Petroleum Open File Report POF 4-86

Petroleum Geology of the Mission Canyon MC-1 Member, Tilston Field, Southwestern Manitoba

By D. Bell

Manitoba
Energy and Mines
Petroleum

1986

Manitoba
Energy and Mines
Petroleum

Petroleum Open File Report POF 4-86

Petroleum Geology of the Mission Canyon MC-1 Member, Tilston Field, Southwestern Manitoba

By D. Bell

Summer, 1985

Energy and Mines

Hon. Wilson D. Parasiuk
Minister

Charles S. Kang
Deputy Minister

Petroleum Branch
H. Clare Moster
Director

TABLE OF CONTENTS

	Page
INTRODUCTION	1
General Introduction	1
Purpose	1
Study Area	1
Previous Work	3
Geological Setting	3
General Stratigraphy	5
Stratigraphic Nomenclature	7
EXPLORATION HISTORY	9
Mission Canyon - 1 A Pool	9
Mission Canyon - 1 B Pool	11
Mission Canyon - 1 C Pool	11
Recent Discoveries	12
GEOLOGY	13
Lithology A. Bioclastic Mudstone-Wackestone	13
B. Laminated Lime Mudstone	14
C. Altered Zone	15
Environment of Deposition	15
Structure	16
Trapping Mechanisms	23
Reservoir Characteristics	24
CONCLUSIONS	25
Future Potential	26
REFERENCES	27
APPENDIX I	29
Tables 1 Structural Data	29
2 Production Data	31
APPENDIX II	32
Core Descriptions	32

LIST OF FIGURES

Page

1. Map showing Mississippian Subcrop Belts and location of Study Area 2

2. Outline of the Williston Basin. 4

3. Schematic section - Southwestern Manitoba 5

4. Stratigraphic column 8

5. Type log - study area .... in pocket

6. Structure contour map - top of the Mississippian Erosional Surface ... 18

7. Isopach map - Lower Amaranth Formation 19

8. Structure contour map - top of the Lower Amaranth Formation 20

9. Structure contour map - top of the Upper Lodgepole Formation 21

10. Isopach map of MC-1 Member 22

11. Structural cross-section A-B .... in pocket

12. Structural cross-section B-C .... in pocket

13. Structural cross-section C-D .... in pocket

INTRODUCTION

General Introduction

The Tilston Field is located along the Manitoba-Saskatchewan boundary in Townships 5-6, Range 29 WPM. Production is obtained from the MC-1 Member of the lower Mississippian Mission Canyon Formation. Entrapment within the field is primarily due to the presence of several closed paleotopographic highs developed on the Mississippian erosional surface. A dense impermeable secondary dolomite resulting from alteration at the unconformity acts as a caprock within the field, with the overlying lower Amaranth Red Beds providing a secondary caprock. Oil accumulation occurs in the underlying porous MC-1 Member limestones.

Purpose

The purpose of this report is to identify the geologic controls affecting localization of hydrocarbons within the MC-1 Member in the Tilston Field. In order to facilitate this, the following topics are presented:

1) Stratigraphy of the Mississippian Mission Canyon Formation.

2) Summary of the exploration history.

3) Description of the lithology and environment of deposition of the MC-1 Member.

4) Reservoir characteristics and trapping mechanics.

Study Area

The Tilston Field area, defined for the purposes of this study as Townships 5 and 6, Range 29 WPM, is shown in Figure 1. It covers an area of

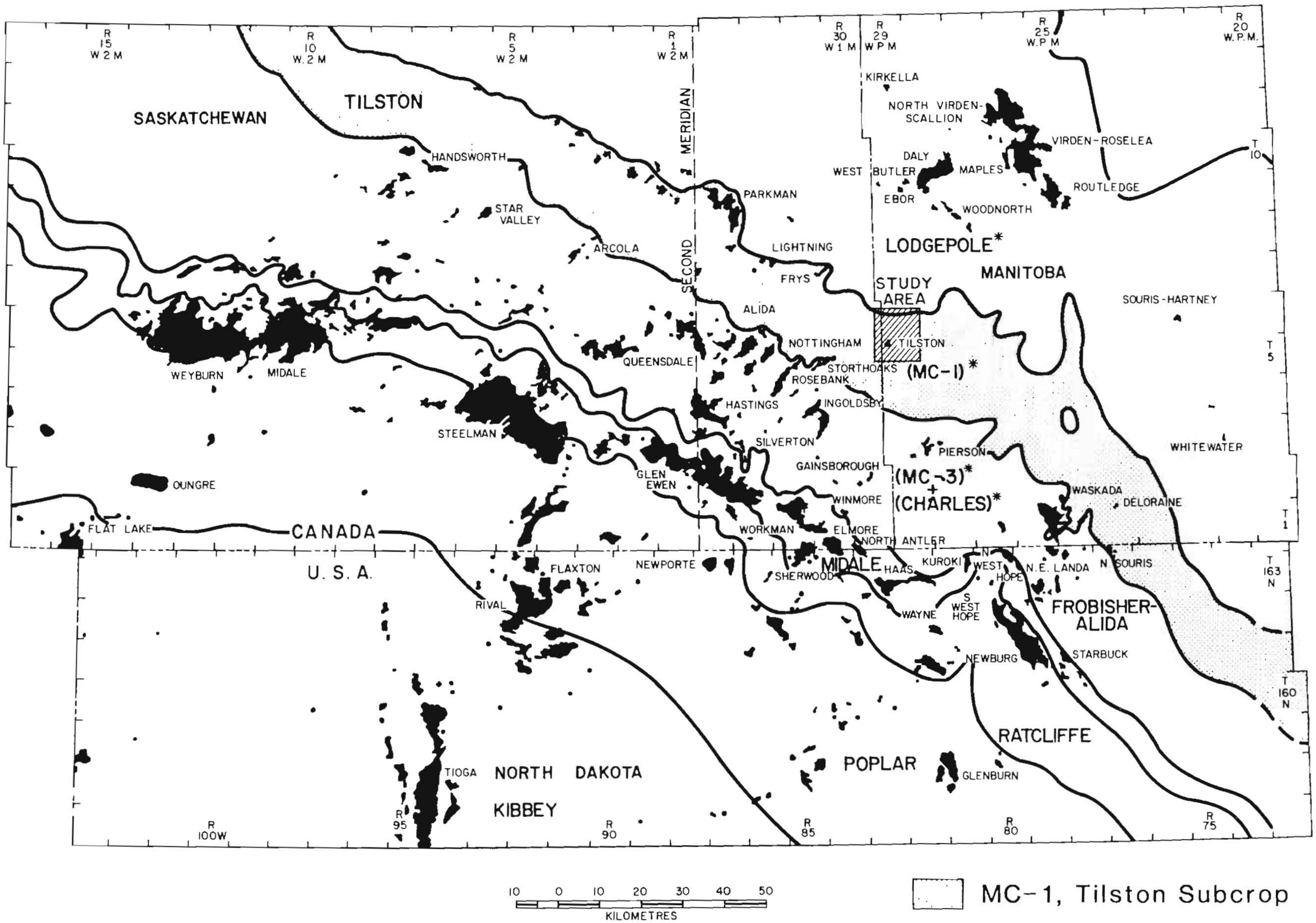


Figure 1: Map showing Mississippian Subcrop Belts and location of Study area

approximately 145 km^2 (56 $miles^2$) and lies entirely within the region of the MC-1 Member subcrop. The paleotopographic highs present in the Tilston Field occur entirely within the defined study area.

Structural data from adjacent areas in Townships 5-6, Ranges 28-30 WPM were incorporated in the study in order to establish regional trends for contouring. This additional information is included in Appendix I.

Previous Work

Limited information is available pertaining to the Tilston Field in southwestern Manitoba. An unpublished B.Sc. thesis written by R. Martin (1984) for the Department of Earth Sciences, University of Manitoba, and an Open File report for the Manitoba Petroleum Branch by Ghazar (1977) are the only reports available concerning the producing MC-1 Member in the Tilston Field. Also, a brief account is presented by McCabe (1963, p. 29-30).

Independent studies of the MC-1 Member, or Tilston beds, have been conducted in other localities by authors such as Kaldi and Hartling (1982) and Miller (1964).

Detailed geology of the Mission Canyon Formation in southwestern Manitoba is discussed by McCabe (1959) and Rodgers (1986).

Geological Setting

The Williston Basin, as shown in Figure 2, is a large irregularly shaped depression on the western edge of the Canadian Shield. The sedimentary package present in southwestern Manitoba forms a basinward thickening wedge-like segment of Paleozoic and Mesozoic strata on the northeastern edge of the basin. The Paleozoic and Mesozoic sections are separated by a major angular unconformity which possibly represents multiple episodes of erosion which occurred during the late Mississippian to early Jurassic time interval. The Paleozoic strata were tilted during the period of erosion which resulted

