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HIGH-CALCIUM LIMESTONE DEPOSITS
of
MANITOBA

by

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FRONTISPIECE: Elm Point limestone exposed in the Steep Rock quarry of Canada Cement Lafarge Ltd.; the older section of the quarry extends northward to Lake Manitoba.

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INTRODUCTION

The purpose of this investigation was to determine distribution, quality, and stratigraphic position of high-calcium limestone deposits in Manitoba, primarily in the southwestern part of the Province (Figure 1). The location of ten limestone zones within the geological section of that area is shown in Figure 2. High-calcium limestone occurs in two thin beds within the Ordovician Red River Formation, in at least six zones within Devonian strata, and as thin interbeds in the Jurassic Reston and the Cretaceous Favel Formations. In Hudson Bay Lowland, recent exploration has indicated scattered occurrences of limestone in lower Paleozoic strata.

All high-calcium limestone produced in Manitoba has been quarried from Devonian strata: from the Elm Point Formation at Spearhill, Steep Rock, Faulkner, and Lily Bay; from the Dawson Bay Formation near Volga; and from the Souris River Formation at Winnipegosis and north of Mafeking (Figure 1). This production has supported a thriving Portland cement, high-calcium lime, and crushed limestone industry.

Previous work

A comprehensive report by Goudge (1944) describes quarry operations and includes numerous chemical analyses of carbonate rocks throughout Manitoba. The geology of the Devonian formations has been reported by Baillie (1951, 1953), and of the Ordovician formations by Baillie (1952). McCabe and Bannatyne (1970) reported high-calcium limestone beds near Lake St. Martin. Other reports of value to a study of high-calcium limestone deposits of Manitoba are listed in the selected references.

Present work and acknowledgements

Current high-calcium limestone quarries at Lily Bay, Spearhill, Faulkner, Steep Rock, and Mafeking were examined. Detailed field work in selected areas has resulted in the location of outcrops previously unreported. A major part of the work has been the study and analysis of diamond drill core from the Winnipeg-southern Interlake area, the Lake St. Martin area, the Devonian outcrop belt, and the Ste. Rose du Lac area. This core was obtained from several drill programs:

1) 1961: Inland Cement Industries Limited, western Winnipeg area.
2) 1961: Canada Cement Lafarge Ltd., western Winnipeg-Stony Mountain area.
3) 1968-1969: FRED-ARDA Manpower Corps training program in the Lake St. Martin area, the Peguis Indian Reserve, and the southern Interlake area.
4) 1969 to 1973: Manitoba Mines Branch stratigraphic and industrial minerals core hole program: drill holes throughout southern Manitoba.
5) 1970: Department of Indian Affairs and Northern Development; drill holes on the Ebb and Flow Indian Reserve.

The writer is indebted to Mrs. A. S. Dawson for the donation of drill core and geological reports from the Inland Cement drill program; permission to make use of the data was kindly granted by the company. J. Selwyn, Canada Cement Lafarge Ltd., kindly provided information on that company's activities in Manitoba. J. D. Godard, Western Minerals Section of the Department of Indian Affairs and Northern Development, made available the core from the Ebb and Flow Indian Reserve. Discussions with H. R. McCabe, Manitoba Mines Branch, have been of assistance in determining stratigraphic positions of some of the Devonian limestone zones.

For information on quarry operations, the writer is indebted to J. Brown, superintendent of Spearhill and Faulkner quarries, Steel Brothers Canada Ltd.; A. Portman, superintendent, Mafeking quarry of Inland Cement Industries Limited; C. Snidal, Steep Rock quarry, and N. Thomas, Lily Bay quarry, superintendents for Canada Cement Lafarge Ltd.

It is a pleasure to acknowledge the drilling prowess of L. Beauchamp, D. Speer, and their assistants during the Manitoba Mines Branch core hole program, and the co-operation of D. Snuggs and his assistants in the Geological Laboratory for sample preparation. Samples for analysis were selected on the basis of stain tests using the alizarin red S method (Warne, 1962). Chemical analyses were made in the Mines Branch Analytical Laboratory, under the direction of A. M. MacKay, by R. Nembhard, D. F. G. Brown, and

J. Gregorchuk. Maps and diagrams were draughted under the direction of R. Sales.

The capable and willing assistance of J. D. Bamburak, during mapping of the Devonian outcrops and quarries in 1971, is also acknowledged.

High-calcium lime and limestone: uses and specifications

In this report, high-calcium limestone is defined as a carbonate rock with a minimum of 95 per cent combined $CaCO_3$ and $MgCO_3$, and a maximum of 5 per cent $MgCO_3$. Magnesian limestone contains 5 to 10 per cent $MgCO_3$, dolomitic limestone 10 to 20 per cent $MgCO_3$, and calcitic dolomite 20 to 40 per cent $MgCO_3$. Dolomite contains over 90 per cent $CaCO_3.MgCO_3$. The reported $CaCO_3$ and $MgCO_3$ contents have been calculated from the determined CaO and MgO contents, assuming only the carbonate forms are present. As a small amount of CaO and MgO may be present in silicate minerals, minor discrepancies occur in some calculated totals.

High-calcium limestones used in various processes generally are required to meet certain minimum specifications in regard to the amount of impurities they contain. However, for certain uses the limits are somewhat flexible, or the process can be adjusted to tolerate the specific compositions of locally available stone. Thus the following lists of specifications (Tables 1 and 2) should be considered as a general guide only. They have been compiled from various references, including Boynton (1966), Hewitt (1960), U. S. Bureau of Mines (1970), and A.I.M.E. (1960).

THE HIGH-CALCIUM LIME AND LIMESTONE INDUSTRY IN MANITOBA

The locations of high-calcium limestone quarries, cement plants, lime plants and in-plant kilns are shown in Figure 1.

NATURAL CEMENT

Prior to production of Portland cement in Manitoba, natural cement was used. The latter was produced at Deerwood from 1898 (?) to 1904 and at Babcock from 1907 to 1924. Both places are on the east slope of Pembina Mountain (Figure 1). The raw material was calcareous shale with a low magnesia content, obtained from the Boyne Member of the Upper Cretaceous Vermilion River Formation. Details of the operation at Babcock have been reported by Wells (1905) and Goudge (1944).

PORTLAND CEMENT

Production of Portland cement in Manitoba began in 1913, at Fort Whyte. Currently, Canada Cement Lafarge Limited produces Portland cement at its Fort Whyte plant, and also supplies clinker to the company's grinding plant at Saskatoon. Inland Cement Industries Limited produces Portland cement at its Tuxedo plant, and also quarries high-calcium limestone north of Mafeking to supply its Portland cement plant at Regina.

Statistics of Portland cement production in Manitoba for the period from 1957 to 1972 are listed in Table 3. Production statistics for the years prior to 1957 are reported by Deir (1957). It is estimated that over 800,000 tons of limestone were quarried in Manitoba in 1971 to supply Portland cement plants in Manitoba and Saskatchewan.

Canada Cement Lafarge Ltd.

At Fort Whyte, Canada Cement Company Limited (Canada Cement Lafarge Ltd., as of May 1, 1970) began construction in 1911 of a Portland cement plant, which was completed in 1913. Originally the plant used the dry process, but it was rebuilt in 1927-28 and converted to the wet process. This part of the plant, containing two 287-foot gas-fired kilns, 10 feet in diameter, has an annual capacity of 327,000 tons of cement. At present, these kilns are used only periodically. An addition to the plant, with provision for two 450-foot rotary kilns, 12 feet in diameter, was built in 1955. The first kiln, with a capacity of 297,500 tons, was completed that year; the second kiln was completed in 1964. The present total

TABLE 1. Uses of limestone

Use	Remarks	Specifications
Fluxstone for pig iron	In blast furnaces; removes mainly Al and Si, also Mn and S	Less than 3% non-carbonate impurities; maximum of 0.1% S, 0.02% P; lump size, 8 inch to 1 inch range; fines not usable
Flux for iron sinters	Pulverized limestone mixed with iron fines, powdered coke, to form agglomerates	Both high-calcium and dolomitic limestones can be used
Open hearth furnace and foundry use	Limestone, being replaced in part by quicklime	As for pig iron, except maximum of 1.5 to 2% SiO_2
Nonferrous metals refining processes	Flux in refining Cu, Pb, Zn, and Sb; also low grade bauxite for alumina	Usually high-calcium limestone used; specifications as for pig iron
Glass; fluxing and conditioning of melt	Used either in limestone or lime form, dependent on quality of glass	Both high-calcium and dolomitic types are used; uniformity in composition important; generally less than 0.06% FeO; SiO_2 plus Al_2O_3 less than 3%
Pulp and paper	Limestone used in sulphite process, reacted with SO_2 to form calcium bisulphite	Minimum 95 to 97% $CaCO_3$; must be in large fragment size
Portland cement	Limestone main ingredient, mixed with clay, silica, and iron to comply with specific limits of composition	Must be low in magnesia; maximum of 5% $MgCO_3$, preferred 3% $MgCO_3$; SiO_2 less than 1.3%; Al_2O_3 less than 3.7%
Filter beds	To aid in purification of sewage plant and other effluents; also used in acid neutralization	Sound, fine-grained stone preferred
Agricultural limestone	Used principally in eastern United States and Canada	Crushed to -0.1 inch; chert undesirable
Mineral feed	High-calcium limestone	98 to 98.5% $CaCO_3$; finely pulverized
Poultry grit	Either limestone or dolomite can be used	Purity unimportant; uniform size, ¼-inch ± ⅛-inch
Building stone	Soundness, bedding, colour, fracture, and appearance are important	No pyrite; any composition from limestone to dolomite
Aggregate, coarse and fine	Angular form in concrete considered to give better set than sand and gravel	Any sound carbonate; chert or clay undesirable
Other construction uses	Road stone, railroad ballast, rip rap, roofing granules	Various specifications

