THE WINNIPEG FORMATION IN MANITOBA

A Thesis
Presented to
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In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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by
George Macauley
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9. Red River No. 2

10. Stony Mountain No. 1

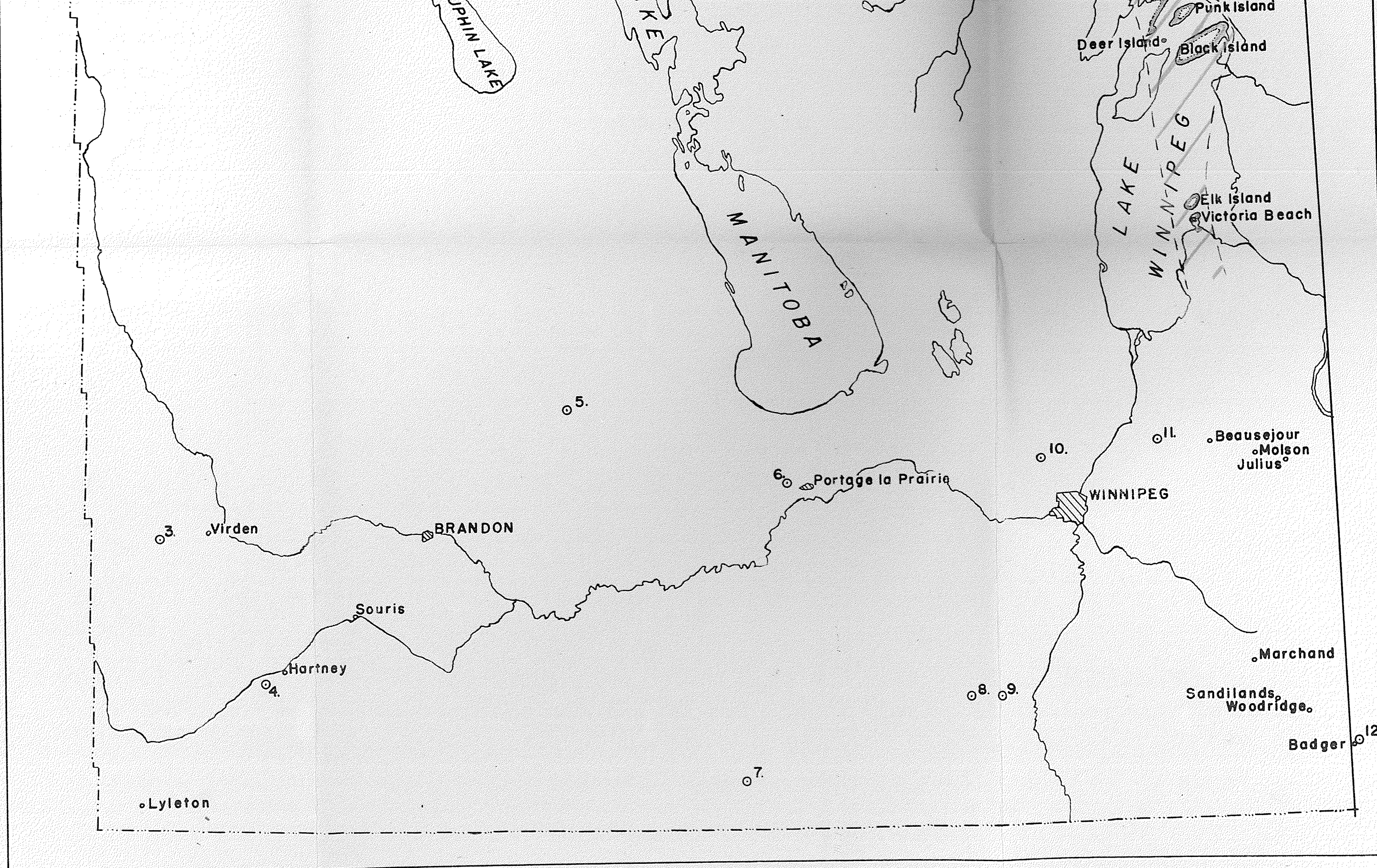
11. Red River No. 1

12. Whiteside No. 1

LEGEND

Outcrop areas of Winnipeg Formation

Outcrop zone



LOCATIONS of WINNIPEG FORMATION IN MANITOBA

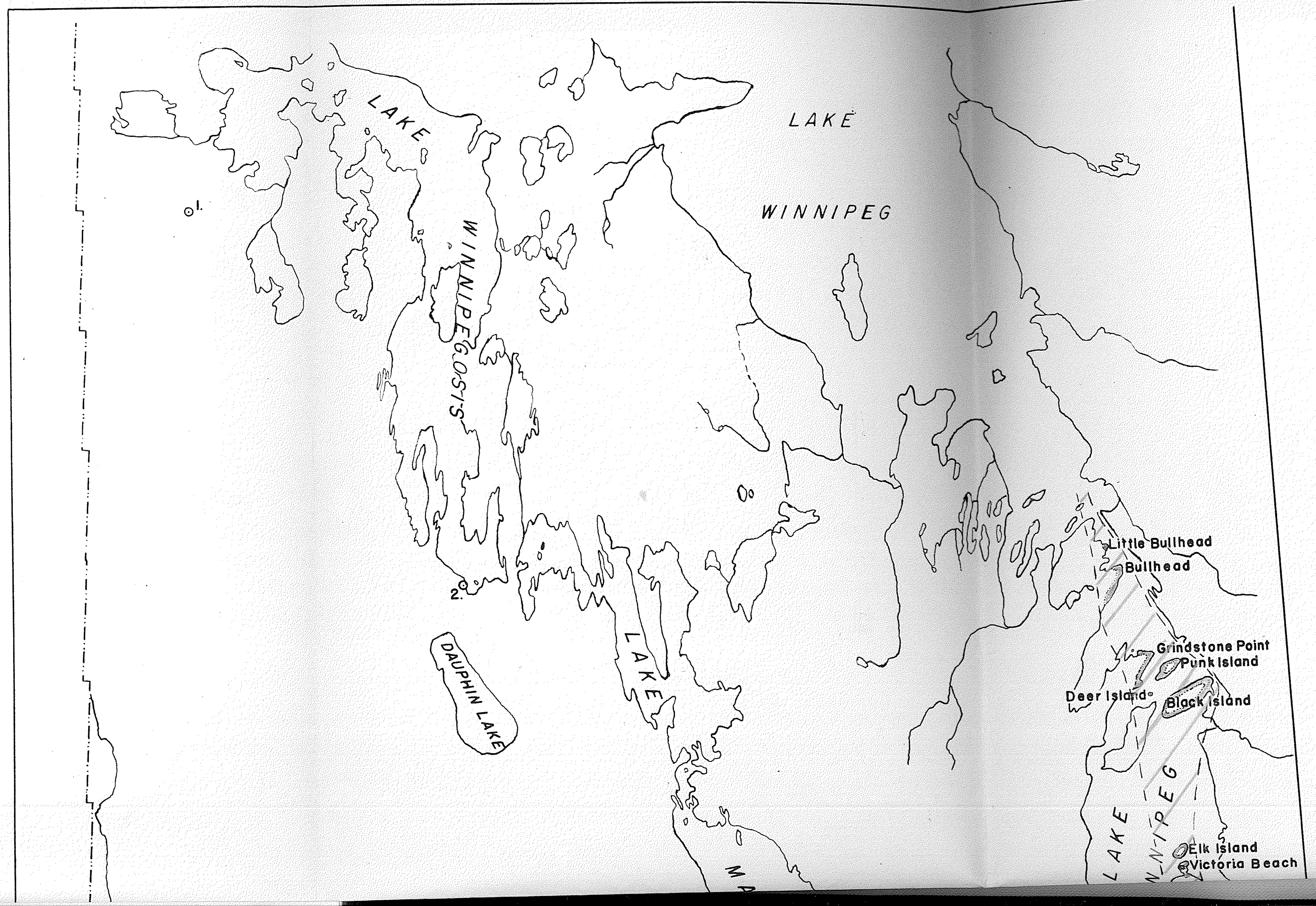
20 10 0 20 40 60 Miles

Scale: *20 Miles = 1 Inch*

Figure I - Locations of Winnipeg formation in Manitoba

WELLS

1. Mafeking No. 3
2. Winnipegosis No. 4
3. Daly 15-18
4. Hartney 16-33
5. Langford No. 1
6. Portage la Prairie No. 1
7. Commonwealth Manitou No. 2
8. Red River Hepner No. 2
9. Red River No. 2
10. Stony Mountain No. 1



CHAPTER I

INTRODUCTION

The Winnipeg formation is the lowermost Ordovician formation in Manitoba. It is underlain by Precambrian rocks and overlain by the Ordovician Red River formation.

The Winnipeg formation outcrops along a narrow band on the shores and islands of Lake Winnipeg, which forms part of the trade and travel route of the early settlers and explorers of Manitoba (see Figure 1). Thus the Winnipeg formation, generally exposed as sandstone cliffs, has been on view from the time of the voyageur to the present. Early geological parties did not fail to examine the Winnipeg formation in its outcroppings along the lake, but their attentions were centered on the overlying more fossiliferous, and, at first appearance, more interesting Red River limestone rather than on the Winnipeg formation. Although the sandstone sections along the lake have been described several times, and some fossils have been collected and identified, the information has always been presented in minor sections of reports dealing with the Red River formation. Consequently no detailed study of the Winnipeg formation has yet been made, and no reports have been published concerning it alone.

This paper attempts to organize, enlarge upon and interpret the existing information. The Winnipeg formation is traced across Manitoba, and, as far as possible, into the neighboring areas of North Dakota and Saskatchewan. Consideration is given to the evaluation of the lithologic changes which take place over this large area in the interpretation of the origin of the formation. Petrographically the emphasis is placed on the sandstone facies with little regard to the shale. Faunas are identified and comparisons are made between the Winnipeg faunule and the faunas of the Red River and Stony Mountain formations, which constitute the remainder of the Manitoba Ordovician (Table I, page 3). Comparisons are made with the Galena-Trenton and Lander faunas, and with the faunas of the Arctic and of Anticosti Island. Included is a short discussion of the Winnipeg sandstone facies as a possible source material for some of the Pleistocene sand deposits in Manitoba.

1. HISTORICAL REVIEW

Richardson in 1817 and 1825-27 (see Whiteaves, 1900)[1] made the first geological investigations of the Winnipeg formation. In 1858, Hind (Whiteaves, 1900)

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[1]. Names and year refer to Bibliography at end of publication.

TABLE of PALEOZOIC FORMATIONS in MANITOBA

AGE	FORMATION	MEMBER	THICKNESS	DESCRIPTION
Miss.	Madison		0 - 900'	limestone, dolomite, shaly limestone, anhydrite and chert
U. Dev.	Jefferson		variable	dolomite, shaly dolomite, limestone and anhydrite
M. or U. Dev.	Upper Manitoban		60 - 70'	shaly limestone
M. Dev.	Lower Manitoban		120'	shaly limestone
	Evaporites		variable	anhydrite, salt, red beds
	Winnipegosan		250'	reef dolomite
	Elm Point		50'	limestone and shaly limestone
Sil.	Ashern		0 - 50'	red beds and red shaly dolomite
	Stonewall		450'	pink, buff, cream dolomite
U. Ordo.	Stony Mountain	Birse	less than 150'	dolomite and dolomitic limestone
		Gunton		dolomite with red bands
		Penitentiary		dolomite, some purple tints
		Stony Mountain		red shale, shaly limestone
	Red River	Selkirk	350 - 500'	grey limestone, blue tints
		Cathead		dolomitic limestone, chert nodules
		Doghead		buff limestone, brown spots
	Winnipeg		0 - 230'	calcareous green shale facies grades to pure quartz sandstone facies
Precambrian				

TABLE I

carried out further survey work. These men showed the lithologic similarity of the Winnipeg sand to the St. Peter sand and suggested the possibility of the same origin for both. Accordingly the age assigned to the Winnipeg formation was Chazy.

Dowling (1898) published a report on geology along the shores and islands of Lake Winnipeg. Whiteaves (1900) described the fossils collected by Dowling. In their reports they gave a Black River age to the Winnipeg formation.

A few fossils, described by Whiteaves (1900), were collected by T. C. Weston in 1884 and by J. B. Tyrrell in 1899.

Wallace (1925) noted the suggestion of a possible correlation of the Winnipeg sandstone to the Potsdam sandstone of Cambrian age on a lithological basis only, with no faunal evidence considered.

The heavy minerals of the Winnipeg formation were described by Wallace and McCartney (1928) as part of a study of heavy minerals in some Manitoba sand deposits.

The first use of the term "Winnipeg formation" was by Kerr (1949), although formational status had never been established previously, nor was this rank established in Kerr's report. Generally the term "Winnipeg sandstone" was used because of the dominance of sandstone in the outcrops.

II. ACKNOWLEDGEMENTS

Financial assistance for research on the Winnipeg formation was granted by the National Research Council of Canada in the form of a research bursary. The Research Council also granted permission for the publication of an abstract of this paper and for its presentation at the annual meeting of the Geological Society of America at Detroit, November, 1951.

The samples of the North Dakota wells were studied at the invitation of Dr. Wilson M. Laird of the North Dakota State Geological Survey. Dr. Laird supplied valuable assistance during a brief but beneficial visit to the Survey offices at Grand Forks, North Dakota.

The staff of the Manitoba Mines Branch was extremely cooperative throughout the entire research program. Special thanks must be given to Dr. J. D. Allan, chief Geologist of the Mines Branch. Through the cooperation of the Mines Branch the writer was able to visit outcrops along Lake Winnipeg and collect samples of the Winnipeg formation. Pleistocene sand samples were also obtained through the aid of the Mines Branch.

Several oil companies added much important information by generously supplying cores and samples from various wells. The Imperial Oil Company supplied the

cores and samples used in the study of the basal Cambrian sandstone of Alberta. The Sohio Oil Company supplied samples from the Plunkett #1 well. The Union Oil Company of California donated excellent fossil specimens from the stratigraphic test well, Anstaadt #1. The California Standard Company released cuttings and cores from its Manitoba wells for this report.

The fossil specimens have been collected by many different persons and groups, who have all kindly donated the specimens to the Geology Department of The University of Manitoba. The Natural History Society of Manitoba donated a large number of excellent specimens from Victoria Beach. Dr. Kirk's collection from the shores and islands of Lake Winnipeg was fully utilized. Among the persons known to have collected specimens are Rand, Hillyer, Stokes, Leith and Allan.

The writer is indebted to Mr. E. I. Leith of the Department of Geology, The University of Manitoba, who suggested the problem and who gave excellent supervision throughout the course of the research work.

CHAPTER II

STRATIGRAPHY

Until wells recently drilled in Manitoba provided new information, the Winnipeg formation was known only by the sandstone facies that outcrops along Lake Winnipeg. However, new ideas must be formulated from the additional knowledge of the shale section that is encountered in wells in south-west Manitoba, North Dakota and Saskatchewan.

I. PREVIOUS WORK

The foremost contribution to date on the stratigraphy and paleontology of the Winnipeg formation was made by D. B. Dowling in 1898 when he prepared his "Report on the Geology of the West Shore and Islands of Lake Winnipeg." This paper discussed and described the Cambro-Silurian (Ordovician) rocks which outcrop along Lake Winnipeg, and listed the more abundant faunas of the Red River and Winnipeg formations. The faunas were identified by J. F. Whiteaves, who, in 1900, prepared a report on "The Fossils of the Galena-Trenton and Black River Formations of Lake Winnipeg and Vicinity." The heavy minerals were described by Wallace and McCartney (1928).

The above constitute the notable contributions to the geology of the Winnipeg formation to date.

II. FORMATIONAL STATUS

The Winnipeg formation is a lithologically distinct, mappable unit, composed of two facies, one dominantly sandstone, the other shale. It is easily distinguished from the underlying Precambrian basement complex and from the overlying Red River formation.

The Winnipeg formation is defined as the sandstone and shale section which underlies the limestone of the Red River formation and which rests upon the Precambrian basement complex.

In North Dakota and Saskatchewan there is some difficulty in distinguishing the Winnipeg shale facies from the underlying Cambrian shales and from overlying shales which are equivalent to the Lander sandstone.

The term "Winnipeg formation" was first used by Kerr (1949), although formational rank was not established.

It is impossible to name the Winnipeg formation under the rules of nomenclature as it consists of two lithologic units. Also, preference is not to include lithologic terms in formation names. Thus the name given must be "Winnipeg formation." The terms "Winnipeg sandstone" and "Winnipeg shale" will be useful in the discussions of the facies present, but they must be recognized as nomenclature of facies only and cannot be used to designate the Winnipeg formation.

III. TYPE SECTIONS

There is no established type section of the Winnipeg formation. Baillie, of the Manitoba Mines Branch, suggests[1] that no type section should be established as the complete Winnipeg formation is not exposed at any one place. The upper part is exposed at Black Island and the lower part at Grindstone Point (Baillie[1]).

The California Standard Company's Cal-Stan Daly 15-18 well (Figure 1, location 3) near Virden, Manitoba, has possibly the best development of the Winnipeg formation of the several wells from which a type well section might be chosen. It was the first well to penetrate the Winnipeg formation in a location where the features of the Winnipeg shale facies are clearly shown.

Some North Dakota wells penetrated the Winnipeg formation section previous to Cal-Stan Daly 15-18, but the Winnipeg formation is not clearly defined in any of these wells as difficulty arises in differentiating the Winnipeg shale from the underlying Cambrian shales in that area.

A complete description of the type well section is given on pages 16-18.

1. personal communication

IV. DISTRIBUTION

The Winnipeg formation is exposed along the west shore and on the islands of Lake Winnipeg in Manitoba (see Figure 1). An outcrop was reported on the Grassy River at Simonhouse Lake on the Hudson Bay Railway, but the exact location of this outcrop could not be determined. However, outcrops of the Winnipeg formation may be expected anywhere along the Paleozoic fringe in Manitoba.

Some sandstone is exposed along the Hudson Bay Railway near Hudson Bay. The writer does not consider this is the Winnipeg sandstone.

To the north, locations have been reported along the Hudson Bay Railway where the Red River limestone rests directly upon the Precambrian floor with no Winnipeg formation present.

In south-western Manitoba, North Dakota and Saskatchewan, the Winnipeg formation is known only from well samples and cores. In the extreme south-west corner of Manitoba wells must penetrate over 6000 feet to encounter the Winnipeg formation. Wells that encountered the Winnipeg formation in Manitoba are shown in figure 1.

V. LITHOLOGY

In outcrop the Winnipeg formation is characteristically a pure, apparently poorly consolidated, in part argillaceous, quartzose sandstone, the grains of which are well rounded, with lesser thin interbeds of light green soft shale. To the south and west of Lake Winnipeg, in well sections, shale gradually becomes the dominant rock type, with lesser sandstone. In North Dakota and Saskatchewan the Winnipeg formation is entirely shale, except for a thin basal sandstone layer and a few arenaceous zones in the shale.

The Winnipeg sandstone is commonly white, but locally bands with higher iron content show brown color and staining. The sand grades from massive to finely bedded in the outcrops, commonly with very finely interbedded green shale laminae, In Manitoba the shale is dominantly medium green, with a dull to waxy lustre, but in North Dakota there is a color gradation to dark grey and black. Traces of drab olive and red shales occur in the section in the south-west part of Manitoba.

The following are descriptions of the Winnipeg formation at various outcrop localities, which are marked on figure 1.

Grindstone Point, Lake Winnipeg. (also described by Dowling in 1898)

2.0' Limestone - dark grey to brownish, mottled, weathers to yellow, flaggy bedded, flat lying

TOP OF WINNIPEG

0.3' Argillaceous sandstone - light to chocolate brown, finely bedded, flat-lying conformable beneath overlying Red River limestone

--- local angular discordance, underlying beds all dipping 12 degrees west

13.0' Sandstone - fresh surface white to pale buff, weathers to dark grey or black, some bands of highly cross-bedded and laminated, few greenish shaly stringers one-quarter to three-quarter inches thick, one 4 inch band of massive sand near top of interval

5.0' Shale and argillaceous sandstone - dull green soft shale interbedded with white and brown (ferruginous?) sandstone, cross-bedding in sand, shale finely laminated in bands one-half to 6 inches thick, shale and sand beds often interlens

Total: 20.3'

Victoria Beach, east shore, southern end Lake Winnipeg

A small outcrop is composed of highly calcareous, medium to coarse grained, well rounded, quartzose, pyritic, slightly argillaceous, poorly fossiliferous sandstone at the base grading upward to highly argillaceous, calcareous sandstone, arenaceous shale and green shale at the top. The upper part contains numerous fossil remains, many of which are pyritized.

Black Island, Lake Winnipeg

On the north and west shores, near the western tip of the island, are two small outcrops of Winnipeg sandstone. Towards the west on the north shore there is a quarry from which a white, very pure, fine grained, well sorted, quartzose Winnipeg sand was once removed for commercial glass-making purposes.

In an outcrop at the center of the north shore is a thin porous sandstone, overlain and underlain by brown soft sand. The central part contains very fine "oolitic-like" pyrite concretions, which are easily mistaken for ostracods. This zone contains a siliceous cement.

Elsewhere along Lake Winnipeg the outcrops are dominantly loose, soft, friable, white to light brown, quartzose sandstone, with little or no shale and argillaceous material. Several other outcrops are described by Dowling (1898).

Descriptions of Manitoba well sections which penetrate the Winnipeg formation, along with locations and elevations are as follows:

<u>Red River Oil Company Hepner #2</u>

Lsd. 3-1-5-2WPM, south-west of Winnipeg
(Figure 1, location 8)
Elevation: 791' ground; 796' K.B. estimated

In this well the Winnipeg formation is a very fine grained, sub-angular to sub-round, quartzose sandstone, which is soft and loose, containing a small amount of a whitish clay cementing matrix. There is some medium green, soft, fissile shale in the section. The shale is encountered at a depth of 915 feet below the well elevation and the sand at a depth of 917 feet.