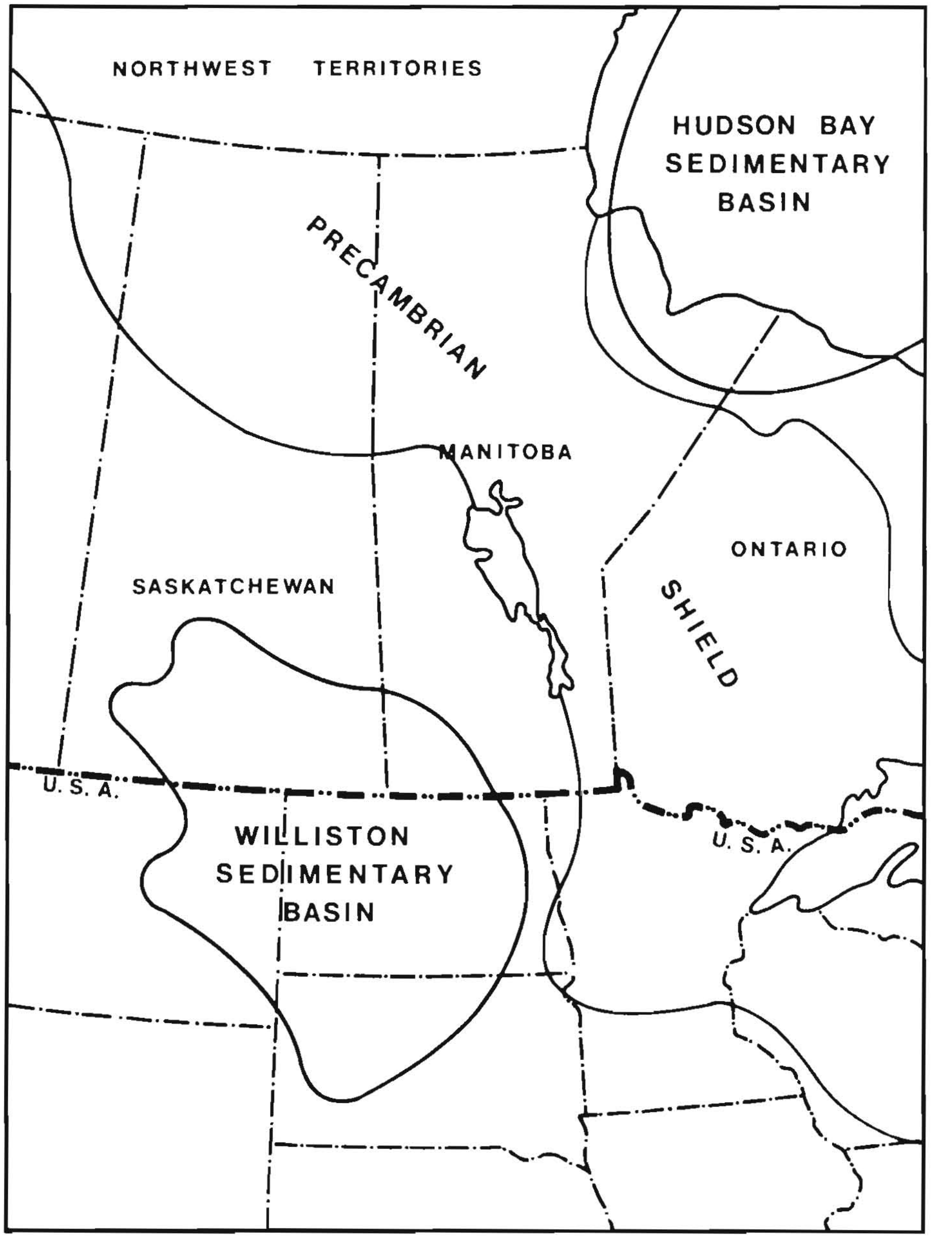


Figure 2: Outline of the Williston Basin

in progressive truncation of the strata towards the basin margin. Deposition was resumed during Mesozoic time, when a thick sequence of Jurassic and Cretaceous strata was deposited on the eroded Paleozoic surface (Barchyn, 1982; McCabe, 1959). A schematic section showing the present configuration of strata in southwestern Manitoba is shown in Figure 3.

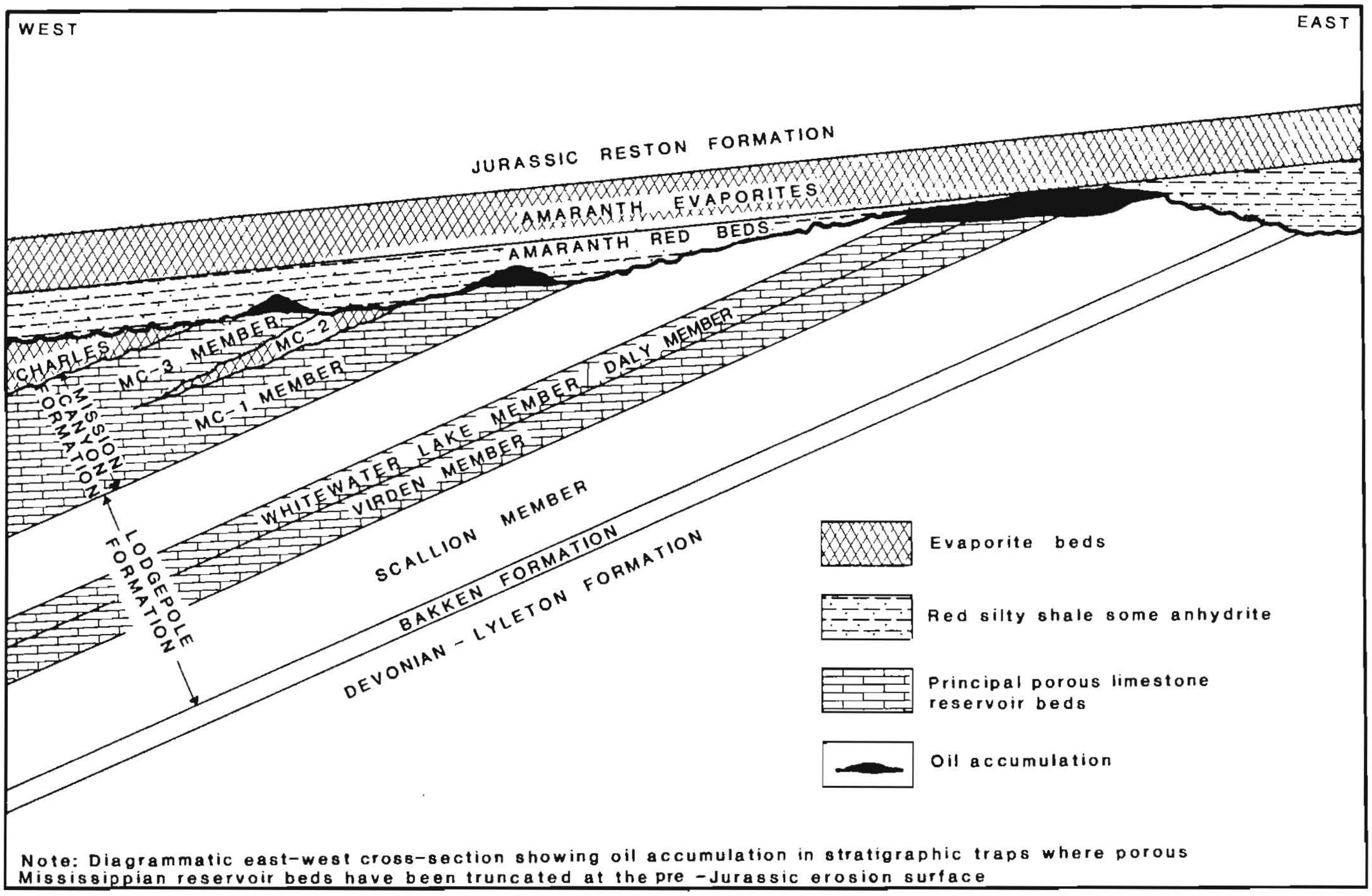


Figure 3: Schematic Section - Southwestern Manitoba (from Mineral Map of Manitoba 80-1)

General Stratigraphy

The entire Mississippian - Madison Group of the Williston Basin area comprises one major sedimentary cycle of marine transgression and regression (McCabe, 1959). Mississippian strata consist of four well-defined lithologic units, in ascending order: the Bakken, Lodgepole, Mission Canyon, and Charles Formations.

Mississippian seas originally advanced from an east-northeast direction depositing the basal black shales and siltstones of the Bakken Formation. Deposition most likely occurred within a widespread marine swamp representing the initial stages of transgression (McCabe, 1959).

Continuing transgression resulted in deepening of the Mississippian seas. Deposition of the predominantly argillaceous limestones of the Lodgepole Formation occurred during this period of transgression. Rapid subsidence within the Williston Basin produced a relatively steep depositional slope with pronounced lateral differentiation of lithofacies in the flank areas of the basin. The maximum extent of Mississippian seas probably was reached during middle Lodgepole time (McCabe, 1959).

During Mission Canyon time the rate of subsidence within the Williston Basin decreased. The bottom slope decreased forming a relatively shallow water shelf environment in which the fragmental, fossiliferous, algal-oolitic limestones of the Mission Canyon Formation were deposited. Cyclic fluctuations in sea level during this period resulted in formation of fringing biostromal shoals during episodes of shallow water deposition. At such times evaporitic conditions occurred in restricted marginal lagoons, which gradually regressed towards the centre of the basin due to a continued decrease in subsidence (McCabe, 1959). Overlying evaporites of the Charles Formation marked the final stages of regression of the Mississippian seas from the Williston Basin area (McCabe, 1959).

Within the study area Mission Canyon limestones are directly overlain by 'Red Beds' of the Jurassic Lower Amaranth Formation (Lower Watrous Formation of Saskatchewan; Spearfish Formation of North Dakota).

Part of the Mississippian sequence in southwestern Manitoba has been removed due to post-Mississippian-pre-Jurassic erosion. Progressive northeastward truncation at the unconformity has resulted in a series of northwest-trending Mississippian subcrop belts, as shown in Figure 1.

Stratigraphic Nomenclature

The Mission Canyon Formation, as defined by McCabe (1959) for Manitoba usage, consists of the predominantly clean fragmental carbonate section overlying the argillaceous marker bed at the top of the Lodgepole Formation and underlying the main evaporite beds of the upper Mississippian Charles Formation. The Mission Canyon Formation in Manitoba is formally divided into three members, in ascending order: the MC-1, MC-2 and MC-3 Members, as illustrated in Figure 4. The lower part of the Mission Canyon Formation, the MC-1 and MC-2 Members, is equivalent to the Tilston beds of Saskatchewan; the MC-3 Member correlates with the lower part of the Frobisher-Alida beds of Saskatchewan (McCabe, 1959) where MC-4 and MC-5 are also defined.

Post-Mississippian erosion has removed nearly the entire Mission Canyon sequence in the study area, leaving only the lowermost portion of the MC-1 Member. For this reason only the MC-1 Member will be discussed in this section and in the remainder of the report.

The MC-1 Member consists of bioclastic limestones and dolomitic limestones, characterized on mechanical logs by a high uniform negative SP response. A type log for the MC-1 Member in the Tilston area is shown in Figure 5. The limestones are predominantly crinoidal-fragmental with scattered rugose coral fragments. The amount of bioclastic material increases up-section. Much of the limestone and dolomitic limestone is finely crystalline, granular appearing, and originally may have been fragmental; however, much of the primary texture has been obscured by secondary recrystallization.

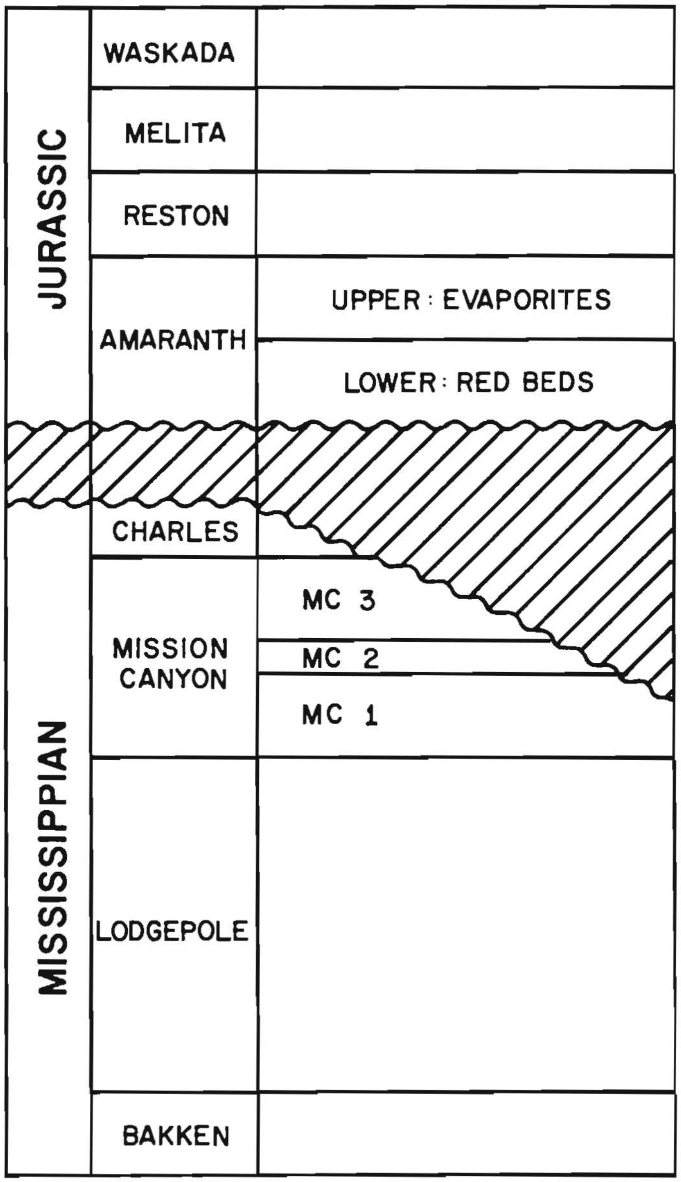


Figure 4: Stratigraphic column

EXPLORATION HISTORY

Mission Canyon - 1 A Pool

The MC-1 A Pool of the Tilston Field was discovered in August of 1952. The discovery well, J.P. Owen Tilston Prov. 5-32-5-29 WPM, was completed in the MC-1 Member with 2.8 m of net pay. Production for the first year averaged 5.6 m^3 per day of 33.8° A.P.I. oil and 55.9 m^3 per day of water. The well was reconditioned in November of 1954 due to excessive water production, but was ultimately abandoned in May of 1959 because of high water cut. Cumulative production for the well was 3 094.3 m^3 of oil and 22 964.1 m^3 of water.

