DEPOSITION AND DIAGENESIS OF THE UPPER RED RIVER FORMATION (UPPER FORT GARRY MEMBER) AND STONY MOUNTAIN FORMATION (UPPER ORDOVICIAN) NORTH AND WEST OF WINNIPEG, 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

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by

Garnet Cecil Grant Wallace

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ABSTRACT

The upper Ordovician (Richmondian) upper Red River and Stony Mountain Formations were studied in detail from drill core and quarry exposures at Headingley, Stonewall and Stony Mountain, Manitoba. The stratigraphy, depositional history and diagenetic alterations were documented for the upper portion of the Fort Garry Member (Red River Formation) and the Gunn, Penitentiary, Gunton and Williams Member (Stony Mountain Formation).

The upper Fort Garry was deposited in a low to high energy tidal flat setting characterized by clean carbonate sedimentation. Following a period of subaerial exposure at the end of Fort Garry time the Gunn Member was deposited. Sedimentation during Gunn time took place in a shallow marine environment characterized by low energy conditions, an influx of terrigenous material and the development of low-relief mud banks. The lower Penitentiary (deposited conformably upon the Gunn Member) represents shallow but open marine conditions while the upper Penitentiary was deposited in a constantly shallowing lagoonal setting which eventually became subaerially exposed. Sedimentation took place predominantly under low energy conditions with a constant influx of terrigenous material. The Gunton Member at Stony Mountain and Stonewall, Manitoba was deposited in an evaporitic tidal flat setting and a laterally equivalent marine setting respectively. Sedimentation took place in both low and high energy settings in a clean carbonate environment. Following a period of emergence which occurred at the end of Gunton time the Williams Member was deposited. Sedimentation during Williams time took place in a shallow marine setting in which slightly emergent mounds developed. The lower

Williams represents a high energy beach setting and the upper Williams represents a low energy intermound setting which eventually became emergent.

Diagenetic processes such as; borings, burrowing, the development of Phase I cements, some secondary porosity, early (primary) dolomite, authigenic feldspar, length slow chalcedony and some pyrite occurred relatively early in the diagenetic history of the sediments in the eogenetic to shallow mesogenetic environments. The development of chert, some pyrite and hematite, Phase II cement, neomorphic spar, secondary dolomite, and some secondary stylolites occurred later in the diagenetic history of the sediments in the mesogenetic environment. The development of Phase III cement, some secondary porosity and some hematite occurred in the telogenetic environment and represent the last diagenetic processes to occur.

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Chapter 1 INTRODUCTION

Location of Study Area

The study area is located in south central Manitoba north and west of the city of Winnipeg (Figure 1). The majority of data was collected from the City of Winnipeg Quarry located at Stony Mountain, Manitoba. Five sections were measured at this locality. One section was obtained from core hold M-2-69, drilled by the Manitoba Department of Mines, Resources and Environmental Management, while the remaining four sections were obtained from quarry exposures (Plate 1).

Additional sections were obtained from core hole M-1-69, drilled at Stonewall, Manitoba, and core recovered from drill hole M-3-74 taken from a locality approximately 5.6 km north of Headingley, Manitoba.

Small outcrops in the Stony Mountain area along with the Standard Limestone Products Quarry located 1.6 km north of the Stonewall junction on Hwy. 7 also were studied.

Stratigraphic Framework

The Stony Mountain Formation, named by Dowling (1900) is Upper Ordovician in age. Based on paleontological studies by Whiteaves (1895, 1897), Twenhofel (1925), Okulitch (1943), and Nelson (1959 a,b), the Stony Mountain Formation is Richmondian in age (Table 1).

Unconformably overlying the Red River Formation is the Stony Mountain Formation. The Stony Mountain Formation is in turn unconformably overlain by the Stonewall Formation. Though the exact position of the Silurian contact has been located in different parts of the Stonewall

Figure 1: Location of the quarries and drill holes used in this study and the approximate subsurface geological boundaries in the Winnipeg area (Modified from Bannatyne, 1975).