<u>Stony Mountain #1</u>[1]

SE$\frac{1}{4}$-29-12-2EPM, north-west of Winnipeg
(Figure 1, location 10)
Elevation: 800' ground

565 - 610 Limestone - light brown

1. description essentially the same as in Kerr (1949)

610	TOP OF WINNIPEG
610 - 650	Shale - greyish-green, soft
650 - 695	Shale - green
695 - 708	Sandstone - light grey, loose, coarse grained, fairly well rounded grains, considerable frosting and pitting, quartzose
708	PRECAMBRIAN
708 -	Igneous rock - grey, biotite

Portage la Prairie #1[1]

Lsd. 3-9-12-7WPM, directly south of Lake Manitoba (Figure 1, location 6)
Elevation: 850 approximately

1390 - 1420	Limestone - grey
1420	TOP OF WINNIPEG
1420 - 1450	Shale - brownish-green, calcareous
1450 - 1480	Shale - green, slightly calcareous, soft
1480 - 1530	Shale - as above, with a little iron staining
1530 - 1540	Sandstone - grey, well rounded quartz, soft, loose, well sorted, pure
	PRECAMBRIAN undetermined

Commonwealth Manitou #2[1]

Lsd. 8-26-2-9WPM, south-central Manitoba, near U. S. border (Figure 1, location 5)
Elevation: 1270? K.B.

2480	TOP OF WINNIPEG
2480 - 2490	Shale - medium green, fairly hard, slightly calcareous
2490 - 2570	Shale - green, very slightly calcareous, and some splintery
2570 - 2580	Shale - dark olive-green, non-calcareous, and some shale as above, traces of pyrite and of sub-rounded quartz grains
2580 - 2600	Shale - bluish-green, to some greenish-black, soft, slightly calcareous
2600 - 2610	Sand - clear and some yellow, well rounded quartz, fine to medium

1. description essentially the same as in Kerr (1949)

	grained, well sorted
2610 - 2613	Shale - green, non-calcareous, trace red shale
2613	PRECAMBRIAN
2613 -	Quartzite

Langford Syndicate #1[1]

Lsd. 5-29-14-14WPM, west of southern tip of Lake Manitoba (Figure 1, location 5)
Elevation: 1139 ground, 1141 K.B.

2300 - 2380	Limestone - light grey to light buff, mottled
2380	TOP OF WINNIPEG
2380 - 2505	Shale - medium to dark green, with some greyish-green in upper 25 feet, fairly hard, generally splintery
2505	PRECAMBRIAN
2505 -	Iron formation

Winnipegosis #4[1]

Sec. 29-30-17WPM, south end of Lake Winnipegosis (Figure 1, location 2)
Elevation: 840 approximately

1270 - 1330	Limestone and Dolomite
1330	TOP OF WINNIPEG
1330 - 1340	Sandstone
1340 - 1365	Shale - brownish-grey, greyer in top part
1365 - 1380	No samples
1380 - 1410	Shale - brownish-grey grading downward to greenish-grey
1410 - 1444	Sand - white, with some buff at top of interval, usually coarse well rounded quartz
1444 - 1447	Clay - light greyish-green
1447 - 1458	Sand - clear, medium to coarse quartz
1458	PRECAMBRIAN
1458 -	Weathered rock

1. description essentially the same as in Kerr (1949)

Coutts Brandon #2

Lsd. 14-16-10-19WPM, near Brandon, not shown in figure 1
Elevation: 1313 K.B.

This well encountered Winnipeg formation at a depth of 3365 feet and drilled a five foot interval of it, consisting of very light green shale with numerous small pyrite concretions. There is a small amount of fine grained white sandstone and a trace of large well rounded clear quartz grains

Cal Stan Hartney 16-33

Lsd. 16-33-5-24WPM, south-west Manitoba (Figure 1, location 4)
Elevation: 1412 ground

This well encountered the Winnipeg formation and the Precambrian at depths of 4958 and 5315 feet respectively. The section is very similar to that of Cal Stan Daly 15-18, the type well section. The brown pellets and phosphate nodules of the type well are also found here. The cored interval 4979-4992 recovered 11 feet as follows:

4'10" Shale - greyish-green, massive, splintery, non-calcareous, waxy, silty, micropyritic, top 1.3' and bottom 1.5' contain numerous clear and buff, fine to medium size, round to sub-angular quartz grains and some reddish-brown pellets; core has pitted appearance; traces finely disseminated pyrite on partings

6'2" Shale - dark green, splintery, non-calcareous, waxy, micropyritic, scattered quartz grains as above, few bands with fine quartzose sandstone, fine clear angular quartz grains in clay matrix, tight 2'10" from base, traces finely disseminated pyrite on partings

Cal Stan Daly 15-18[1]

Lsd. 15-18-10-27WPM, west of Virden (Figure 1, location 3)
Elevation: 1608 ground, 1620 K.B.

1. description essentially that of E. A. Brownless, California Standard Company

5195 - 5220	Limestone - pale and dark grey, mottled, a little buff, microcrystalline to dense, fragmental, argillaceous, trace pyrite nodules, tight
5220	TOP OF WINNIPEG
5220 - 5225	Shale - greenish-grey, calcareous, soft, silty, few included fine quartz grains; 10% loose quartz, fine to medium grains, clear to buff, rounded, traces small oval brown pellets
5225 - 5230	As above, with trace yellow-brown shale
5230 - 5235	Shale - as above, pale green to pale grey, soft, silty, calcareous to non-calcareous; 5% loose quartz grains, some dark brown pellets and a few large black phosphate nodules (sedimentary apatite)
5235 - 5245	Shale - and a few scattered quartz grains, as above
5245 - 5255	Shale - as above; 5% very fine clear and buff rounded quartz grains
5255 - 5260	50-50 Shale and Quartz - as above, trace brown pellets
5260 - 5270	Shale - as above, traces yellow-brown shale, trace loose scattered quartz grains
5270 - 5280	Shale - greenish-grey, calcareous to slightly calcareous, trace yellow-brown, silty, some loose clear and buff rounded quartz grains
5280 - 5285	40% Shale - as above; 60% Shale - dull brick red, grading to some purple, non-calcareous, silty
5285 - 5290	Shale - as above, 50-50 mixture
5290 - 5295	Shale - 60% greenish-grey, 40% red to purple
5295 - 5300	Shale - 70% greenish-grey, 30% red to purple
5300 - 5315	Shale - greenish-grey, slightly calcareous, silty, soft
5315 - 5320	Shale - as above, trace scattered, loose, fine, clear, rounded quartz grains
5320 - 5325	90% Shale - as above; 10% Quartz - loose, fine, clear, rounded, some frosting and pitting, trace pyrite nodules

5325 - 5335	Shale - with numerous loose quartz grains
5335 - 5340	90% Shale - as above; 10% Quartz; trace clear tight quartzose sandstone
5340 - 5345	60% Shale - greenish-grey, slightly to non-calcareous, silty, soft, trace pale green splintery shale; 40% Sand- loose quartz, clear and frosted, fine to coarse grained, well rounded, trace clear tight quartz sandstone, trace pyrite nodules
5345 - 5350	70% Sand; 30% Shale
5350 - 5353	80% Sand; 20% Shale
5353 - 5363	Cored interval

Core description: 5353-5363; recovered 8'2"

6'0" Sandstone - grey to greenish with some black mottling, fine to medium grained, non-calcareous, quartzose, round to sub-round grains, clear and frosted, poorly consolidated, fine pyrite crystals and nodules

2'2" weathered chlorite schist

PRECAMBRIAN at 5359 by electrolog

The California Standard Company's Cal Stan Daly 15-18 well described above may be considered as a type well section as it was one of the first wells to penetrate the shale facies representing the thickest part of the Winnipeg formation in south-west Manitoba.

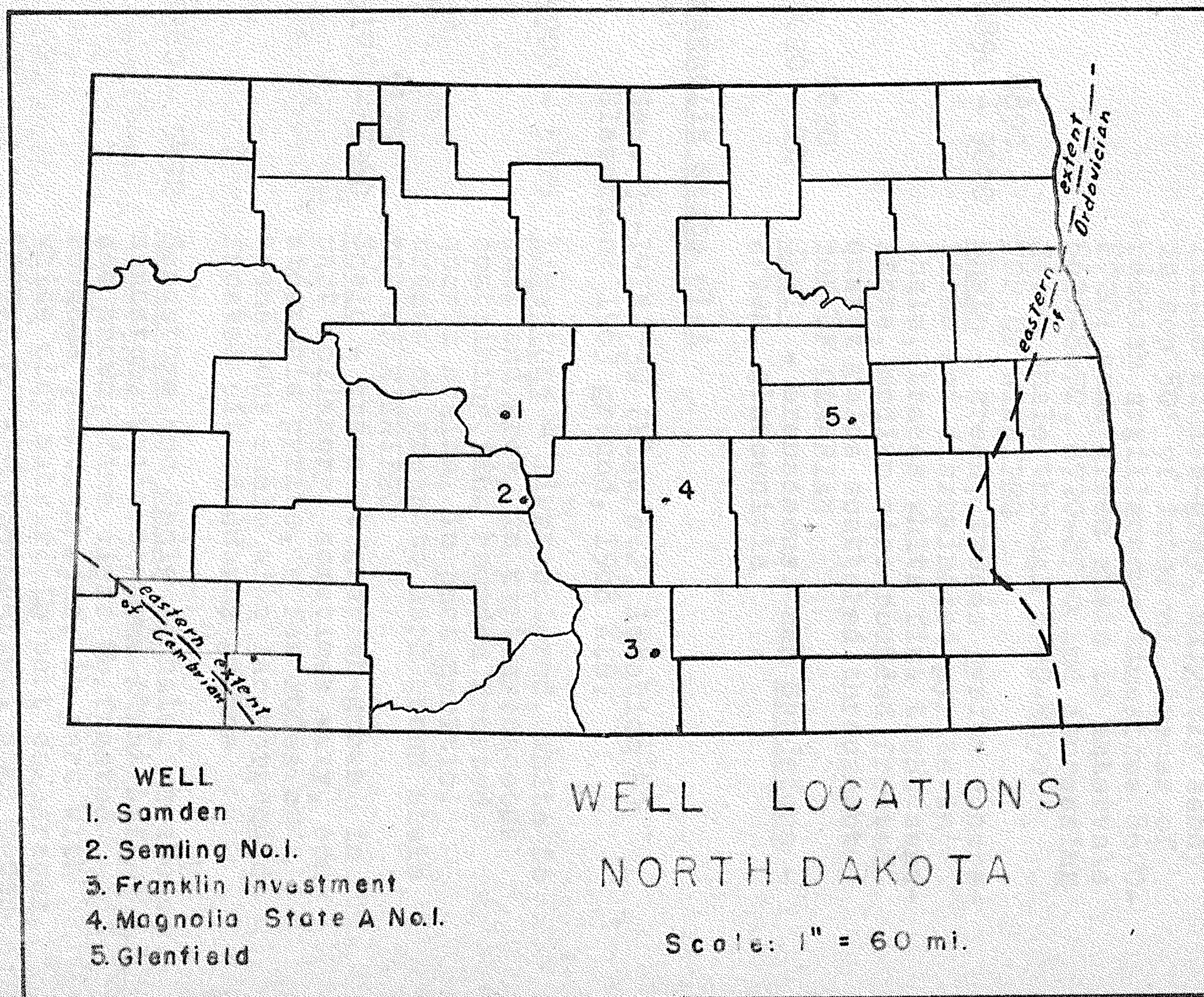
The North Dakota wells have considerable Cambrian strata below the Winnipeg formation. Several wells (see figure 2, page 19) were examined and their descriptions are as follows:

Samedan Vaughn Hanson #1

Sec. 10-146N-81W (Figure 2, location 1)
Elevation: 1995 ground

The contact of the Red River and Winnipeg formations in this well is rather indistinct

Figure 2 - North Dakota Well Locations



with some interbedding of shale and limestone

8600 - 8890	Limestone - white to grey and a little bluish-grey, slightly sandy in top 50' of interval, traces of reddish argillaceous limestone 8670-8720; some green shale in intervals 8620-8670, 8720-8740 and increasing green shale through 8740-8890
8890	TOP OF WINNIPEG
8890 - 9020	Shale - green, traces pyrite concretions and disseminated pyrite in shale, traces white fine tight sandstone, medium size rounded frosted quartz grains scattered throughout
9020	TOP OF CAMBRIAN
9020 - TD	Shale - arenaceous; and Sandstone - green, glauconitic

Magnolia State #1-A

Sec. 36-141N-73W (Figure 2, location 4)
Elevation: 1963 ground, 1968 K.B.

4900 - 5175	Limestone - light colored, white to buff and grey, in part arenaceous containing fine rounded frosted quartz grains, in part pyritic, traces of green to dark green shale
5175	TOP OF WINNIPEG
5175 - 5360	Shale - green to greyish-green, in part splintery, sometimes waxy, considerable pyrite, a few zones of arenaceous shale with large rounded frosted pitted quartz grains
5360 - 5492	Sandstone and Shale - shale, as above; sandstone white to some light buff and brown, fine clear to frosted rounded quartz grains, in part with white clay matrix, in part calcareous, traces pyrite cementation, some zones of loose quartz sand
5492	TOP OF CAMBRIAN
5492 - 5609	Shale and Sandstone - shale, as above; sandstone, light brown to white, some red and green, in part highly glauconitic, pyritic, generally fine to

medium size, clear to frosted well rounded quartz grains

<u>Carter Emma L. Semling #1</u>

SE-SE-18-141N-81W (Figure 2, location 2)
Elevation: 2025 ground, 2034 K.B.

8310	TOP OF WINNIPEG
8310 - 8476	<u>Shale</u> - green, calcareous, some splintery, in part pyritic, some black phosphate pellets, some drab brown to orange shale
8476 - 8491	<u>Sand</u> - white, clear, medium to coarse grained, sub-round, soft, poorly consolidated, iron stains in top 5', in part argillaceous, traces phosphate pellets (sedimentary apatite), cored interval 8481-8491
8491 - 8570	<u>Shale</u> - green, in part splintery, arenaceous zones, small amounts sandstone and loose quartz, a few phosphate nodules
8570	TOP OF CAMBRIAN
8570 - 8605	<u>Limestone</u> - grey, arenaceous, tight, glauconitic, pyritic, some green shale as above
8605 - 8830	<u>Shale</u>, <u>Limestone</u> and <u>Sandstone</u> - glauconitic
8830	PRECAMBRIAN

<u>Northern Ordnance Franklin Investment #1</u>

NW-SW-35-133N-75W (Figure 2, location 3)
Elevation: 1909 K.B.

4880	TOP OF WINNIPEG
4880 - 4903	<u>Sandstone</u> - grey, fine, slightly calcareous, traces limestone and green shale
4903 - 5060	<u>Shale</u> - green to greenish-grey, traces red to olive and brown, sandy at top, in part splintery
5060 - 5080	<u>Sandstone</u> - white to clear, fine grained, sub-angular, silty, slightly calcareous, traces coarse frosted quartz and green shale
5080	TOP OF CAMBRIAN

5080 - 5105	<u>Shale</u> - dark brown and some green, much as above
5105 - 5350	<u>Sandstone</u> - white to light green, much as above, frosted, friable, in part dolomitic, glauconitic, trace green shale as above
5350	PRECAMBRIAN

In Saskatchewan, the Winnipeg formation is almost entirely shale and is difficult to differentiate from underlying Cambrian shales.

The Norcanols Ogema #1 (Lsd. 4-24-7-23 W2M, Elev. 2620 K.B., Figure 3, location 15) and Norcanols Parry #1 (Lsd. 16-8-9-21W2M, Elev. 2547 ground, Figure 3, location 16) wildcat wells were examined, but in neither well could the Winnipeg shale be definitely distinguished from the Cambrian. The top of the Winnipeg in the Parry well appears to be at a depth of 8555 feet below Kelly Bushing elevation, where there is a fine white sandstone and black shale below buff arenaceous dolomite. The dolomite represents the Red River formation in this well. The first glauconitic sandstone is at a depth of 8749 feet, and probably represents the top of the Cambrian. Thus the Winnipeg formation has a thickness of 194 feet in this well. The Winnipeg formation could, of course, be thinner than this amount. Other wells also examined are shown in figure 3 on page 23.

FIGURE #3 — WELL LOCATIONS IN SASKATCHEWAN AND ALBERTA

LOCATIONS of WELLS in SASKATCHEWAN and ALBERTA

VI. THICKNESS

From a maximum thickness of 317 feet in the Magnolia State #1-A well (Figure 2, location 4) in North Dakota, the Winnipeg formation pinches out completely to the north in Manitoba along a line parallel to the present Paleozoic escarpment. The highs and lows in the Precambrian basement account for some of the variations in thickness of the Winnipeg sandstone facies which outcrops along Lake Winnipeg.

The thickness increases uniformly to the south and to the west, and apparently reaches a general maximum of approximately 200 feet where it rests on Cambrian sediments.

VII. RELATION TO OVERLYING AND UNDERLYING STRATA

In Manitoba the Winnipeg formation rests unconformably upon the weathered Precambrian surface with no noticeable basal layers of arkose or conglomerate. Well sections are the only method of determining the nature of the contact as it is not seen in outcrop. The contact was cored in Cal Stan Wawanesa 3-1 (Lsd. 3-1-8-18WPM, not shown in Figure 1, but located about 15 miles southeast of Brandon) and in Cal Stan Daly 15-18 (Figure 1, location 3). There was no basal arkose or conglomerate present in either of these wells.

As stated previously, the Winnipeg formation is difficult to differentiate from Cambrian sediments in North Dakota and Saskatchewan because of lithologic similarities. However, the contact is considered to be unconformable because of varying thickness of the Cambrian strata, extreme variation in Cambrian lithology immediately below the Winnipeg formation and lack of sedimentary record for much of the Ordovician.

In outcrop, the contact with the overlying Red River formation is extremely sharp and may even present local angular discordances as in the Grindstone Point section (see page 11). In south-west Manitoba the upper part of the Winnipeg shale becomes quite calcareous and the lower part of the Red River limestone is somewhat arenaceous and rather argillaceous as compared to similar rocks in the outcrop areas. The Vaughn Hanson well (Figure 2, location 1) in North Dakota shows a slight interfingering of the shale and limestone at the contact of the two formations. Although the lithologic change in this latter example is still distinct, there is a suggestion of a gradational change from shale to limestone as opposed to the sharp change in the outcrop area.

CHAPTER III

PETROGRAPHY

With the exception of the report on heavy minerals by Wallace and McCartney (1928), the descriptions of the quartz in some reports which mention the Winnipeg sandstone, there has been little or no petrographic work done on the Winnipeg formation. Numerous sieve analyses have been made of the Black Island sand and several of the Elk Island sand (see Figure 1 for locations). These data are available in Cole (1928). The sand at Black Island was at one time quarried for the production of glass, and Cole (1928) discusses the properties of the Winnipeg sand as required for that industry.

I. PROCEDURES

Sorting analyses were carried out by the use of Tyler standard sieves, mesh sizes 4, 8, 14, 28, 48, 100, 200 and pan. The data were plotted as a Tyler standard cumulative logarithmic diagram (Figure 4, p. 29). Calculations of median, quartiles, percentiles, quartile deviation (Qda), Sorting (So) and Skewness (Sk) were made.

A few histograms were constructed, but, as they were found to be of little value, this method of presentation was rejected.

Roundness of grains was studied by the use of a roundness visual comparison chart (Pettijohn, 1949, p. 52).

Sphericity was calculated by standard procedure as outlined in Pettijohn (1949, p. 49).

Heavy mineral separations were made with bromoform, $CHBr_3$, S.G. 2.87, as the separating medium.

Thin sections were prepared for mineral identification and for the study of authigenesis, of grain arrangement and of cementation.

Several minerals were identified by X-ray analyses to substantiate petrographic interpretations.

II. COMPOSITION

The Winnipeg sandstone facies is composed essentially of detrital quartz grains, with scattered heavy minerals, and minor amounts of calcite, dolomite and argillaceous cements. A small zone of siliceously cemented sandstone occurs in an outcrop at Black Island. Pyritization, best seen in the Victoria Beach outcrop, is irregularly scattered through the formation.

III. SORTING

Several sorting analyses were made of the Winnipeg sandstone from scattered points throughout Manitoba, including several wells and many of the outcrops along Lake Winnipeg. The results show that the Winnipeg formation, in its sandstone facies, is generally fairly fine grained and well sorted.

Data of eleven sievings are presented briefly in Table II on this page.

As a sorting coefficient (So) of 2.5 or less signifies a well sorted sand, the average value of 1.33 for the Winnipeg sand shows extremely good sorting. A value of 1.0 represents the theoretically perfect degree of sorting. The log value of the sorting coefficient is also tabled as it is a common method of presentation of sorting.