Two years after the initial discovery at Tilston three development wells were drilled. Northern Development (now Tundra) Tilston 9-31-5-29 WPM was completed in the MC-1 Member in March of 1954. The well was converted to a dual completion well in May of 1958, but went back on production as an oil well in November of 1959 and was eventually abandoned in July of 1980. The second well, J.P. Owen (now Tundra) Tilston Prov. 12-32-5-29 WPM, was successfully completed in the MC-1 Member in March of 1954. The last well, J.P. Owen Tilston 11-32-5-29 WPM was drilled in July of 1954 but was unsuccessful.

During 1955 three more development wells were drilled at Tilston with moderate success. The first of these wells, J.P. Owen Tilston 4-32-5-29 WPM, was drilled in February of 1955 but was unsuccessful. The second well, Northern Development 16-31-5-29 WPM was completed in the MC-1 Member in April of 1955, but was converted to a salt water disposal well in July of 1959 and was ultimately abandoned in July of 1981. The only successful well, Northern Development Tilston 8-31-5-29 WPM, was completed in the MC-1 Member in September of 1955.

The following year Great Sweet Grass (well names now changed to Tundra) drilled three successful development wells, all completed in the MC-1 Member. The first of these wells, 15-31-5-29 WPM was completed in October of

1956. Production was suspended in January of 1977 due to excessive water production and the well was subsequently abandoned in October of 1983. The remaining two wells, 7-31-5-29 WPM and 10-31-5-29 WPM, were both completed in November of 1956. Poor completion of the wells coupled with water encroachment made production from the wells uneconomic and both were subsequently abandoned. Both of these locations were re-drilled in 1980 by Tundra Oil and Gas.

Over the next few years, drilling activity decreased. In 1957, one development well, 1-6-6-29 WPM was drilled by Mandak (formerly Mandak-Poke) and was completed in the MC-1 Member. The well has been inactive since September 1984. In 1958, two development wells were completed in the MC-1 Member. The first, Great Sweet Grass (now Tundra) Tilston 11-31-5-29 WPM, was drilled and abandoned in November of 1984 due to excessive water production. The second well, Mandak Tilston 2-6-6-29 WPM, did not go on production, and was subsequently converted to a salt water disposal well in May of 1973.

During the periods 1959-1965 and 1967-1977 no wells were drilled in the Tilston area. One wildcat well was drilled north of the MC-1 A Pool (7-8-6-29 WPM) in 1966, but was unsuccessful.

Activity resumed in the Tilston area in the late 1970's and continued on into the 1980's. Development drilling began again in 1978 with an unsuccessful Corona Tilston 8-6-6-29 WPM well drilled in January. Over the next six-year period, Tundra Oil and Gas drilled ten development wells in the MC-1 A Pool, eight of which were successfully completed. Four of these, A5-32-5-29 WPM, A7-31-5-29 WPM, A9-31-5-29 WPM, and A10-31-5-29 WPM were previously drilled locations in 1980. A9-31-5-29 WPM was subsequently converted to a salt water disposal well in May of 1980. Newscope Resources in a joint venture with Tundra also drilled one development well 14-30-5-29 WPM within that six-year period, which was successfully completed in January of 1983.

Over a thirty-three year history, twenty-two development wells have been drilled in the Tilston MC-1 A Pool, four of which were redrilled locations. As of April 30, 1985, there are ten producing wells, one suspended well, one inactive well, and two salt water disposal wells in the pool. Cumulative production to April 30, 1985 was 82 629.7 m^3 of oil and 500 759.6 m^3 of water.

Mission Canyon - 1 B Pool

In July of 1983 Tundra Oil and Gas drilled an exploratory outpost well one kilometer south of the Tilston MC-1 A Pool on the downdip edge of the same paleotopographic high. Tundra Tilston 3-30-5-29 WPM, the discovery well for the MC-1 B Pool, was successfully completed in the MC-1 Member with 0.7 m of net pay. Initial production from the well was poor and in December of 1984 it was abandoned due to low production rates. Cumulative production for the well was 27.3 m^3 of 33.8^o A.P.I. oil and 1162.0 m^3 of water. Because of these poor results no further attempts were made to enlarge the MC-1 B pool from its one well status. This well was originally designated as a separate pool but then was incorporated into the MC-1 A Pool. MC-1 B Pool no longer exists.

Mission Canyon - 1 C Pool

The discovery well for the Tilston MC-1 C Pool, Newscope et al Tilston 12-9-6-29 WPM, was drilled in August of 1983 on a Mississippian paleotopographic high north of the MC-1 A Pool. This well, completed in the MC-1 Member, penetrated 1.6 m of net pay and yielded 35.4^o A.P.I. oil.

An earlier exploratory wildcat well, KCL et al North Tilston 7-8-6-29 WPM, drilled in 1966, penetrated the northwest flank of the high, but was too low to intersect the main oil accumulation. Drill stem tests from this well yielded 18.3 m of oil cut mud; however, no further drilling in the area was done at that time.

Following the initial discovery Newscope drilled ten development wells in 1983 and 1984. Nine of these were successfully completed in the MC-1 Member. Columbia Gas Development of Canada Ltd. also drilled one development well in the Tilston MC-1 C Pool. Colgas Cymric Tilston Prov. 9-6-6-29 WPM was drilled and completed in the MC-1 Member in September of 1984 on the southwest flank of the MC-1 C Pool. The well was on production for only three months and has remained inactive since November of 1984 due to poor production rates.

Currently the Tilston MC-1 C Pool contains ten producing wells. Cumulative production for the pool up to April 30, 1985, was 9 103.3 m^3 of oil and 6 829.2 m^3 of water.

Recent Discoveries

A Mississippian paleotopographic high, possibly an extension of the MC-1 C Pool paleohigh, was discovered north of the Tilston MC-1 C Pool in July of 1984. The discovery well, Newscope et al Tilston 5-15-6-29 WPM was completed in the MC-1 Member with 0.8 m of net pay. Initial production for the well to April 30, 1985, was 222.2 m^3 of oil and 703.6 m^3 of water. As of August, 1985, no further development drilling in the area has been done.

In general, production from the Tilston Field has been characterised by the high water-oil ratio and strong aquifer drive.

Production data on wells from all pools in the Tilston Field are included in Appendix I.

GEOLOGY

Lithology

Ten cores were examined from both producing and non-producing wells within the designated study area. Selection of core was based on availability and recovery of the cored interval. Lithologic descriptions were based on Dunham's (1962) classification of carbonate rocks according to depositional texture. Porosity was described according to Choquette and Pray (1970). This report does not attempt any detailed petrologic or diagenetic analysis, but merely outlines the lithologies present in the MC-1 Member within the study area. Core descriptions for each of the ten wells examined are given in Appendix II.

Three separate lithologic types have been identified through the examination of core. Each lithology was distinguished on the basis of mineralogical and textural features and was named accordingly.

A. Bioclastic Mudstone-Wackestone

This rock type is characterized by an abundance of micrite with bioclastic material comprising from 5 to 25 per cent of the rock. The rock is generally mud-supported, but approaches grain-supported in more fragmental sections. The bioclastic material consists of fragments of crinoid stems, brachiopod fragments, and solitary rugose corals. Identification of the bioclastic material is difficult due to the fragmental nature and fine grain size of the bioclasts. Bioclasts are often filled with micrite.

Few fractures were observed in this lithology. Some evidence of post-depositional compaction is indicated by the presence of microstylolites. The microstylolites commonly occur as irregular dark organic and argillaceous films in a horizontal to subhorizontal position.

Thin zones of finely crystalline to microsucrosic dolomite occur interbedded with relatively undolomitized limestone. This dolomite is interpreted to be related to an early diagenetic event (possibly Mississippian?) which preceded dolomitization of the altered zone developed at the Mississippian unconformity. Isolated masses of coarsely crystalline anhydrite are present in this lithology. The anhydrite crystals are commonly dark brown (oil stained?) and are also thought to be related to an earlier diagenetic event which predates the formation of the altered zone.

Units of very hard siliceous material were noted in some cores. These units are not laterally continuous within the study area as they could not be traced in core between wells. Some units show a concentric banded appearance and are interpreted as representing nodular structures.

Visible porosity within this lithology is generally fair to poor. The best porosity is found in coarser, more fragmental sections. The most prominent type of porosity is intercrystalline matrix porosity with limited interparticle porosity between bioclasts and intraparticle porosity within bioclasts. Minor fine vuggy porosity and fracture porosity are also present. Oil staining is patchy throughout this lithology.

B. Laminated Lime Mudstone

This rock type is almost totally micrite with little or no coarser bioclastic material. Laminations commonly showing irregular to wavy bedding are characteristic of this lithology. Partings of green calcareous shales and dark mudstones are common, imparting a dull green-grey colour to this lithology. Minor bioturbation (burrowing?) was observed in some beds. Microstylolites, indicative of post-deformational compaction, are concentrated in several zones. These microstylolites contain insoluble material such as hematite, pyrite, and argillaceous material. Vertical fractures are common in this lithology.

Visible porosity within this lithology is poor. The main type of porosity present is very fine intercrystalline porosity. Minor fracture porosity and vuggy porosity (possibly mouldic after fossil debris?) are also present. No oil stain was observed in this lithology.

C. Altered Zone

The altered zone is not a separate depositional-related lithology as are the previous lithologies, but rather it is a diagenetic feature related to processes which occurred at the Mississippian erosional surface. The altered zone directly underlies the Mississippian erosional surface and ranges in thickness from 2 to 10 m. Mineralogically the altered zone consists of finely crystalline dolomite and crystalline anhydrite. Distinctive mineralogical and textural characteristics developed within the altered zone necessitate its description as a separate lithology.