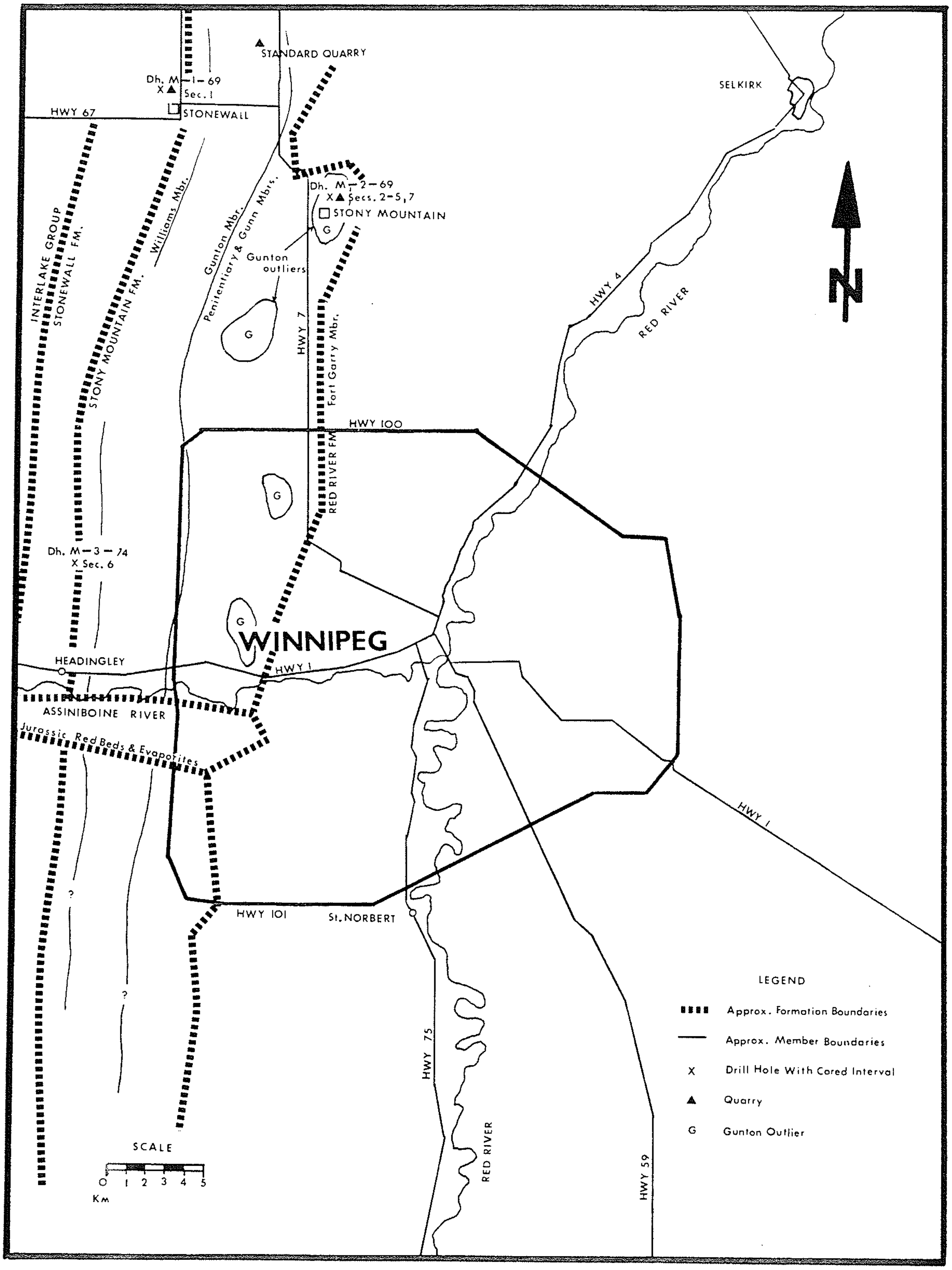

STANDARD QUARRY
Dh. M-1-69
Sec. 1
HWY 67
STONEWALL
SELKIRK
Dh. M-2-69
Secs. 2-5,7
STONY MOUNTAIN
INTERLAKE GROUP
STONEWALL FM.
STONY MOUNTAIN FM.
Williams Mbr.
Gunton Mbr.
Penitentiary & Gunn Mbr.
Gunton outliers
HWY 7
Fort Garry Mbr.
RED RIVER FM.
HWY 4
RED RIVER
HWY 100
Dh. M-3-74
Sec. 6
WINNIPEG
HEADINGLEY
HWY 1
ASSINIBOINE RIVER
Jurassic Red Beds & Evaporites
HWY 101
St. NORBERT
HWY 75
HWY 59
SCALE
0 1 2 3 4 5
Km
LEGEND
Approx. Formation Boundaries
Approx. Member Boundaries
X Drill Hole With Cored Interval
Quarry
G Gunton Outlier

Table 1: Stratigraphic table of formations encompassing the upper Red River, Stony Mountain, Stonewall and Interlake strata of southwestern Manitoba.