TABLE II

SIEVING DATA OF WINNIPEG SANDSTONE

	Average	Highest value	Lowest value
Median	0.23 mm.	0.27 mm.	0.18 mm.
Q_3 (25%)	0.36 mm.	0.94 mm.	0.25 mm.
Q_1 (75%)	0.20 mm.	0.33 mm.	0.15 mm.
P_{90}	0.15 mm.	0.32 mm.	0.11 mm.
P_{10}	0.54 mm.	1.20 mm.	0.29 mm.
QD_a	0.12 mm.	0.24 mm.	0.05 mm.
So	1.33	1.53	1.21
Log So	0.12	0.18	0.09
Sk	1.023	1.157	0.889

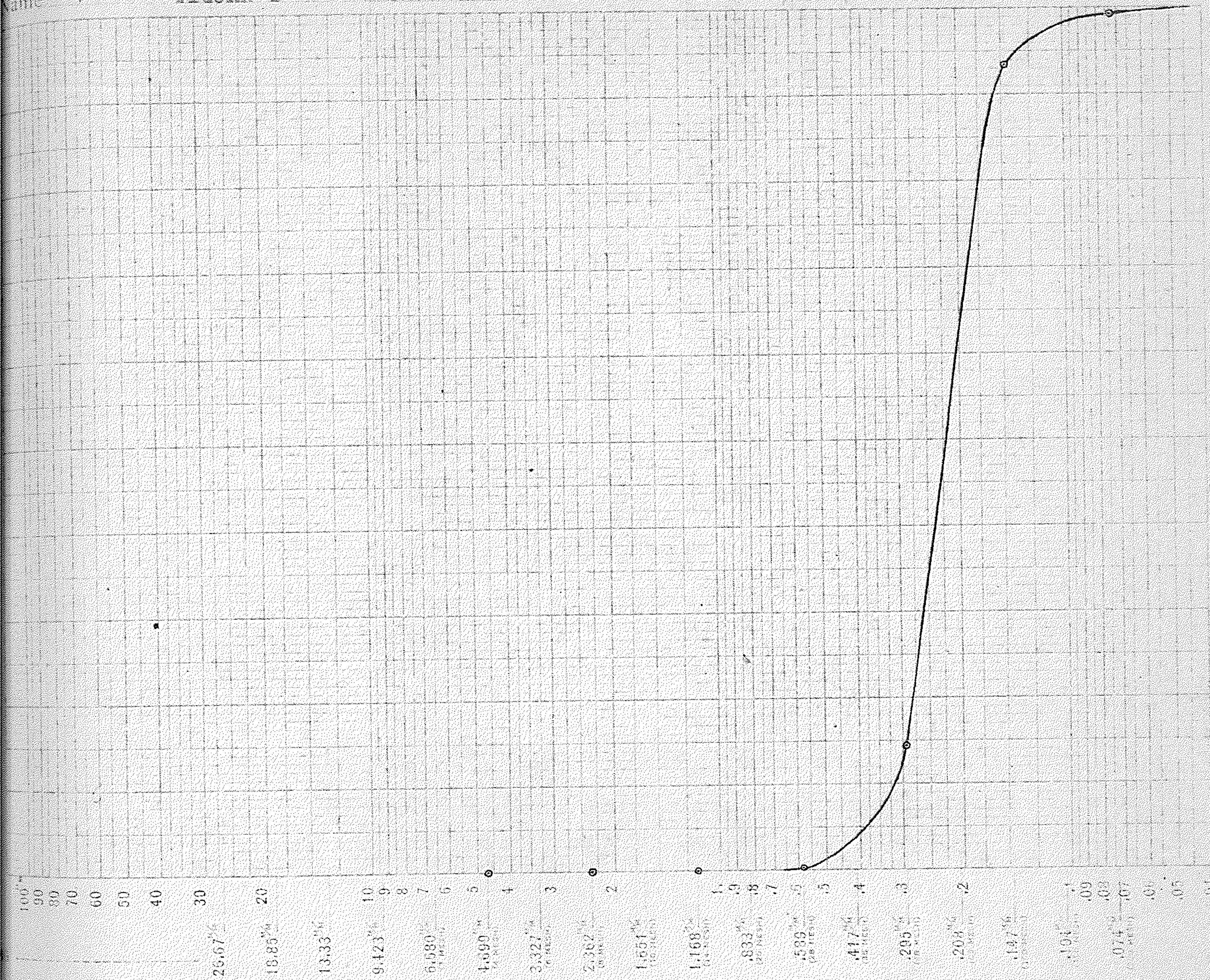
Symbols as in Pettijohn (1949)

The skewness value (Sk) of 1.023 indicates that there is slightly more material on the coarse than on the fine side of the median size value by weight. When coarse and fine material balance each other the skewness becomes 1.00. Thus the Winnipeg sandstone is almost balanced in this respect.

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of [illegible] Ss. - Grindstone Pt.

Name FIGURE 4 Date Oct. 22/50.



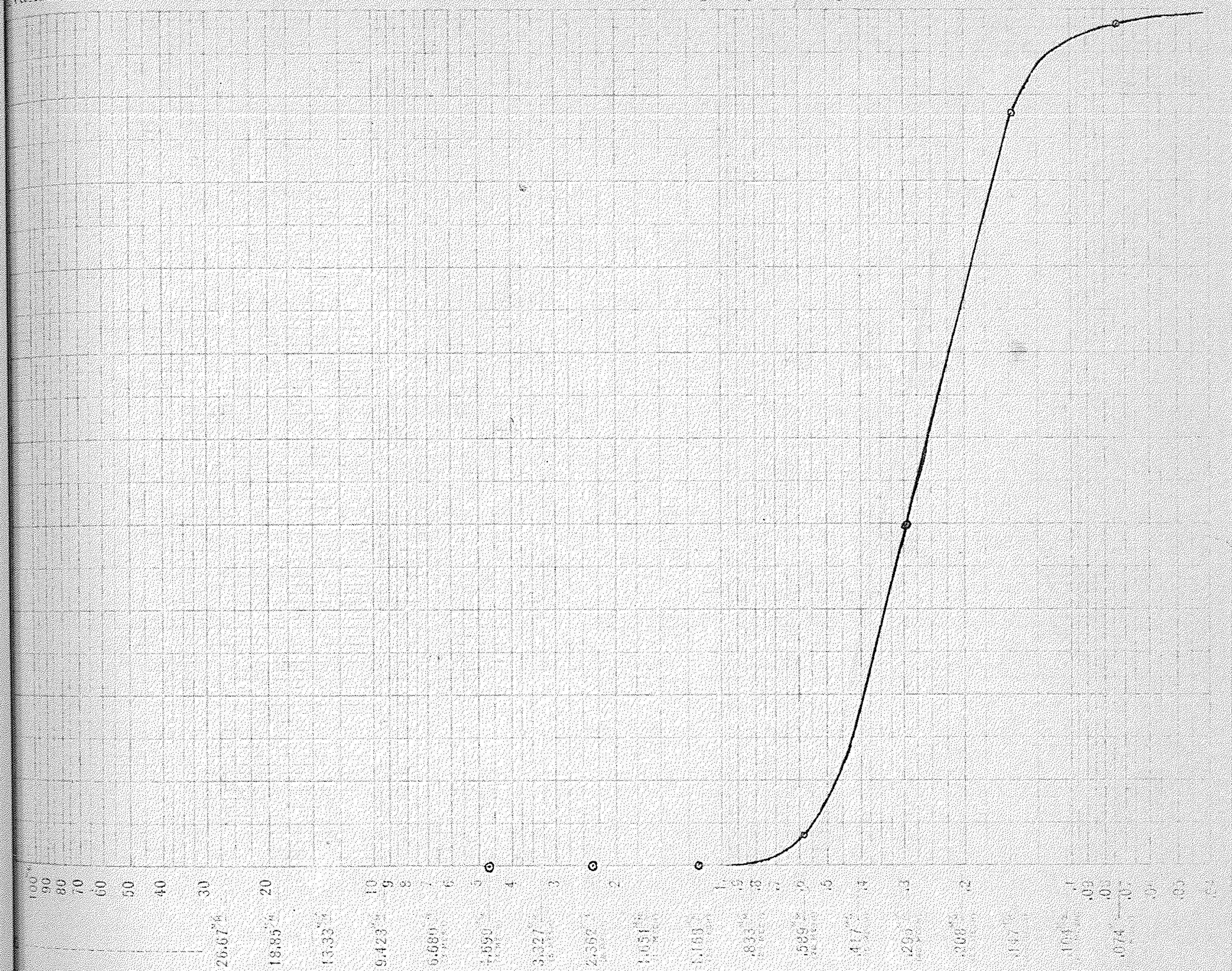
SCREEN SCALE RATIO 1.414						
Openings		Mesh	Diameter Wire Inches	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches					
26.67	1.050		.149			
18.85	.742		.135			
13.33	.525		.105			
9.423	.371		.092			
6.680	.263	3	.070			
4.699	.185	4	.065	0.000	0.000	0.000
3.327	.131	6	.036			
2.362	.093	8	.032	0.000	0.000	0.000
1.651	.065	10	.035			
1.168	.046	14	.025	0.000	0.000	0.000
.833	.0328	20	.0172			
.589	.0232	28	.0125	0.060	0.12	0.12
.417	.0164	35	.0122			
.295	.0116	48	.0092	7.012	14.45	14.57
.208	.0082	65	.0072			
.147	.0058	100	.0042	[illegible]	77.96	[illegible]
.104	.0041	150	.0026			
.074	.0029	200	.0021	[illegible]	[illegible]	[illegible]
.074	.0029	200	.0021	[illegible]	[illegible]	100.00
			Totals	48.524	100.00	--

The W. S. Tyler Company, Cleveland, Ohio

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of [illegible] Sa. – North side of Black Island.

Name FIGURE 5 Date Nov. 15/30.



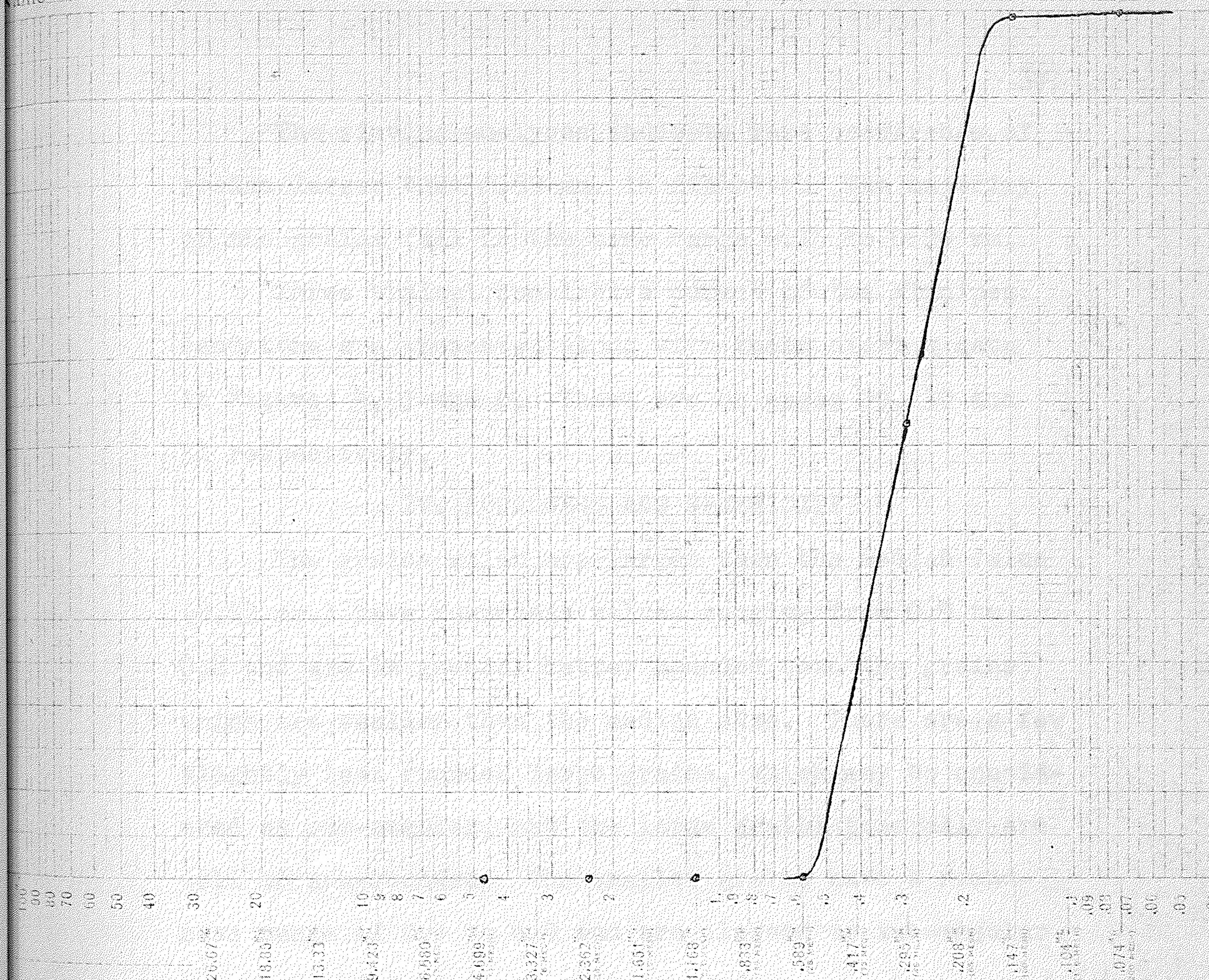
...Screen ...through ...First ...ing ...en	SCREEN SCALE RATIO 1.414 Openings Milli-meters	Inches	Mesh	Diameter Wire Inches	Sample Weights	Per Cent	Per Cent Cumulative Weights
	26.67	1.050		.149			
	18.85	.742		.135			
	13.33	.525		.105			
	9.423	.371		.092			
	6.680	.263	3	.070			
	4.699	.185	4	.065	0.000	0.000	0.000
	3.327	.131	6	.036	—	—	—
	2.362	.093	8	.032	0.000	0.000	0.000
	1.651	.065	10	.035	—	—	—
	1.168	.046	14	.025	0.000	0.000	0.000
	.833	.0328	20	.0172	—	—	—
	.589	.0232	28	.0125	1.461	6.80	6.80
	.417	.0164	35	.0122	—	—	—
	.295	.0116	48	.0092	10.868	33.14	39.94
	.208	.0082	65	.0072	—	—	—
	.147	.0058	100	.0042	10.404	48.00	87.94
	.104	.0041	150	.0026	—	—	—
100	.074	.0029	200	.0021	3.917	10.21	97.15
	.074	.0029	200	.0021	0.716	1.85	100.00
				Totals,	28.366	100.00	—

 Form No. L-3

The Tyler Standard Screen Scale

[illegible]mulative Logarithmic Diagram of Screen Analysis on Sample of [illegible]

[illegible]ame FIGURE 6 Date [illegible]



SCREEN SCALE RATIO 1.414

[illegible] Screen [illegible] Through [illegible] First [illegible]	Openings Milli-meters	Openings Inches	Mesh	Diameter Wire Inches	Sample Weights	Per Cent	Per Cent Cumulative Weights
	26.67	1.050		.149			
	18.85	.742		.135			
	13.33	.525		.105			
	9.423	.371		.092			
	6.680	.263	3	.070			
	4.699	.185	4	.065	0.000	0.000	0.000
	3.327	.131	6	.036	—	—	—
	2.362	.093	8	.032	0.000	0.000	0.000
	1.651	.065	10	.035	—	—	—
	1.168	.046	14	.025	0.000	0.000	0.000
	.833	.0328	20	.0172	—	—	—
	.589	.0232	28	.0125	[illegible]	[illegible]	[illegible]
	.417	.0164	35	.0122	—	—	—
	.295	.0116	48	.0092	[illegible]	[illegible]	57.71
	.208	.0082	65	.0072	—	—	—
	.147	.0058	100	.0042	[illegible]	[illegible]	99.27
	.104	.0041	150	.0026	—	—	—
	.074	.0029	200	.0021	[illegible]	[illegible]	[illegible]
	.074	.0029	200	.0021	[illegible]	[illegible]	100.00
				Totals	[illegible]	[illegible]	—

The sieving analyses indicate rare occurrence of grains larger than 0.59 mm. in diameter. The majority of the grains fall in the size range 0.15 to 0.30 mm.

Three typical cumulative curves of the Winnipeg sandstone are presented along with their sieving data in Figures 4, 5 and 6. These are on pages 29, 30 and 31 respectively.

IV. ROUNDNESS AND SPHERICITY

The grains which are larger than the median value (0.23 mm.) have roundness values ranging from 0.9 to 0.8 and are in general better rounded than the grains which are smaller than the median size. There are a few slightly less rounded large grains, which may be considered as sub-angular, but the large grains generally are well to sub-rounded. The smaller grains have a roundness range of 0.4 to 0.9 and are classed as sub-angular to sub-rounded, in part well rounded.

Illustrations of grain roundness may be seen in the microphotographs in Plate I. The lower left illustration is of the smaller grains and the lower right is of the larger grains.

The sphericity of the larger grains is high, almost approaching the theoretically perfect spherical value, 1.00. The sphericity of these grains ranges from 0.95 to 0.70. They are generally spheroidal, rarely discoidal or elongate.

The smaller grains are slightly less spherical, but this is to be expected as they are less rounded than the larger grains.

In summary the larger grains are better rounded and more spherical than the smaller grains.

V. SURFACE FEATURES

The larger quartz grains are all highly frosted and many are marked by considerable pitting (Plate I, lower right). The degree of frosting decreases as grain size diminishes, so that the smaller grains are almost non-frosted, generally fairly clear and glassy (Plate I, lower left). There is no evidence of pitting on any of the smaller grains or on any grains of the fine sand phases in the shale facies. The maximum development and best examples of frosting and pitting were noted on the grains from the Victoria Beach outcrop, which also contains the largest grains as yet found in the Winnipeg formation.

The degree of surface frosting and pitting is fairly uniform throughout the formation.

VI. HEAVY MINERALS

Heavy minerals are rare in the Winnipeg sandstone. A sieving of 50 grams of sample from which the heavy grains were separated would yield at most perhaps 40 or

50 heavy grains.

The heavy grains are generally less than 0.18 mm. in diameter, with all grains of any one mineral type fairly uniform in size.

The heavy minerals of the Winnipeg sandstone and their descriptions are:

TOURMALINE: (Plate I, center right) The tourmaline grains range from very fine to 0.3 mm. in diameter with an average size of about 0.15 mm. diameter. They are well rounded to rounded elongate, commonly a wheat grain shape. In reflected light the color is jet black, the surface shiny and smooth. Under the microscope the grains are noted as round to sub-triangular in cross-section. A few elongate grains show good zonal growth. Pleochroism is strong from yellowish-brown to black, with a few grains changing from greyish-blue to black. Many are so black that they are dark in transmitted light.

STAUROLITE: (Plate I, upper left) Staurolite has the same size range as tourmaline, but a slightly smaller average diameter. The external appearance shows two types of staurolite present; one is a pale yellowish-brown variety with an excellent hackly fracture and the other a slightly deeper colored variety with an irregular sub-conchoidal fracture. The grains of the former type are generally well rounded, but some are angular, whereas the grains of the latter are always angular. In strong reflected light both varieties are orangy-red, with the color distinction only noticeable under transmitted light.

ZIRCON: (Plate I, upper right) The zircon grains are well rounded, perfectly clear to highly frosted. A few sub-rounded grains have fair crystal outlines. Elongate zoned pyramidal forms dominate in this latter group. There are also a few yellowish slightly angular zircons.

GARNET: Garnet grains range from small to medium size, are pink to purplish colored and have good conchoidal fracture.

HORNBLENDE: Hornblende occurs as deep green pleochroic grains which are elongate angular with some rounding of the ends. Its occurrence is rare.

MONAZITE?: Rare Monazite grains are well rounded, smooth, shiny, pale green to pale yellowish-green slightly pleochroic. No other characteristics were determinable and there is a slight doubt of the validity of the identification.

RUTILE: As only two grains of foxy-red rutile were noted, this mineral is extremely rare.

UNIDENTIFIED MINERAL: (Plate II, upper left, center left and right) There is a small amount of an unidentified yellowish-brown mineral. As it is almost non-transparent under crossed nicols and shows only a pale tint along thin edges, interference values cannot be determined. It occurs as irregular masses, as poorly formed small crosses and as elongate fibre-like grains. In some instances it appears to be a cement surrounding other grains. None could be obtained for X-ray examination as its occurrence is too rare.

The distribution of the heavy minerals throughout all the samples studied was fairly uniform, except for the rarer types such as monazite, hornblende and rutile.

The heavy minerals of the Winnipeg sandstone are only the stablest types, hard and resistant to both chemical and mechanical wear. The roundness of these grains indicates much abrasion.

VII. AUTHIGENESIS

A few grains noted in thin sections showed authigenic quartz development over formerly rounded quartz grains (Plate II, center left). One grain had two rounded layers of quartz over the original rounded grain, indicating three possible depositional cycles. A few authigenic grains showed good crystal outline (Plate II, center left).

Only two grains of feldspar were noted. These were rounded grains of microcline, which were completely enclosed and protected by a secondary quartz overgrowth which was also rounded.

Authigenesis and secondary quartz overgrowth are rare features in the Winnipeg sandstone.

VIII. SEDIMENTARY APATITE

The black phosphate nodules mentioned in the stratigraphic descriptions are a sedimentary apatite, not in any way detrital, but probably formed by chemical processes of sedimentation. The nodules are large, as much as one-quarter inch in diameter, and soft. They are black on the outer surface, but are buff to light brown with a very fine grained texture resembling that of a carbonate when broken. The mineral is readily soluble in cold dilute hydrochloric acid. As the mineral was identified by X-ray analysis, no optical properties were determined. There are very fine veinlets of pyrite or marcasite crossing most of the nodules.

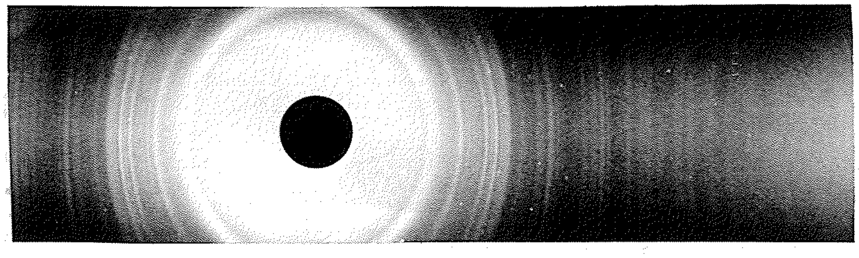


Figure 7 - X-ray of Sedimentary Apatite
by Miss P. Clark   Geology Dept., U. of Manitoba

IX. PYRITE

Pyrite occurs in several forms in the Winnipeg formation - 1) as small concretionary bodies with good development of cubes and octahedra, 2) as irregular massive and radiating nodular concretions, 3) as cementing material, 4) as small round "oolitic" pellets, 5) as replacement of fossils.