Few vertical fractures were observed in core. Most fractures present were healed with crystalline anhydrite; however, some unfilled fractures showed traces of oil staining.

Within the Tilston field the altered zone acts as an impermeable caprock impeding updip migration of fluids. Some vertical movement of hydrocarbons through the caprock has occurred as indicated by the presence of oil-stained fractures within the caprock.

Environment of Deposition

The change from the argillaceous and crinoidal limestones of the Lodgepole Formation to the oolitic limestones and dolomites of the Mission Canyon Formation reflects a major lithologic and environmental change during Mississippian sedimentation (McCabe, 1959). McCabe divided the Mission Canyon into a series of evaporitic cycles with each cycle constituting a complete sequence of marine transgression and regression. The lithologies present in the MC-1 Member within the study area correlate with the initial stages of the first Mississippian evaporite cycle (lower portion of the unit I limestone, McCabe, 1959, p. 53-58). These limestones represent the transition period from the predominantly deeper-water, marine environment present during Lodgepole time, to the shallow-water, shelf-type depositional environment prevalent during Mission Canyon time.

The laminated lime mudstone directly overlies the Lodgepole Formation. This lithology is associated with the minor shaly response on SP logs overlying the argillaceous marker beds at the top of the Lodgepole Formation. The unit consists predominantly of very fine grained carbonate material with a corresponding lack of coarser grained particles. This implies a low energy marine depositional environment, which is further supported by the laminated nature of the sediments. The laminated lime mudstone is interpreted to have been deposited in a relatively deep water marine environment well below wave base.

The bioclastic mudstone-wackestone lithology overlies the laminated lime mudstone. This unit has a clean uniform response on the SP log. The presence of coarse grained bioclastic material indicates a higher energy depositional environment than that suggested for the laminated lime mudstone lithology. The lack of sorting of the coarse grained material and lack of winnowing of the fine grained matrix indicates that the energy conditions were relatively low. The amount and size of bioclastics increase upwards in the section reflecting a corresponding increase in energy conditions. The bioclastic mudstone-wackestone lithology represents shallower-water conditions than those proposed for the laminated lime mudstone lithology. The depositional environment is interpreted to be close to, but still below, wave base. The coarser, more fragmental interbeds may represent periodic lowering of wavebase due to storm activity.

Structure

The Tilston Field comprises a line of discontinuous northeast-trending structural/paleotopographic highs present on the Mississippian erosional surface, as shown in Figure 6. Paleo-relief on these highs ranges from 15 to 20 m, but because of the regional dip of the Paleozoic strata the closure on these highs is much less than the paleo-relief, having a maximum value of approximately 10 m.

The paleotopography of the Mississippian erosional surface is best illustrated by the isopach map of the Lower Amaranth Formation (Fig. 7). The top of the Lower Amaranth 'Red Beds' is essentially a time-stratigraphic horizontal marker. Therefore, thinning of the 'Red Beds' overlying highs present on the Mississippian erosional surface indicates that the highs are paleotopographic features. The 'Red Bed' isopach is the best measure of paleotopography because it is not affected by post-Jurassic regional tilting or local structural deformation. The highs present on the Mississippian erosional surface (Fig. 6) correspond closely to areas of thinning of the overlying Lower Amaranth 'Red Beds' (Fig. 7).

The structure contour map on the top of the Lower Amaranth Formation shows a generally uniform surface dipping towards the southwest (Fig. 8). The uniform nature of this surface indicates there has been no local post-Amaranth structural deformation; the dip represents post-deformational regional tilting. Slight relief is present on the top of the Lower Amaranth Formation directly above the Mississippian paleotopographic highs (Fig. 8) which may indicate minor post-deformational differential compaction within the Lower Amaranth sediments.

The factors controlling development of the paleotopographic highs on the Mississippian erosional surface are difficult to evaluate. Within the study area deep well data are insufficient to accurately define any pre-Amaranth structural or tectonic deformation which could control the development of the paleotopopgraphic highs. The structure contour map on the top of the Upper Lodgepole Formation shows a structural high present in the MC-1 A Pool area (Fig. 9) which is reflected on the Mississippian erosional surface. This structural deformation is not reflected on the top of the Lower Amaranth Formation, therefore it must have predated deposition at the Lower Amaranth 'Red Beds'. In the MC-1 C Pool area the paleotopographic high does not have an element of structural control and is interpreted as representing an erosional remnant of MC-1 Member lithology on the Mississippian erosional surface.

The isopach map of the MC-1 Member illustrates the thickened sections of MC-1 strata related to the paleotopographic highs (Fig. 10). The amount of MC-1 sediment preserved is a function of the extent of post-Mississippian erosion.

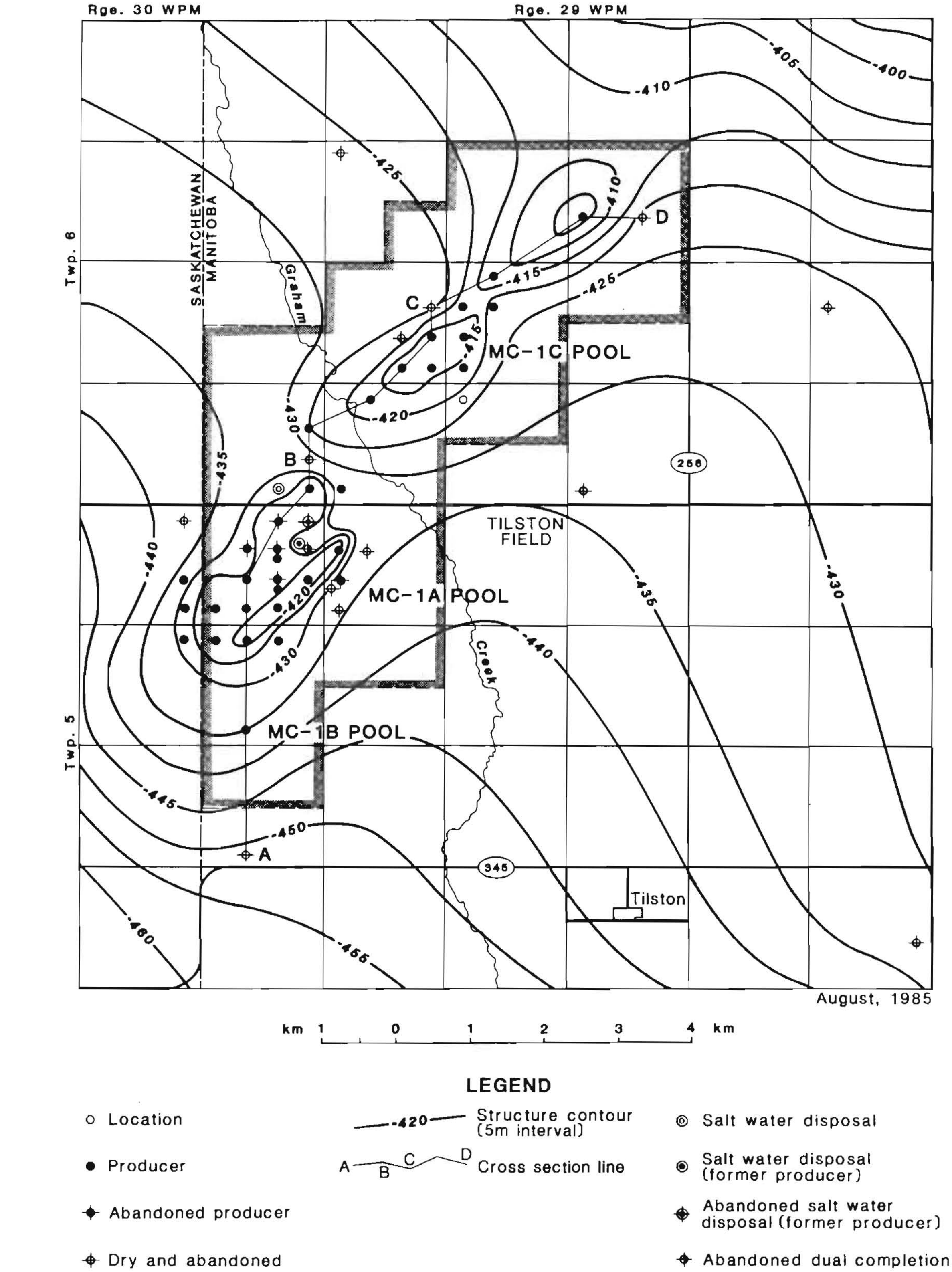
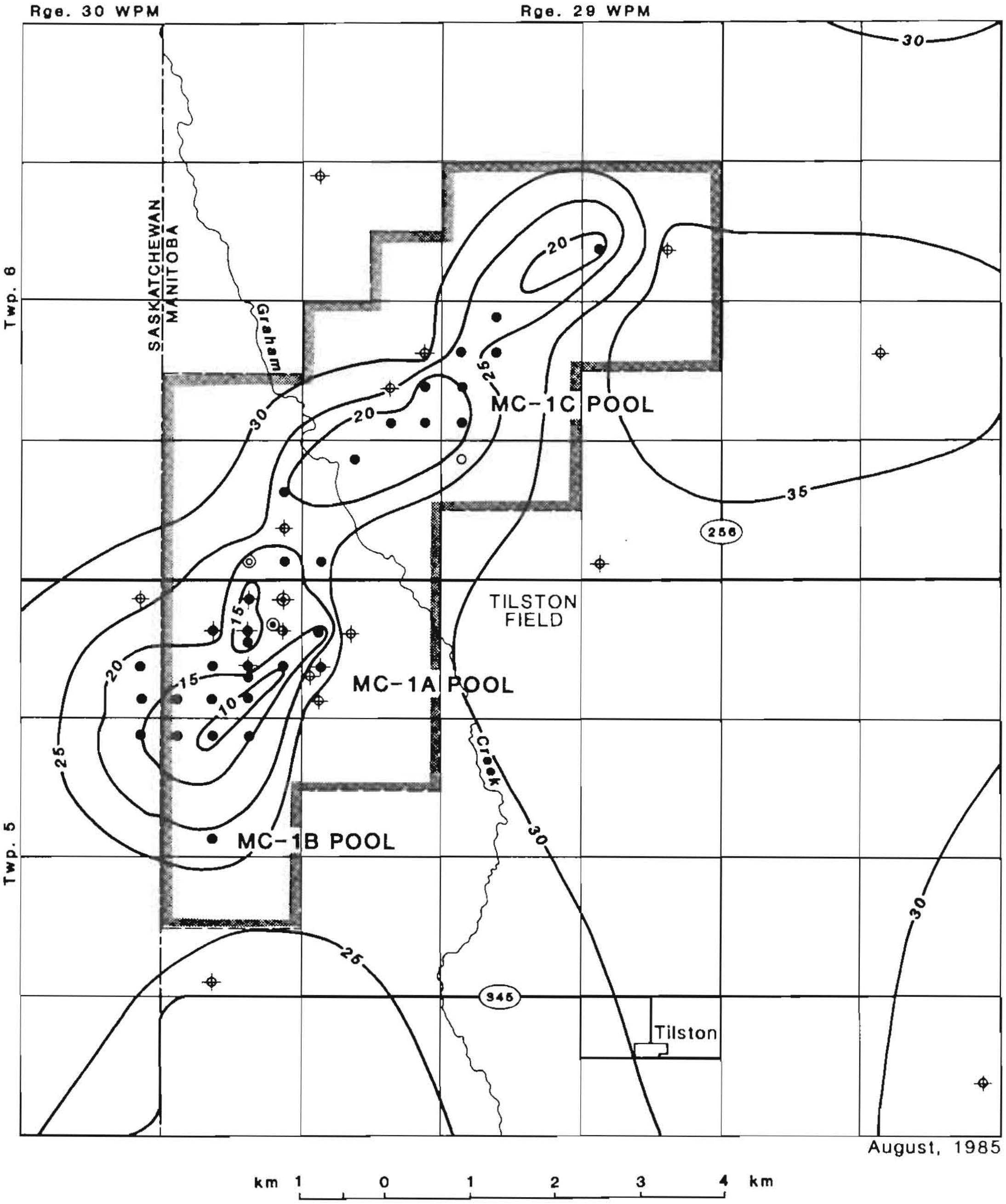