TABLE 2. Uses of lime

Use	Remarks	Specifications
Steel manufacture	As a flux; promotes removal of P, Si, and S	Generally high-calcium lime, low in MgO, SiO_2 and S
Nonferrous processes	In magnesia-from-seawater processes; in neutralization of acid leaching solutions from uranium mills; in flotation of some Zn, Ni, and Pb ores; in cyanidation process of gold milling; in Bayer process for Al_2O_3	Various specifications
Pulp and paper	Lime used in sulphate process in Kraft paper plants, to regenerate caustic soda; calcium carbonate recovered, calcined in plant kilns; also used in soda process. Used in some sulphite processes for pulp and paper	High-calcium lime, 92.5% CaO, less than 2.5% MgO, less than 3% combined SiO_2, Fe_2O_3 and Al_2O_3; dolomitic lime used in some sulphite process plants
Chemicals	Soda ash, bicarbonate of soda, and caustic soda by the Solvay process; calcium carbide for acetylene process; calcium chloride	High-calcium lime; for calcium carbide, less than 0.02% P
Sugar refining	Sucrose extracted from sugar beets is treated with lime to remove phosphatic materials and organic acids	Pulverized quicklime from on-site kilns; CO_2 required in processing; less than 1.5% SiO_2 + insolubles, and less than 1% $MgCO_3$ in the limestone
Water treatment	Combined with soda ash in the lime-soda softening process; also used in purification processes	Mainly high-calcium lime
Sewage and waste	Added to neutralize acidity, and thus to promote biological oxidation processes; also used in chemical treatment of sewage and wastes from a variety of industrial plants	Mainly high-calcium lime; dolomitic lime may be used in acid neutralization
Sand-lime brick and cellular blocks	Formed in autoclaves from a mixture of sand and lime; lightweight cellular concrete blocks are produced from special mixtures	High-calcium lime; either hydrated lime or pulverized quicklime
Soil stabilization	Lime reacts with clay minerals to reduce plasticity, and acts as a cementing agent; used extensively in road construction	Laboratory testing of specific soil required to determine whether high-calcium or dolomitic lime is more effective (see Wicks and Whitehead (1965) for application to Manitoba soils)
Miscellaneous uses	Soil liming; bituminous paving; plaster and stucco; insecticides; bleaches; paints; tanning	Variable with use

TABLE 3. Cement production in Manitoba, 1957 to 1972

Year	Short tons	Barrels[1]	Processed value	Value/ton
1957	412,998	(2,359,870)	$ 6,820,697	$16.52
1958	378,823	(2,164,590)	6,580,276	17.37
1959	402,562	(2,300,240)	7,314,552	18.17
1960	429,788	(2,455,810)	8,105,802	18.86
1961	395,134	(2,257,800)	7,768,334	19.66
1962	432,079	(2,468,900)	8,715,034	20.17
1963	455,325	(2,601,730)	9,684,760	21.27
1964	350,762	(2,004,250)	7,530,860	21.47
1965	421,840	(2,410,390)	8,884,734	21.06
1966	508,152	(2,903,580)	10,221,927	20.12
1967	415,059	(2,371,650)	9,033,093	21.76
1968	528,522	(3,019,970)	11,937,900	22.59
1969	538,057	(3,074,460)	12,919,303	24.01
1970	407,396[2]		9,778,540	24.00
1971	487,356		13,143,214	24.46
1972	556,019		14,750,762	26.53

[1]Canadian units for cement include:
1 bbl. (Canadian) = 350 lbs.
1 short ton = 5.714 bbls.
1 bag of cement = 80 lbs.

[2]In 1970, the 350-lb. barrel unit was replaced in production statistics by the 2,000-lb. ton unit; also, a "bag of cement" was reduced from 87½ lbs. to 80 lbs., giving 25 bags to 1 ton (Stonehouse, 1971).

annual capacity of the plant is rated at 922,000 tons. Details of the Fort Whyte plant operations are given by Gutschick (1956) and Colborne (1957). Various types of Portland cement and masonry cement are produced, in bulk or bagged form. Kali-crete, a special sulphate resistant cement containing more iron and silica, is used where required to resist reaction with alkali soils in the Prairie region. Canada Cement Lafarge Ltd. operates a clinker grinding facility at Saskatoon, which is currently supplied from the Winnipeg plant.

The major raw materials required for cement production at the Fort Whyte plant are high-calcium limestone from the company's quarries at Steep Rock and Lily Bay (described below), and low magnesia glacial lake clay from a pit near the Fort Whyte plant. The clay pit is approximately 75 acres in area, and in places is 50 to 60 feet deep. Colborne (1957) reported 4.97 per cent MgO in the clay from Fort Whyte. Additional raw materials include sand, from the Alsip Brick, Tile and Lumber Company Limited pit at Beausejour, that contains about 80 to 90 per cent SiO_2; gypsum from the Silver Plains mine of Westroc Industries Limited; and iron oxide from Ontario. A typical mix, which is fired at 2800° to 2900°F, consists of 74.8 per cent limestone, 20 per cent clay, 4.6 per cent sand, and 0.6 per cent iron oxide (Gutschick, 1956). About 5 per cent of gypsum is added as a retarder to the ground clinker.

Steep Rock quarry

At Steep Rock, high-calcium limestone of the Elm Point Formation is quarried by Canada Cement Lafarge Ltd. (Frontispiece). Annual production is of the order of 600,000 tons. The rock is used both by the company and by Inland Cement Industries Limited in their Portland cement plants in Winnipeg (Fort Whyte and Tuxedo). The quarry is located mainly in NW¼ sec. 34. tp. 28, rge. 10WPM (Figure 1). Production began about 1912. The older, shallow quarry extends from the crushing plant north for 3,200 feet towards the shore of Lake Manitoba. This was the site of early excavation when annual production was at a low rate. In 1971, the main quarry area had a maximum width from east to west of about 2,600 feet and of 3,000 feet from north to south, although it is irregular in shape. The quarry is 35 to 45 feet deep. The company holds quarrying claims on adjacent land, and also in the area 1.5 to 3.5 miles south of the village of Steep Rock, assuring reserves for several decades at the current rate of production.

The quarry is operated on a year-round basis. Quarry operations consist of rotary drilling, followed by blasting, using ammonium nitrate as explosive, both in the loose form and as Amex prills. Hydromex 25 is used if water is present. The broken rock is loaded into trucks by a Bucyrus-Erie 85-B shovel, and transported to the crushing plant. The stone is reduced to -8 inch size in a Traylor Type T gyratory cone crusher. At present, no further milling is done at Steep Rock. The rock is transported by rail 153 miles to Fort Whyte in open hopper cars of 82-ton capacity. It is further reduced in hammer mills in the company's cement plant.

Lily Bay quarry

Canada Cement Lafarge Ltd. began production of high-calcium limestone of the Elm Point Formation in late August 1971, from a quarry one mile west of Lily Bay, in the NW¼ sec. 33, tp. 20, rge. 6WPM (Figure 1). By October 1971, the quarry was approximately 140 feet square, with a depth of 30 feet. In the quarrying operation, blast holes are loaded with 75 per cent Amex powder. The broken rock is transported by front-end loader to a 48-inch primary jaw crusher. It is reduced to -5 inch size and conveyed to a stockpile. Annual production is expected to exceed 150,000 tons. The rock is trucked 96 miles to the company's Fort Whyte plant. At present, this stone is supplementing the main source of limestone from the Steep Rock quarry. Limestone is present at or near the surface over several square miles in the Lily Bay area, but reserves are difficult to estimate because of the variable content of magnesium (see section on Elm Point Formation). The company holds quarrying claims and leases on more than 3,000 acres.

Inland Cement Industries Limited

In October 1965, Inland Cement Industries Limited, the cement division of Sogemines Limited, opened a modern, highly automated wet-process plant at 1191 Kenaston Boulevard, Tuxedo, in southwestern Winnipeg. A gas-fired rotary kiln 450 feet in length and 14.5 feet in diameter is used. The plant has a maximum annual capacity of 350,000 tons of cement. In the first years of operation, the plant used limestone that had been stockpiled as fines at the Spearhill quarry of The Winnipeg Supply and Fuel Company Limited. Following depletion of that source, limestone has been obtained from the Steep Rock quarry of Canada Cement Lafarge Ltd. The company holds quarrying permits and leases in the Lily Bay area, but to date no development has taken place. Other raw materials are glacial lake clay from a pit west of the plant, sand from Beausejour, iron oxide from northwestern Ontario, and gypsum from the Silver Plains mine. Major products of the Tuxedo plant are Portland cement, sulphate-resistant cement, high-early-strength cement, and masonry cement. Details of the plant operations are given by Tyre (1965).