Time Rock Units (Systems / Series / Stages)	Okulitch 1943	Baillie 1952	Porter & Fuller 1959	Smith 1963	Cowan 1971	This Study 1978
Silurian		Interlake Group	Interlake Group		Interlake Group	
Silurian	Stonewall Formation	Stonewall Formation	Stonewall Formation	Stonewall Formation	S/O Stonewall Formation	Stonewall Formation
Upper Ordovician / Cincinnatian / Richmondian	S/O Stony Mountain Formation: Birse Member	S/O Stony Mountain Formation: Gunton Member	S/O Stony Mountain Formation: Gunton Member	S/O Stony Mountain Formation: Williams Member	Stony Mountain Formation: Williams Member	S/O Stony Mountain Formation: Williams Member
	Gunton Member			Gunton Member	Gunton Member	Gunton Member
	Penitentiary Member	Penitentiary Member	Stony Mountain Shale Member	Penitentiary Member	Penitentiary Member	Penitentiary Member
	Stony Mountain Shale Member	Stony Mountain Shale Member		Gunn Member	Gunn Member	Gunn Member
		Red River Form. / Selkirk Member	Red River Form. / Upper		Red River Form. / Fort Garry Member	Red River Form. / Fort Garry Member

S/O Silurian/Ordovician contact proposed by the authors.

section by various authors (Table 1), it has been placed at the base of a conglomeratic unit located at the top of the Williams Member. For the purpose of this study the lower Stonewall conglomerate is considered Silurian in age.

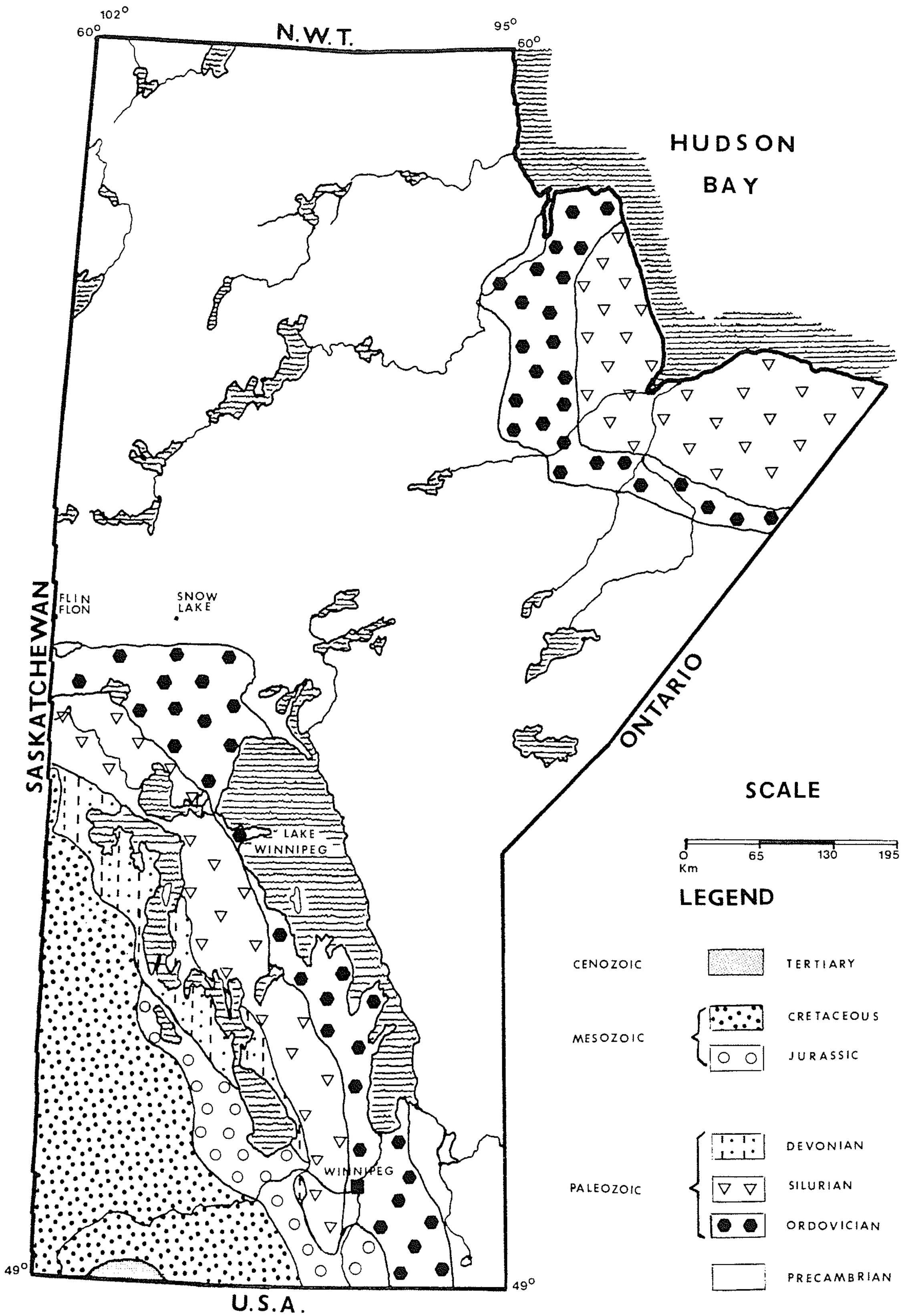
Regional Geology

The Paleozoic strata which outcrops in the northeastern and southwestern corners of the province (Figure 2) unconformably overlies the Precambrian surface.