Figure 6: Structure Contour Map - top of the Mississippian Erosional Surface



LEGEND

- Location
- Producer
- Abandoned producer
- Dry and abandoned
- Isopach contour (5m interval)
- Salt water disposal
- Salt water disposal (former producer)
- Abandoned salt water disposal (former producer)
- Abandoned dual completion

Figure 7: Isopach Map - Lower Amaranth Formation

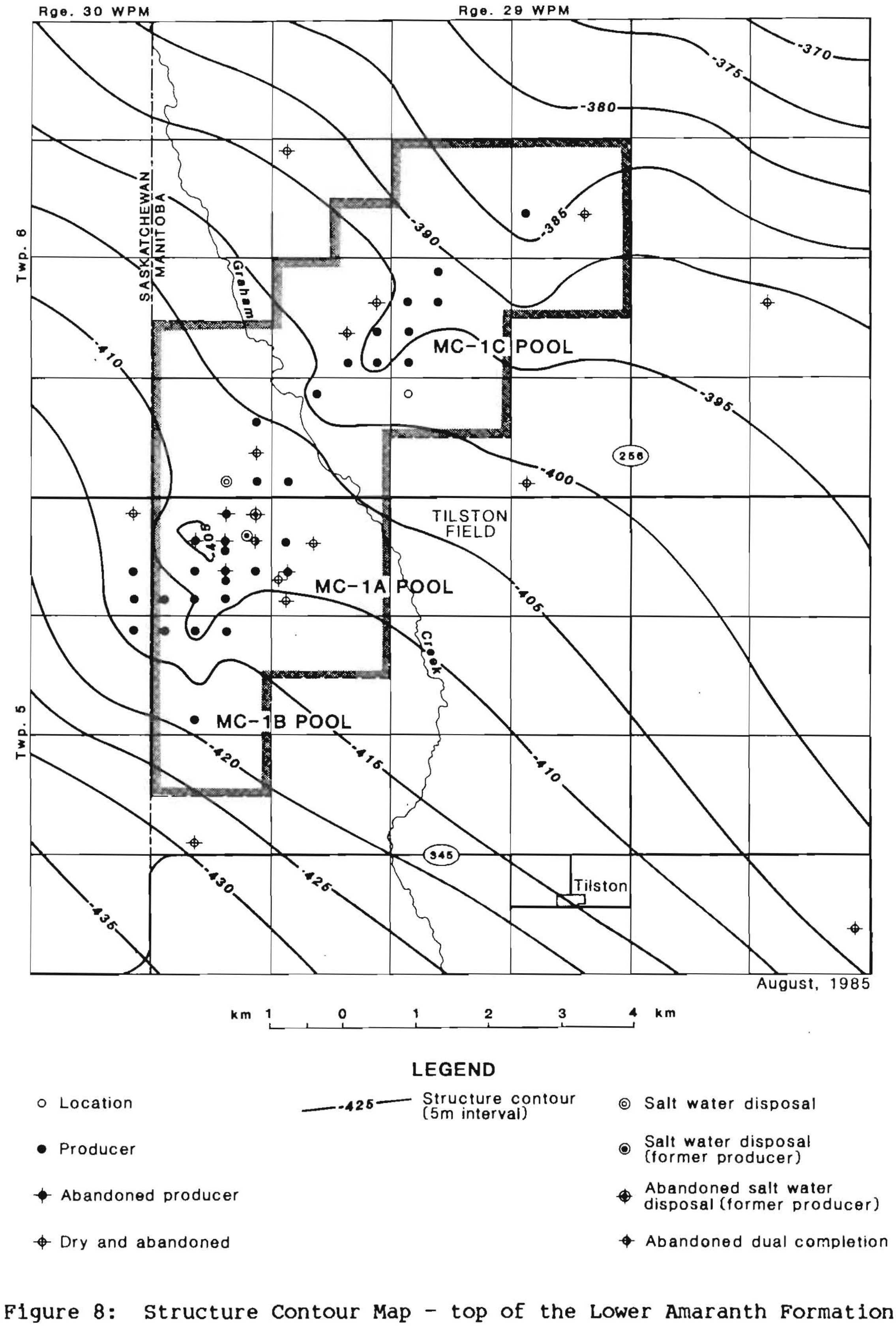


Figure 8: Structure Contour Map - top of the Lower Amaranth Formation

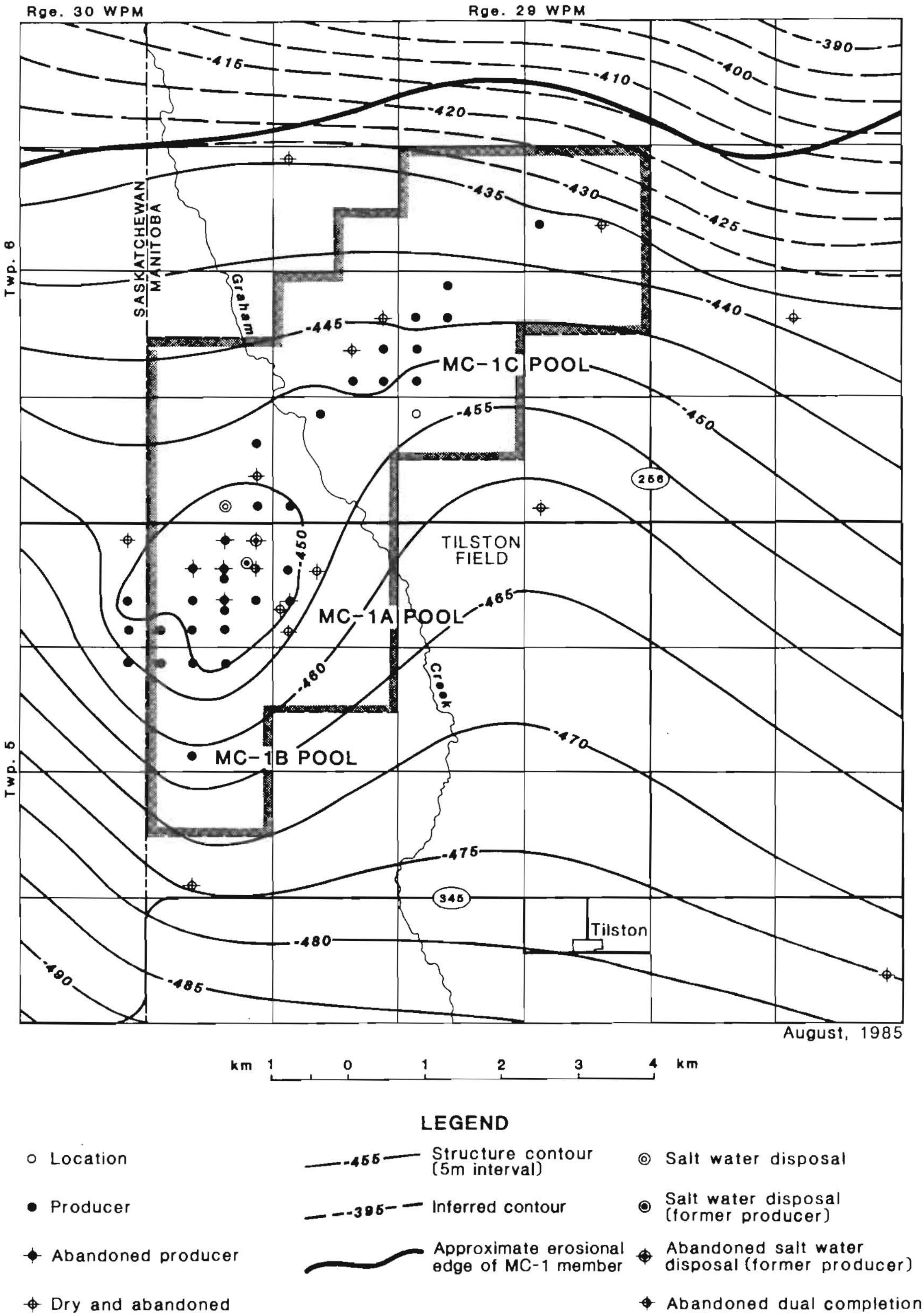


Figure 9: Structure Contour Map - top of the Upper Lodgepole Formation

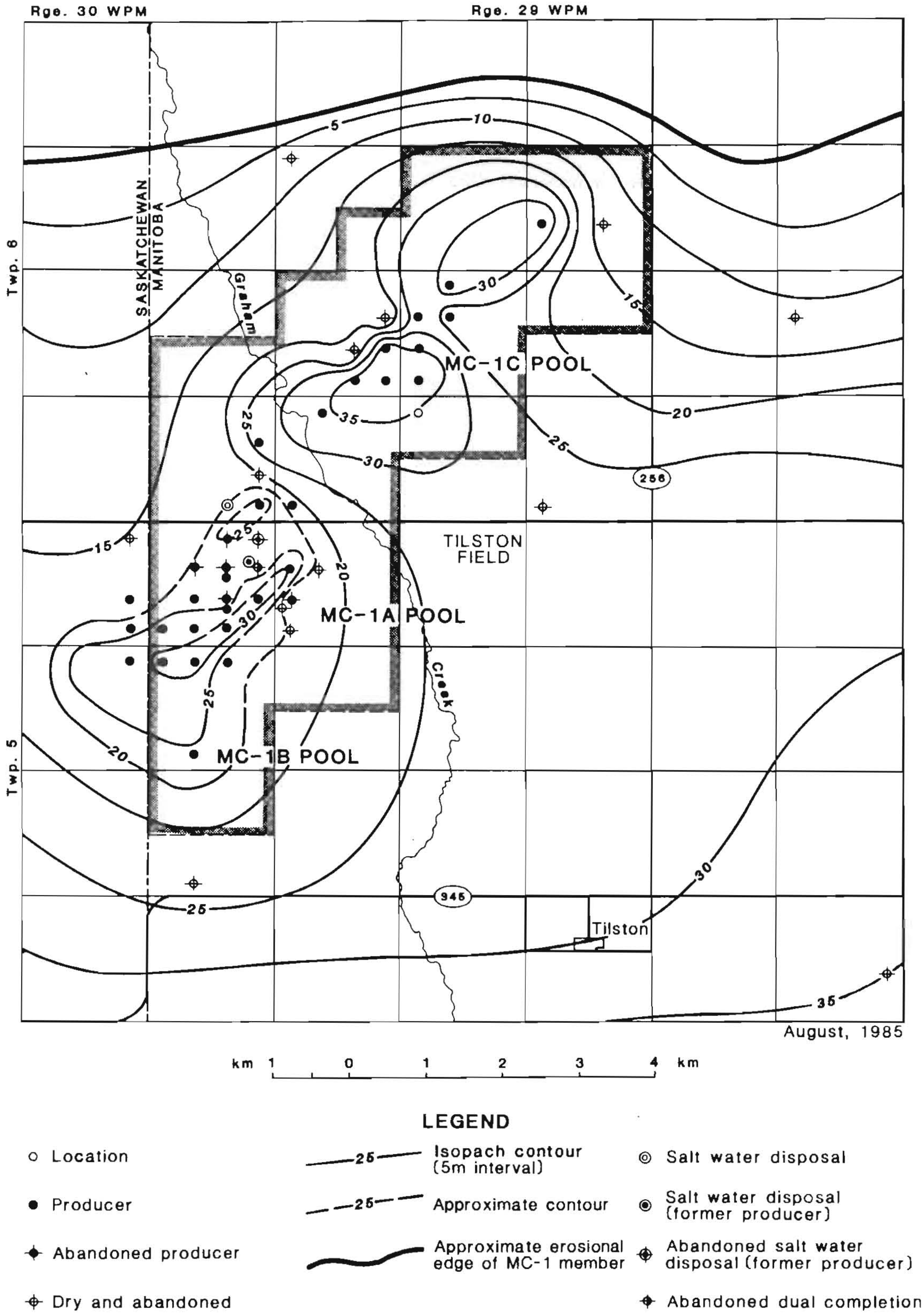


Figure 10: Isopach Map - MC-1 Member

Trapping Mechanisms

The Tilston Field is part of a regional stratigraphic trap setting present in southwestern Manitoba. Porous Mississippian reservoir beds have been truncated updip along the Mississippian erosional surface. Diagenetic processes occurring at the erosional surface have produced a dense anhydritic dolomite which acts as a caprock impeding updip hydrocarbon migration within the reservoir beds. In areas where the dolomite caprock has not been developed, the overlying Lower Amaranth 'Red Beds' provide the necessary seal.

Production in the Tilston Field is obtained from paleotopographic highs near the updip limit of the MC-1 Member subcrop belt. Structural cross-sections have been constructed across the three major paleotopographic highs within the Tilston Field to illustrate the truncation of the porous MC-1 reservoir beds at the erosional surface (Figs. 11-13). Hydrocarbon accumulation occurs within the MC-1 porosity underlying the dolomite caprock. Perforated intervals are situated directly below the impermeable cap.

The thickness of the altered zone underlying the Mississippian erosional surface ranges from approximately 2 m to 10 m within the study area. As noted from the structural cross-sections (Figs. 11-13), the altered zone tends to thicken over paleotopographic high areas, which correspond to areas of thinning of the overlying Lower Amaranth 'Red Beds'. This thickness relationship of the altered zone to the overlying 'Red Bed' cover has been observed in other fields in southwestern Manitoba. Downward percolation of hypersaline brines (through the Lower Amaranth 'Red Beds') associated with the deposition of the Upper Amaranth 'Evaporites' is the suggested mechanism for diagenetic alteration of limestone units situated directly below the Mississippian unconformity (McCabe, 1959; Rodgers, 1986). Paleotopographic high areas with correspondingly thin overlying 'Red Beds' facilitate the movement of the hypersaline brines through the 'Red Beds' and thus, create a thick altered zone. In areas with little or no paleotopographic elevation the altered zone is very thin or non-existent.

In the Tilston Field it has been observed that anhydrite occurs within the 'Red Beds' indicating that evaporitic conditions existed at least intermittently during deposition of the 'Red Beds'; some or even most of the alteration may have occurred prior to deposition of the Upper Amraranth 'Evaporites'.

Reservoir Geology

All production within the Tilston Field is obtained from the lower Mission Canyon MC-1 Member. The producing beds consist of bioclastic mudstone-wackestone with primarily intercrystalline matrix porosity and minor interparticle, intraparticle vuggy, and fracture porosity. Crystalline anhydrite is present in small amounts but does not greatly affect reservoir quality. Stylolites indicate some post-depositional compaction which would have reduced primary porosity.

Oil accumulation occurs directly below the altered zone associated with the Mississippian erosional surface. Preliminary attempts to determine the evaluation of the oil/water interface have indicated that it is not at a uniform elevation in the pools and may have an element of lithologic control. Detailed formation evaluation of the MC-1 Member is beyond the scope of this report.

CONCLUSIONS