Mafeking quarry

Inland Cement Industries Limited, in 1956, began quarrying high-calcium limestone 10 miles north of Mafeking, in sections 29 and 32, tp. 44, rge. 25WPM (Figure 1). The limestone is transported about 275 miles by rail to the company's Portland cement plant in Regina. The plant, formerly owned by Saskatchewan Cement Corporation Limited, was acquired by Inland in 1957. The Mafeking quarry produces 250,000 to 400,000 tons of limestone annually; this figure is included as "stone production" in available statistical data for Manitoba, and not as cement. The limestone is from the Point Wilkins Member of the Souris River Formation (Plate 1).

By 1971, the quarry had a maximum length of 2,200 feet (southeast to northwest) and a maximum width of 1,100 feet. The depth of the quarry, measured from the highest point on the southeast wall to the lowest point on floor, is 92 feet. It is worked on two levels. The first bench is at a level 45 to 55 feet below the high point on the east wall. In the eastern part of the quarry, an area 550 feet by 350 feet has been quarried out to an additional depth of 35 to 47 feet. Abundant reserves are available in the area east and south of the quarry, and very large reserves are available in the Steeprock Point-Mafeking quarry area.

Production began in 1956 at a rate of 200,000 tons per year. Current production averages 400,000 tons per year. The quarry is in operation generally from May to November. Overburden of till and soil is thin. In quarrying, blast drill holes are put down in an 11-foot

PLATE 1. North wall, Mafeking quarry of Inland Cement Industries Limited; the gently dipping beds represent the flanks of domal structures.

by 12-foot pattern and loaded with Amex powder. A front-end loader is used for secondary breaking of any larger masses resulting from the blasting.The broken rock is trucked to the crushing plant on the southeast side of the quarry. A 48-inch by 36-inch jaw crusher reduces the rock to minus 7-inch size. It is conveyed to surge piles by means of an overhead Syntron vibrating feeder with 8 drop-outs. The rock is then drawn off to the railroad loadout for transport to Regina.

Initially, both the Point Wilkins limestone and the underlying argillaceous limestone between the Point Wilkins Member and the First Red Bed were quarried. At present, only the Point Wilkins Member is being extracted. The long freight haul to Regina dictates that only the highest quality material can be shipped.

DOLOMITIC LIME

High-calcium lime and dolomitic or high-magnesia lime ("dolime") are both produced in Manitoba. Dolomitic lime is not discussed in detail in this report, but is noted here as available statistics on lime production in Manitoba include both types in a single "lime" category. Dolomitic lime is currently produced by Steel Brothers Canada Ltd. in a plant at Wilkes Avenue near Kenaston Boulevard in Tuxedo. The plant is supplied with dolomite of the Ordovician Gunton Formation from the Stonewall area. Dolomitic lime was formerly produced by The Winnipeg Supply and Fuel Company Limited at Stonewall from dolomite of the Stonewall Formation, and by Building Products and Coal Limited at Inwood from dolomite of the Interlake Group. Both these operations were shut down in 1967.

HIGH-CALCIUM LIME

Most of Manitoba's high-calcium lime is currently produced by Steel Brothers Canada Ltd. in two plants, at Spearhill and Fort Whyte. The lime plants were acquired from The Winnipeg Supply and Fuel Company Limited in 1972. High-calcium lime is produced also by The Manitoba Sugar Company Ltd. and by Churchill Forest Industries (Manitoba) Ltd. from in-plant kilns.

Lime production in Manitoba for the period 1957 to 1972 is given in Table 4. Figures for lime production prior to 1957 are included in Deir (1957).

TABLE 4. Production of lime in Manitoba, 1957 to 1972

Year	Short tones	Processed value	Value/ton
1957	64,922	$1,089,728	$16.79
1958	72,561	1,168,514	16.10
1959	60,503	1,022,953	16.91
1960	48,383	834,698	17.25
1961	48,791	833,238	17.08
1962	46,348	800,418	17.27
1963	54,879	908,952	16.56
1964	57,196	916,693	16.03
1965	52,199	846,253	16.21
1966	55,835	939,643	16.83
1967	45,364	753,263	16.60
1968	42,454	670,207	15.79
1969	51,823	834,817	16.11
1970	47,484	836,805	17.62
1971	n.a.	972,254	n.a.
1972 (est.)	n.a.	1,016,000	n.a.

A projection of lime production, including both the high-calcium and dolomitic varieties, was made by Cote *et al.* (1968); their figures are given in Table 5.

TABLE 5. 1980 forecast of consumption by industry of lime produced in Manitoba (Reproduced, with kind permission, from Cote et al., 1968).

Use	Short tons
Pulp and paper mills	15,000
Iron and steel furnaces	11,000
Sugar refineries	8,000
Builders' lime	5,000
Nonferrous smelters	18,000
Road stabilization	12,500
Water and sewage treatment	10,000
Other	2,000
TOTAL	81,500

Steel Brothers Canada Ltd.

Spearhill lime plant (SE¼ sec. 22, tp. 27, rge. 7WPM)

The lime plant consists of five vertical steel-shell kilns. Four of the kilns use crushed rock from 3 inches to 6 inches in size; a small-stone kiln uses 2-inch to 3-inch limestone. The kilns are fired with producer gas obtained from coal in a standard R. D. Wood gas producer. The limestone is calcined at 2400°F. Products include pulverized and pebble lime, available in bagged and bulk form. Bulk lime is stored in bins with a total capacity of 680 tons, for later transport by rail in covered hopper cars of 75 to 80 tons capacity. Full capacity of the plant is rated at 175 tons of lime per day.

Fort Whyte lime plant

A lime plant, using a Corson vertical kiln with a vibratory grate, began full production in January, 1968. Capacity is 75 tons of lime per day. Both dolomitic and high-calcium lime are produced under controlled conditions. Storage capacity is 1,200 tons of lime.

The high-calcium lime from these plants is used in pulp and paper mills, iron and steel furnaces, road stabilization, builders' lime, nonferrous smelters, purification processes, glass-making, and cyanide and flotation mills.

Spearhill quarry

Limestone of the Elm Point Formation is quarried at Spearhill, in SE¼ sec. 22, tp. 27, rge. 7WPM (Figure 1), as a source of chemical limestone and lime (Plate 2). The quarry was first operated in 1913 by Manitoba Gypsum Company. It was acquired by Moosehorn Lime Company in 1927, and later by The Winnipeg Supply and Fuel Company Limited. In 1972, Steel Brothers Canada Ltd. became owners of the property.

PLATE 2. Lime plant at Spearhill; Steel Brothers Canada Ltd.; lime storage bins, with kilns in background.

In the quarrying operation at Spearhill, Powerfrac (75 per cent ammonium nitrate) is mixed with diesel fuel and used to break the rock, which is trucked to the crushing plant. Two-inch to 6-inch stone is used in the lime plant at Spearhill; ½-inch to 2-inch stone is used in an industrial minerals plant in Winnipeg; ¾-inch to 1¼-inch stone is used in the company's Fort Whyte lime plant, and minus 2-inch material is used by CN Rail for ballast material. The company also supplies 10,000 to 16,000 tons per year of limestone to the Manitoba Sugar Company, for use in processing sugar beets. In the mid 1960s, a large stockpile of fines was sold to Inland Cement Industries Limited for use in its Portland cement plant at Winnipeg. Limestone reserves at Spearhill were close to depletion in 1973.

Faulkner quarry

The Winnipeg Supply and Fuel Company Limited opened a quarry in 1969 in l.s. 11, sec. 23, tp. 28, rge. 10WPM, 4 miles west of Faulkner and 2 miles southeast of Steep Rock (Figure 1). High-calcium limestone of the Elm Point Formation is quarried. Since 1972, when the property was acquired by Steel Brothers Canada Ltd., the stone has been used to supply the company's lime plants at Spearhill and at Fort Whyte.

The limestone is exposed in several outcrops and is present under a thin soil and drift cover in the vicinity of the quarry. In July 1971, the quarry was 350 feet long in a northeasterly direction, 300 feet wide, and 18.5 feet deep. In the first few years of production, the quarry was operated intermittently, using portable crushing equipment. The stone is stockpiled in five sizes: fines less than ¾-inch, ¾-inch to 2 inches, 2 inches to 3 inches, 3 inches to 6 inches, and rubble. Abundant reserves are available under the company's claims in the west half of section 23, township 28, range 10WPM.

The Manitoba Sugar Company Ltd.

Several thousand tons of limestone are purchased annually from the Spearhill quarry and calcined in a one-stack kiln at the company's sugar beet plant in Fort Garry, Winnipeg. The kiln, which began operation in 1940, is 13.1 feet in diameter and 55.8 feet in height. It has a total capacity of 135 tons of limestone, or 65 tons of lime, per 24 hours. The lime is slaked with water to form $Ca(OH)_2$, and is added along with CO_2 to raw juice from sugar beets. The precipitate formed, $CaCO_3$, settles to the bottom of the tank, removing phosphatic materials and organic acids, thus clarifying the liquid sucrose.

Churchill Forest Industries (Manitoba) Ltd. (Manitoba Forestry Resources Ltd.)