In the northeastern corner of the province, south-southeast of Churchill, the Paleozoic strata are Ordovician, Silurian and Devonian in age. These rocks are remnants of the sediments deposited within the Hudson Bay Platform during the Paleozoic era. Cumming (1971) noted that these rocks are essentially carbonates and that the Ordovician Churchill River Group is equivalent to the Stony Mountain Formation of southwestern Manitoba.

In the southwestern corner of Manitoba (the ancestorial north-eastern flank of the Williston Basin) Paleozoic, Mesozoic, and Cenozoic strata were originally deposited. However, as a result of many periods of emergence and erosion many portions of the section are absent. The Paleozoic section in this area of the province consist of Ordovician, Silurian, Devonian and Mississippian strata. All but the Mississippian strata are exposed in southwestern Manitoba; this age of strata is present only in the subsurface of the extreme southwestern corner of Manitoba. The remaining portion of the Paleozoic strata have been removed during the pre-Jurassic erosional period.

Figure 2: Geological map of Manitoba (Modified after Manitoba Mines Branch Publication, Map 65-1).


102°
60°
N.W.T.
95°
60°
HUDSON
BAY
SASKATCHEWAN
FLIN
FLON
SNOW
LAKE
ONTARIO
LAKE
WINNIPEG
WINNIPEG
49°
U.S.A.
49°
SCALE
0
65
130
195
Km
LEGEND
CENOZOIC
TERTIARY
MESOZOIC
CRETACEOUS
JURASSIC
PALEOZOIC
DEVONIAN
SILURIAN
ORDOVICIAN
PRECAMBRIAN

The Ordovician outcrop in southwestern Manitoba is exposed in a north-south direction stretching from the United States border along the west shore of Lake Winnipeg. Seventy kilometers north of Lake Winnipeg the outcrop belt changes direction and trends in an east-west direction approximately 30-40 km south of Snow Lake and Flin Flon, Manitoba.

The Ordovician Winnipeg Formation, which overlies the Precambrian erosional unconformity in southwestern Manitoba, is composed of sandstone and interbedded shales. The basal portion is predominantly a sandstone sequence and the upper portion is predominantly shale. The total thickness of this formation is highly variable, ranging from zero to 66 m (McCabe, 1971, p. 171).

Conformably overlying this formation is the early Upper Ordovician Red River Formation. McCabe and Bannatyne (1970) subdivided this carbonate unit into four Members, in ascending order these are; the Dog Head, Cat Head, Selkirk and Fort Garry. The Red River Formation varies in thickness throughout the province from 52.5 to 150 m (McCabe, 1971, p. 171).

Unconformably overlying the Red River Formation is the Upper Ordovician Stony Mountain Formation. Smith (1963) subdivided the Stony Mountain Formation into four Members, in ascending order these are; the Gunn, Penitentiary, Gunton and Williams (Table 1). The Ordovician Silurian contact in this study has been placed at the top of the Williams Member. The Gunn and Penitentiary Members are composed of very argillaceous (up to 35 weight percent illite) and argillaceous (up to 25 weight percent illite) dolomite respectively. The Gunton is the cleanest carbonate member in which the basal 1.5 meters contain 12 weight percent clay and the remaining portion less than 2 weight percent. The Williams Member is a dolomite unit with up to 37 weight percent of arenaceous and argillaceous material. The thickness of the Stony Mountain Formation throughout the province ranges from 33 to 49 m (McCabe, 1971, p. 171).

Unconformably overlying the Stony Mountain Formation is the Stonewall Formation. The Stonewall Formation is predominantly dolomite but contains thin argillaceous beds in the middle and upper portion of the formation. The Stonewall Formation ranges in thickness from 9 to 21 m (McCabe, 1971, p. 171).

Objectives

The main purpose of this study is to provide a detailed examination of the uppermost portion of the Fort Garry Member of the Red River Formation and the Stony Mountain Formation in the Winnipeg area, emphasizing sedimentation and diagenesis. The objectives were to:

(1) provide a detailed petrographic description of these units,

(2) interpret their depositional history, and

(3) document their diagenetic history.

Previous Work

Following the initial study by Dowling (1900) on the Ordovician strata of Manitoba many similar studies have followed. Cowan (1971, Table 1, p. 237) described the evolution of stratigraphic nomenclature for the Ordovician and Silurian in southern Manitoba over the last 77 years. Regional stratigraphic mapping of the Paleozoic by the Geological Survey of Canada and the Manitoba Mines Branch has been documented by McCabe (1971).

Descriptions of the fauna of the Stony Mountain type section, of Richmondian age, are found in Nelson (1975, p. 464-476) and Baillie (1952, p. 32-36).