The Mission Canyon Formation is part of a major cycle of marine transgression and regression which took place during Mississippian Madison time. The Mission Canyon Formation in Manitoba is divided into three members, in ascending order: the MC-1, MC-2 and MC-3 Members. Only the lower portion of the MC-1 Member is present within the defined study area of the Tilston field. The lower portion of the MC-1 Member represents the initial stages of the first Mississippian regressive evaporitic cycle. Deposition took place in a low to moderate energy marine environment below wave base.

Production within the Tilston Field is obtained from the upper portion of the MC-1 Member. Lithologically this unit consists of bioclastic wackestones which grade downward to mudstones. The main type of porosity is intercrystalline matrix porosity.

The Tilston Field is part of a regional stratigraphic trap setting in southwestern Manitoba. Trapping occurs where porous Mission Canyon MC-1 reservoir beds have been truncated updip at the Mississippian erosional surface. Diagenetic alteration of the MC-1 limestones at the unconformity have produced a dense anhydritic dolomite which acts as a caprock within the field. Hydrocarbon accumulation and production occur in paleotopograohic highs developed on the Mississippian erosional surface. The paleotopographic high associated with the MC-1 A Pool has an element of structural control; the paleohigh associated with the MC-1 C Pool has no indication of structural control and merely represents an erosional remnant of MC-1 strata.

Exploration within the Tilston Field has been sporadic with two main periods of activity: 1952-1959 and 1979-1984. Three producing areas have been designated within the field as the MC-1 A, MC-1 B and MC-1 C pools. Cumulative oil production as of April 30, 1985, for each pool is 82 622.7 m^3, 27.3 m^3, and 910.3 m^3, respectively.

Future Potential

Most of the oil produced from the MC-1 Member in southwestern Manitoba comes from the MC-1 A and MC-1 C Pools of the Tilston Field. Production from the MC-1 Member is also obtained from six small accumulations within the Waskada Field, and also from three wildcat locations just east of the Waskada Field.

Future exploration considerations should be given to the MC-1 Member subcrop trend in Manitoba. Using the Tilston Field as a model, any other paleotopographic high features near the updip limit of the MC-1 Member subcrop could provide suitable locations for hydrocarbon accumulation.

Future development potential exists within the Tilston Field itself. Geologic data indicate the pools within the Tilston Field are not entirely drilled out, in particular the MC-1 C Pool. Development potential also exists in the area north of the MC-1 C Pool following the recent discovery in the 5-15-6-29 WPM well.

REFERENCES

Barchyn, D.
1982: Geology and hydrocarbon potential of the Lower Amaranth Formation, Waskada-Pierson area, southwestern Manitoba; Manitoba Energy and Mines, Geological Report GR82-6, 30 p.

Choquette, P.W. and Pray, L.C.
1970: Geological nomenclature and classification of porosity in sedimentary carbonates; A.A.P.G. Bulletin, v.54. p. 207-250.

Dunham, R.J.
1962: Classification of carbonate rocks according to depositional texture, A.A.P.G. Memoir 1, p. 20-32.

Ghazar, W.
1977: Geological considerations in Tilston and Waskada areas, Manitoba; Manitoba Petroleum Branch Report, 13 p.

Kaldi, J. and Hartling, A.
1982: Diageneses of supratidal anhydrite: the Mississippian Tilston beds, Williston basin of southern Saskatchewan (abstract only); Fourth International Williston Basin Symposium, p. 181.

Martin, R.
1984: The Tilston Field, diagenetic alteration of a paleotopographic high; unpublished B.Sc. thesis, Department of Earth Sciences, University of Manitoba.

McCabe, H.R.
1959: Mississippian stratigraphy of Manitoba; Manitoba Mines Branch, Publication 58-1.

1963: Mississippian oil fields of southwestern Manitoba; Manitoba Mines Branch, Publication 60-5.

Miller, E.
1964: Parkman field: Third International Williston Basin Symposium, p. 204-214.

Rodgers, M.
1986: Petroleum geology of the Mississippian Mission Canyon Formation, Waskada Field, southwestern Manitoba; Manitoba Petroleum Branch Report PR1-85, 34 p.

APPENDICES

APPENDIX I

Table 1: Structural Data - Tilston Field and Surrounding Area (Twps. 5-6, Rges. 28-30 WPM)