This company, located near The Pas, uses lime in its Kraft paper plant which began full production in 1971. Several thousand tons of limestone from Manitoba sources are used annually. Limestone is calcined in an on-site kiln to produce the slaked lime required in the sodium sulphate Kraft process. The GATX Fuller-Taylor lime kiln is 8.5 feet in diameter, 250 feet long, and has a capacity of 120 tons of lime per day. Calcium carbonate precipitate is recovered from the white liquor clarifiers and is washed, thickened, and fed back to the lime kiln.

OTHER USES AND OPERATIONS

Crushed high-calcium limestone, for use as poultry grit, was produced in the 1940s by L. K. McArdle, from a small quarry and hammer mill located 12 miles north of Mafeking, in l.s. 7, sec. 8, tp. 45, rge. 25WPM. Some limestone was supplied from a second deposit 5 miles northeast of the mill. The Winnipeg Supply and Fuel Company Limited in the 1920s quarried high-calcium limestone 1.5 miles northwest of Winnipegosis, at l.s. 14, sec. 9, tp. 31, rge. 18WPM. It was shipped to Winnipeg for the manufacture of whiting by Gypsum, Lime and Alabastine Company Limited. Limestone of high purity was also quarried southeast of Winnipegosis, in sec. 29, tp. 30, rge. 17WPM. The history of this quarry has not been reported. These quarries (Figure 1) have been inactive for several decades.

It should be noted that limestone has also been quarried and used as road metal or aggregate material, e.g. the quarry 2½ miles north of Lily Bay. Limestone deposits of high-calcium quality are an important industrial mineral resource, and should not be used for road metal where other aggregate materials such as sand and gravel, or dolomite, are available. This is particularly important for the more accessible deposits.

OCCURRENCES OF HIGH-CALCIUM LIMESTONE IN MANITOBA

ORDOVICIAN RED RIVER FORMATION

The Red River Formation, formally named by Foerste (1929), forms the bedrock surface in a linear belt near the eastern edge of the Manitoba Plain (Figure 1). This belt parallels the Paleozoic-Precambrian contact but is separated from it by the sandstone and shale of the Winnipeg Formation. Dowling (1900) originally described the strata, defining the Lower Mottled, Cat Head, and Upper Mottled limestones; Foerste re-named these the Dog Head, Cat Head, and Selkirk Members respectively. Because of extensive drift deposits, particularly to the south in Red River valley, a fourth unit at the top of the section was not recognized by early workers. It was reported in the subsurface by the late 1950s, and was defined formally as the Fort Garry Member by McCabe and Bannatyne (1970).

Prior to 1958, the Red River Formation was not considered a likely source of high-calcium limestone. Since then, exploratory drilling has indicated numerous occurrences of magnesian limestone, and of high-calcium limestone of marginal to excellent quality. The stratigraphic positions of the limestone beds are shown in Figure 2, and the occurrences are described in detail in the following sections. In general, the limestone zones are thin, and the calcium carbonate content is highly variable. More exploration would be required to confirm the continuity and quality of the zones.

The total thickness of the Red River Formation is 550 feet near the southern boundary of Manitoba, decreasing northward to 180 feet in The Pas area. McCabe (1967) has noted that the isopach trends of the Red River Formation are east-west, almost at right angles to the trend of the outcrop belt in southern Manitoba. This relationship could explain the apparently localized occurrences of high-calcium limestone along the outcrop belt, based on the assumptions that the limestone facies are of a linear nature and parallel the isopach trend. It would also suggest that any future core from any part of the area should be checked for intervals of limestone.

Depositional history

The depositional history of the Ordovician strata has been described by Cowan (1971):

> "Sedimentation of the Winnipeg Formation began in late Ordovician time with the deposition of interbedded sand and clay in a shallow marine environment, as evidenced by the presence of numerous small brachiopods and limonitic and phosphatic oolites. The end of Winnipeg deposition was marked by further subsidence, drowning (of) the clastic sediment source area, and deposition of the Red River carbonates.
>
> The Dog Head, Cat Head and Selkirk Members of the Red River Formation were deposited in approximately the same environment throughout most of the (southern Interlake) area. During this time, a shallow water open circulation marine environment prevailed as evidenced by the presence of abundant brachiopods and crinoids along with large, well preserved cephalopods, gastropods and corals. Much of the deposition probably occurred in a low energy infratidal environment. Evidence of this is the lack of sorting and random orientation of the bioclasts. The comminution of the skeletons was possibly achieved by bottom-dwelling scavengers who left evidence of their burrows in the form of tubular structures in the rock. These tubules appear to have localized subsequent diagenetic dolomitization. The end of Selkirk deposition was marked by a regression of the sea and establishment of an alternating intertidal and supratidal environment in which the interbedded massive and laminar bedded dolostones of the Fort Garry Member were deposited. The sea began to transgress in the latter portion of Fort Garry time, creating an environment in which stromatoporoids and tabulate corals flourished. As transgression continued, a light grey brachiopod biomicrite was deposited in a shallow marine environment which persisted to the end of Red River time.
>
> Deposition of the Gunn and Penitentiary Members was marked by a sudden influx of terrigenous detritus."

It should be noted that the limestone zones within the Red River Formation are associated with periods of regression or transgression of the Ordovician seas, that is, at the start of Dog Head deposition, near the end of Selkirk time, and at the end of Fort Garry deposition.

Economic use and potential

The Dog Head and Cat Head Members consist of magnesian limestone, dolomitic limestone, and dolomite. These rocks have been used as a source of crushed stone, rubble and rip rap. Lime was made at one time from rock of the Dog Head Member at Hecla village and at Grindstone Point (Goudge, 1944). The Selkirk Member is the source of the well known Tyndall building stone; recent drill results indicate a bed of high-calcium limestone is present in the upper part of the member. The Fort Garry Member is predominantly dolomite, and is a source of crushed stone. It contains one, and possibly two, thin beds of high-calcium limestone. In general, the dolomite content of the Red River Formation increases northward. The most northerly known occurrences of high-calcium limestone are in the Lake St. Martin area.

Dog Head Member

The dolomitic limestone of the Dog Head Member is distinctively mottled. The mottles are brown to grey, finely crystalline dolomite, in a matrix of light buff biomicrite limestone. The rock is slightly argillaceous, and is fossiliferous. The basal 1 to 2-foot section consists of silty, argillaceous nodular dolomitic limestone containing pyrite nodules and quartz grains.

TABLE 6. Analyses of Dog Head magnesian limestone

Location	Scanterbury	Hecla Island	Lake St. Martin LSM-2 30.5′-34′	Lake St. Martin LSM-2 34′-38′
SiO_2	7.25	7.14	4.74	4.9
Al_2O_3	1.86	2.12	0.33	0.35
Fe_2O_3	1.06	0.98	0.65	0.75
CaO	46.14	45.47	46.4	44.85
MgO	3.25	3.84	5.10	6.22
Na_2O	n.d.	n.d.	0.05	0.03
K_2O	n.d.	n.d.	0.25	0.24
P_2O_5	0.07	0.06	0.03	0.03
S	0.46	0.10	0.07	0.06
LOI	39.31	39.76	41.8	41.63
Total	99.42	99.47	99.4	99.05
$CaCO_2$	82.35	81.09	82.81	80.05
$MgCO_3$	6.79	8.03	10.67	13.01
Thickness	Not reptd.	10 feet	3.5 feet	4 feet

Scanterbury: exposed in bank of Brokenhead River, tp. 16, rge. 7EPM; Goudge (1944, p. 48).
Hecla Island: "Hecla village; top 10 feet in cliff just south of dock"; tp. 25, rge. 6EPM; Goudge (1944, p. 48).
Lake St. Martin: drill hole LSM-2, SW¼ sec. 10, tp. 32. rge. 7WPM; angle: 45°; azimuth: 330°.

TABLE 7. Limestone in Red River Formation, North Dakota (from: Anderson and Haraldson, 1968)

Hole No. Footage	P-1 487-490	P-1 490-495	P-1 495-500	P-1 500-505	GF-3 241-253	GF-3 253-258	GF-3 258-260
$CaCO_3$	83.002	83.680	84.252	85.323	85.912	83.056	84.269
$MgCO_3$	7.130	7.193	6.084	5.269	7.464	6.628	6.586

P-1: NW SE sec. 28, tp. 164N, rge. 51W, Pembina County, N.D.; top of Red River Fm. at 308′; cored to 505′, well above base of formation.

GF-3: NE NW NE sec. 35, tp. 154N, rge. 51W, Grand Forks County, N.D.; bedrock at 214′, within Red River Fm.; base of formation at 270.5′.

In southern Manitoba, the member ranges from 95 to 125 feet in thickness.

Some sections in the lower part of the member have a low dolomite content, and are classed as magnesian limestones. Analyses (Table 6) are available from Lake St. Martin, Scanterbury and Hecla Island. In the section in hole LSM-2 at Lake St. Martin (Figure1), the basal Dog Head beds are mottled dolomitic limestone, consisting of buff biomicrite with slightly coarser grained brownish dolomitized patches. The sampled thickness at Scanterbury was not reported by Goudge. However, 12 feet of the Dog Head magnesian limestone is exposed in an outcrop along Brokenhead River, on the southwest bank, ¼ mile east of Scanterbury.

A decrease in the amount of dolomitization is apparent towards the south, suggesting that higher quality material may be present south of the Scanterbury area. Some limestone with minor dolomite was noted in Manitoba Mines Branch core hole M-3-69, in a quarry at Garson. The limestone occurs near the base of the Dog Head Member, at a depth of 161.5 to 163.5 feet. A partial analysis indicated 87.19 per cent $CaCO_3$ and 4.62 per cent $MgCO_3$.