Local study of the outcropping portion of the Stony Mountain and Stonewall Formations by Smith (1963) indicated that this carbonate succession was subjected to periodic influxes of terrigenous material. The high argillaceous Gunn and Penitentiary Members are thought to represent open marine deposits which gave way to shallower and somewhat hypersaline conditions by middle Gunton time. During deposition of the Williams Member beach mounds developed in which quartz and argillaceous material were deposited. Following a short break in sedimentation a deepening of the waters occurred during Stonewall time allowing the development of small reefs to take place (Smith, 1963).

A regional study of the Ordovician and Silurian Formations around the Cedar Creek Anticline of southeastern Montana led Roehl (1967) to conclude that the environment of deposition of these Formations could be compared to the Recent low-energy marine and subaerial carbonate environments in the Bahamas.

Kendall (1976) studied the Ordovician carbonate succession in southern Saskatchewan and felt that emphemeral tidal flats developed along the marginal periphery of the Williston Basin. Evaporitic brines formed on these tidal flats and migrated basinward during withdrawal of the seas. This resulted in the formation of anhydrite beds which marked the end of a cyclic depositional period in the subtidal environment.

Methods of Study

The field work consisted of describing four quarry sections and one drill core (M-2-69) at Stony Mountain, Manitoba and drill core at Stonewall (M-1-69) and Headingley (M-3-74), Manitoba. From the total 153 m of measured sections 225 samples were collected.

Two hundred and twenty-five polished slabs were prepared and etched in mild hydrochloric acid from which 175 slabs were selected for thin section study and 50 slabs for acetate peel preparation. All thin sections were stained with potassium ferricyanide and alizarian red S (Dickson, 1965) to identify ferroan and non ferroan calcite and dolomite. Five hundred to six hundred point counts per thin section were used for modal analysis of selected slides.

X-ray diffraction analysis was used to identify carbonate and terrigenous minerals. X-ray diffraction analysis was also used to provide semi-quantitative measurements of the weight percent calcite in dolomite according to Royse et al. (1971).

Acknowledgements

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Chapter 2 STRATIGRAPHY AND DEPOSITIONAL HISTORY

Introduction

The upper Red River Formation and Stony Mountain Formation are carbonate units with varying amounts of terrigenous material. Figure 3 demonstrates that the insoluble residue content ranges from less than 1 to 35 weight percent in the sections measured. This chapter will discuss the lithological variations of the carbonate rock types characteristic of each formation and document their environmental interpretation.

