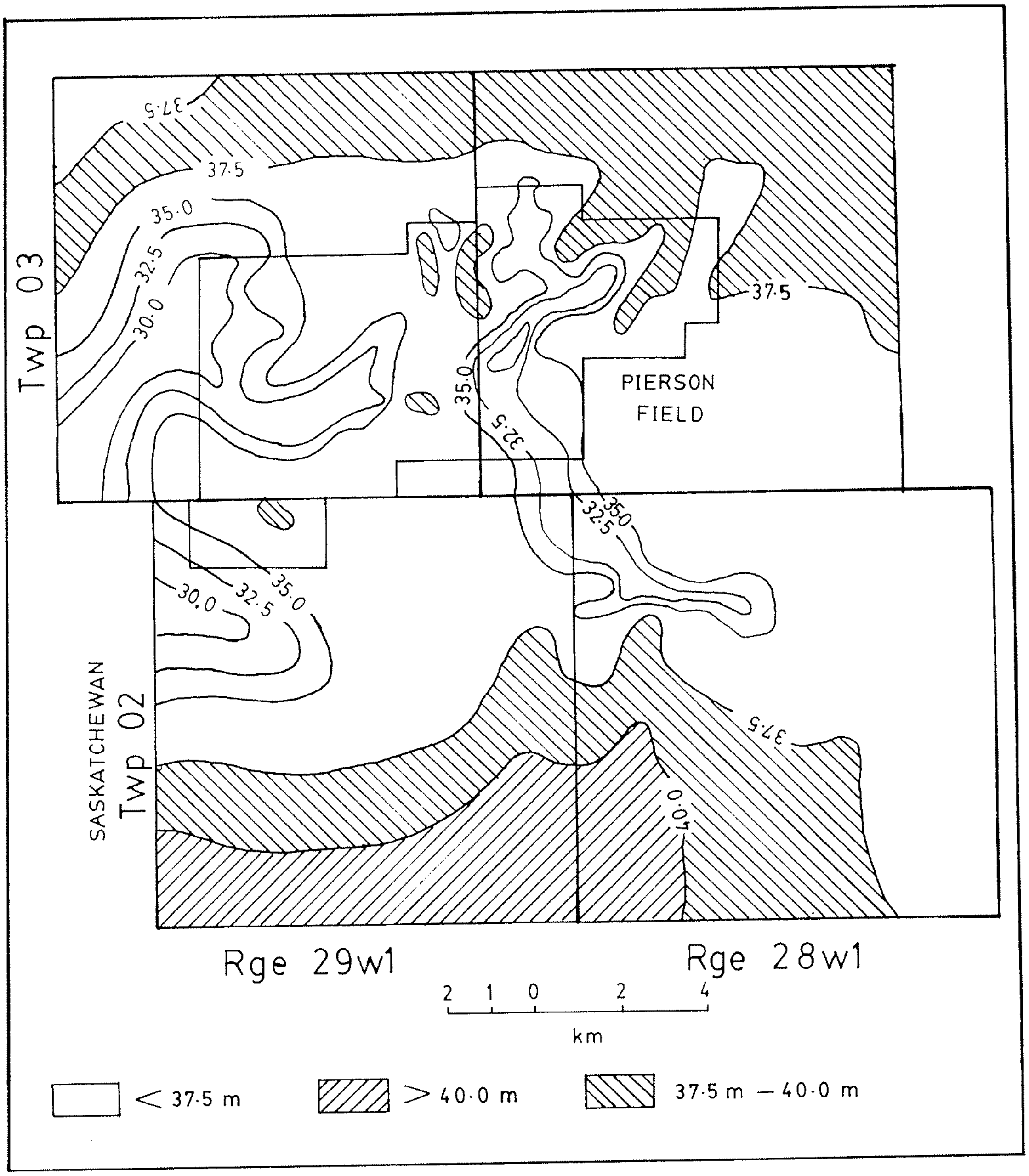
McCabe (1959) suggested that these "highs" on the Mississippian erosion surface are structural, and originated for the most part subsequent to the period of erosion, and prior to, or contemporaneous with, red beds deposition. Alternatively, they may represent principally topographic "highs", created by the differential erosion during the

Fig. 7 Structure contour map (in meters) on Mississippian erosion surface. (After Halabura, 1984).


480
485
490
495
500
505
510
515
520
525
530
535
540
545
550
555
560
565
07 43B
Twp 03
Twp 02
PIERSON
FIELD
SASKATCHEWAN
Rge 29w1
Rge 28w1
2 1 0 2 4
km

Fig·7

Fig. 8 Isopach map (in meters) of the Lower Amaranth Formation. (After Halabura, 1984).


37·5
37·5
35·0
32·5
30·0
Twp 03
35·0
32·5
37·5
PIERSON
FIELD
35·0
32·5
35·0
32·5
30·0
SASKATCHEWAN
Twp 02
37·5
40·0
Rge 29w1
Rge 28w1
2 1 0 2 4
km
< 37·5 m
> 40·0 m
37·5 m — 40·0 m

Fig· 8