Farther south, in North Dakota, an exploration drilling program (Anderson and Haraldson, 1968) indicated that the lowest dolomite content in the Ordovician section occurred at two levels within the Red River Formation (Table 7).

The $CaCO_3$ content of the GF-3 samples is 0.7 to 3.5 per cent higher than the Scanterbury sample. Samples from the two areas are from approximately the same zone within the Dog Head Member. The exact position of the P-1 samples is uncertain, but they may be correlative with a limestone bed near the top of the Selkirk Member. Further work is required to determine the quality of the limestone in the southern part of Red River Valley in Manitoba. However, no outcrops are known, and drift thickness in the area ranges from 40 to more than 150 feet.

Cat Head Member

Dolomite and dolomitic limestone of the Cat Head Member have a more subdued mottled texture than the Dog Head and Selkirk Members. The rock is dolomitized to a greater extent than the adjacent members, and limestone has not been reported. A quarry in NW¼ sec. 22, tp. 24, rge. 4EPM, north of Riverton, was opened in October 1970, as a source of rock fill and armour coating for the Hecla Island causeway. Twelve feet of a finely crystalline, partially mottled dolomite of the basal part of the Cat Head Member is exposed in the quarry. The Cat Head Member has a thickness of approximately 60 feet in south-central Manitoba.

Selkirk Member

The Selkirk Member consists predominantly of strikingly mottled dark brown and buff dolomitic limestone. In Red River valley, recent drilling has outlined a bed of high-calcium limestone at the top of the member. In the Lake St. Martin area, the lithology of the Selkirk Member changes locally to interbedded high-calcium limestone and dolomite. The Selkirk Member is 135 feet thick in Red River Valley, decreasing to 65 feet at Lake St. Martin. The possibility of producing a limestone concentrate from the dolomitic limestone, and the details of the high-calcium limestone occurrences, are discussed in the following sections.

Dolomitic limestone ("Tyndall stone")

Beds below the middle of the Selkirk Member are quarried at Garson for building stone. Mines Branch core hole M-3-69 (Figure 1), drilled in the floor of a quarry at Garson, in l.s. 15, sec. 3, tp. 13, rge. 6EPM, intersected 32 feet of the Selkirk Member, overlying the Cat Head Member.

The dark brown mottles in the dolomitic limestone consist of a three-dimensional network of finely crystalline to saccharoidal dolomitized rock, comprising an estimated 30 to 40 per cent of the total volume. The lighter buff matrix consists of a high-calcium biomicrite. The rock is characterized by the abundance of large, well preserved fossils, including sponges, corals, gastropods and cephalopods. Analyses of separated fragments of the dolomitic mottles and the limestone matrix, as reported by Wallace (1913), Birse (1928), and Goudge (1944) are listed in Table 8. The analyses indicate that the matrix fraction is of high-calcium quality, and also that a higher proportion of iron oxide occurs within the dolomitic mottles.

It is possible that a high-calcium limestone concentrate could be prepared from crushed stone, by means of sorting machines utilizing either differences in colour or in specific gravity. However, the economics of such processes seem dubious in view of other available sources of high-calcium limestone in the Province.

Limestone in the Selkirk Member

Occurrences of high-calcium to magnesian limestone at or near the top of the Selkirk Member have been intersected in recent drilling in the area extending from Red River Valley northward to Lake St. Martin. In general, the intersections consist of buff, fine- to medium-grained crystalline limestone, in part showing fine laminations. Dolomite is present within the limestone, either as disseminated grains or in thin layers. In Red River

Valley, the limestone zone occurs at the top of the Selkirk Member and is overlain by dense, buff to yellowish grey dolomite of the Fort Garry Member; it is underlain by faintly mottled dolomitic limestone that, in many of the occurrences, contains numerous white chert nodules. In the Lake St. Martin area, a bed of high-calcium limestone occurs 11.5 feet below the top of the Selkirk Member; it is both thicker and of higher quality than the limestone to the south, and may represent a separate zone.

TABLE 8. Analyses of dolomitic and limestone fractions of Tyndall stone, Selkirk Member[1]

Sample	Wallace (1913) A	Wallace (1913) B	Birse (1928) A	Birse (1928) B	Goudge (1944)[2] A	Goudge (1944)[2] B
SiO_2	1.56	1.56	1.85	1.02	1.44	0.78
Al_2O_3	2.27	0.06	4.15	0.25	0.34	0.09
Fe_2O_3	1.94	0.16	0.63	0.03	0.91	0.13
FeO	0.45	0.12	0.43	0.00	–	–
CaO	39.80	52.68	39.11	52.90	38.67	54.50
MgO	11.16	2.07	11.12	2.07	13.47	0.80
P_2O_5	–	–	–	–	0.04	0.02
S	–	–	–	–	0.03	Trace
LOI	43.42	43.60	42.89	43.77	45.00	43.57
Total	100.60	100.25	99.75	100.04	99.90	99.79
$CaCO_3$	71.03	94.02	69.81	94.41	68.98	97.09
$MgCO_3$	23.35	4.33	23.31	4.33	28.16	1.68

[1] All samples are from quarries in the Garson area:
A series: Tyndall stone, dolomitized mottles (containing calcareous fossil fragments and limestone inclusions).
B series: Tyndall stone, micritic limestone matrix.

[2] Goudge (1944): samples from "No. 2 quarry, Western Stone Co.," in l.s. 10, sec. 9, tp. 13, rge. 6EPM.

Available information on the limestone occurrences is summarized in Table 9, and chemical analyses of selected intervals are listed in Tables 10 and 11. The locations of the drill holes are shown in Figure 3.

South of Winnipeg, a thin bed of high-calcium limestone occurs in the Ste. Agathe area (hole E-21). It consists of medium-grained crystalline pale brown limestone, with faint purplish orange mottling. Dolomite is scattered through the limestone, which grades downward to dolomitic limestone.

Data on the Selkirk limestone zone are available from seven core holes in the Winnipeg area. For two of the holes, WSF and CC-1, the only data available are core descriptions from logs on file at the Manitoba Mines Branch. In the Winnipeg Central Gas hole No. 4 (WCG-4 in Table 9), 3.3 feet of high-calcium limestone occurs within a 12-foot zone consisting mainly of magnesian to dolomitic limestone. Partial analyses of the zone are listed in Table 11; a detailed analysis of the high-calcium limestone interval is listed in Table 10. The limestone is off-white, finely laminated, and microcrystalline to dense.

The high purity of the 7-foot limestone zone in the Bridge Engineer hole No. 3, along the North Perimeter Highway at the Red River (P.H. 101-3, Tables 9 and 10), is of special interest because of its thickness and its location close to Winnipeg. The hole was located on ice in the Red River and intersected the river bed at a depth of 5 feet; 38 feet of overburden was present above light greyish buff limestone bedrock. As the limestone is presumably eroded in part, the full thickness of the bed is not known. The limestone is shown in Plate 3, samples 1 and 2.

In Birds Hill hole No. 3 (BH-3, Tables 9 and 10), sand and gravel were intersected to a depth of 12 feet. The interval from 12 to 16 feet consists of dolomite with chert nodules, overlying 0.7 feet of buff, dense high-calcium limestone. The total thickness of the limestone layer was not determined; its location and elevation suggest it is at the top of the Selkirk Member.