The first two occurrences are common to pyrite and need no explanation. The first is found in the sandstone and the second in the sandstone and the shale. There are a few scattered pyrite crystals throughout the shale. Some of the radiating bodies, which may be marcasite, are as much as one inch in diameter, There is a considerable amount of pyrite cement in the sandstone at Victoria Beach, thin sections show pyrite surrounding quartz grains. It appears to be a later replacement of the original carbonate cement, occurring at the same time as the pyritization of the fossils. Some of the best fossil preservations are pyrite molds and replacements.

The small "oolitic" structures occur on Black Island in a siliceously cemented band of sandstone. They are composed of numerous thin concentric laminae around black soft carbonaceous nuclei, Their discoidal shape gives them an appearance similar to ostracods and they are possibly the species _Aparchites_ _tyrrellii_ Jones identified by Whiteaves (1896).

The exact nature of the brown pellets described in Cal Stan Hartney 16-33 and Cal Stan Daly 15-18 is not known. Their appearance is the same as that of the pyrite "oolites" described above, as they have a concentrically layered "oolitic" structure. They appear to be some form of iron, and are possibly related in some manner to the deposition of the pyrite "oolites".

X. CEMENT

In well sections and lower parts of the outcrops the Winnipeg sandstone is very soft, friable and unconsolidated except for some slightly harder zones with clay matrices. The upper part of the sandstone in outcrops, and somewhat in wells, has argillaceous and calcite cements. At Victoria Beach the sand is well bonded by calcite with some pyritic replacement of the calcite. Samples there average 45% calcite by weight. The Black Island outcrop has a narrow band with a fairly hard siliceous cement.

There has been some dolomitization of the calcite cement, indicated by very fine dolomite rhombs with enclosed zoned carbonaceous material (Plate I, center left) found in outcrops and most wells. These are typical replacement dolomite rhombs.

CHAPTER IV

CAMBRIAN AND PLEISTOCENE SAND INVESTIGATIONS

I. CAMBRIAN SANDS

A study was made of the sieving analyses and mineral contents of the basal Cambrian sandstone present in several Alberta wells.

The Alberta basal sandstone investigated is largely composed of fine to coarse, white to yellow, frosted, pitted, quartz grains, which resemble those of the Winnipeg sandstone except for the partial yellow color. Much of the Cambrian sandstone is tinted pink to pale green, with the greenish parts slightly to highly glauconitic. The sandstone is associated with red and green, in part micaceous, shale. The sandstone is much harder and better cemented than is the Winnipeg sandstone. The rounding, sphericity and sorting of this sandstone is not so good as that of the Winnipeg sandstone.

Descriptions of the Cambrian sandstone samples studied are as follows. Well locations are indicated in Figure 3, page 23.

Imperial Provost #2

Lsd. 1-33-7-33W4M (Figure 3, location 8)
Elevation: ?

Interval 6680-6690 at 1373' above Precambrian
Red micaceous shale is interbedded with fine to medium grained sandstone. The quartz

is white and pink, with some large grains, sub-rounded, frosted and pitted, grading to some fine grained angular. There are traces of yellow quartz. The lamination of the sandstone is very poor.

In addition there is some coarse grained quartz sandstone, with sub-angular to sub-round grains, in variegated white and purple layers. The purple coloration is a stain on the quartz. The quartz is dull, frosted, pitted, with some good secondary faces. The sand is non-calcareous, siliceously cemented.
Interval 6905-6970

Interval is mostly red and green shale, with some fine quartz sand, a little white glauconitic sandstone, a little biotitic sandstone, and a few large highly frosted bright non-pitted sub-round quartz grains.

<u>Imperial Clyde #1</u>

Lsd. 9-29-59-24W4M (Figure 3, location 4)
Elevation: 2065 K.B.

7323 - core at top of basal sand, Precambrian at 7340

Sandstone is white with greyish-green patches, weathered? brown, poorly sorted. The quartz is dull, frosted, pitted, rounded, with a few yellow grains. The cement is siliceous. Bedding is massive.

<u>Imperial Plain Lake #1</u>

Lsd. 1-11-53-12W4M (Figure 3, location 6)
Elevation: 2271 ground, 2282 K.B.

Cored interval 6369-6371, at 284' above Precambrian

The core has variegated bands of green and white sandstone. The white has large poorly rounded frosted to glassy quartz grains with euhedral quartz cement and a few grains of yellow quartz. The green is composed of dull glassy quartz with conchoidal fracture, The two color types interlens.

Imperial Grosmont #1

Lsd. 13-17-67-23W4M (Figure 3, location 1)
Elevation: 2055 ground, 2066 K.B.

Core at 6330, 25' below top of basal sandstone. Precambrian is at 6390
A quartzitic appearing sandstone has an overall pinkish-brown color. Large quartz grains, in part a yellow color, are fairly rounded, dull, frosted, pitted and cemented by siliceous material.

Several other samples were examined from the other wells marked in Figure 3, but their descriptions are not included.

The sorting of this sand is not so good as that of the Winnipeg sandstone, nor is there the same high degree of roundness and sphericity (Plate II, lower right).

Sorting cumulative curves and data for two of the sand samples are presented in Figures 8 and 9 on pages 43 and 44.

The heavy mineral suite of the Cambrian sandstone is almost identical to that of the Winnipeg sandstone. Tourmaline, zircon, rutile, garnet, pyrite and magnetite are the most common with lesser hornblende.

Some dolomite cement in the Cambrian sandstone occurs as large irregular crystalline masses (Plate II, lower left) rather than as the small rhombs as found in the Winnipeg formation.

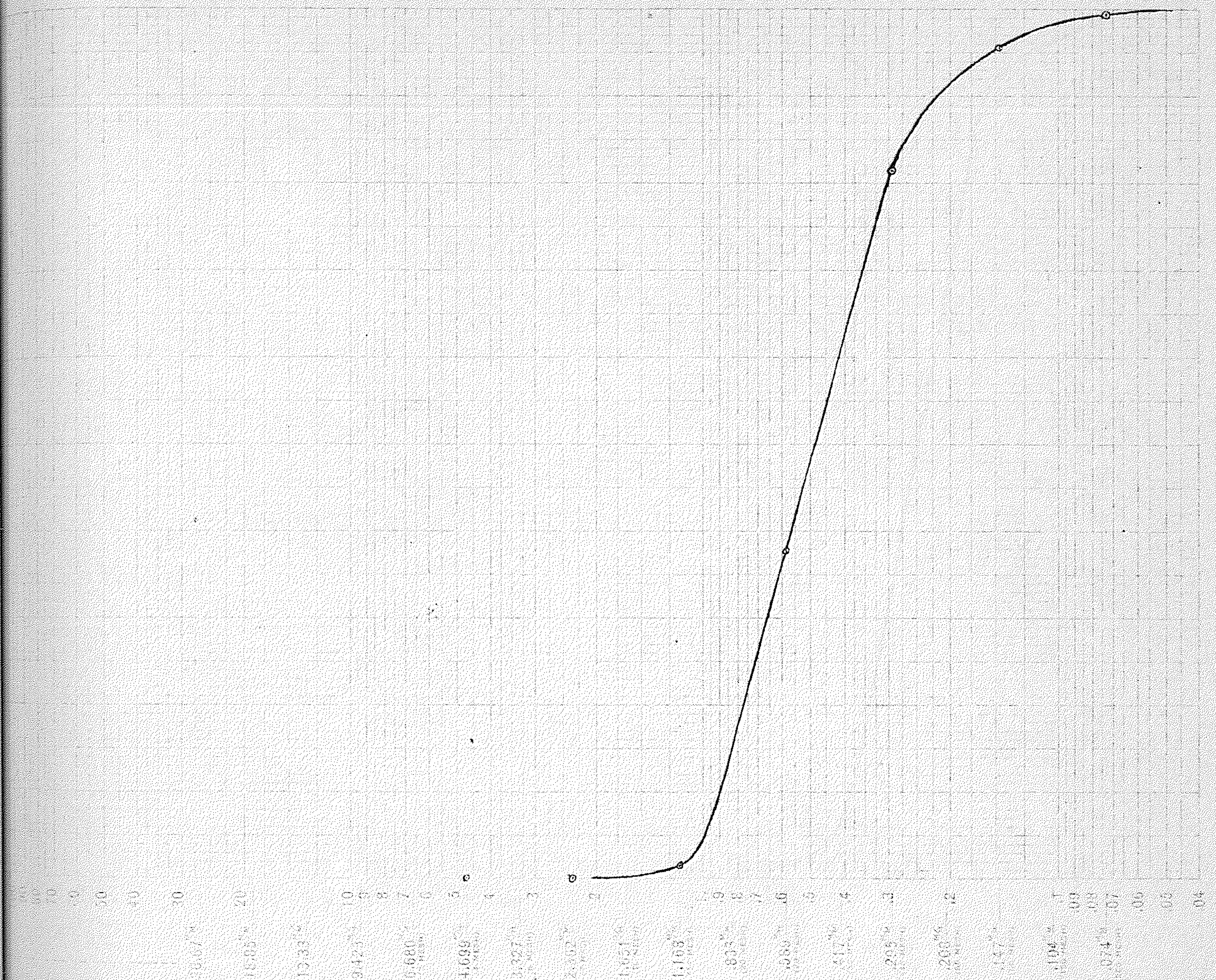
A notable feature of the Cambrian sandstone is the

Please mention above when ordering

The Tyler Standard Screen Scale

…mulative Logarithmic Diagram of Screen Analysis on Sample of Imp. Provost [illegible].

…ame FIGURE 8 Date Feb. 2/51.

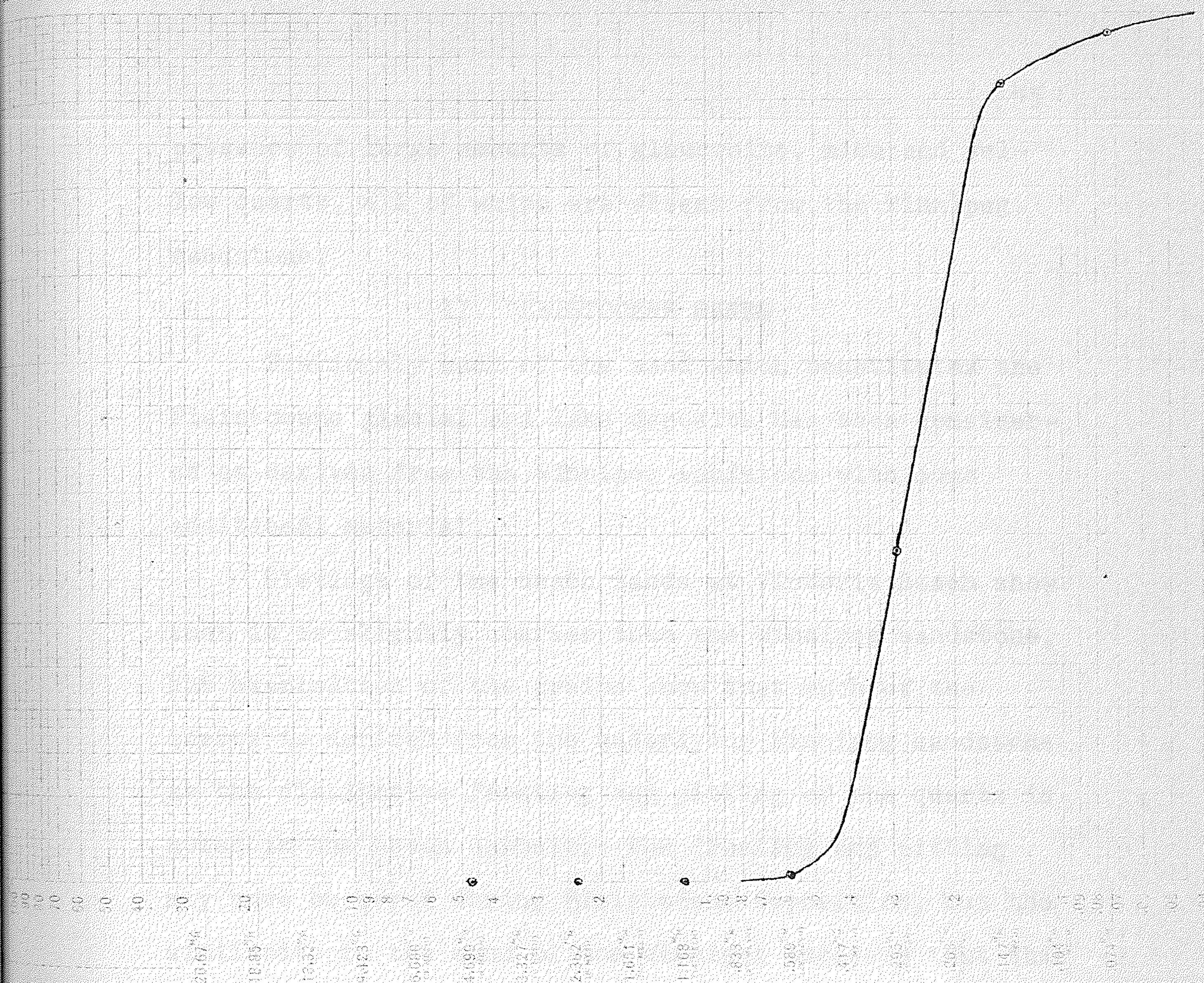


SCREEN SCALE RATIO 1.414

[illegible]	Inches	Tyler Mesh	U.S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
…67	1.050											
…85	.742											
…33	.525											
…423	.371											
…680	.263	3										
…699	.185	4	4	0.2[illegible]0	0.000	0.000						
…327	.131	6	6	—	—	—						
…362	.093	8	8	0.000	0.000	0.000						
…651	.065	10	12	—	—	—						
…168	.046	14	16	[illegible]	1.[illegible]	1.[illegible]						
…833	.0328	20	20	—	—	—						
…589	.0232	28	30	[illegible]	[illegible]	[illegible]						
.417	.0164	35	40	—	—	—						
…295	.0116	48	50	[illegible]	[illegible]	[illegible]						
…208	.0082	65	70	—	—	—						
…147	.0058	100	100	[illegible]	[illegible]	[illegible]						
…104	.0041	150	140	—	—	—						
…074	.0029	200	200	[illegible]	[illegible]	[illegible]						
…074	.0029	200	200	[illegible]	[illegible]	100.[illegible]						
			Totals.	[illegible]	[illegible]	—						

Cumulative Logarithmic Diagram of Screen Analysis on Sample of [illegible]

Name FIGURE 9 Date Feb. [illegible]



SCREEN SCALE RATIO 1.414													
Openings													
Millimeters	Inches	Tyler Mesh	U.S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	
26.67	1.050												
18.85	.742												
13.33	.525												
9.423	.371												
6.680	.263	3											
4.699	.185	4	4	[illegible]	[illegible]	[illegible]							
3.327	.131	6	6	—	—	—							
2.362	.093	8	8	[illegible]	[illegible]	[illegible]							
1.651	.065	10	12	—	—	—							
1.168	.046	14	16	[illegible]	[illegible]	[illegible]							
.833	.0328	20	20	—	—	—							
.589	.0232	28	30	[illegible]	[illegible]	[illegible]							
.417	.0164	35	40	—	—	—							
.295	.0116	48	50	[illegible]	[illegible]	[illegible]							
.208	.0082	65	70	—	—	—							
.147	.0058	100	100	[illegible]	[illegible]	[illegible]							
.104	.0041	150	140	—	—	—							
.074	.0029	200	200	[illegible]	[illegible]	[illegible]							
.074	.0029	200	200	[illegible]	[illegible]	[illegible]							
			Totals	[illegible]	[illegible]	—							

presence of large amounts of glauconite, mica and yellow quartz, all of which are absent from the Winnipeg sandstone.

II. PLEISTOCENE SANDS

Previously much of the sand which constitutes the Pleistocene glacial and lake deposits has been considered as derived from the Winnipeg sandstone with some additional material.

Sievings of the beach sands at Victoria Beach show that it is slightly coarser than the Winnipeg sandstone, but examination of the grains show that much of the quartz is derived from the underlying Winnipeg sandstone as the distinctive frosting and pitting of the quartz is noted in the beach deposit. The frosting and pitting may have occurred during Pleistocene deposition, but the similarity to the sand of the Winnipeg suggests that this is unlikely.

The beach sands along the lake have included in them many more heavy minerals than has the Winnipeg sandstone. Notable added heavies are the less stable augite and biotite, and much more hornblende.

The Sandilands Forest Reserve (Figure 1, general area around Sandilands, Woodridge and Badger in southeast Manitoba) has a topsoil of highly wind-blown loamy sand. It is much finer than the Winnipeg sandstone although the grains do resemble the finer material of the Winnipeg sandstone. No distinct relationship can be established, but possibly the wind has sorted the fine material from the coarser of the Winnipeg sandstone to form this Pleistocene deposit. A cumulative sorting curve of this sand is illustrated in Figure 10 on page 47.

The sand in the Beausejour pits (Figure 1, near Beausejour) is partly wind and partly water bedded. The exposed basal part shows an angularly bedded sandstone in which much muscovite lies along the bedding planes. The top part shows deltaic water bedding. The lower part appears to have been a wind-formed dunal beach deposit which was submerged and subsequently covered by a delta. The entire deposit is of shore-line depositional nature. Cole (1928) refers to this as a fluvioglacial (esker) deposit, but this does not appear to be so.

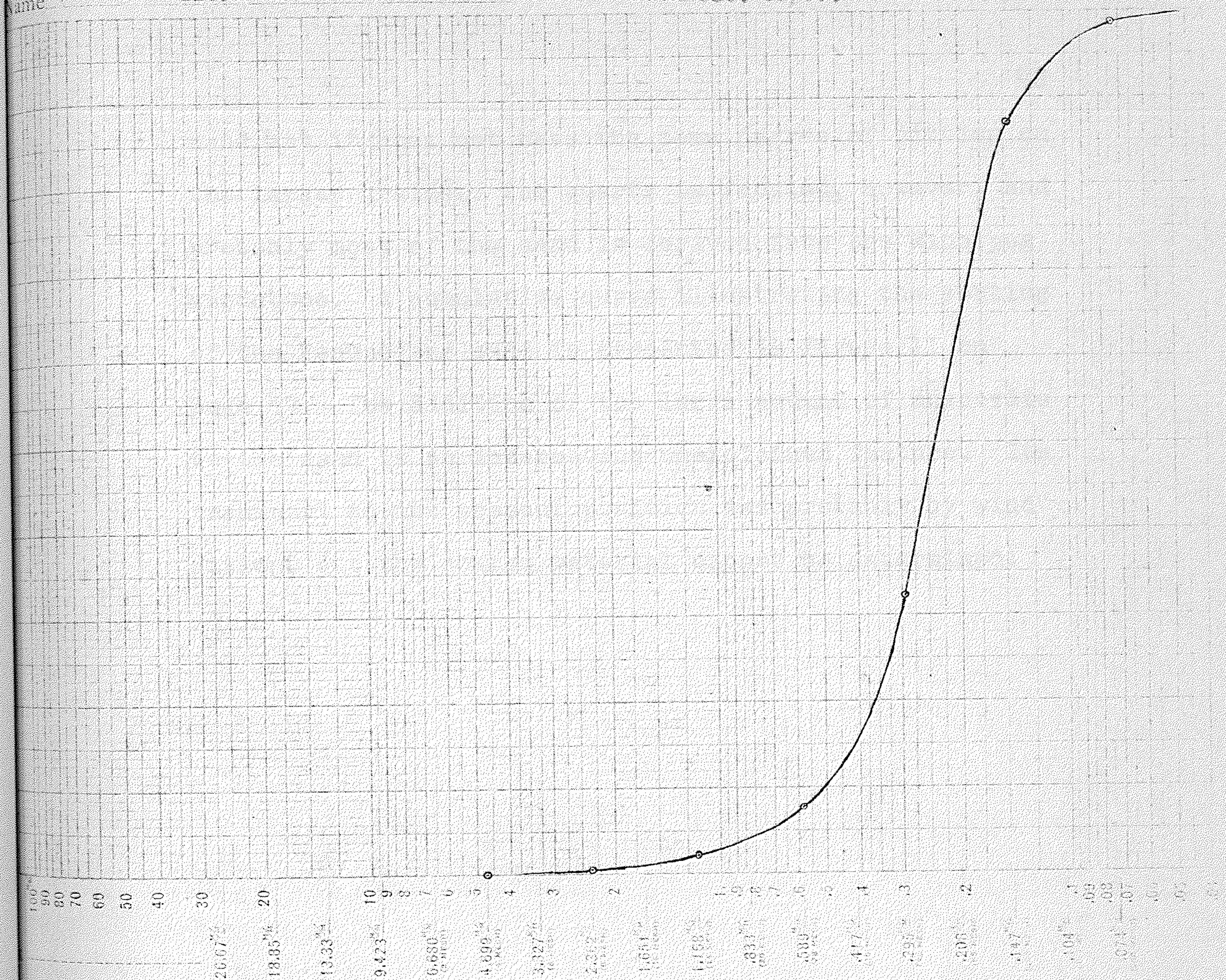
The sand pit has been drilled to a depth of 110 feet, where clay and sandstone were encountered. Hardpan was noted at a depth of 85 feet near the Beausejour railroad station. The Pleistocene sands are fairly thick, and apparently the Winnipeg formation is not encountered to a considerable depth.

The Beausejour sand is as fine as the Winnipeg

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of [illegible]

Name FIGURE 10 Date Oct. 3[illegible]/50.