Red River Formation

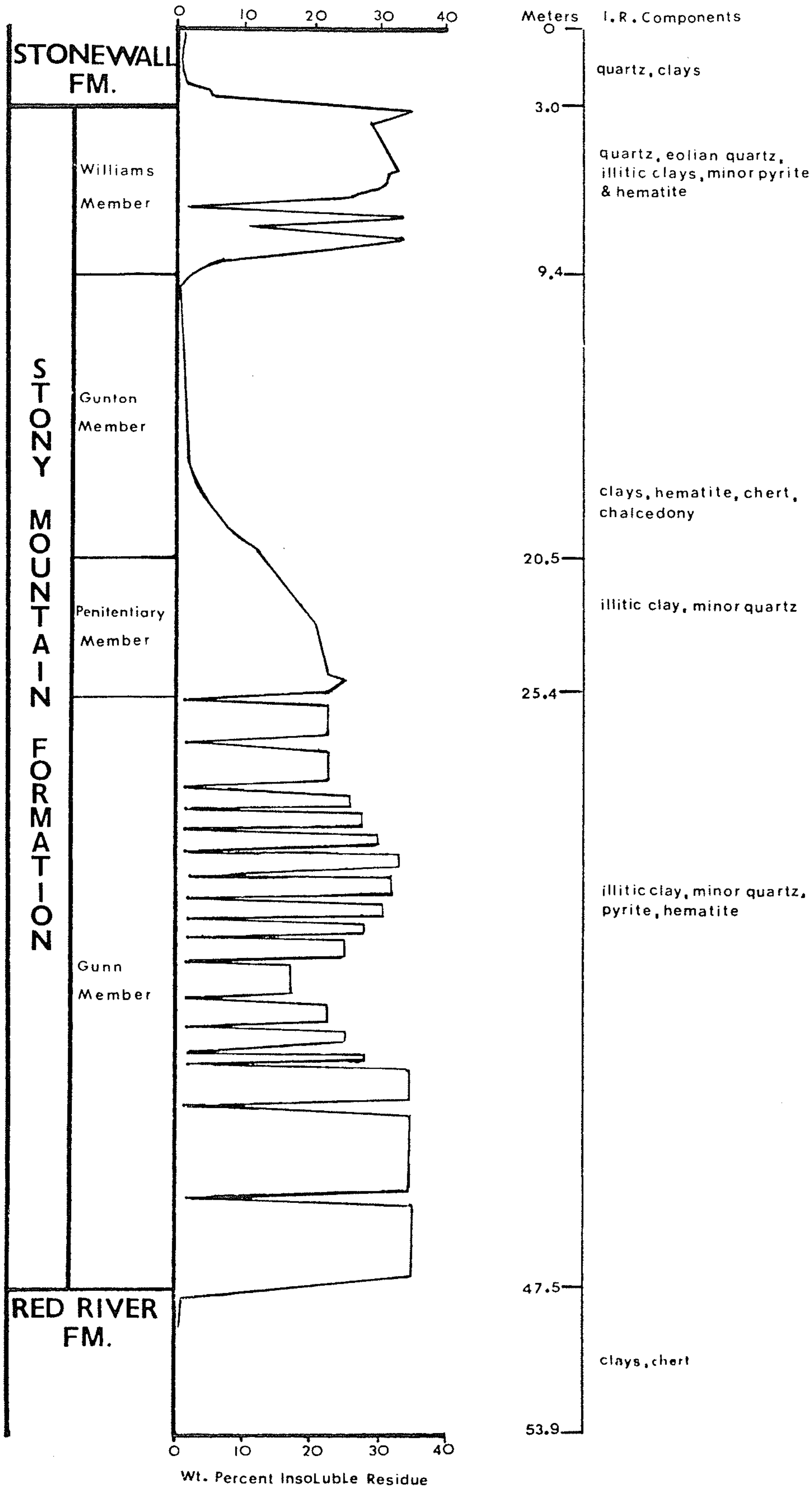
Fort Garry Member

Introduction

The upper Fort Garry Member of the Red River Formation near Winnipeg can be divided informally into an upper dolomite and an overlying upper limestone unit (McCabe, personal communication, 1976). Drill core of the upper Fort Garry Member was taken at Section 6 and 7. As shown in Figure 4 (back pocket) the deepest drill core of the Fort Garry Member was obtained at Section 6 measuring 6.3 m while the core hole at Section 7 recovered approximately 3.9 m. The upper limestone unit varies from 1.3 to 3.0 m respectively as shown in Figure 4 (back pocket).

The upper contact of the Fort Garry Member in the study area is a sharp well defined surface. The variations in thickness of the upper limestone unit, the nature of the contact and the sharp lithologic change (see Figure 3) in the overlying Gunn Member of the Stony Mountain

Figure 3: Insoluble residue (in weight percent) in the interval between the top of the Red River Formation and the lower portion of the Stonewall Formation.


0 10 20 30 40
Meters
I.R. Components
STONEWALL FM.
quartz, clays
3.0
Williams Member
quartz, eolian quartz, illitic clays, minor pyrite & hematite
9.4
STONY MOUNTAIN FORMATION
Gunton Member
clays, hematite, chert, chalcedony
20.5
Penitentiary Member
illitic clay, minor quartz
25.4
Gunn Member
illitic clay, minor quartz, pyrite, hematite
47.5
RED RIVER FM.
clays, chert
53.9
Wt. Percent Insoluble Residue

suggest that the upper contact is an erosional surface.