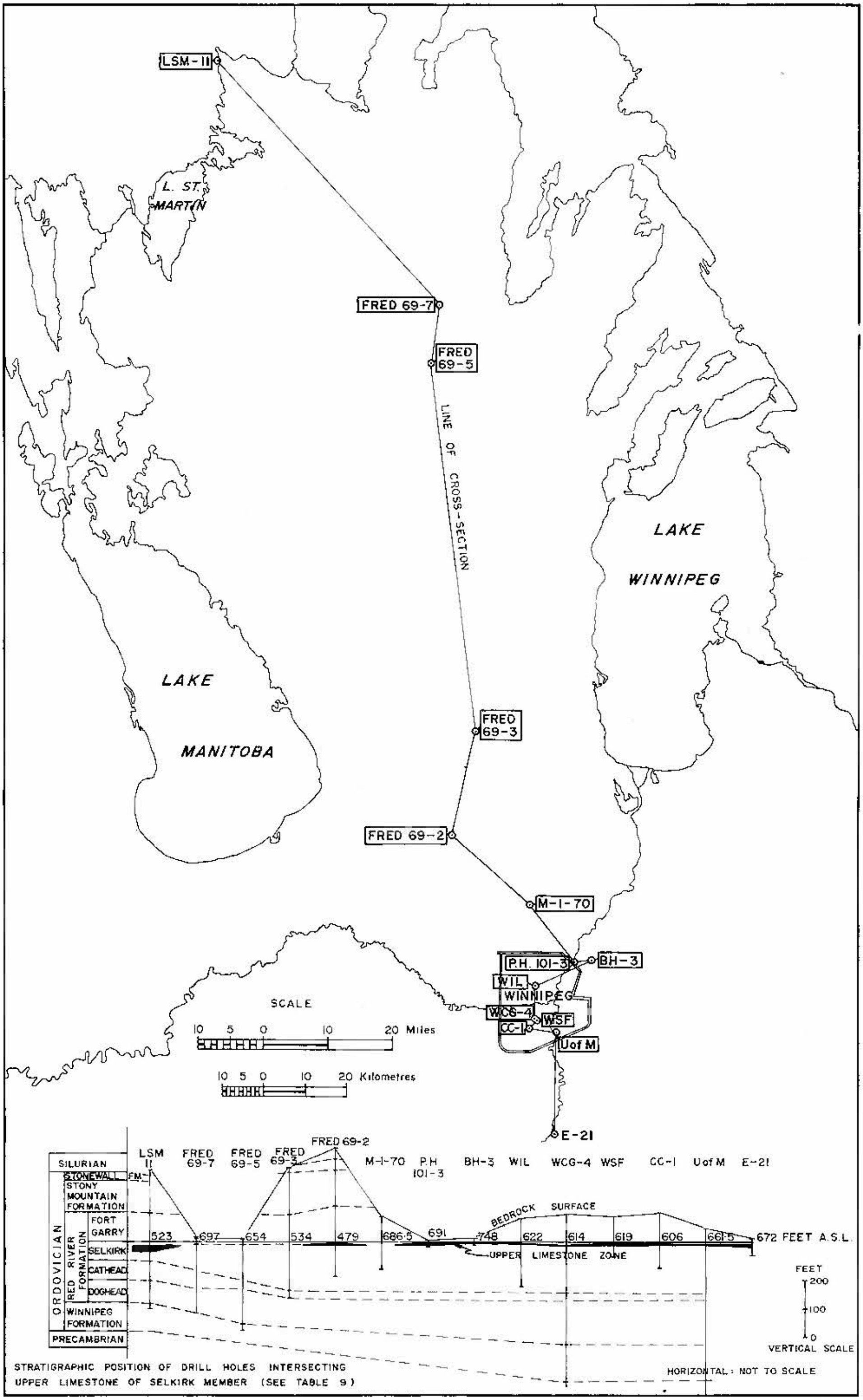

Figure 3: Selkirk Member limestone: location of core holes

TABLE 9. Summary of limestone occurrences within the Selkirk Member

Hole No.	Hole location	Surface elevation (feet a.s.l.)	Drift thickness (feet)	Limestone zone (footage)	Remarks
	South of Winnipeg				
E-21	13-21-7-3EPM (Lot 592, R.M. of Ritchot); Westroc Industries Limited	775	92	116.3-118.0	Limestone, crystalline, pale brown; faint mottling. 95.58% $CaCO_3$; 4.12% $MgCO_3$ (see analysis, Table 10)
	Winnipeg area				
U. of M.	Dept. of Earth Sciences, University of Manitoba	763	59	104.5-111.5	Limestone, dolomitic; 70.8 to 86.5% $CaCO_3$; 12.70 to 28.53% $MgCO_3$
CC-1	Fort Whyte plant, Canada Cement Lafarge Ltd.	766	56	163.1-172.0	"Limestone, light grey, laminated and limestone, moderately dolomitic, buff, fine to medium crystalline, cherty near base"; core not available
WSF	The Winnipeg Supply and Fuel Co. Ltd., NW14-13-10-2EPM	766	56	147-158	"Limestone, fine to medium crystalline, massive; with chert"; core not available
WCG-4	Winnipeg Central Gas #4 SW4-24-10-2EPM	766	61	152-158.9	Limestone; 3.3 feet of high-calcium stone; also magnesian, and dolomitic (see Tables 10 and 11)
WIL	Westroc Industries Limited, 1200 Empress St., Winnipeg	767	66	146.5-153	Limestone, magnesian; upper 2.7 feet: 90.31% $CaCO_3$, 9.31% $MgCO_3$; lower 3.8 feet: 82.51% $CaCO_3$, 11.94% $MgCO_3$
P.H. 101-3	North Perimeter Highway 101, at Red River	734	43	43-50	Drilled from ice level of Red River; 5 feet of water; 38 feet of drift over 7 feet of high-calcium limestone (see analysis)
BH-3	Tallman Sand and Gravel Company, C.P. pit, Birds Hill; SE1-5-12-4EPM	760	12	16-16.7 (total depth)	0.7 feet limestone, high-calcium (see analysis); overlain by 4 feet Fort Garry dolomite; total thickness not known
	Southern Interlake area				
M-1-70	10-27-13-3EPM, Stony Mountain	770	22	83.5	Limestone zone is absent in upper part of Selkirk Member
FRED 69-2	NE¼-2-15-1WPM, Woodroyd	870	60	391.5-397	Limestone, marginal high-calcium; 91.51% $CaCO_3$, 5.25% $MgCO_3$ (see analysis)
FRED 69-3	SW¼-28-17-1EPM, Norris Lake	860	54	326-333	Limestone, magnesian (see analysis)
FRED 69-5	NW¼-32-26-1WPM, Peguis Indian Reserve 1B	750	69	96-98	2 feet of core recovered between 96 and 100 feet, contains some impure limestone fragments
FRED 69-7	NE¼-28-28-1WPM, 5 miles south of Red Rose	745	26	48-50.5	2.5 feet of core recovered between 45 and 53 feet; laminated high-calcium limestone at base, less than 0.5 feet thick
	Lake St. Martin area				
LSM-11	SW¼-1-35-7WPM, Dauphin River	795	21	284.5-302	Limestone, high-calcium (see analysis)

TABLE 10. Limestone analyses, Selkirk Member

Hole No. Footage	E-21 116.3-118.0	WCG-4 155.6-158.9	P.H. 101-3 47-50	P.H. 101-3 50-54	BH-3 16	FRED 69-2 391.5-397	FRED 69-3 326-329	FRED 69-3 329-333	LSM-11 285-295	LSM-11 295-305
SiO_2	0.84	2.49	0.39	0.35		3.49	3.02	3.30	0.45	0.22
Al_2O_3	0.12	0.12	0.10	0.13	} 0.44	0.26	0.40	0.38	0.31	0.28
Fe_2O_3	0.22	0.13	0.23	0.16		0.14	0.13	0.13	0.08	0.06
CaO	53.55	52.85	54.74	55.03	53.14	51.27	47.25	47.6	55.34	55.51
MgO	1.97	1.87	1.16	0.91	1.91	2.51	6.16	5.68	0.29	0.26
Na_2O	0.01	0.02	0.02	Trace	n.d.	0.01	0.04	0.04	0.03	0.02
K_2O	0.04	0.04	0.03	0.03	n.d.	0.11	0.14	0.16	0.05	0.02
P_2O_5	0.06	0.02	0.01	0.01	0.05	0.05	0.08	0.09	Nil	0.31
S	0.02	0.01	0.02	0.02	n.d.	0.03	0.11	0.04	n.d.	n.d.
LOI	43.73	43.17	43.98	43.87	43.47	42.65	43.35	43.12	43.59	43.68
Total	100.56	100.7	100.7	100.5	100.16	100.5	100.68	100.54	100.14	100.36
$CaCO_3$	95.58	94.33	97.70	98.22	94.84	91.51	84.33	84.96	98.77	99.07
$MgCO_3$	4.12	3.91	2.43	1.90	3.99	5.25	12.88	11.88	0.61	0.54
Thickness	1.7 feet	3.3 feet	3.0 feet	4.0 feet	8 inches	5.5 feet	3 feet	4 feet	10 feet	10 feet

Explanation of PLATE 3: High-calcium limestones of Manitoba (I)

Ordovician Red River Formation

Selkirk Member, limestone bed at top of member

1) *Hole P.H. 101-3: 47.5 feet; Winnipeg*

Limestone, finely crystalline, laminated. Upper part: very fine grained, slightly laminated. Middle part: fine grained, with silicified fossil fragments and minor allochems oriented parallel to laminations. Lower part: medium to fine grained, brownish buff; rounded translucent calcite grains in micritic matrix; contains a lens of very finely crystalline dense dolomite.

2) *Hole P.H. 101-3: 43 feet; Winnipeg*

Limestone, grading from finely laminated micrite to alternating micritic and finely crystalline layers; stylolitic partings.

Fort Garry Member, upper limestone bed

3) *Hole ASD-1: 114 feet; Winnipeg*

Limestone, pale buff, finely laminated; mainly micrite, some finely crystalline limestone at base. Cross fractures, lined with very fine grained calcite crystals, and some pyrite grains.

4) *Hole ASD-1: 116 feet; Winnipeg*

Limestone, finely crystalline, light brownish buff, layered. Buff micrite irregular layer at top. Abundant brachiopod shell fragments oriented parallel to laminations; slightly vuggy; minor stylolitic parting. Fractures filled with calcite; some calcite blebs.

5) *Hole ASD-1: 119 feet, Winnipeg*

Limestone, biomicrite, light buff. Randomly oriented shell fragments, mainly brachiopods and gastropods; scattered vugs lined with calcite crystals; stylolitic parting. Allochems of slightly darker buff micrite in buff micrite matrix; shows a poorly developed layering.

Devonian Elm Point Formation

6) *Hole M-2-70: 7 feet; Lily Bay*

Magnesian limestone, mottled. Brownish buff mottles of micrite with abundant fossil fragments (bioclasts) in matrix of light buff dolomitized micritic limestone, containing calcitic bioclasts. Bioclasts are predominantly brachiopod and gastropod debris. Contacts of mottles range from sharp, to gradational over ⅛-inch.