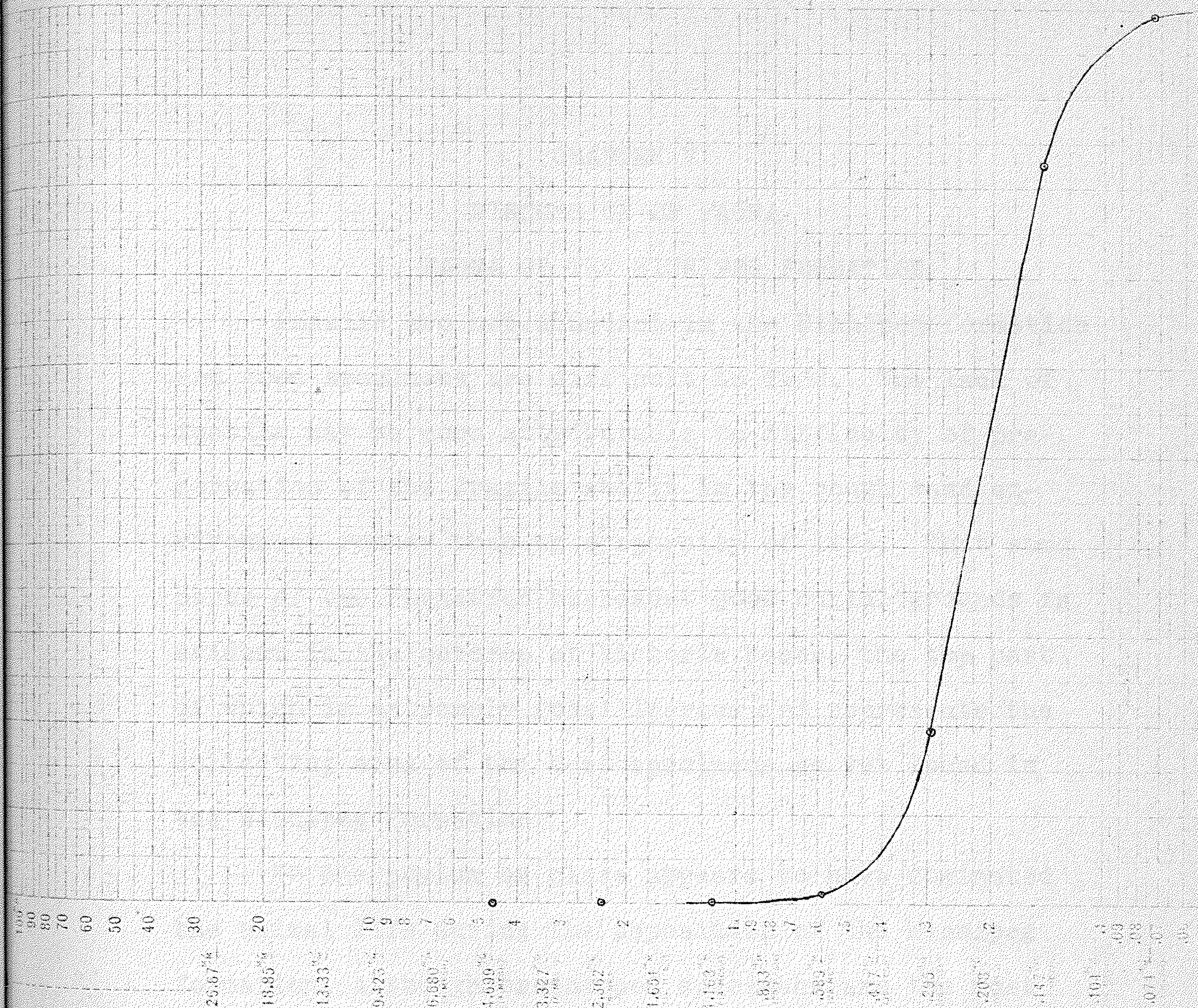
... Screen Through ... First ... Screen	SCREEN SCALE RATIO 1.414 Openings Milli-meters	Inches	Mesh	Diameter Wire Inches	Sample Weights	Per Cent	Per Cent Cumulative Weights
	26.67	1.050		.149			
	18.85	.742		.135			
	13.33	.525		.105			
	9.423	.371		.092			
	6.680	.263	3	.070			
	4.699	.185	4	.065	0.000	0.000	0.000
	3.327	.131	6	.036			
	2.362	.093	8	.032	0.227	0.59	0.59
	1.651	.065	10	.035			
	1.168	.046	14	.025	0.812	2.11	2.70
	.833	.0328	20	.0172			
	.589	.0232	28	.0125	1.994	5.18	7.88
	.417	.0164	35	.0122			
	.295	.0116	48	.0092	9.381	24.39	32.27
	.208	.0082	65	.0072			
	.147	.0058	100	.0042	21.056	54.74	87.01
	.104	.0041	150	.0026			
	.074	.0029	200	.0021	4.561	11.87	98.88
	.074	.0029	200	.0021	0.430	1.12	100.00
				Totals,	38.461	100.00	

sand but it does not have the same degree of pitting on the larger grains. The quartz is frosted, however, and probably most of the sand is derived from the Winnipeg sandstone. A cumulative curve illustrating the sorting of the Beausejour sand is presented in Figure 11 on page 49. The addition of the large amount of muscovite to the sand is an interesting unexplained feature. Its transport to its present position was probably by wind action, but the source material cannot be determined.

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of [illegible]

Name FIGURE 11 Date Oct. [illegible] [illegible]



SCREEN SCALE RATIO 1.414						
Openings						
Millimeters	Inches	Mesh	Diameter Wire Inches	Sample Weights	Per Cent	Per Cent Cumulative Weights
26.67	1.050		.149			
18.85	.742		.135			
13.33	.525		.105			
9.423	.371		.092			
6.680	.263	3	.070			
4.699	.185	4	.065	0.000	0.000	0.000
3.327	.131	6	.036	—	—	—
2.362	.093	8	.032	0.000	0.000	0.000
1.651	.065	10	.035	—	—	—
1.168	.046	14	.025	[illegible]	[illegible]	[illegible]
.833	.0328	20	.0172	—	—	—
.589	.0232	28	.0125	[illegible]	[illegible]	[illegible]
.417	.0164	35	.0122	—	—	—
.295	.0116	48	.0092	[illegible]	[illegible]	[illegible]
.208	.0082	65	.0072	—	—	—
.147	.0058	100	.0042	[illegible]	[illegible]	[illegible]
.104	.0041	150	.0026	—	—	—
.074	.0029	200	.0021	[illegible]	[illegible]	[illegible]
.074	.0029	200	.0021	[illegible]	[illegible]	[illegible]
			Totals	[illegible]	[illegible]	—

CHAPTER V

DISCUSSION OF FAUNA

I. FAUNA OF THE WINNIPEG FORMATION

Fossils are not abundant in the Winnipeg formation and good specimens are difficult to find. The lack of fossils may be more attributable to difficulty of preservation of the fragile shells in the rough sand environment rather than to a sparsity of life. That some parts of the formation represent good burial grounds is evident in the outcrop at Victoria Beach, the top part of which is extremely fossiliferous and represents the collecting area of the best specimens as yet found in the Winnipeg formation.

No one phylum or class appears to have dominated the animal life during the deposition of the Winnipeg formation, although brachiopod specimens are the most widespread and are found in the greatest numbers. Bryozoa are extremely abundant in some shale zones. Crinoid columnals accur throughout the entire formation, although crowns and calyces are rare. Pelecypods, gastropods, cephalopods, corals, trilobites and algae are present in lesser numbers.

Thirty-eight species in all have been reported, of which thirty-three are described herein. A list of fauna is as follows:

Coelenterata
- Climacograptus typicalis Hall
- Conularia formosa Miller and Dyer
- Conularia sp.
- Climaconus cf. C. clarki Sinclair
- Streptelasma winnipegensis n. sp.
- Streptelasma simplicitas n. sp.

Annelida
- Scolithus sp.
- X Serpulites dissolutus Billings

Bryozoa
- Hallopora multitabulata (Ulrich)
- Rhinidictya mutabilis (Ulrich)
- Escharopora sp.

Brachiopoda
- Lingula sp.
- Platystrophia reversata (Foerste)
- Plectorthis plicatella (Hall)
- Rhynchotrema inaequivalvis (Castelnau)
- Rhynchotrema inaequivalvis var. laticostata Winchell and Schuchert
- XX Orthis (Hesperorthis) tricenaria (Conrad)
- Cyclospira bisulcata (Emmons)
- Sowerbyella sp.
- Strophomena sp.
- Dalmanella sp.

Pelecypoda
- Cyrtodonta sp.
- Modiolodon patulus Ulrich

Gastropoda
- Sinuites cancellatus (Hall)
- Salpingostoma sp.
- Hormotoma gracilis (Hall)
- Hormotoma sp. ind. (cf. H. major (Hall) or H. winnipegensis (Whiteaves)
- X Solenospira pagoda var. occidentalis Whiteaves

Cephalopoda
- Endoceras sp.
- Ephippiorthoceras formosum Billings
- Spyroceras sp.
- Westonoceras manitobense (Whiteaves)

Trilobata
- Ceraurinus icarus (Billings)

Ostracoda
- Leperditia sp.
- XX Aparchites tyrrellii Jones

Crinoidea
  Crinoid columnals
X Glyptocrinus sp.
Algae
  Licrophycus
  Paleophycus

X - reported elsewhere; not seen by author
XX - reported elsewhere; identification doubted by author

II. MANITOBA ORDOVICIAN FAUNAS

The faunas of the Winnipeg formation will be compared to those of the Red River and Stony Mountain formations, which constitute the remainder of the Manitoba Ordovician.

Climacograptus typicalis of the Winnipeg is slightly modified in the Red River where it occurs in the varietal form *C. typicalis* var. *spinothecatus*. There is no evidence of this graptolite elsewhere in the Manitoba Ordovician.

Conularia formosa of the Winnipeg sandstone is possibly ancestral to the genus *Metaconularia* which first occurs in the Red River formation and is commonly found throughout the remainder of the Ordovician as *M. asperata*.

The newly established species *Streptelasma winnipegensis* is a small ancestral form to the large cup corals, such as *S. profundum* and *S. robustum*, which are abundant in the Red River and Stony Mountain.

The absence of any species of Halysites, Favosites or Palaeofavosites in the Winnipeg is notable considering their abundance in the overlying Ordovician strata.

Receptaculites arcticus, an extremely abundant form in the Red River, is also missing in the Winnipeg.

The two species and one genus of bryozoa of the Winnipeg continue unmodified through the Stony Mountain. However, many more species are also present in the Stony Mountain. Numerous zones in the Winnipeg contain large numbers of unidentifiable bryozoa, which are poorly preserved as sand and shale replacements. Perhaps many other species also existed at the time of deposition of the Winnipeg.

Platystrophia reversata of the Winnipeg is found unaltered, and also slightly changed with further development of the costae, in the Red River and in the Stony Mountain.

Rhynchotrema inaequivalvis is found in all the Manitoba Ordovician strata. It is probably related, possibly ancestral, to the large species such as Lepidocyclus (Rhynchotrema) capax and L. (R.) dentata, which are more abundant toward the top of the Ordovician beds in Manitoba.

Cyclospira bisulcata is found in the Winnipeg and Red River, although it has not been reported from the

Stony Mountain.

Sowerbyella, *Strophomena* and *Dalmanella* range throughout the Manitoba Ordovician. Unfortunately the significance of the forms present in the Winnipeg is not known as the specimens are too poor for specific identifications and comparisons.

Sinuites cancellatus and *Salpingostoma* are found in the Winnipeg and Red River and rarely in the Stony Mountain.

Hormotoma gracilis is abundant in all the Ordovician strata. *H.* cf. *H. major* or *H. winnipegensis* is probably related to, or the same as, *H. winnipegensis* of the Red River.

Cephalopods are minor in the Winnipeg whereas they dominate the fauna of the Red River. The species present in the Winnipeg are all found in the Red River. The Red River, however, has a large number of other cephalopod species.

Cyrtodonta is found in the Red River, but the presence of *Modiolodon patulus* of the Winnipeg in the Red River and Stony Mountain has never been established.

Ceraurinus icarus is found throughout the Ordovician in Manitoba. The existence of *Leperditia* is of little value as its range is too great.

III. OTHER FAUNAL COMPARISONS

All species thus far found in the Winnipeg with the exceptions of Climacograptus typicalis, Conularia formosa, Climacoconus cf. C. clarki and the two new species of Streptelasma occur in the Galena-Trenton. Twenty-seven species are common to the Winnipeg and the Galena-Trenton.

Streptelasma winnipegensis is probably derived from S. corniculum of the Galena-Trenton and appears to compare to a described unidentified species reported from the Stewartville. Unfortunately no visual comparison could be made with this specimen.

The Stewartville has a greater fossil assemblage than the Winnipeg. Streptelasma, bryozoa, Platystrophia, Rhynchotrema, Hormotoma, Sinuites, Endoceras and Ephippiorthoceras are common to both formations. Except for Streptelasma these genera have species which were noted as common to the two formations wherever a specific identification was possible on the Winnipeg specimen. Receptaculites oweni and Halysites gracilis occur in the Stewartville and not in the Winnipeg.

The Winnipeg fauna is somewhat different from that of the Dubuque, although there are several common forms, such as Cyclospira bisulcata, Dalmanella, Platystrophia reversata, Lingula, Sowerbyella, Cyrtodonta, Endoceras, trilobites related to <u>Ceraurinus icarus</u> and some of the bryozoa. Otherwise the Dubuque fauna more closely resembles that of the Red River than that of the Winnipeg.

Faunal lists of the Arctic (Teichert, 1928), Anticosti (Twenhofel, 1928) and Greenland (Troedsson, 1929) show that the faunas of these regions are more closely comparable to the faunas of the Red River and Stony Mountain than to that of the Winnipeg.

Correlations of the Lander fauna to the Red River fauna and of the Bighorn fauna to those of the Red River and Stony Mountain is adequately discussed by Foerste (1928) and by Miller (1930, 1932). There is no doubt that the Lander has a slightly younger fauna than the Winnipeg and that it is equivalent to that of the Dog Head, the lowest part of the Red River.

Figure 12, on page 57, shows the distribution of the species throughout the various formations and areas.

IV. FAUNAL CONCLUSIONS

In general the fauna of the Winnipeg is very similar to those of the Galena-Trenton and Red River, with the exception of the Coelenterata, which varies greatly over the three formations. The Coelenterata of the Galena-Trenton are ancestral to those of the Winnipeg which are in turn ancestral to those of the Red River.

Figure 12. Distribution of Fauna in Formations Studied

	Winnipeg	Red River	Stony Mountain	Galena-Trenton	Stewartville	Dubuque	Lander	Anticosti	Arctic	Greenland
Climacograptus typicalis	X	X								
Conularia formosa	X	E						E		
Climaconus cf. C. clarki	X									
Streptelasma winnipegensis	X				?					
Strepbelasma simplicitas	X									
Hallopora multitabulata	X	X	X	X		?				
Rhinidictya mutabilis	X	X	X	X		?				
Escharopora	X	X	X	X		?				
Platystrophia reversata	X	X	X		?	?				
Plectorthis plicatella	X	X		X						
Rhynchotrema inaequivalvis	X	X	X	X	X		X	X	X	X
R. inaequivalvis var. laticostata	X			X						
Cyclospira bisulcata	X	X		X		X				
Sowerbyella	X	X	X	X	X	X	X	X	X	X
Strophomena	X	X	X	X	X	X	X	X	X	X
Dalmanella	X	X	X	X	X	X	X	X	X	X
Cyrtodonta	X	X		X		X	X	X		
Modiolodan patulus	X	X		X						
Sinuites cancellatus	X	X	X	X	X		X			
Salpingostoma	X	X	X	X			X			
Hormotoma gracilis	X	X	X	X	X					
Hormotoma cf. H. winnipegensis	X	X	X	X	X		X			
Endoceras	R	X	X	R	X		X	X	X	X
Spyroceras	R	X	X	R			X	X	X	X
Ephippiorthoceras formosum	X	X	X		X		X		X	
Westonoceras manitobense	X	X	X		X		X		X	
Ceraurinus icarus	X	X	X					X		

X = Species present
R = Species present but rare
E = Evolved species present

A good example of this evolutionary sequence is found in Streptelasma winnipegensis, the intermediary species found in the Winnipeg.

The remaining species represent a faunule which is found throughout the Galena-Trenton, the Stewartville, the Winnipeg and the Red River. However the Winnipeg fauna represents only a small part of any of the other three faunas.

The Winnipeg has a selective fauna derived from the Galena-Trenton or the Stewartville fauna. This selective fauna has formed a nucleus for part of the Red River fauna. The remaining Red River fauna was apparently derived from Arctic sources as it is more comparable to the Arctic faunas than to the faunas of the Galena-Trenton and Stewartville. This is especially evident in the cephalopods.

Halysites gracilis of the Stewartville is also found in the Red River and in the Arctic formations. Its introduction to the Red River may easily have been by an Arctic route, or its absence in the Winnipeg could be explained by environmental factors.

Receptaculites oweni of the Stewartville has been demonstrated in Miller (1930, 1932) to be different from R. arcticus of the Red River. R. arcticus was introduced to the Red River from the north. As no continuous phylogenetic succession is necessary between these species, neither form need occur in the Red River.

The similarity of the Winnipeg fauna to part of that of the Red River suggests a possible faunal unit for the two formations. Further study might indicate that the Stony Mountain fauna may be part of a faunal unit embracing all the Manitoba Ordovician faunas.

V. CORRELATION AND AGE

Although the faunas are not identical, those of the Winnipeg and the Dubuque are possibly equivalent in age.

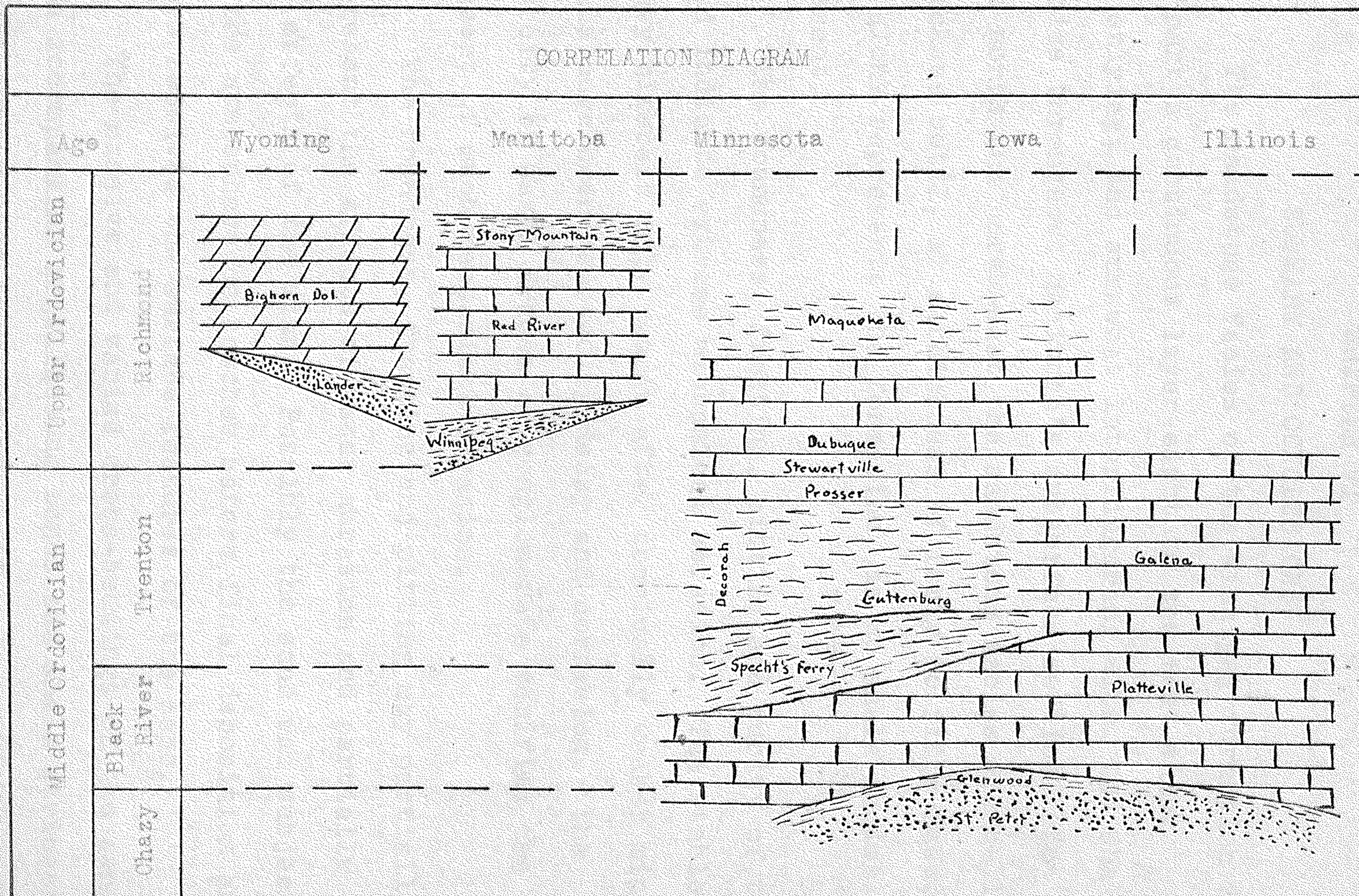
From a study of the common forms the Winnipeg fauna appears to correlate with that of the Stewartville or the Galena-Trenton, but the presence of species in the Winnipeg derived from the species of the Stewartville and Galena-Trenton suggest that the Winnipeg is the youngest formation.

The Winnipeg fauna may represent the commencement of the Upper Ordovician in Manitoba. It contains numerous hold-over species from the Middle Ordovician, but this is to be expected as it represents a selection of the hardier species from the Stewartville. If not Upper Ordovician, the Winnipeg fauna is certainly very high in the Middle Ordovician.

The Winnipeg fauna is definitely a part of a unit which also includes the Red River and possibly the Stony Mountain faunas.

A general correlation diagram is presented in Figure 13 on page 61.