Location	K.B. (m)	Top of Lower Amaranth (Subsea) (m)	Top of Mississippian (Subsea) (m)	Top of Upper Lodgepole (Subsea) (m)	Lower Amaranth Isopach (m)	MC-1 Member Isopach (m)
03-03-5-28 WPM	470.6	398.4	425.5	474.9	27.1	49.4
15-22-5-28 WPM	466.6	385.3	410.3	444.8	25.0	34.5
05-12-5-29 WPM	483.1	416.7	447.1	489.2	30.4	42.1
08-13-5-29 WPM	489.2	402.8	431.8	462.3	29.0	* 30.5
03-19-5-29 WPM	508.1	428.9	451.1	474.0	22.2	22.9
03-30-5-29 WPM	512.9	414.1	435.1	* 460.1	21.0	* 25.0
13-30-5-29 WPM	516.1	412.0	423.0	454.0	11.0	31.0
14-30-5-29 WPM	516.4	408.6	417.6	448.6	9.0	31.0
15-30-5-29 WPM	511.9	414.1	429.1	449.6	15.0	20.5
02-31-5-29 WPM	512.9	408.1	417.1	-	9.0	-
03-31-5-29 WPM	513.6	410.4	421.9	449.4	11.5	27.5
04-31-5-29 WPM	516.3	410.7	423.7	* 450.7	13.0	* 27.0
06-31-5-29 WPM	515.6	409.4	424.8	447.9	15.5	* 23.1
07-31-5-29 WPM	512.5	406.2	424.5	-	18.3	-
A7-31-5-29 WPM	513.0	405.5	423.5	-	18.0	-
08-31-5-29 WPM	514.2	406.6	416.7	-	10.1	-
09-31-5-29 WPM	512.4	408.4	428.5	-	20.1	-
A9-31-5-29 WPM	512.8	407.2	426.2	-	19.0	-
10-31-5-29 WPM	513.0	406.8	420.9	-	14.1	-
A10-31-5-29 WPM	513.6	406.9	419.4	-	12.5	-
11-31-5-29 WPM	514.8	403.3	425.5	-	22.2	-
15-31-5-29 WPM	513.0	407.8	420.3	-	12.5	-
16-31-5-29 WPM	512.1	406.6	424.2	-	17.6	-
04-32-5-29 WPM	511.8	-	-	-	-	-
A5-32-5-29 WPM	511.5	409.0	433.4	-	24.4	-
A5-32-5-29 WPM	511.9	408.1	430.3	-	22.2	-
11-32-5-29 WPM	507.2	407.2	434.6	-	27.4	-
12-32-5-29 WPM	508.3	404.9	418.9	-	14.0	-
04-03-6-29 WPM	501.4	400.8	434.3	* 463.3	33.5	* 29.0
04-05-6-29 WPM	506.0	406.3	431.3	-	25.0	-
14-05-6-29 WPM	508.0	399.0	417.0	450.5	18.0	33.5
01-06-6-29 WPM	510.5	406.3	421.9	-	15.6	-
02-06-6-29 WPM	512.4	408.7	427.9	-	19.2	-
08-06-6-29 WPM	508.6	407.6	432.9	* 451.4	25.3	* 18.5
09-06-6-29 WPM	508.3	404.7	425.2	452.2	20.5	17.0
01-08-6-29 WPM	512.7	394.4	411.4	448.4	17.0	38.0
02-08-6-29 WPM	511.4	395.7	412.2	448.7	16.5	36.5
07-08-6-29 WPM	511.8	398.0	423.3	447.4	25.3	24.1
08-08-6-29 WPM	513.5	394.0	410.5	446.0	16.5	35.5
09-08 6-29 WPM	513.0	398.0	430.0	445.0	32.0	15.0
04-09-6-29 WPM	509.8	396.7	415.7	453.7	19.0	38.0
05-09-6-29 WPM	511.4	393.1	412.6	447.1	19.5	34.5
11-09-6-29 WPM	507.2	394.4	422.4	444.4	28.0	22.0
12-09-6-29 WPM	513.1	393.4	416.4	443.4	23.0	27.0

*indicates estimated values

Table 1: Structural Data - Tilston Field and Surrounding Area (Twps. 5-6, Rges. 28-30 WPM) (Cont'd)

Location	K.B. (m)	Top of Lower Amaranth (Subsea) (m)	Top of Mississippian (Subsea) (m)	Top of Upper Lodgepole (Subsea) (m)	Lower Amaranth Isopach (m)	MC-1 Member Isopach (m)
14-09-6-29 WPM	508.15	391.9	412.4	443.4	20.5	31.0
12-12-6-29 WPM	499.93	391.1	428.1	438.6	37.0	10.5
05-15-6-29 WPM	502.3	383.2	402.2	436.0	19.0	33.8
07-15-6-29 WPM	496.2	386.8	422.8	435.9	36.0	13.1
13-17-6-29 WPM	518.2	394.1	427.3	434.9	33.2	7.6
16-34-6-29 WPM	511.1	359.7	388.7	* 345.0	29.0	Eroded
10-36-6-29 WPM	499.5	351.5	371.6	* 350.0	20.1	Eroded
15-36-6-29 WPM	501.4	350.2	372.8	* 345.0	22.6	Eroded
03-13-6-28 WPM	473.98	346.5	378.0	409.0	31.5	31.0
02-17-6-28 WPM	477.2	382.6	415.9	430.5	33.3	14.6
03-22-6-28 WPM	483.3	353.7	388.7	421.2	35.0	32.5
12-32-6-28 WPM	490.7	345.4	372.8	* 346.0	27.4	Eroded
07-35-6-28 WPM	479.3	341.2	379.0	393.6	37.8	14.6
14-03-5-30 WPM	517.2	455.7	478.9	520.9	23.1	42.1
13-06-5-30 WPM	525.2	477.6	507.2	-	29.6	-
16-07-5-30 WPM	523.4	468.4	498.8	-	30.4	-
09-11-5-30 WPM	517.9	442.1	467.1	577.1	25.0	*110.0
16-25-5-30 WPM	518.6	414.4	429.4	456.4	15.0	27.0
01-36-5-30 WPM	518.0	411.0	430.0	453.0	19.0	23.0
08-36-5-30 WPM	517.3	412.2	429.7	447.7	17.5	18.2
16-36-5-30 WPM	517.8	411.8	439.2	454.2	22.4	15.0
06-08-6-30 WPM	543.9	425.3	445.2	-	19.9	-
14-08-6-30 WPM	544.8	417.1	432.7	-	15.6	-
16-08-5-30 WPM	541.6	416.7	432.2	458.1	15.5	25.9
12-09-6-30 WPM	541.6	418.5	438.0	458.4	19.5	20.4
06-10-6-30 WPM	535.8	416.2	428.7	* 454.2	12.5	* 25.5
10-10-6-30 WPM	535.2	410.6	423.4	451.4	12.8	28.0
16-10-6-30 WPM	535.5	408.5	420.5	-	12.0	-
04-11-6-30 WPM	530.7	418.2	440.4	453.8	22.2	13.4
12-11-6-30 WPM	532.78	410.2	429.7	445.2	19.5	15.5
06-14-6-30 WPM	528.8	408.1	429.8	438.3	21.7	9.1
02-15-6-30 WPM	537.4	404.6	432.1	* 433.6	27.5	* 1.5
10-16-6-30 WPM	543.8	415.7	447.4	-	31.7	-
02-17-6-30 WPM	545.6	415.4	425.5	* 453.5	10.1	* 28.0
06-17-6-30 WPM	547.1	417.3	430.1	452.6	12.8	22.5
10-17-6-30 WPM	545.0	415.1	434.3	448.7	19.2	14.4
12-17-6-30 WPM	547.7	413.9	431.0	452.6	17.1	21.6
16-19-6-30 WPM	551.7	413.3	426.4	* 446.2	13.1	* 19.8
09-29-6-30 WPM	546.2	404.2	425.5	* 434.6	21.3	* 9.1
12-29-6-30 WPM	551.7	407.8	432.4	442.5	24.6	10.1
04-33-6-30 WPM	549.4	398.5	421.4	* 424.7	22.9	* 3.3
06-34-6-30 WPM	541.9	396.2	426.1	421.2	29.9	Eroded

*indicates estimated values

APPENDIX I

Table 2: Production Data-Tilston Field (Twps. 5-6, Rge. 29 WPM)

Location	Initial On-Production Date	Avg. Daily Production (1st year of production) (m^3)		Cumulative Production to Apr.30/1985 (m^3)		Water Cut (%) based on cumulative production (Apr. 30/85)	Tilston Pool
		Oil	Water	Oil	Water		
03-30-5-29 WPM	July/83	0.3	11.5	27.3	1 162.0	98	MC-1 A
	abd. Dec/84						
13-30-5-29 WPM	Sept/84	2.0	3.3	429.6	731.1	63	MC-1 A
14-30-5-29 WPM	Jan/83	2.2	2.5	1 341.1	2 925.9	69	MC-1 A
15-30 5-29 WPM	Aug/83	0.7	4.6	464.2	2 441.1	84	MC-1 A
02-31-5-29 WPM	Oct/79	1.2	3.7	3 324.9	3 547.6	52	MC-1 A
03-31-5-29 WPM	Sept/82	3.9	1.8	2 843.5	2 521.4	47	MC-1 A
04-31-5-29 WPM	Sept/84	1.1	4.8	206.0	933.8	82	MC-1 A
06-31-5-29 WPM	Sept/82	1.1	1.5	1 790.7	4 829.0	73	MC-1 A
7-31-5-29 WPM	Nov/56	4.2	7.9	10 713.9	116 167.5	92	MC-1 A
	abd. July/80						
A7-31-5-29 WPM	Aug/80	1.5	4.4	1 759.7	2 560.2	59	MC-1 A
08-31-5-29 WPM	Sept/55	4.0	7.8	8 870.3	72 688.9	89	MC-1 A
09-31-5-29 WPM	March/55	7.0	0.1	13 657.0	63 479.6	82	MC-1 A
	abd. July/80						
A9-31-5-29 WPM	Nov/80	0.2	8.4	16.3	773.1	98	MC-1 A
	convert to SWD May/80						
10-31-5-29 WPM	Nov/56	1.1	1.2	5 521.5	54 379.1	91	MC-1 A
	abd. July/80						
A10-31-5-29 WPM	Sept/80	2.6	3.6	2 637.7	3 437.4	57	MC-1 A
11-31-5-29 WPM	Aug/58	2.1	0.8	4 460.3	29 462.9	87	MC-1 A
	abd. Nov/84						
15-31-5-29 WPM	Oct/56	3.8	6.0	7 040.0	53 547.4	88	MC-1 A
	abd. May/84						
16-31-5-29 WPM	April/85	1.7	3.8	464.4	923.1	67	MC-1 A
	abd. Nov/59						
05-32-5-29 WPM	Aug/52	5.6	55.9	3 049.3	22 964.1	88	MC-1 A
	abd. May/84						
12-32-5-29 WPM	March/54	4.5	1.7	7 146.9	34 346.9	83	MC-1 A
04-05-6-29 WPM	Jan/59	1.8	0.1	1 095.7	1 092.6	50	MC-1 A
14-05-6-29 WPM	July/84	1.3	0.7	311.0	175.3	36	MC-1 C
01-06-6-29 WPM	Aug/57	1.2	0.3	5 797.1	27 000.0	82	MC-1 A
09-06-6-29 WPM	Sept/84	0.3	1.4	34.0	148.7	81	MC-1 C
01-08-6-29 WPM	Feb/84	3.3	0.7	1 086.7	238.8	20	MC-1 C
02-08-6-29 WPM	Feb/84	6.9	1.27	1 814.9	463.8	20	MC-1 C
08-08-6-29 WPM	Dec/83	6.5	1.3	2 253.1	683.5	23	MC-1 C
04-09 6 29 WPM	March/84	1.8	5.6	661.4	2 083.1	76	MC-1 C
05-09 6-29 WPM	Nov/83	5.8	1.5	1 870.6	545.9	23	MC-1 C
11-09-6-29 WPM	Mar/84	0.5	2.5	98.3	528.3	84	MC-1 C
12-09 6-29 WPM	Aug/83	1.9	1.9	790.5	874.3	53	MC-1 C
14-09-6-29 WPM	July/84	0.8	4.6	182.8	1 087.5	86	MC-1 C
05-15-6-29 WPM	July/84	0.9	3.0	222.2	703.6	76	MC-1 C

APPENDIX II

Core Descriptions

Newscope et al Tilston
14-9-6-29 WPM

926.0 m - 929.1 m	- Dolomite: white, cream, hard, microcrystalline, abundant anhydrite crystals (1.0 mm), massive blue grey anhydrite bands, anhydrite healed fractures, no visible porosity, tight, no oil staining.
929.1 m - 930.2 m	- Packstone: dull grey, medium hard, muddy, abundant bioclastic material, crinoid debris, ooids?, slightly dolomitic, poor interparticle porosity, predominantly tight, no oil staining.
930.2 m - 936.9 m	- Wackestone: dull grey to dirty white, hard, medium grained bioclastic material, crinoid, brachiopod, rugose coral, few fragmental units approach packstone, fair interparticle porosity, poor to fair oil staining.
936.9 m - 944.8 m	- Wackestone: cream, brown, medium hard, chalky texture, partly bioclastic, poor interparticle porosity, poor patchy oil staining. - Shale, dull green, calcareous, interbedded at the base.