7) *Hole M-2-70: 29 feet; Lily Bay*

Limestone, mottled. Light greyish brown to purplish buff micrite mottles, with abundant bioclasts; some grains orange to reddish purple. Matrix is light grey partially dolomitized cryptocrystalline limestone, with abundant bioclasts. Contacts between mottles and matrix are less well defined than in (6).

8) *Spearhill quarry (outcrop sample)*

Limestone, irregularly mottled; abundant bioclasts include crinoid fragments. Only slight degree of dolomitization in the lighter buff patches completely enclosed in light brownish buff limestone. Greyish buff biomicrite is present on the left.

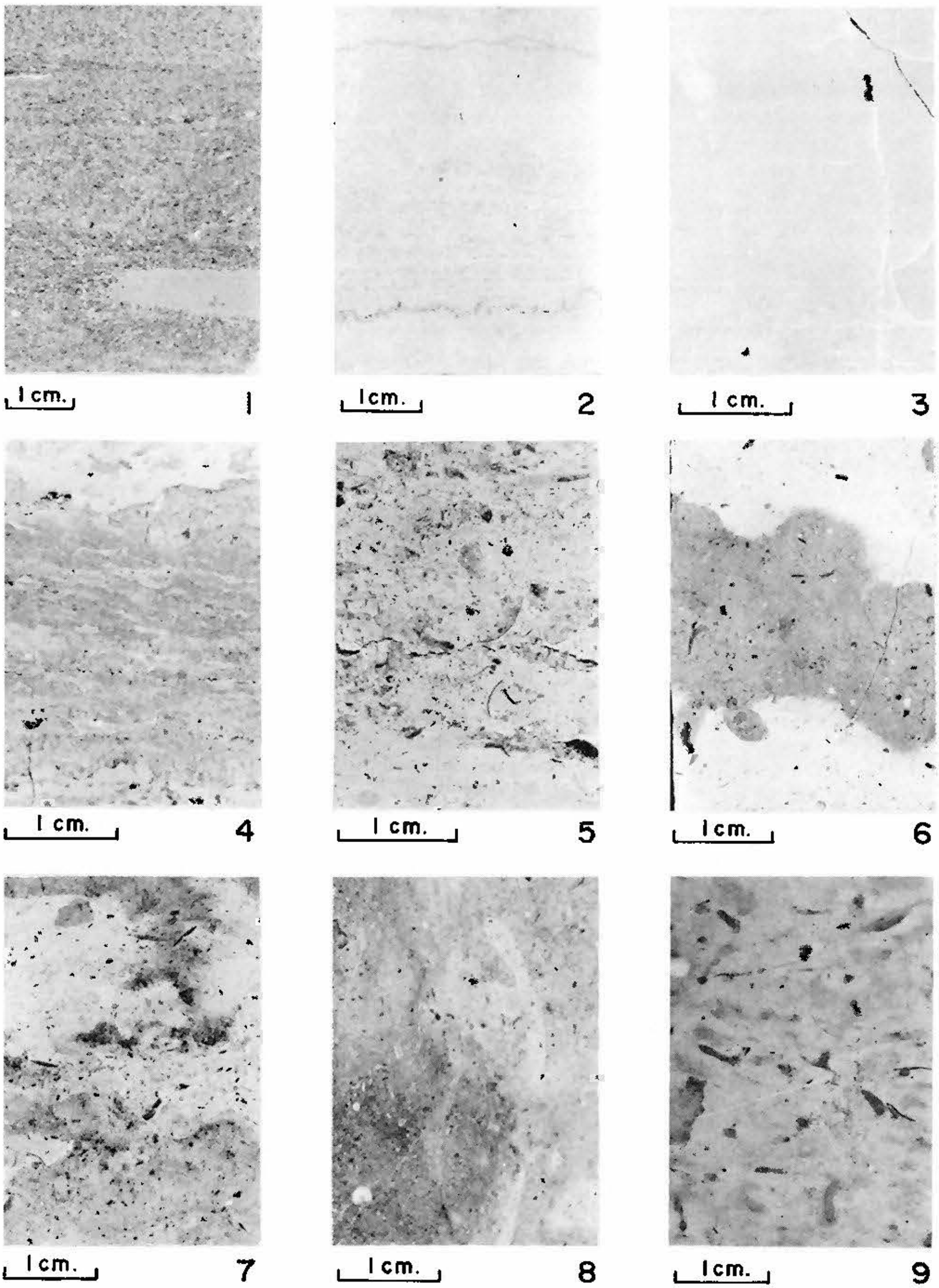

PLATE 3. High-calcium limestones of Manitoba (I)

Devonian Dawson Bay Formation

Lower limestone zone

9) *Hole M-8-71: 10 feet; Kinosota*

Limestone, mottled, mauve to greyish buff; smooth micrite. Darker streaks are purplish red, associated with minute specks of pyrite. Orange to reddish orange iron oxide occurs also as discrete thin streaks and as diffuse patches.

TABLE 11. Partial analysis, limestone zone in Selkirk Member, WCG-4

Hole No. Footage	WCG-4 152.0-154.0	WCG-4 154.0-155.6	WCG-4* 155.6-158.9	WCG-4 158.9-161.2	WCG-4 161.2-164.0
$MgCO_3$	8.99	21.98	3.91	12.57	8.45
$CaCO_3$	90.31	74.75	94.33	86.92	90.69
Thickness	2.0 feet	1.6 feet	3.3 feet	2.3 feet	2.8 feet

Winnipeg Central Gas hole #4, Wilkes Ave. near Kenaston Blvd., Tuxedo, Winnipeg.

*See detailed analysis, Table 10.

In the southern Interlake area, the upper Selkirk limestone zone is thin or absent. In Mines Branch core hole M-1-70, the upper Selkirk limestone zone is absent. The top of the Selkirk Member is at 83.5 feet (Cowan, 1971), at the top of a mottled dolomite zone. The overlying Fort Garry Member consists of laminated buff to reddish brown dolomite, with abundant chert in layers. Not only is the limestone interval absent, but the calcareous content of the upper part of the Selkirk Member is anomalously low. In the FRED Interlake drill holes, the limestone interval ranges from a few inches to 7 feet of magnesian to dolomitic limestone (Tables 9 and 10). The zone is apparently less than 1 foot thick in the Peguis Indian Reserve No. 1B area; however, core recovery was poor in the two holes (FRED 69-5 and 69-7, Table 9) that intersected the zone.

A possibly unique occurrence of high-calcium limestone within the Selkirk Member is present in the Lake St. Martin area. A FRED-Manitoba Mines Branch drill program in the Gypsumville-Lake St. Martin area outlined a 14-mile diameter crypto-explosion crater structure (McCabe and Bannatyne, 1970). In hole LSM-11, near Dauphin River 19 miles northeast of Gypsumville (Figure 1), the Selkirk Member was intersected from a depth of 272 to 330 feet. Dolomitic limestone of the member does not exhibit the typical mottled pattern found in southern Manitoba, for example at Garson. Instead, it consists mainly of thin bands and linear patches of brownish grey dolomite in a limestone matrix, interbedded with calcareous dolomite. High-calcium limestone occurs from a depth of 283.5 to 307 feet (Table 10) and is a light greyish buff micrite grading downward to a crystalline biosparite. This is the only cored intersection of the Selkirk Member in the area. From projections based on regional strike and dip, the limestone, if it is of more than local extent, should form the bedrock surface under the eastern part of Sturgeon Bay, Lake Winnipeg.

Summary

The limestone in the Selkirk Member, rather than being one continuous horizon, could occur as several linear zones developed roughly parallel to isopach trends. The limestone occurs at mineable depths in the Winnipeg area, and, indeed, below the Portland cement plants. Detailed checking of any future drill core from this area should be made as a 10-foot bed over an area of only one square mile would contain more than 20 million tons of limestone.

The thick, high purity limestone intersected in the LSM-11 hole near Dauphin River is of particular interest. This zone was not previously known.

Fort Garry Member

In the Winnipeg area, the Fort Garry Member is 120 to 130 feet thick and consists predominantly of dolomite in places containing chert or argillaceous material. Two limestone zones occur in the member (Figure 2). One zone, the middle limestone unit occurs 50 feet below the top of the member, but is not persistent. A more widespread limestone bed, the upper limestone unit, occurs at the top of the member and may be as much as 12 feet thick.

In the Lake St. Martin area, a limestone zone occurs 16 feet below the top of the Fort Garry Member (Figure 2). Correlation of this unit with the limestone beds to the south has not been established.

Middle limestone unit, Fort Garry Member

Winnipeg and southern Interlake areas

Limestone, possibly of high-calcium quality, is present in a thin bed in the middle part of the Fort Garry Member. Its distribution is erratic, and in some cored holes its presence was not noted. The reported occurrences are listed in Table 12.

A minor interval of limestone was noted in Manitoba Mines Branch core hole M-1-70, 6 miles northeast of Stony Mountain. The interval, at a depth of 42.9 to 43.4 feet, is 40.1 feet above the base of the Fort Garry Member (Cowan, 1971), and is thus 30 feet lower in the section than the other occurrences. As noted previously, the lithology in this hole is anomalous.