Stratigraphy

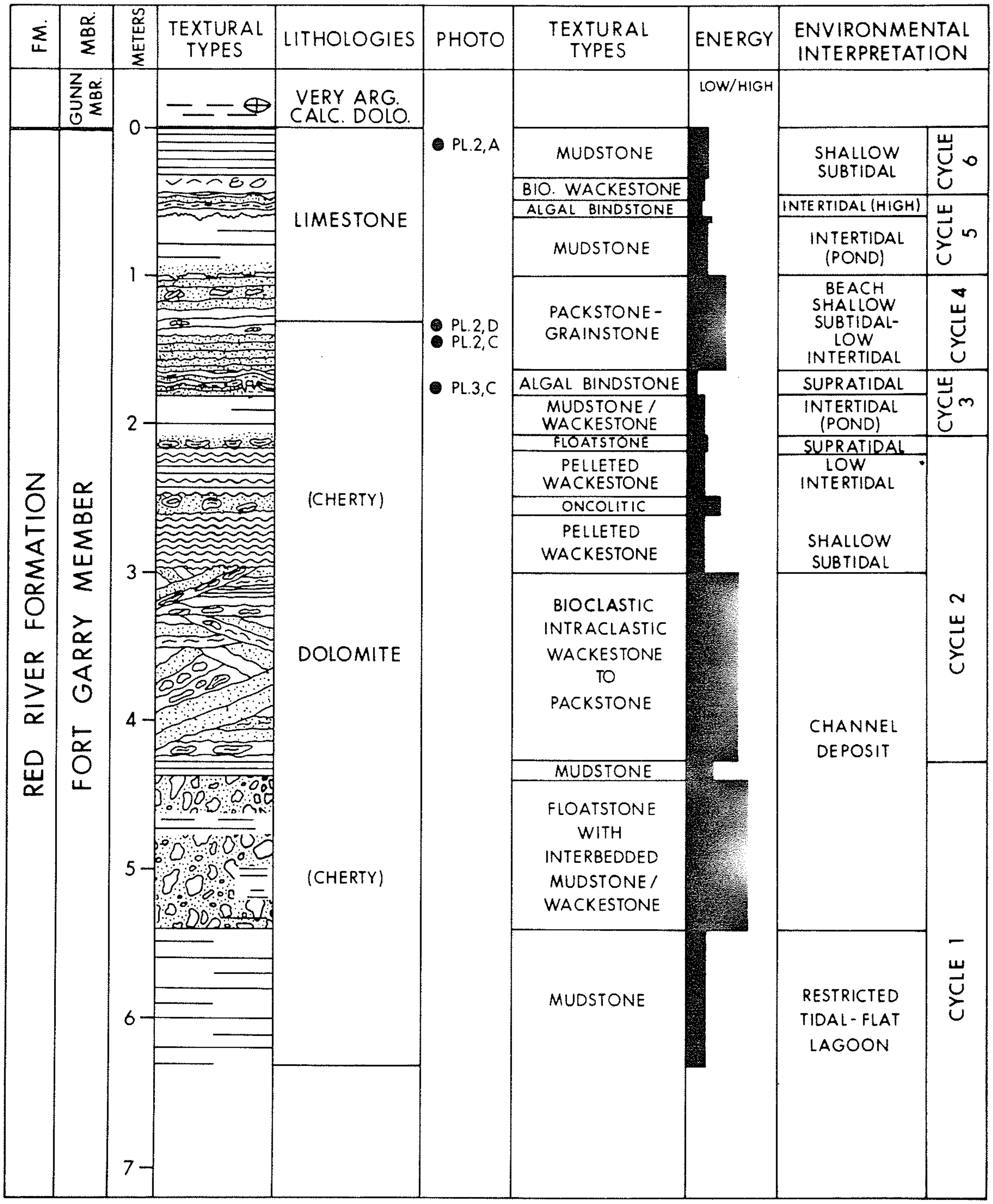
Figure 3 shows that the upper Fort Garry Member is a clean carbonate. Insoluble residue analysis of the upper limestone unit reveals that less than 1 weight percent insoluble residue is present. Clay is the insoluble residue in the upper limestone unit whereas clay and chert characterize the underlying dolomite unit.

The diagrammatic stratigraphic section presented in Figure 5 displays the textural types of carbonate rocks which are present in the drill core of the Fort Garry interval of Section 6 (M-2-69). Lithologies, textural types (based on Embry and Klovan's (1971) classification system for carbonate rocks), energy conditions and environmental interpretations are discussed.

The basal 0.90 m of the Fort Garry Member is composed of a thickly bedded uniformly dense carbonate mudstone similar to the mudstone displayed in Plate 2, Figure A. White chert nodules (up to 3 cm in size) are found along the bedding planes of this interval. Bivalve remnants, crinoid ossicles, unknown skeletal debris and scatter pellets comprise less than 5 percent of the interval.

Overlying the mudstone interval is a 1 m thick unit composed of a crudely bedded, dark grey, intraclastic floatstone with minor interbedded pale yellow mudstone to wackestone. Scattered throughout the interval are white chert nodules similar to those in the underlying mudstone. The intraclasts are randomly oriented, range from 0.3 to greater than 2.5 cm in size, are rectangular to equant in shape, angular to subangular and form the main component in beds which range from 15 to

Figure 5: A diagrammatic stratigraphic section of the Fort Garry interval measured from Section 6. (Headingley, Manitoba)


FM.
MBR.
METERS
TEXTURAL TYPES
LITHOLOGIES
PHOTO
TEXTURAL TYPES
ENERGY
ENVIRONMENTAL INTERPRETATION
GUNN MBR.
VERY ARG. CALC. DOLO.
LOW/HIGH
RED RIVER FORMATION
FORT GARRY MEMBER
0
1
2
3
4
5
6
7
LIMESTONE
(CHERTY)
DOLOMITE
(CHERTY)
PL.2,A
PL.2,D
PL.2,C
PL.3,C
MUDSTONE
BIO. WACKESTONE
ALGAL BINDSTONE
MUDSTONE
PACKSTONE-GRAINSTONE
ALGAL BINDSTONE
MUDSTONE / WACKESTONE
FLOATSTONE
PELLETED WACKESTONE
ONCOLITIC
PELLETED WACKESTONE
BIOCLASTIC INTRACLASTIC WACKESTONE TO PACKSTONE
MUDSTONE
FLOATSTONE WITH INTERBEDDED MUDSTONE / WACKESTONE
MUDSTONE
SHALLOW SUBTIDAL
INTERTIDAL (HIGH)
INTERTIDAL (POND)
BEACH SHALLOW SUBTIDAL-LOW INTERTIDAL
SUPRATIDAL
INTERTIDAL (POND)
SUPRATIDAL
LOW INTERTIDAL
SHALLOW SUBTIDAL
CHANNEL DEPOSIT
RESTRICTED TIDAL-FLAT LAGOON
CYCLE 6
CYCLE 5
CYCLE 4
CYCLE 3
CYCLE 2
CYCLE 1

20 cm in thickness.