Newscope et al Tilston
14-5-6-29 WPM

929.0 m - 933.9 m	-	Dolomite: creamy, white, microcrystalline, very hard, abundant anhydrite crystals (1.0 mm), massive anhydrite beds, anhydrite healed fractures, no visible intercrystalline porosity, tight, no oil staining.
933.9 m - 937.6 m	-	Wackestone: dull grey to medium dark brown, fragmental, bioclastic, hard, medium grained fragmental bioclasts, crinoid, brachiopod?, and pebble sized rugose corals, rare intercrystalline porosity and pin-point vuggy porosity, minor intraparticle porosity, fair oil staining.
937.6 m - 945.2 m	-	Wackestone: greyish white to medium brown,bioclastic, hard, fine to medium grained bioclasts, crinoid and brachiopod, chalky texture, fragmental decreases down section, poor matrix porosity and pin-point vuggy porosity, poor oil staining.
	-	argillaceous irregular shale partings near base with sharp based packstone units.
945.2 m - 945.7 m	-	Wackestone: whitish grey, hard, chalky texture, fine to medium grained bioclastic material, poor matrix porosity, patchy oil staining.

Newscope et al Tilston

5-9-6-29 WPM

927.0 m - 930.9 m	-	Dolomite: white, cream, tan, hard, microcrystalline, abundant anhydrite crystals (1.0 mm), rare stylolites (dark infilling), no visible porosity, no oil staining.
930.9 m - 932.8 m	-	Wackestone: dirty white to brown, moderately hard to hard, dolomitized near top, good matrix porosity and pin-point vuggy porosity, fair oil staining.
932.8 m - 933.6 m	-	Dolomite: mottled, tan, brown, anhydrite infilling, crinoids and solitary rugose corals, poor intercrystalline porosity, patchy oil staining.
933.6 m - 938.4 m	-	Wackestone: dull grey to brown, hard, crinoids, rugose corals, brachiopods, coarse grained fragmental bioclasts, fair matrix porosity, minor intraparticle porosity, fair oil staining.
938.4 m - 945.8 m	-	Wackestone: dirty grey, bioclastic, hard, chalky texture, medium grained crinoid debris, vertical fracture, few horizontal stylolites, poor to fair matrix porosity, poor patchy oil staining.
945.8 m - 947.0 m	-	Core missing.

Newscope et al Tilston
5-15-6-29 WPM

909.0 m - 915.1 m	-	Dolomite: cream, white microcrystalline, hard, abundant anhydrite crystals (1.0 mm), massive anhydrite beds and anhydrite healed fractures, no visible porosity, no oil staining.
915.1 m - 915.7 m	-	Dolomitic Limestone: tan, brown, hard, microcrystalline, fragmental bioclastic material (crinoid), poor intercrystalline porosity, poor patchy oil staining.
915.7 m - 925.4 m	-	Wackestone: white, dirty grey, fragmental, hard, crinoids, rugose corals, brachiopods, medium grained bioclastic materials, few horizontal stylolites (shaly infilling), few vertical fractures, fair matrix porosity and pin-point vuggy porosity, patchy oil staining.
	-	thin zones of interbedded packstone and mudstone near base.
925.4 m - 927.0 m	-	Wackestone: cream, brown, chalky texture, hard, little fragmental, bioclastic, poor matrix porosity, few horizontal stylolites, no oil staining.

Tundra Tilston

9-31-5-29 WPM

3060' - 3078.5' (932.7 m - 938.3 m)	-	Shale: red to earthy brown, medium hard, fissile, non-calcareous, few small angular anhydrite inclusions, thinly laminated texture, slightly sandy towards base.
3078.5' - 3085' (938.3 m - 940.3 m)	-	Shale: red to earthy brown, not as fissile as above, more sandy anhydrite infillings resembling clasts, pseudoconglomeratic appearance.
3085' - 3092.8' (940.3 m - 942.7 m)	-	Dolomite: light brown to pink, hard, finely crystalline, abundant sandy shale partings, angular anhydrite clasts, pseudobreccia appearance.
3092.8' - 3106.2' (942.7 m - 946.8 m)	-	Dolomite: light grey to tan brown, very hard, microcrystalline, abundant fine grained anhydrite crystals, massive anhydrite bands, anhydrite healed fractures, slight oil staining seen around some fractures, trace bioclastic, rugose corals, poor intercrystalline porosity, very poor patchy oil staining observed near bottom of the section.
3106.2' - 3108.4' (946.8 m - 947.4 m)	-	Wackestone: dull grey to brown, medium hard, medium grained bioclastic material, crinoid debris, good matrix porosity and pin-point vuggy porosity, dark oil staining.

California Standard North Tilston
4-3-6-29 WPM

3063' - 3068.6' (933.6 m - 935.3 m)	-	Siltstone: earthy red, laminated, partly sandy, abundant interbedded dolomite and anhydrite.
3068.6' - 3078' (935.3 m - 938.2 m)	-	Dolomite: pink-grey, dense, cryptocrystalline, massive appearance, few vertical fractures (oil staining?), small anhydrite healed fractures.
3078' - 3089' (938.2 m - 941.5 m)	-	Dolomite: creamy white, dense, microcrystalline, abundant anhydrite crystals (1.0 mm), anhydrite healed fractures, slight oil staining around some fractures.
3089' - 3092' (941.5 m - 942.4 m)	-	Dolomite: dull grey-green, fossiliferrous, finely crystalline, poor visible intercrystalline porosity, poor mottled oil staining.
3092' - 3115' (942.4 m - 949.4 m)	-	Wackestone: cream to brown, chalky texture, medium hard, fine grained bioclasts, crinoid, brachiopod, few subhorizontal stylolites, vertical fractures, packstone interbed 3101' - 3104', thin seam of dolomite 3094' - 3095', poor interparticle porosity, poor patchy oil staining.

Adnac Tilston

4-5-6-29 WPM

3072' - 3080' (936.3 m - 938.8 m)	-	Dolomite: grey to white, hard, microcrystalline, massive grey anhydrite filled fractures and anhydrite bands, no visible porosity, no oil staining.
3080' - 3089.3' (938.8 m - 941.6 m)	-	Wackestone: tan, brown, medium hard, bioclastic, medium grained crinoid debris, pebble sized rugose corals, fair intercrystalline porosity and pin-point vuggy porosity, also some large vugs, fair oil staining decreasing in section.
3089.3' - 3103.8' (941.6 m - 946.0 m)	-	Wackestone: light brown, medium hard, partly bioclastic, crinoid debris, brachiopod mold, few horizontal stylolites, poor matrix porosity, poor patchy oil staining.
3103.8' - 3110.6' (946.0 m - 948.0 m)	-	Wackestone: dirty white to grey, soft muddy, horizontal laminations, fine grained mud, green, calcareous, horizontal stylolites, poor porosity, poor oil staining.
3110.6' - 3127' (948.0 m - 953.0 m)	-	Wackestone: grey to brown, interbedded sequence, predominantly wackestone, some packstone intervals, also some chalky, fine grained carbonate intervals, few siliceous nodules? present, poor to fair intercrystalline matrix porosity, fair oil staining in coarse interval.

J.P. Owen Tilston

11-32-5-29 WPM

3089' - 3097.5' (941.5 m - 944.1 m)	-	<u>Dolomite</u>: grey to brown, very hard, abundant anhydrite crystals (1.0 mm), massive anhydrite beds, blue-grey crystalline anhydrite, green dolomite near base, rugose coral debris, very poor intercrystalline porosity, poor patchy oil staining near base.
3097.5' - 3128' (944.1 m - 953.4 m)	-	<u>Wackestone</u>: tan brown to dirty white colour, medium hard, medium grained crinoid debris, decreases down section, few horizontal stylolites, calcareous shale parting 3109' - 3109.5', interbedded packstone interval, 3106' - 3106.8', dolomitic, fragmental, crinoid and rugose coral, poor to fair interparticle porosity, poor patchy oil staining.
	-	few siliceous nodules? near base, banded, bleach white.
3128' - 3141' (953.4 m - 957.4 m)	-	<u>Mudstone</u>: grey-green, soft, fissile, finely laminiated, few hard shaly units not fissile, interbedded with fine grained calcareous mudstone, light pink-grey, few crinoids, burrows?, no visible porosity, no oil staining.
3141' - 3150' (957.4 m - 800.1 m)	-	<u>Mudstone</u>: pink-grey colour, medium hard, calcareous, abundant iron staining along bedding, lining burrows, abundant green laminations, calcareous, irregular bedding, poor matrix porosity, few large vugs (0.5 - 1.0 mm), no oil staining.

Tundra Tilston

6-31-5-29 WPM

944.0 m - 944.5 m - Dolomite: grey to light brown, hard, microcrystalline, anhydrite healed fractures, few fossil fragments, horizontal anhydrite band, no visible porosity, very slight oil staining near base.

944.5 m - 945.2 m - Dolomitic limestone: light brown, finely crystalline, hard, bioclastic, some anhydrite fracture filling, poor visible porosity, poor to fair oil staining.

945.2 m - 953.5 m - Wackestone: grey-tan, brown, medium hard, medium grained crinoid debris, few rugose coral tests, slightly dolomitic, vertical fractures, few horizontal stylolites, anhydrite nodules near top, fair visible interparticle porosity, fair to poor oil staining, decreases at the base.

953.5 m - 955.9 m - Wackestone: grey, light brown, medium hard, little bioclastic debris, chalky texture, few vertical fractures, trace pyrite in fractures, poor porosity, poor oil staining.

Tundra Tilston
7-31-3-29 WPM

3085' - 3087.6' (940.3 m - 941.1 m)	-	Dolomite: greyish white, hard, abundant anhydrite crystals (1.0 mm), thick (8.0 cm) blue-grey crystalline anhydrite seam, no visible porosity, no oil staining.
3087.6' - 3120' (941.1 m - 951.0 m)	-	Wackestone: tan to light grey, medium hard, bioclastic, crinoid debris decreasing down section, few rugose corals, few horizontal stylolites, few vertical fractures, slightly dolomitic at top interparticle porosity and pin-point vuggy porosity, fair to poor oil staining decreasing down section.
3120' - 3128.4' (951.0 m - 953.4 m)	-	Wackestone: grey to brown, medium hard, few coarser sections approaching packstone, slightly dolomitic, fragmental, fair interparticle porosity, fair oil staining.
3128.4' - 3135' (953.4 m - 955.5 m)	-	Wackestone: dirty white, little bioclastic material, chalky texture, poor interparticle porosity, trace poor patchy oil staining.