FIGURE 13


CORRELATION DIAGRAM
Age
Wyoming
Manitoba
Minnesota
Iowa
Illinois
Upper Ordovician
Richmond
Middle Ordovician
Trenton
Black River
Chazy
Stony Mountain
Bighorn Dol.
Red River
Lander
Winnipeg
Maquoketa
Dubuque
Stewartville
Prosser
Decorah
Galena
Guttenberg
Specht's Ferry
Platteville
Glenwood
St. Peter

CHAPTER VI

SUMMARY AND CONCLUSIONS

The sandstone facies of the Winnipeg formation is in part a continuous layer eight to ten feet thick underlying, and somewhat interfingering with, the shale facies throughout Manitoba's subsurface section. To the north and north-east the sandstone facies gradually thickens until, at a thickness of forty to fifty feet, it alone represents the formation, as no shale facies is present.

The roundness, frosting, pitting and purity of the sand indicate extreme mechanical abrasion. The stable heavy minerals only remain after chemically weaker minerals have been removed by decay and corrasion. The scarcity of basal arkose or conglomerate verifies the concept of much mechanical abrasion.

The roundness, frosting and pitting may partially represent the effects of water abrasion and partially the effects of the wind. Possibly the sand was subjected to the atmosphere on beaches before final deposition and there received the surface features of the sand.

The massive and varied cross-beddings of the sand, with accompanying argillaceous zones and shale stringers result from varied areas of shore-line deposition, such as aeolian and sub-aqueous dunes, bars, lagoonal sediments and deltas. These variations in conditions of deposition, created the minor fluctuations in sorting and grain size.

Although authigenesis is rare, the Winnipeg sandstone must be considered as second or third cycle. Possibly a few authigenic grains were incorporated from previous Precambrian or Cambrian sediments. The few good crystal shapes present necessitate some authigenesis during the deposition of the sandstone. Possibly some has been siliceously cemented and reworked as shore-line conditions varied. Definitely much of the quartz has been derived from previous sandstones.

Thus the Winnipeg sandstone facies represents the various phases of deposition along the shore-line of a sea.

The fair regularity in character and thickness of the basal sand deposit below the shale indicates a rather uniform advance of the sea. As the advance slowed with the northward transgression of the sea, the sand deposit thickened. The basal deposit must transgress time lines.

The shale facies represents the deeper water deposition seaward from the shore-line shallow water sand deposits. It is composed of very fine material which was easily held in suspension in the near-shore agitated water, but which was dropped in the deeper calmer water.

The fine sand phases in the shale facies occurred as off-shore and deep water currents carried scattered sand grains into the zone of shale deposition. The irregular sand zones in the shale are therefore non-correlatable.

The lack of shale facies along the outcrop belt present today suggests that the sea did not advance much farther north or east of this position, as no deep water zone is represented.

The small brown pellets in the shale section may correspond to the pyrite "oolites" on Black Island. The varying mineralogy may be accounted for by variations in oxidizing-reducing conditions in the different areas of deposition. This zone may represent a time line established by a high influx of iron into the sea.

The relationship of the shale facies to the southwest and south of the sandstone facies indicates that the sea advanced from the south northward into Manitoba. This is also verified by the fauna, which had a southern origin in the Stewartville.

The calcareous cement, which is more prevalent at the top of the sandstone, and the prevalence of calcareous shale toward the top of the shale facies, indicate a gradual change in source material, with the addition of much lime. This may have resulted as source material became less and carbonate became more dominant than sand and argillaceous material. This would result as the sea advanced on a smaller and smaller landmass. The sandstone to the north in Manitoba, similar to the Winnipeg sandstone, suggests a similar basal facies for a sea advancing southward from the north. This would rapidly cover the intermediary land mass and diminish the source of sedimentary supply.

Eventually the two seas joined, at which time there was deposition of limestone, as the large sea formed would be shallow and widespread, making transport of clastics much more difficult than that of dissolved carbonate. Sea currents could carry irregular amounts of sand into the basinal area of lime deposition. The sand zones would be scattered, irregular and non-correlatable. The sand grains could come from areas near the line of junction of the two seas, where sand is at some places absent as the Red River limestone rests directly on the Precambrian.

With the junction of the two seas, deposition of the Red River formation commenced.

The faunal evidence, as previously stated, also points to the uniting of a southern with a northern sea, each of which contributed a part of the fauna which made up the Red River fauna.

The Lander sandstone, younger than the Winnipeg sandstone, represents a westward extension of the sea after the two initial seas had united. Some of the shale in the Saskatchewan section must then represent the deep water facies of the Winnipeg formation and some must be equivalent to the Lander sandstone.

The land movement which caused the sea transgression that deposited the Winnipeg formation was a tectonic break, possibly that which separated the Middle from the Upper Ordovician. There was no other tectonic break comparable to this at any time in the Middle or Upper Ordovician in the area discussed. However it may have occurred during the Middle Ordovician.

In North Dakota and Saskatchewan the Winnipeg formation may be differentiated from the Cambrian by several features, all of which are present in the Cambrian and lacking in the Winnipeg. These are: glauconite, red sands, limestone interbedded in the sandstone, highly angular quartz grains, considerable yellow quartz, irregular coarse dolomite cement and much red shale.

There is Cambrian represented in most of the North Dakota wells. The erosional extent of the Cambrian as shown in Figure 2 is the interpretation of the North

Dakota Geological Survey.

The sandstone studied from Alberta wells appears to constitute a basal sandstone similar in origin to the Winnipeg sandstone, but with much less mechanical wear. Probably the advance of the sea was much more rapid, which may be confirmed by the amount of red shale, possibly indicating much rapid burial of the finer sediments.

CHAPTER VII

PALEONTOLOGY

I. INTRODUCTION

Fossils are rare throughout the Winnipeg formation and those found are poorly preserved.

The greater part of the fossil collections studied is from an outcrop of the Winnipeg formation at Victoria Beach on the east shore of Lake Winnipeg. This small outcrop, which shows the upper two feet of the Winnipeg formation overlain by Red River limestone, is covered by the lake at all but the lowest of water levels.

The fossils from Punk Island, Deer Island, Black Island, Bull Head and Little Grindstone Point on Lake Winnipeg are all from the upper ten feet of the formation. Fossils which are at least twenty-five feet below the overlying Doghead limestone were collected at an outcrop of the Winnipeg sandstone about one-quarter mile west of Grindstone Point on Lake Winnipeg.

Fossil fragments and microfossils were obtained from cores and cuttings of several wells.

The synonymy is restricted to the more readily available publications in which the species have been described. A more complete synonymy may be found in Bassler's Index (1915).

The specimens described herein are deposited at the Geology Department of the University of Manitoba, Fort Garry, Manitoba.

As classification of faunas varies greatly from author to author, Shimer and Schrock (1944) is used as a guide for classification wherever possible because of its general accessibility to all persons.

The Victoria Beach specimens are mostly pyritized molds, although a few brachiopods are well preserved pyrite replacements of the original shell materials. The few complete specimens in the collection are from this locality. The specimens found at the other localities along Lake Winnipeg are usually preserved as poor sandstone molds.

Thin sections were difficult to prepare as the specimens have a soft sandy matrix which disintegrates when cut or ground. This difficulty was most evident with the cup corals. The bryozoans, generally soft and shaly, tended to break up easily upon sectioning.

II. DESCRIPTIONS

PHYLUM COELENTERATA

CLASS GRAPTOZOA

ORDER GRAPTOLOIDEA LAPWORTH

SUBORDER AXONOPHORA FRECH

Family DIPLOGRAPTIDAE LAPWORTH

Genus CLIMACOGRAPTUS Hall 1865

Climacograptus typicalis Hall 1865
(Plate I, figures 27, 28)

Climacograptus typicalis Hall, Geol. Surv. Canada, Can. Org. Remains, 1865, pp. 27, 28, 57, Pl. A, figs 1-9. - Ulrich, Amer. Geology, 1, 1888, p. 183. - Walcott, Bull. Geol. Soc. Amer., 1, 1890, p. 339. - Ruedemann, Bull. New York State Mus., 42, 1901, p. 523.
Climacograptus typicus Grabau and Shimer, N. A. Index Foxsils, 1, 1906, p. 32, fig. 51b.

The synrhabdosome was not observed. The rhabdosome, greater than 30 mm. long, has a width of 1.6 to 2.0 mm. in the mature part. The sicula was not observed. The thecae are closely spaced, 11 to 15 in 10 mm., overlapping each other a quarter to a third in the mature region. The aperture is almost horizontal with a sharp spine projecting outward from its ventral margin.

DISCUSSION: No features were noted by which this specimen could be placed as a variety of C. typicalis. The species as found in the Winnipeg is possibly ancestral to the variety C. typicalis var. spinothecatus Wilson found in the lower portion of the Red River. This varietal form has a spinal development at the central curve of the theca rather than at the apertural lip as in the specimen from the Winnipeg. A closely similar species, C. bicornis (Hall), has been reported from the Red River and could be related to some of the Winnipeg specimens. The Macasty shale of Anticosti has a varietal form C. typicalis var. magnificus (Twenhofel) which is similar to the Winnipeg species, except that it is much larger. The number of thecae in 10 mm. is the same for both forms but the Macasty specimens are twice as wide as those of the Winnipeg.

HORIZON AND LOCALITY: Winnipeg formation, shale facies, Union Oil Company of California Anstaadt No. 1 stratigraphic test well at a depth of 1548 feet below sea level and 128 feet above the Precambrian.

CLASS SCYPHOZOA

ORDER CONULARIIDA MILLER AND GURLEY

Family CONULARIIDAE WALCOTT

Genus Conularia Miller ?

Conularia formosa Miller and Dyer 1878
(Plate I, figure 25)

Conularia formosa Miller and Dyer, Jour. Cincinatti Soc. Nat. Hist., 1878, p. 38, pl. 1, figs. 12, 12a.

Size, apical angle and degree of tapering cannot be determined as the specimen is incomplete. A single specimen with strong transverse ridges, about 3 to 4 in one mm., which are directed obtusely upward toward the center of the face, is referred to this species. The ridges are uniformly spaced with round tubercles occurring regularly along them. The tubercles are slightly greater in diameter than the greatest width of the ridges. Small longitudinal bars, about 6 in one mm., occur between the tubercles, but not as extensions of the latter. The small bars are narrow, with interspaces about four times their own width. There is no median ridge.

DISCUSSION: C. formosa has the pustules and longitudinal bars of Metaconularia. In the former the bars are placed between the pustules and in the latter the bars are extensions of the pustules. This Winnipeg species may be ancestral to Metaconularia, which is common in the Red River as M. asperata (Billings). M. asperata is the same as C. asperata Billings, described from Anticosti. C. formosa is considered to be a Maysville or Richmond form.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Grindstone Point on Lake Winnipeg.

Conularia sp. ind.
(Plate I, figure 26)

A portion of one apecimen of an indeterminable _Conularia_ measures 30 mm. in length, 5 mm. wide at the base of the face and 8 mm. wide at the top of the face. The four faces form a rhomboid, but they may have been flattened from an original square shape upon burial. Neither the apex nor the aperture is preserved, but an estimate of the apical angle is 10 to 12 degrees. Undulating transverse ridges meet at an upward angle of 150 degrees in the middle of the face. There is a faint suggestion of a ridge separating the faces.

DISCUSSION: The ridges in this specimen are more undulating than those of _C. formosa_ and resemble the curving type of _C. splendida_ (Billings) of the Anticosti Ordovician.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, exact locality unknown, but lithology of enclosing rock suggests that it may be from Deer Island or Punk Island on Lake Winnipeg.

Genus CLIMACOCONUS Sinclair 1942

Climacoconus cf. C. clarki Sinclair 1942
(Plate I, figure 24)

Climacoconus clarki Sinclair, The Chazy Conularida and Their Congenors, Annals of Carnegie Museum, Vol. 39, Oct. 1, 1942, pp. 219-240.

A single face, preserved by pyritic replacement, was studied. The part available is 40 mm. long and 10 mm. wide, with little apparent taper along the length. The apex is not retained, but an approximation of the apical angle is 10 degrees. Large strong transverse bars, about 4 in one mm., arch gently convex upward toward the center of the face. Centrally the bars are very gently curved. Projections of the outer portions of the bars meet in the center at an angle of approximately 150 degrees. The interspaces between bars are as much as twice as large as the bars themselves. Along the center of the face is a median keel, which is the same height as the transverse bars where the two intersect, but is depressed between bars. Both the bars and median keel are slightly wrinkled. Between the bars and keel the surface is crossed by fine transverse striae. At the edge of the face a thickened ridge is crossed by fine transverse lines. At some places this ridge is rounded; at other places it is angular.

DISCUSSION: The species C. clarki is the most similar form to this specimen but differs as it has only 2 bars in one mm., whereas the described specimen has four. The species is readily distinguishable from other species of the genus which have opposed well rounded ridges at the keel. The specimen is also much larger than any noted in the literature.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, uppermost beds at Victoria Beach on Lake Winnipeg.

CLASS ANTHOZOA

SUBCLASS TETRACORALLA

Family ZAPHRENTIDAE EDWARDS AND HAIME

Genus STREPTELASMA Hall 1847

Streptelasma winnipegensis n. sp.
(Plate I, figures 31-33)

The new species is based on two fairly complete specimens. One specimen was first sectioned longitudinally and then one portion was cross-sectioned at the top of the pseudo-columella. Both specimens are quite large, 44 and 39 mm. long respectively and the greatest diameter in both is 34 mm. They are straight, conical, with an apical angle of 45 degrees. Externally the epitheca is complete and well developed. There are a few irregular growth wrinkles. The septa show as longitudinal grooves on the external surface. At the base of the calyx, which is two-fifths to one-half the depth of the corallum, there are 50 major, but no minor septa. The major septa twist together to form a pseudo-columella which forms a small rise in the base of the calyx. Sometimes two or more septa unite before reaching the center. In cross-section the pseudo-columella appears to be vesiculose. In the upper part of the corallum the septa are very short, about one-tenth the diameter of the corallum. A secondary set of minor septa, 50 in number alternating with the major septa, are one-twentieth the diameter of the corallum. Tabulae, dissepiments and cystosepiments are all absent.

DISCUSSION: This new species of cup coral, S. winnipegensis, lacks both tabulae and dissepiments, has a deep calyx, and has a late development of the secondary septa. These features disappear, either singly or in combination, in such forms as S. profundum (Conrad) and S. robustum (Whiteaves) of the Red River and Stony Mountain. The Winnipeg species is also smaller, straighter and more conical than the later species. The new species may be ancestral to the larger forms of the Red River and Stony Mountain. The new species has more septa and is larger than S. corniculum Hall, the first true Streptelasma, which is found in the Galena-Trenton. Possibly

S. corniculum and S. winnipegensis are two stages in the development from Lambeophyllum to the larger forms of Streptelasma.

The size of S. winnipegensis suggests that this species is at least Trenton or younger in age and that it may possibly be Upper Ordovician in age.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Streptelasma simplicitas n. sp.
(Plate I, figures 29-30)

Several small poorly preserved specimens and one excellent specimen are available for study. The corallite expands from a conical tip to a diameter of 13 mm. in a height of 8 mm. There are 38 major septa which twist slightly in the center where they unite to form a psuedo-columella. The septa thicken toward the outer margin. A few scattered minor septa are about one-fourth the diameter of the corallum. The cardinal, counter and alar septa are well developed. The convex side is fairly flat and slopes rapidly outward from the apex. The alar septa are situated toward the counter septum. Tabulae and dissepiments are lacking. No calyx is evident. The outer wall is not preserved.

DISCUSSION: S. simplicitas may be mistaken for Holophragma anticonvexa Okulitch but it does not have the reverse curvature of the latter.

This is a simple form of Streptelasma and is possibly transitional from some other genus to the larger species of Streptelasma of the Red River.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

PHYLUM ANNELIDA

CLASS SIPUNCULOIDEA

Genus SCOLITHUS Haldemann 1840

Scolithus (?) sp. ind.

There is one good specimen available for study in which almost straight to slightly curving cylindrical tubes 2.2 mm. in diameter pass through a well consolidated sandstone. They are generally empty but are occasionally filled with sand.

DISCUSSION: There are too few recognizable structural features upon which a specific determination could be based.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Punk Island and Victoria Beach on Lake Winnipeg. Specimens occur along with Paleophycus at Punk Island.

PHYLUM ECHINODERMATA

CLASS CRINOIDEA

Crinoid columnals

Large multi-shaped crinoid columnals are abundant throughout the Winnipeg. They are small to large (1 cm. in diameter), round, pentagonal, hexagonal, star-shaped, thin to thick and ribbed or smooth.

DISCUSSION: Although crinoid columnals are common in the Winnipeg, crowns and calyces are exceedingly rare. *Glyptocrinus* sp. has been reported by Dowling (1898) and Whiteaves (1900).

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, shaly zone, along with bryozoa at Victoria Beach on Lake Winnipeg; sandstone facies in all well sections, especially Red River Hepner No. 2.

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES AND RESEARCH

Dr. E.I. Leith,
Dept. of Geology & Mineralogy,
University of Manitoba.

Dear Sir:

The Graduate Studies Committee has appointed you a member of the Committee of Examiners to report upon the Master's thesis submitted by: Mr. George Macauley.

The regulations state that theses, if satisfactory, shall be graded "approved".

Copies of the thesis are submitted in an unbound condition in order to permit alterations and corrections desired by the Committee of Examiners before they are finally bound.

You are requested to send your report on the thesis to the Chairman of the examining committee, and to return your copy of the thesis to him. The Chairman will submit the thesis report to the Dean and will forward to the Dean the four required copies of the thesis, <u>but not until these have been revised by the student, if revision is necessary, and have been put in a form ready for binding</u>. Please note that September 24th is the deadline for the final report if the student is to graduate in October.

Yours truly,

W.H. McEwen,
Dean of Graduate Studies and Research.

/ah

Committee of Examiners:

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PHYLUM BRYOZOA

CLASS *ECTOPROCTA*

ORDER TREPOSTOMATA ULRICH

SUBORDER INTEGRATA ULRICH AND BASSLER

Family HALLOPORIDAE BASSLER

Genus HALLOPORA Bassler 1911

Hallopora multitabulata (Ulrich) 1886
(Plate I, figures 21-23)

Monotrypella multitabulata Ulrich, 14th Ann. Rep. Geol. Hat. Hist. Surv. Minnesota, 1886, p. 100.
Callopora multitabulata Ulrich, Geol. Minnesota, 3, 1893, p. 200, pl. 23, figs. 11, 12, 16, 17, 24-26, 30, 31.
Hallopora multitabulata Bassler, Bull. U. S. Nat. Mus., 77, 1911, pp. 326, 327, fig. 202.

The zoaria are sub-cylindrical irregular branches as much as 25 mm. long and 8 mm. wide. The individual zooecia are hexagonal in outline, separated by a dark dividing line. There are 8 zooecia in a distance of 3 mm. Mesopores are few in number, triangular in outline. Some of the mesopores appear to be the beginnings of new zooecia. Acanthopores are absent. The axial region is immature with a large number of diaphragms. The mature region is short with abundant closely spaced diaphragms and cystiphragms.

DISCUSSION: The species is highly tabulate. The only similar forms outside the Galena-Trenton and remaining Manitoba Ordovician are some in Anticosti, but they are not nearly so tabulate.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, shaly zone, Victoria Beach on Lake Winnipeg; poor remnants from sandstone facies, shaly zone, Grindstone Point on Lake Winnipeg.

ORDER CRYPTOSTOMATA VINE

Family RHINIDICTYONIDAE ULRICH

Genus RHINIDICTYA Ulrich 1882

Rhinidictya mutabilis (Ulrich) 1886
(Plate I, figures 18-20)

Strictopora mutabilis Ulrich (part), 14th Ann. Rep. Geol. Nat. Hist. Surv. Minnesota, 1886, p. 66.
Rhinidictya mutabilis Ulrich, Geol. Minnesota, 3, 1893, p. 125, pl. 6, figs. 1-6, 12, 13; pl. 7, figs. 10-23, 25-28; pl. 8, figs. 1-3, - Whiteaves, Geol. Surv. Canada, Pal. Foss., 3, 1897, p. 240

The branches range in width from 1.5 to 3.0 mm. and in thickness from 0.5 to 1.1 mm., with the thinner type dominant. They divide dichotomously every 5 to 10 mm., generally about every 8 mm. The edges are quite sharp. The zooecia are built up in 14 rows, increasing to 20 rows prior to branching. Longitudinally there are about 14 zooecia in 5 mm. Across the specimen there are generally 10 to 12 zooecia in 2 mm. The interspaces between zooecial rows are wider than the rows themselves. Vertical sections show that the zooecia form an angle of about 55 degrees with the surface.

DISCUSSION: Rhinidictya obliqua Whiteaves is reported by Whiteaves (1900) but R. mutabilis appears to be the same as Whiteaves species. Differences as noted by Whiteaves are to be found in Whiteaves (1900).

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, shaly zone, Victoria Beach on Lake Winnipeg; poor specimens in sandstone facies on almost all island outcrops along Lake Winnipeg; shale facies, throughout Manitoba and North Dakota wells.

Family PTILODICTYONIDAE ULRICH

Genus ESCHAROPORA Hall 1847

Escharopora sp.

Escharopora Hall, Pal. New York, 1, 1847, p. 72.
- Ulrich, Geol. Minnesota, 3, 1893, p. 167.
Nicholsonia Waagen and Wentzel, Pal. Indica, 13th ser., 1886, p. 874.
Ptilodictya (in part) of other authors.

No specimens of Escharopora are available in the collections which were studied. However, several specimens were noted in well samples.

DISCUSSION: Dowling (1898) reports Escharopora ramosa Ulrich from Deer Island on Lake Winnipeg.

HORIZON AND LOCALITY: Winnipeg formation, shale facies, North Dakota well sections.

PHYLUM BRACHIOPODA

CLASS INARTICULATA

ORDER ATREMATA BEECHER

Superfamily OBOLACEA SCHUCHERT

Family LINGULIDAE GRAY

Genus LINGULA Bruguiere 1792

Lingula sp. ind.
(Plate I, figure 14)

Lingula Bruguiere, Encyclopedia Methodique, 1, 1792, pl. 250. - Emmons, Amer. Geology, 1, pt. 2, 1885, p. 189. - Billings, Canadian Nat. Geol., 1, 1856, p. 33. - Hall, Pal. New York, 4, 1867, p. 5. - Hall and Clarke, Pal. New York, 8, pt. 1, 1892, pp. 2, 161.