Unidentified fossil debris, crinoid ossicles and bivalve remains comprise less than 5 percent of the interval and occur in both intraclasts and matrix. Thin horizontal shale partings are present in minor amounts throughout this interval.

The contact between the floatstone and underlying mudstone interval is not exposed in the drill core, however, the rather sudden change in component size over such a short interval suggests that the contact is a scoured surface.

Gradationally overlying the floatstone is a thin bedded mudstone interval, 13 cm thick, containing 2 cm thick white chert nodules along the bedding planes and a distinct absence of fossil remains.

Succeeding this is a 1.31 m thick interval of bioclastic-intraclastic wackestone to packstone. This unit is characterized by moderate to high angle cross bedding (20^{o} to 30^{o}), scoured surfaces, slumping fabrics and undulating bedding surfaces. The skeletal components consist of unknown debris, highly comminuted bivalve remains, crinoid ossicles, gastropods and algal mat fragments. The intraclasts vary in size and shape, are characteristically tabular in form, and are predominantly carbonate, although some are composed of very argillaceous carbonate. Scattered throughout the allochems are pellets of unknown origin.

Overlying the upper scoured surface of the bioclastic-intraclastic wackestone to packstone interval is a 0.76 m thick interval of pelleted wackestone. This interval is characterized by thin bedding and small scale ripples. Interbedded within this interval (see Figure 5) is a thin bed of concentric laminated oncolitic structures less than 0.5 cm in size. White chert nodules developed parallel to bedding are present in the lower 40 cm of this interval.

Faunal allochems are mainly unknown debris, bivalve remains and to a lesser extent, small low spired gastropods and crinoid remains. Pellets may have originally been more abundant in this interval but have been obscured by dolomitization.

Overlying the pelleted wackestone to mudstone is a 3 cm thick floatstone interval composed of finely laminated mudstone with desiccated intraclasts up to 2 cm in length and 0.6 cm in thickness.

Immediately above the floatstone is a uniformly dense carbonate mudstone interval 0.33 m thick. The mudstone is characterized by a homogenous but somewhat mottled appearance, a very minor biological component and moderately thick horizontal bedding.

The succeeding 14 cm interval is composed of a very finely laminated algal bindstone. As seen in Plate 3, Figure 3, the algal bindstone is characterized by desiccation features, birdseye structures and the development of fenestral porosity. Between some laminae very minor micro-intraclastic and bioclastic debris has accumulated.

Figure 5 shows that the overlying 0.70 m thick interval is a thinly bedded packstone to grainstone. The interval is characterized by thin low angle cross bedding, small scale graded bedding, scoured surfaces and a parallel alignment of intraclasts to bedding plane surfaces. The interval is dominated by the presence of peloids, intraclasts and well developed moldic porosity after peloids (Pl. 2, Figs. C and D; Pl. 10, Fig. D respectively). Some of the peloids which have not been highly altered during diagenesis have an internal microstructure which indicates they were originally oolites.

The intraclasts are extremely variable in size, shape and composition; however, the majority are composed of dolomite. The intraclasts may be finely laminated or composed of dense dolomite mud. A unique intraclast found only in this interval is composed of argillaceous dolomite and contains finer, subangular to angular intraclasts of the same material (Pl. 2, Fig. D).

The skeletal components are comprised of unknown debris, bivalve remains, and to a lesser extent, gastropods and crinoid pieces. In all cases the biological components are highly comminuted.

Succeeding the packstone to grainstone interval is a 0.56 m interval of limestone mudstone and algal bindstone. The 0.40 m interval immediately overlying the packstone to grainstone interval is comprised of a uniformly dense, thickly bedded, non-fossiliferous mudstone. This mudstone is similar to the overlying mudstone shown in Plate 2, Figure A except that the bedding is thicker. Immediately overlying the mudstone is a 16 cm interval comprised of a poorly preserved algal bindstone. This interval is characterized by burrowing, ripped up algal mat intraclasts and poorly preserved fenestral porosity.

Overlying the algal bindstone is a 15 cm thick bioclastic wackestone. This interval contains disarticulated and articulated thin-shelled bivalves, gastropods and large quantities of pellets floating in a mudstone matrix.

Succeeding the bioclastic wackestone and forming the uppermost bed of the upper Fort Garry Member is a 29 cm interval of thinly bedded non-fossiliferous carbonate mudstone. As shown in Plate 2, Figure A the mudstone has a very dense uniform appearance and lacks sedimentary structures.

The upper contact is a sharp surface which separates the very