Many linguloid shell fragments were examined. Ornamentation generally consists of very fine growth lines, usually without any radiating features. A few specimens with a peculiar strong ribbing are also though to belong to this genus. A few of the specimens are punctate or pseudo-punctate. Possibly several species are represented.

DISCUSSION: L. iowensis Owen, L. elongata Hall and L. obtusa Hall have been reported by Whiteaves as occuring in the Doghead immediately above the Winnipeg. The presence of these species in the Winnipeg could not be established.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg; shale facies of North Dakota wells.

CLASS ARTICULATA

IMPUNCTATE ARTICULATA

Superfamily ORTHACEA WALCOTT AND SCHUCHERT

Family ORTHIDAE WOODWARD

Genus PLATYSTROPHIA King 1850

Platystrophia reversata (Foerste) 1885
(Plate I, figures 12, 13)

Platystrophia biforata var. lynx forma reversata Foerste, Bull. Sci. Lab. Denison Univ., Vol. 1, 1885, p. 81, pl. 13, fig. 7.
Orthis (Platystrophia) biforata (part) Foerste, Pal. Ohio, Vol. 7, 1895, p. 579, pl. 25, fig. 8.

The posterior half of one specimen was available for study. The specimen has a sub-rectangular to sub-elliptical outline and is 18.4 mm. wide and 12.9 mm. thick. The form is globose with the dorsal valve slightly more convex than the ventral. The species belongs to the Biplicate C Group of McEwan (1919). The first plication of the sulcus bifurcates and then two plications are added laterally to give a total of four. Apparently there are 5 plications on the fold but their mode of origin is indeterminable. The species is sulcate with a low rounded fold and a shallow sulcus. Each flank has 12 plications, separated by furrows equal in size to the plications. The hinge line is slightly less than the greatest width of the shell. The cardinal extremities are obtuse. Each valve has a prominent interarea; that of the dorsal is slightly larger than that of the ventral. The beaks are strongly incurved, touching, with the dorsal less curved than the ventral.

DISCUSSION: P. reversata is found in the Winnipeg and Red River formations, although in the latter there is a greater development of the plications in the sulcus and and on the fold. The species very much resembles P. biforata Hall and P. crassa James but these have different developments of the plications.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Family PLECTORTHIDAE SCHUCHERT AND COOPER

Subfamily PLICTORTHINAE SCHUCHERT

Genus PLECTORTHIS Hall and Clarke 1929

Plectorthis plicatella (Hall) 1847
(Plate I, figures 10, 11)

Orthis plicatella Hall, Pal. New York, Vol. 1, 1847, p. 122, pl. 32, fig. 9.
Orthis plicatella Billings, Geol. Canada, 1863, p. 165, fig. 145.

One well preserved specimen available for study is transverse, 7.7 mm. wide, 5.9 mm. long and 3.7 mm. thick, with a sub-rectangular outline. The species is sulcate with a low rounded fold and a shallow sulcus. There are 24 distinct sharply rounded costae; six are on the fold and five in the sulcus. The costae are unbifurcated. At the anterior commissure the specimen appears to be finely lamellose. The hinge line is almost equal to the greatest width of the shell. The cardinal margin is submegathyrid with the cardinal extremities a little greater than 90 degrees. The ventral valve has a large triangular apsacline interarea with an uncovered triangular delthyrium. The dorsal interarea is small, orthocline to anacline, with an uncovered triangular notothyrium.

DISCUSSION: The absence of bifurcation of the costae is a marked feature of this species. It is considered to be a Maysville form as reported in Bassler (1915).

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Superfamily RHYNCHONELLACEA SCHUCHERT

Family RHYNCHONELLIDAE GRAY

Subfamily RHYNCHOTREMATINAE SCHUCHERT

Genus RHYNCHOTREMA Hall 1860

Rhynchotrema inaequivalvis (Castelnau) 1843)
(Plate I, figures 6, 7)

Spirifer inaequivalvis Castelnau, Essae sur le Systeme Silurien di l'Amerique Septentrionale, 1843, p. 40, pl. 14, fig. 8.
Atrypa increbescens (partim) Hall, Pal. New York, Vol. 1, 1847, pp. 146, 289, pl. 33, figs. 13a-h, ?pl. 79, fig. 6.
Rhynchonella increbescens Billings, Geology of Canada, 1863, p. 18, fig. 153.

Two well repserved complete specimens and several fragments of sandstone molds were examined. The species is small, slightly transverse and sub-triangular in outline. It is biconvex. The dorsal valve is fairly convex; the ventral is almost flat. The species is uniplicate with a low fold and a shallow sulcus. The sulcus has three costae, the fold four, and the flanks six or seven. The anterior portions of the specimens show very fine lamellae. The cardinal margin is terebratulid to sub-terebratulid. The hinge line is short. The ventral beak is rostrate and incurving; the dorsal is strongly incurved. The dorsal valve has a strong median septum with a simple undivided ridge-like cardinal process.
DISCUSSION: Bassler (1915) does not recognize the validity of the European species R. inaequivalvis in North

America, but places this form in the American species R. increbescens (Hall). The specimens studied exhibit no features by which they may be differentiated from either the European or the American species. Thus the prior European species is used in the nomenclature.

R. inaequivalvis is found in the Winnipeg formation along with its varietal form R. inaequivalvis var. laticostata Winchell and Schuchert.

R. increbescens from the Lander sandstone supposedly had coarser plications than the form described here but the species are hardly separable on such a minor detail. It is quite probable that they are identical. R. anticostiense (Billings) has a slightly more erect beak than the species from the Winnipeg, but again this is a gradational feature and the two species are difficult to separate. R. minnesotense Sardeson is slightly larger than R. inaequivalvis.

Many of the species of Rhynchotrema have been placed in the new genus Lepidocyclus Wang by Wang (1949). These include many of the larger species such as L. (R.) capax (Conrad) and L. (R.) dentata (Hall). The generic differentiation is based on internal features. R. inaequivalvis remains under its present generic classification.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Rhynchotrema inaequivalvis
var. laticostata Winchell and Schuchert 1892
(Plate I, figures 1-5)

Rhynchotrema inaequivalvis var. laticostata Winchell and Schuchert, American Geologist, Vol. 9, 1892, p. 293.

The ventral beak is not preserved in any of the 3 specimens available for study. The variety resembles R. inaequivalvis, but is larger, more transverse, and more elliptical. The dorsal valve is more convex than the ventral. The variety is uniplicate with strong costae, four on the fold, three in the sulcus and six to seven on the flanks. One specimen has 3 costae on the fold and two in the sulcus. The fold is low and rounded near the posterior part, but becomes high and sharp towards the anterior. The sulcus is shallow posteriorly, becoming deep towards the anterior. The cardinal margin is sub-terebratulid. The dorsal beak incurves strongly. The species appears to be finely lamellose. A median septum is well developed in the dorsal valve.

DISCUSSION: The discussion of the variety is included under that of R. inaequivalvis.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Superfamily SPIRIFERACEA WAAGEN

Family SPIRIFERIDAE KING

Subfamily SUESSIINAE WAAGEN

Genus CYCLOSPIRA Hall 1893

Cyclospira bisulcata (Emmons) 1842
(Plate I, figures 16, 17)

Orthis bisulcata Emmons, Geology of New York, 1842, Report Second District, p. 396, fig. 4, not described.
Atrypa bisulcata Hall, Pal. New York, Vol. 1, 1847, p. 139, pl. 33, fig. 3.
Cyclospira bisulcata Hall and Clarke, Pal. New York, 8, pt. 2, 1893, p. 147, figs. 133-136, pl. LIV, figs. 38-40.

One well preserved specimen in the collection is small, ovoid, ventro-convex, with the dorsal valve almost flat and the ventral valve tumid. The species is parasulcate. The sulcus of the ventral valve is bounded on either side by a sharp fold which disappears toward the beak. The dorsal valve has a smooth shallow rounded sulcus with a small plication opposing the ventral sulcus near the anterior margin only. The surface is crossed by fine striae. The cardinal margin is terebratulid. The hinge line is short. The ventral beak curves back onto a strongly incurved dorsal beak. There is a high ventral umbo. In the dorsal valve a median septum continues from the beak to the anterior margin.

DISCUSSION: Although the brachial supports were not studied the external features were considered of great enough significance to identify the species.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

PSEUDOPUNCTATE ARTICULATA

Superfamily STROPHOMENACEA SCHUCHERT

Family STROPHOMENIDAE KING

Subfamily RAFINESQUINIDAE SCHUCHERT

Genus SOWERBYELLA Jones 1928

Sowerbyella sp. ind.
(Plate I, figure 9)

Leptaena Dalman (part), Uppstallning och Beskrifning af de i Sverige Funne Terebratuliter, Kongl. Vetenskaps-Academiens Håndlingar for Ar 1928, Stockholm, P. 94, pl. 1, fig. 4.

Plectambonites Hall and Clarke (not Pander), An Introduction to the Study of the Genera of Paleozoic Brachiopoda, Part 1, Geol. Surv., State of New York, Vol. 8, 1892, pt. 1, p. 295, pl. 15, figs. 25-29; pl. 16, figs. 34, 35.

Sowerbyella Jones, Geol. Surv., Great Britain, 1, pt. 5, 1928

One external mold of the ventral valve is available for study. The specimen is 10 mm. wide and 5.5 mm. long. The surface ornamentation consists of numerous raised radiating striations which are separated by greater number of very fine thread-like striae. The number of these very fine striae between any two striations is variable. The ventral valve is of medium convexity.

The hinge line is megathyrid, bent slightly at the beak.

DISCUSSION: Plectambonites (Sowerbyella) sericea (Sowerby) has been reported by Whiteaves (1900) from Elk Island on Lake Winnipeg.

HORIZON AND LOCALITY: Winnipeg formation, shale facies, 52 feet below the Red River limestone in the Union Oil Company Anstaadt No. 1 test well in North Dakota.

Subfamily ORTHOTETINAE WAAGEN

Genus STROPHOMENA Blainville 1825

Strophomena (?) sp. ind.
(Plate I, figure 8)

Strophomena Blainville, Man. Malacol. et Conch., 1, 1825, p. 513, pl. 53, fig. 2. - Emmons, Amer. Geol. pt. 2, 1885, pp. 186, 197. - Hall and Calrke, Pal. New York, 8, pt. 1, 1892, p. 245.

There is available for study one poorly preserved specimen of the dorsal? valve. The valve is slightly convex, highly costate. The costae, grading to costellae, are bifurcated. There are a few concentric lamellae. The hinge line appears to be long and is bent slightly at the beak. The beak is somewhat incurved but does not protrude over the hinge line.

DISCUSSION: The specimen is poorly preserved and the identification is doubtful. S. incurvata (Shepard) has been reported by Whiteaves (1900) from the Winnipeg and

Red River at various localities along Lake Winnipeg.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg; possible fragment in shale facies, Union Oil Company Anstaadt No. 1 well in North Dakota.

PUNCTATE ARTICULATA

Superfamily DALMANELLACEA SCHUCHERT AND COOPER

Family DALMANELLIDAE SCHUCHERT

Genus DALMANELLA Hall and Clarke 1892

Dalmanella (?) sp. ind.
(Plate I, figure 15)

Orthis (group of O. testudinaria) Hall, Bull. Geol. Soc. Amer., 1, 1889, p. 21
Dalmanella Hall and Clarke, Pal. New York, 8, 1892, pp. 205, 223. - Winchell and Schuchert, Geol. Minnesota, 3, 1893, p. 439.

Only one specimen, preserved as a sandstone mold, is available for study. This appears to be a ventral valve, with a semi-circular outline. It is convex with a shallow sulcus. The beak is incurved.

DISCUSSION: The identification of the specimen is doubtful. D. testudinaria (Dalman) is reported in the Winnipeg formation by Dowling (1898) and by Whiteaves (1900).

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

PHYLUM MOLLUSCA

CLASS PELECYPODA

ORDER PRIONODESMACEA DALL

SUBORDER TAXODONTA NEUMAYR

Superfamily ARCACEA DESHAYES

Family CYRTODONTIDAE ULRICH

Genus CYRTODONTA Billings 1858

Cyrtodonta sp. ind.
(Plate II, figure 3)

Cyrtodonta Billings, Geol. Surv., Canada, Rep. Prog. for 1857, 1858, p. 179. - Ulrich, Geol. Minnesota, Pal., 3, pt. 2, 1894, p. 354.
Palearca Hall, Pal. New York, 3, 1859, p. 27

The anterior portion of one poorly preserved specimen was studied. The height is 43 mm. and the thickness 32 mm. The length is unknown. The specimen is quite large, strongly convex and equi-valved. The beaks are prominent, incurved as to be almost touching and are situated at the anterior extremity of the shell. The surface is finely concentrically lined.

DISCUSSION: *C. canadensis* Billings is reported from the Winnipeg formation from Little Grindstone and Grindstone Points on Lake Winnipeg.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Little Grindstone Point on Lake Winnipeg.

Superfamily ANOMIACEA HERRMANNSEN

Family MODIOLOPSIDAE ULRICH

Genus MODIOLODON Ulrich 1894

Modiolodon patulus Ulrich 1894
(Plate II, figure 2)

Modiolodon patulus Ulrich, Geol. Minnesota, 3, pt. 2, 1894, p. 521, pl. 37, figs. 20-24.
Modiolopsis patulus Miller, N. A. Beol. Pal., 2nd App., 1897, p. 782 (gen. ref.).

A single pyrite internal mold of a right valve in the collection is broadly ovate, 40 mm. long and 35 mm. high. The beak is small, prominent, erect. The species is highly inequilateral. The hinge line is probably short. The valve is uniformily convex. There is a large muscle scar which is almost centrally located. A few growth lines are evident. There is a small flaring extension below the beak.

DISCUSSION: The species is uncommon in the Manitoba Ordovician, occurring only in the Winnipeg. It may in some way be related to Modiolopsis which is found in the Red River.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

CLASS <u>GASTROPODA</u>

SUBCLASS <u>EUGASTROPODA</u>

SUPERORDER PROSOBRANCHIA VORDERKIEMER

ORDER ARCHAEOGASTROPODA?

SUBORDER BELLEROPHONTACEA ?

Family PROTOWARTHIDAE ?

Genus SINUITES (Ulrich and Schofield) 1847

Sinuites cancellatus (Hall) 1847
(Plate I, figure 35)

Bellerophon bilobatus Emmons (not Sowerby), Geol. New York, 2, 1842, p. 392, fig. 6; Pal. New York, 1, 1847, p. 184, pl. 40, figs. 3a-d. - Billings, Geol. Canada, Geol. Surv. Canada, 1863, p. 84, figs. 180a-b.
Bellerophon cancellatus Hall, Pal. New York, 1, 1847, p. 307, pl. 83, figs. 10a-c.
Protowarthia cancellata Ulrich and Schofield, Geol. Minnesota 3, pt. 2, 1897, p. 872, pl. 63, figs. 1-14.

There are two small pyritic internal molds in the collection which show no evidence of external ornamentation or of a keel. The coiling is a bellerophontid involute type, with rapid flaring on the last volution. The umbilicus is narrow and deep. The last volution of the specimen is incomplete, but enough is present to indicate the absence of a slit and apertural sinus. If an apertural sinus is present, it must be very small.
DISCUSSION: The lack of external features make comparisons difficult with specimens of the same species through-

out the remainder of the Manitoba Ordovician and the Galena-Trenton.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Family BUCANIIDAE ULRICH AND SCHOFIELD

Genus SALPINGOSTOMA Roemer 1876

Salpingostoma sp. ind.
(Plate I, figure 34)

Salpingostoma Roemer, Leth. Geog., 1, Leth. Pal. Atlas, 1876, pl. 5, fig. 12. - Ulrich and Schofield, Geol. Minnesota, 3, pt. 2, 1897, pp. 851-897.
Bellerophon and Bucania (part) of other authors.

The specimen available for study shows one half of a double volution. The specimen, about 8 mm. high, has two volutions. The outer volution barely coils over the inner volution, with a slight impressed zone on the ventral side. The volutions are slightly wider than high. The cross-section of the aperture is rhomboidal; the back is rounded and the sides are sub-angular. There is a shallow dorsal sinus. A slit of one-quarter volution in length passes posteriorly into a raised dorsal selenizone. The anterior of the slit is separated from the sinus by a narrow band. At the aperture the whorl has a moderate flare. Possibly a large lip may have been lost on burial. There are low rounded transverse growth lines which laterally are well developed convex toward the aperture.

DISCUSSION: The specimen is much smaller than any species described in the literature available. The development of the band across the slit at the aperture suggests that the specimen belongs to an early species of the genus. The dorsal slit is short and the number of volutions is few in comparison to other species.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach, Lake Winnipeg.

Family PLEUROTOMARIIDAE D'ORBIGNY

Genus HORMOTOMA Slater 1859

Hormotoma gracilis (Hall) 1847
(Plate I, figure 36)

Murchisonia gracilis Hall, Pal. New York, 1, 1847, p. 181.
Murchisonia angustata Hall, Pal. New York, 1, 1847, p. 41.
Murchisonia gracilis Hall, Whiteaves, Pal. Foss., Geol. Surv. Canada, 3, pt. 2, 1895, p. 123
Hormotoma gracilis Whiteaves, Pal. Foss., Geol. Surv. Canada, 3, pt. 3, 1897, p. 192.

The one specimen studied is a poorly preserved internal mold consisting of two volutions. The apical angle is estimated to be 30 degrees. The coiling is apparently fairly tight. The thickness is about 25 mm. The height of a volution is 32 mm. Generally the shape is turbinate.

DISCUSSION: Although the specimen is incomplete a visual comparison with specimens from the Red River indicates that this is a correct identification.
HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Hormotoma sp. ind.
(Plate I, figure 37)

A small portion of two volutions of a large specimen is available for study.
DISCUSSION: The specimen may be identified as _H_. cf. _H_. _major_ (Hall) or _H_. cf. _H_. _winnipegensis_ Whiteaves, but either identification would be doubtful.
HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

CLASS CEPHALOPODA

SUBCLASS NAUTILOIDEA

ORDER HOLOCHOANITES HYATT

Family INDOCERATIDAE HYATT

Genus ENDOCERAS Hall 1847

Endoceras (?) sp. ind.
(Plate II, figure 7)

Endoceras Hall, Amer. Jour. Sci. Arts, 47, 1844, p. 109; Pal. New York, 1, 1847, p. 207 footnote. - Emmons, Amer. Geol., 1, pt. 2, 1885, pp. 148, 151.
Diploceras Conrad, Jour. Acad. Nat. Sci. Philadelphia, 8, 1847, p. 267.
Colpoceras Hall, 3d Rep. New York State Cab. Nat. Hist., rev. ed., 1850, p. 181.

A portion of a large orthocone in the collections is preserved as an external mold with some internal structure evident at one end of the specimen. It is 300 mm. long, and thickans from a diameter of 55 mm. to a diameter of 76 mm. along the length. The cross-section is circular. External ornamentation consists of fine straight lines spaced every 6.5 to 7.0 mm. along the specimen. Internally the septa appear to be spaced every 6 mm. or less.

A second specimen has fine straight lines, 5.5 mm. apart, around it over its entire length. The indicated shape is ovate, but the specimen may be compressed. If compressed this may be the same species as the above-described specimen.

DISCUSSION: The specimens resemble both Endoceras and Cyclendoceras.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, first specimen from exposure west of Grindstone Point on Lake Winnipeg, second specimen from Victoria Beach on Lake Winnipeg.

ORDER ORTHOCHOANITES HYATT

Family ORTHOCERATIDAE M'COY

Genus EPHIPPIORTHOCERAS Foerste ?

Ephippiorthoceras formosum Billings 1856
(Plate II, figure 6)

Orthoceras formosum Billings, Geol. Surv. Canada, Rept. Prog., 1853-1856, fig. 317.
Ephippiorthoceras formosum Foerste, Trans. Royal Soc. Canada, ser. 3, ?, sec. 4, 226, pl. 3, figs. 1A-C, 4A,B.

One poorly preserved specimen was studied. It is 32 mm. long, and enlarges from 12 mm. to 14 mm. in dorso-ventral diameter along the length. Projection of the dorso-ventral sides gives an apical angle of nearly 10 degrees. The cross-section is oval, but the specimen may be laterally compressed. The camerae are each a little over 3 mm. long. Laterally the septal sutures curve downward in lobes which produces dorsal and ventral saddles. The siphuncle, 3 mm. in diameter, is displaced to make its position to the camerae indeterminable. There is no indication of external ornamentation.

DISCUSSION: The specimen is identified on comparison with specimens of the species which are abundant in the Ordovician of Anticosti.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

Family KONIOCERATIDAE HYATT

Genus SPYROCERAS Hyatt 1844

Spyroceras (?) sp. ind.
(plate II, figure 1)

Spyroceras Hyatt, Proc. Boston Soc. Nat. Hist., 22, 1844, p. 276.

There are many incomplete specimens of apparently oval cephalopods in the collections. These are crossed by strong sharp distinct annulations. One specimen, 120 mm. long, is obviously only a small part of the complete individual. The annulations are 5 to 6 mm. apart. The diameter is thought to be very large.

DISCUSSION: The specimens are too incomplete to attempt specific identification. The generic identification is somewhat in doubt.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

ORDER CYRTOCHOANITES HYATT

Family WESTONOCERATIDAE TEICHERT

Genus WESTONOCERAS Foerste 1924

Westonoceras manitobense (Whiteaves) 1890
(Plate II, figures 8,9)

Cyrtoceras manitobense Whiteaves, Trans. Royal Soc. Canada, 7, 1890, sec. 4, p. 80, pl. 13, figs. 3, 4, 5, pl. 15, fig. 4.
Westonoceras manitobense Foerste, Jour. Sci. Lab., Denison Univ., 1924, pp. 20, 253.

Four camerae of the lower portion of one specimen in the collections are retained. The 4 camerae total 11 mm. in length. The dorso-ventral diameter at the lower camera is 12 mm.; at the top camera it is 15 mm. Lateral thickness increases adorally from 10 to 12 mm. The dorsal side is convex outward; the ventral is almost straight. The cross-section is ovate. Sutures curve downward laterally to produce a rounded saddle dorsally and an angular saddle ventrally. The siphuncle, 3.5 mm. in diameter, is 2 mm. from the ventral margin.

DISCUSSION: Although only the lower portion of the species is retained, the specimen compares excellently with those of the Cathead and Doghead in Manitoba.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

PHYLUM ARTHROPODA

CLASS CRUSTACEA

SUBCLASS TRILOBATA

ORDER PROPARIA BEECHER

Family CHEIRURIDAE SALTER

Subfamily CHEIRURINAE RAYMOND

Genus CERAURINUS Barton 1913

Ceraurinus icarus (Billings) 1860
(Plate II, figure 5)

Ceraurinus icarus Billings, Canadian Nat. Geol., 5, 1860, p. 67, fig. 2; Geol. Surv. Canada, 1863, p. 219, fig. 231. - Whiteaves, Pal. Foss., Geol. Surv. Canada, 3, pt. 2, 1895, p. 128
Ceraurinus icarus Clarke, Geol. Minn., 3, pt. 2, 1894, p. 128.
Ceraurinus icarus Barton, Bull. Mus. Comp. Zool., 54, 1913, p. 551, pl. ?, fig. 7.

One half of a glabella in the collection is preserved as a thin black film on sandstone. The glabella is sub-quadrate in outline, rounded anteriorly, 15 mm. long and about 11 mm. wide. There are 5 short deep glabellar furrows, of which the last curves slightly toward the occipital ring. The frontal lobe is the largest; the posterior lobe is the next largest; and the two smaller lobes are of equal size. The frontal lobe is much larger than the other three lobes. The last glabellar furrow is unseparated from the rest of the glabella as the posterior furrow and the occipital ring do not merge.

DISCUSSION: The features of the glabella serve to distinguish the specimen from any of the species of _Cheirurus_ or _Ceraurus_. The specimen described has identical measurements to specimens of _C. icarus_ described from the Stony Mountain of Manitoba.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

HYPOSTOMA

In the collection there are two specimens preserved as molds in the sandstone which appear to be hypostomae. The specimens are 15 mm. long and 15 mm. side with prongs which are 6 mm. in length.

DISCUSSION: These specimens resemble the hypostoma of _Isoteles_.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Victoria Beach on Lake Winnipeg.

SUBCLASS _OSTRACODA_

Superfamily LEPERDITIACEA BASSLER AND KELLETT

Family LEPERDITIIDAE JONES

Genus LEPERDITIA Rouault 1851

Leperditia sp.
(Plate II, figure 4)

Leperditia Rouault, Bull. Soc. Geol. France, 2d ser., 8, 1851, p. 337.

A single specimen, referred to *Leperditia* sp., is small, 1.1 mm. long, 0.5 mm. high and 0.5 mm. thick. The outline is elongate to sub-oblong. The hinge line is 0.7 mm. long. There is a slight angularity at the posterior end of the hinge line whereas the anterior end is well rounded. The greatest gibbosity is located centrally toward the ventral beak, and the right valve is slightly more gibbous than the left valve. The right valve overlaps the left, with the edge of the left valve flattened ventrally.

DISCUSSION: The literature available did not allow a specific identification of the specimen.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Red River Oils Hepner No. 1 well, southern Manitoba at a depth of 345 to 350 feet below ground elevation.

OTHER FAUNA REPORTED

Several other species have been reported in the literature but they are not represented in the collections studied for the preparation of this report.

Hume (1928) reports the presence of *Orthis* (*Hesperorthis*) *tricenaria* (Conrad), but does not report the locality at which the specimen was found. This identification is doubted by the author. Dowling (1898) and Whiteaves (1900) list the annelid *Serpulites dissolutus*

Billings from Deer Island and Punk Island, the crinoid Glytocrinus sp. from Punk Island and Grindstone Point, and the ostracod Aparchites tyrrellii Jones from Black Island. The latter is thought by the author to be a type of pyrite "oolite". This is discussed in Chapter III on page 38. Dowling (1898) listed the gastropod Solenospira pagoda (Salter) var. occidentalis Whiteaves.

ALGAE

Genus LICROPHYCUS Billings 1865

Licrophycus sp.
(Plate II, figures 10, 12)

Licrophycus Billings, Pal. Foss., 1, Geol. Surv. Canada, 1865, p. 99.

In the collections there are a large number of well preserved specimens of Licrophycus and two types are present.

Several specimens have elongate slender stems, 3.2 to 5.3 mm. in diameter, originating from a common root which may be as much as 8 mm. thick. The stems divide into numerous branches, often at acute angles, or quite flexibly and loosely, producing a tuft-like mass.

A second type has stems reaching a maximum of 15 mm. in diameter. Bifurcation occurs repeatedly along the stem, with often as much as 6 inches between bifurcations. In some places the stem produced after bifurcation is the same size as the original stem.

DISCUSSION: The first type resembles both L. ottawaensis Billings and L. hudsonicus. The second type resembles L. hiltonensis and is commonly associated with Paleophycus.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, first type from Deer Island and Grindstone Point on Lake Winnipeg, second type from Punk Island on Lake Winnipeg.

Genus PALEOPHYCUS Hall 1847

Paleophycus sp.
(Plate II, figure 11)

Paleophycus Hall, Pal. New York, 1, 1847, p. 7.

Many specimens of apparently two species were examined. The specimens consist of rod-like stems which are almost 4 mm. in diameter and as much as 6 inches long. In the other type associated with Licrophycus the stems are 9 mm. in diameter. The stems in both types are of constant width along the length. They are straight to slightly curving. Stems cross each other commonly but only rarely do they appear to branch and this feature is doubted.

DISCUSSION: The assignment of specific names to these types is not considered to be of any value.

HORIZON AND LOCALITY: Winnipeg formation, sandstone facies, Punk Island on Lake Winnipeg.

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PLATE I

Upper left	- Staurolite grains of Winnipeg sandstone X25	(p. 34)
Upper right	- Zircons, of which some show good zoning, of the Winnipeg sandstone; one shiny sub-round grain of monozite (?) at right X34	(p. 35)
Center left	- Dolomite replacement rhombs of the Winnipeg sandstone showing some carbonaceous zoning; note dark irregular shaped unidentified mineral at bottom which may have grown around quartz grains X25	(p. 39)
Center right	- Tourmaline of the Winnipeg sandstone with one monazite grain X25	(p. 34)
Lower left	- Quartz grains of the Winnipeg sandstone which are less than median sorting size X3	(p. 33)
Lower right	- Quartz grains of the Winnipeg sandstone which are greater than median size X3	(p. 33)

PLATE I

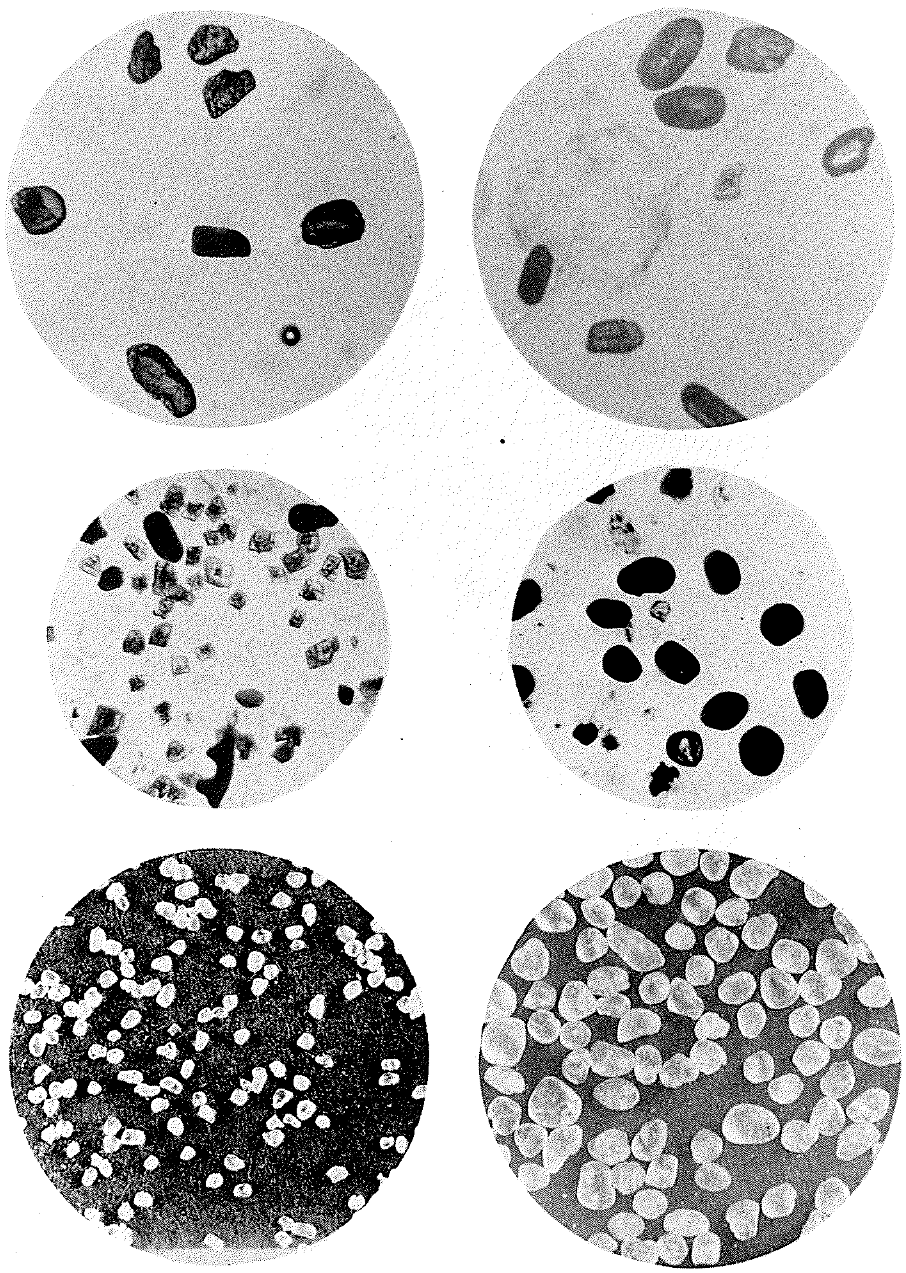

PLATE II

Upper left - Thin section of Winnipeg sandstone showing tourmaline with quartz inclusions, bryozoa, grain shape and fine carbonate matrix X 12

Upper right - Thin section of Winnipeg sandstone showing bryozoa, well rounded grains and long sliver of unidentified mineral, also two tourmaline grains at right, one with and one without inclusions X13

Center left - Authigenesis in the Winnipeg sandstone with two grains showing good crystal outlines X28 (p. 36)

Center right - Rounding of grains and unidentified sliver mineral in Winnipeg sandstone. Two dark patches are cementing material introduced to aid in sectioning X25

Lower left - Large dolomite grains of Cambrian sandstone in Alberta X25 (p. 42)

Lower fight - Thin section of angular grained Cambrian sandstone in Alberta X60 (p. 42)

PLATE II

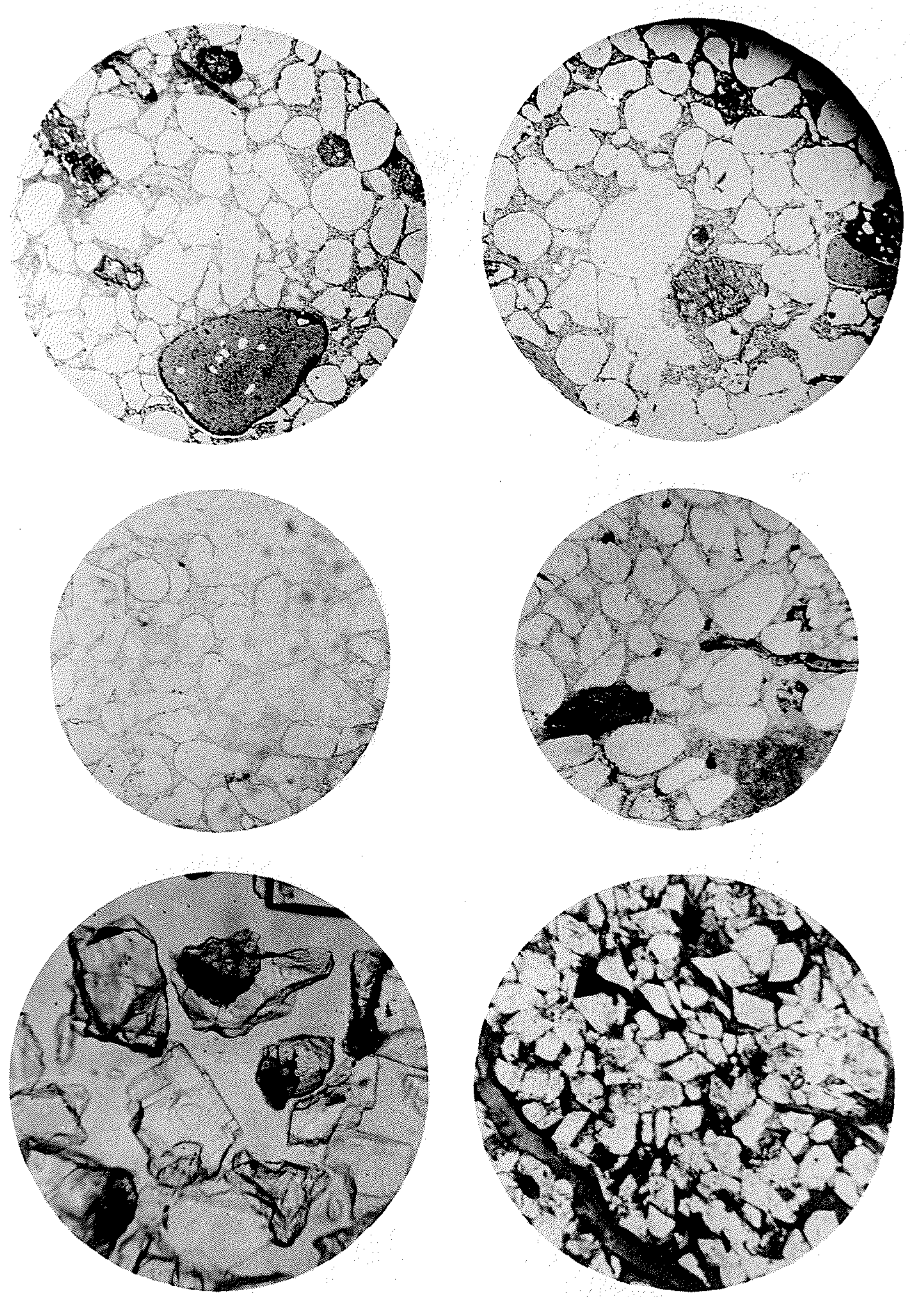

PLATE III

Figures		
1-5	Lepidocyclus inaequivalvis var. laticostata Winchell and Schuchert - 1) dorsal view X1 - 2) ventral view, showing only two costae in sulcus X1 - 3) dorsal view, showing only three costae on fold X1 - 4) dorsal view X1 - 5) ventral view X1	(p. 89)
6-7	Lepidocyclus inaequivalvis (Castelnau) - 6) dorsal view X1½ - 7) ventral view X1½	(p. 87)
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9	Sowerbyella sp. ind. - ventral view X1½	(p. 91)
10-11	Plectorthis plicatella (Hall) - 10) dorsal view X2 - 11) ventral view X2	(p. 85)
12-13	Platystrophia reversata (Foerste) - 12) dorsal view X1 - 13) ventral view X1	(p. 84)
14	Lingula sp. X1½	(p. 83)
15	Dalmanella? sp. - ventral? view X1	(p. 93)
16-17	Cyclospira bisulcata (Emmons) - 16) dorsal view X2 - 17) ventral view X2	(p. 90)
18-20	Rhinidictya mutabilis (Ulrich) - 18) cross-section X3 - 19) longitudinal section X3 - 20) external view X4	(p. 81)
21-23	Hallopora multitabulata (Ulrich) - 21) longitudinal section X3 - 22) broken internal view X2 - 23) cross-section X6	(p. 80)
24	Climacoconus cf. C. clarki Sinclair X1¼	(p. 74)
25	Conularia formosa Miller and Dyer X2	(p. 71)
26	Conularia sp. ind. X1	(p. 73)

PLATE III

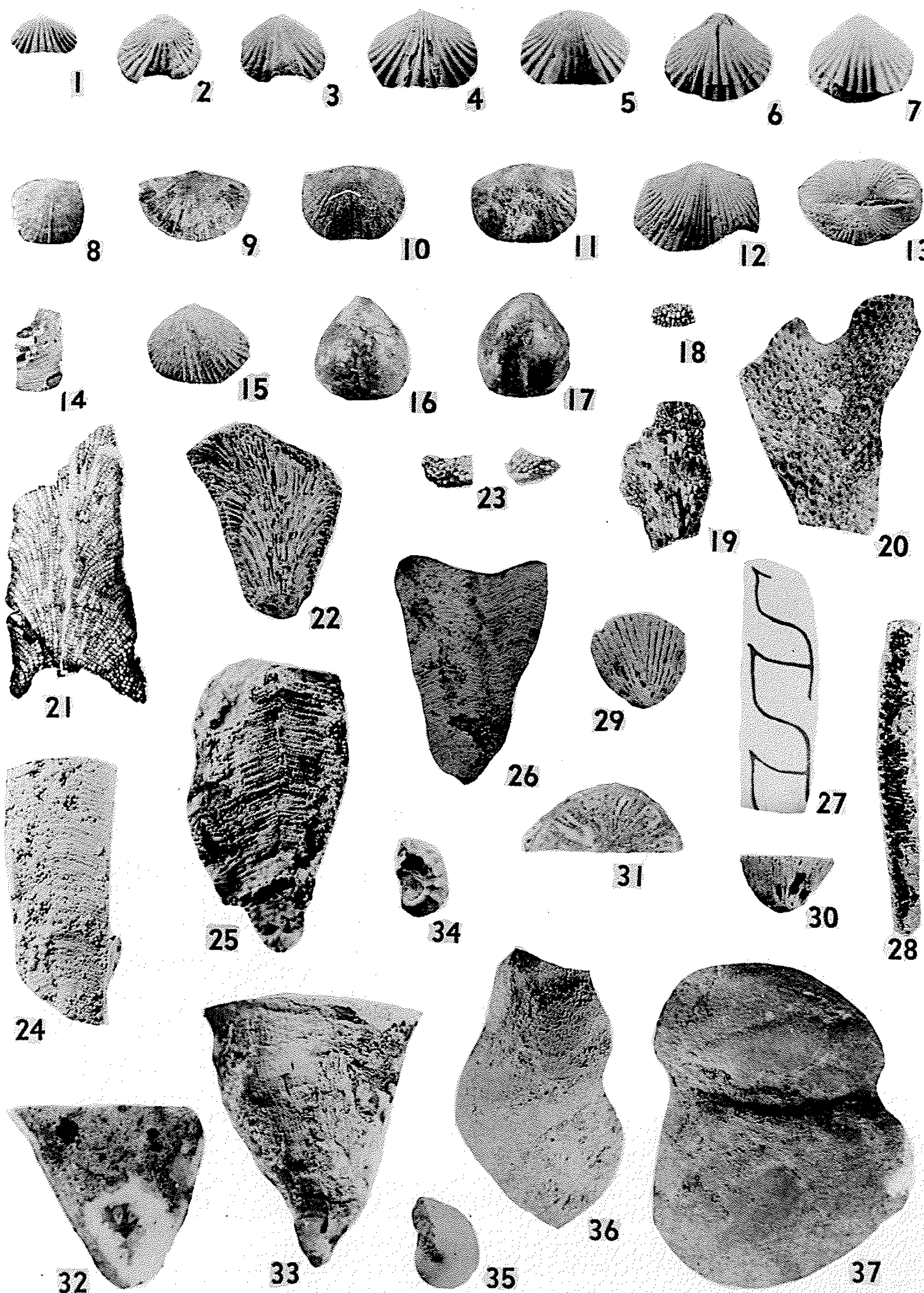
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PLATE III (cont'd)

27-28 Climacograptus typicalis Hall - 27) thecal arrangement diagram X20 - 28) X2 (p. 70)

29-30 Streptelasma simplicitas Macauley n. sp. - 29) cardinal view X1 - 30) counter view X1 (p.77)

31-33 Streptelasma winnipegensis Macauley n. sp. - 31) cross-section at top of pseudo-columella X1 - 32) longitudinal section X1 - 33) external view X1 (p. 75)

34 Salpingostoma sp. ind. - X1 (p. 97)

35 Sinuites cancellatus (Hall) - X1 (p. 96)

36 Hormotoma gracilis (Hall) - X1 (p. 98)

37 Hormotoma sp. ind. - X1 (p. 99)

PLATE IV

Figures

1	Spyroceras? sp. - X1	(p. 102)
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3	Cyrtodonta sp. ind. - X1	(p. 94)
4.	Leperditia sp. ind. - X6	(p. 105)
5	Ceraurinus icarus (Billings) - X1	(p. 104)
6	Ephippiorthoceras formosum Gillings - X1	(p. 101)
7	Endoceras sp. ind. - X 4/5	(p. 102)
8-9	Westonoceras manitobense (Whiteaves) - 8) cross-sectional view X1 - 9) lateral view X1	(p. 103)
10,12	Licrophycus sp. - X1	(p. 107)
11	Paleophycus - two possible species - X1	(p. 108)

PLATE IV