Although available evidence suggests that the middle limestone unit is thin and probably of marginal quality, more detailed checks for its presence should be made on any core obtained from the area in the future.

Lake St. Martin and the area to the north

In the area north from Winnipeg to Lake St. Martin, the Fort Garry Member thins from 135 feet to 95 feet. In the Lake St. Martin area a high-calcium limestone zone has an erratic distribution. It is well developed and of good quality (94.72% $CaCO_3$ and 4.50% $MgCO_3$) in drill hole LSM-11, where it occurs at a depth of 192 to 197 feet, 16 feet below the top of the Fort Garry Member. A complete analysis is listed in Table 15. The limestone is brownish buff and finely crystalline, with some argillaceous partings. Correlation with either the middle or upper unit in the Winnipeg area has not been established. It is possibly of local occurrence, but more data in the intervening areas are required.

The Fort Garry Member was intersected in two other holes in the area: in LSM-7 in NW¼ sec. 5, tp. 32, rge. 9WPM; and in LSM-10, in SE¼ sec. 12, tp. 34, rge. 7WPM. In both of these holes, little trace of the limestone zone was noted in the core. Dolomite is the predominant rock type, although two small pieces of core of an earthy calcareous rock were noted in LSM-10, 14 feet below the top of the Fort Garry Member.

North of the Lake St. Martin area the next available data are from Grand Rapids. Examination of cored sections have indicated that the entire Fort Garry Member, as well as the Selkirk Member, is devoid of any magnesian or high-calcium limestone. To date, limestone has not been reported in any of the cores recovered in the area north and northwest of Grand Rapids, where numerous holes have been drilled through the Paleozoic cover to investigate possible mineral deposits in the underlying Precambrian rocks.

Upper limestone unit, Fort Garry Member

The extent and quality of the limestone unit at the top of the Fort Garry Member have been outlined in several drill programs in the Winnipeg area. The locations of the drill holes and a summary of results are listed in Table 13. The depth to the limestone zone, and a cross-section, are shown in Figure 4.

Inland Cement Industries Limited drill program

The possibility of economically recoverable high-calcium limestone in the upper part of the Fort Garry Member was first indicated from data from Sun Oil Company Manitoba test hole #7, near Headingley. On the combined lithological-mechanical log of this well, the zone is marked by a high resistivity and a strong response on the neutron log from a depth of 208 to 220 feet. Examination of cuttings from this interval, by H.R. McCabe, Manitoba Mines Branch stratigrapher, determined the presence of light buff microcrystalline to cryptocrystalline high-calcium limestone. An analysis of a ½-gram sample, obtained from the Mines Branch by the late A. S. Dawson, was made in the Inland Cement Industries Limited laboratory at Edmonton. The analysis showed 98.86 per cent $CaCO_3$, 0.11 per cent $MgCO_3$, and 0.26 per cent acid insoluble.

On the basis of this information, an exploration drill program, under the direction of A. S. Dawson, was carried out in 1961 for Inland Cement Industries Limited. Twelve cored sections of the limestone zone were obtained in an area eight miles by twelve miles centred near Headingley (see Figure 4D). The results are summarized in Table 13, and analyses are listed in Tables 14 and 15. The limestone may occur as one thick bed of high-calcium

TABLE 12. Middle limestone unit, Fort Garry Member

Hole No.	Location	Elevation (feet a.s.l.)	Drift thickness (feet)	Top of Fort Garry (feet)	Middle limestone unit (footage)	Depth to base of Fort Garry (feet)	Remarks
CC-13	NE l.s. 8, sec. 3, tp. 10, rge. 2EPM	768	62	Eroded	72.8-84.2	Not reached	Logged as: "limestone, light greyish buff, faint darker mottles; some chert; appears high-calcium in grab samples"; core not available
CC-1	Fort Whyte plant, Canada Cement Lafarge Ltd.	769	54	Eroded	78.8-89	164	Logged as: "limestone, slightly dolomitic"; core not available
Winnipeg Central Gas #4	Wilkes Avenue at Kenaston Blvd.	766	61	Eroded	72-78	150	Core: dolomite, calcareous; in part, dolomitic limestone
The Winnipeg Supply and Fuel Co. Ltd.	Fort Whyte-Tuxedo lime plant	766	56	Eroded	69-76	147	Logged as: "limestone, probably slightly dolomitic"; core not available
Sun Core Hole No. 7	SW l.s. 4, sec. 19, tp. 11, rge. 1EPM	786	30	215	260-270	330	Chip samples: "limestone, light buff, very finely crystalline; chert; some dolomite"
FRED 69-3	SW¼ sec. 28, tp. 17, rge. 1WPM	860	54	200	233-236	310	Core: limestone, dolomitic; slightly argillaceous, mottled

quality (ASD-1), as two thin beds separated by dolomite (ASD-7), or as a thin bed of magnesian limestone (ASD-9). In holes ASD-1 and ASD-4, the limestone is directly in contact with the overlying Gunn Member; in holes ASD-5 and ASD-12, an intervening layer of dolomite, up to 7.8 feet thick, is present. The limestone is shown in Plate 3, samples 3, 4 and 5.

Canada Cement Lafarge Ltd. drill program

A separate drill program was carried out in 1961 by Canada Cement Lafarge Ltd. in the Fort Whyte-Headingley-Stony Mountain area (Figure 4D). Twenty-one holes were drilled and the results are summarized in Table 13. Analyses of the high-calcium limestone horizon at the top of the Fort Garry Member are available for three of the holes (Table 15), courtesy of J. Selwyn. These analyses indicate the presence of a fairly persistent zone of limestone in the area to the northeast of that explored in the Inland Cement Industries drill program.

High-calcium limestone was reported from two other drill holes in this exploration program, but chemical analyses are not available, and some doubt exists as to the quality of these zones. In drill hole CC-3, limestone of unknown thickness was reported at a depth of 104 feet; in hole CC-11, limestone was reported from 120 to 130 feet in depth.

Government drill programs

The upper part of the Fort Garry Member has been intersected in several other drill holes in the southern Interlake area. Locations of the three holes discussed are shown in Figure 1. In two of the holes, the limestone zone is absent. It has not been determined whether the zone was removed by erosion prior to deposition of the overlying Gunn Member, or whether the limestone facies was not developed in these areas.

In Manitoba Mines Branch core hole M-2-69, drilled through the floor of the City of Winnipeg quarry at Stony Mountain, the limestone unit was intersected from 78 to 81 feet. It analyzed 94.45 per cent $CaCO_3$ and 5.29 per cent $MgCO_3$; a detailed analysis is listed in Table 15. The unit consists of light yellowish grey slightly vugular biomicrite with some chert at the base of the sampled interval.

In hole FRED 69-2, 1 mile south of Woodroyd, the upper part of Fort Garry Member, from a depth of 263 to 270 feet, consists of a dense, microcrystalline to finely crystalline dolomite with calcite in thin layers and as disseminated grains throughout the interval. However, the interval does not contain any significant amount of high-calcium limestone. In hole FRED 69-3, drilled through the ice on Norris Lake, the top of the Fort Garry Member was intersected at a depth of 200 feet. A 1-inch bed of dolomite with heavily disseminated calcite grains is present at the top of the unit, overlying a thin layer of mottled dolomitic limestone, and dense dolomite.

The occurrence of limestone within the Fort Garry Member in the Lake St. Martin area has been described previously.

Summary: upper limestone unit

The foregoing evidence indicates the presence in some areas of a bed of high-calcium limestone at the top of the Fort Garry Member. The erratic distribution of the limestone suggests that the deposits may have been formed in localized areas, possibly in shallow-water lagoons that existed near the end of Red River time.

The results of the drill programs in the Winnipeg area are significant in that beds of high-calcium limestone of mineable thickness are present in some localities. Maximum thicknesses of 8.5 feet were reported in two holes, ASD-6 and CC-19 (Table 13). Two thin limestone zones are separated by a layer of dolomite in some drill cores. In other cores, a layer of dolomite up to 7.8 feet thick separates the limestone zone from the overlying Gunn Member of the Stony Mountain Formation.

The highest quality limestone, as presently known, occurs in a crescent-shaped area extending from 4 miles south and southwest of Headingley, northeastward to an area 5 to 9 miles south of Stony Mountain (Figure 4D). Depth to the limestone decreases from 260 feet to 42.5 feet across this area. More data are required to evaluate the potential of the upper limestone unit in the area south from Headingley.

The results suggest two possible methods of recovering the limestone: either by quarry-

TABLE 13. Summary of geological data, Winnipeg area drill holes

Hole No.	Location (l.s., sec. tp., rge.)	Elevation (feet a.s.l.)	Total depth (feet)	Drift thickness (feet)	Depth to Stonewall Formation (feet)	Depth to Gunton Member (feet)	Depth to Penitentiary and/or Gunn[2] (feet)	Depth to Fort Garry Member (feet)	Fort Garry limestone (footage)	Carbonate content %$CaCO_3$:$MgCO_3$	Thickness (feet)
ASD-1	SW13-29-11-2EPM	787	135	40	–	–	40	113.5	113.5 to 119.5	98.43:0.58	6.0
ASD-2	NE1-8-12-1EPM	799	193	25	25	46	98	179.2	182.8 to 184.8	95.78:3.69	2.0
ASD-3	Lot 53-54, Parish of Headingley	786	194	22	22	32	95	176.4	178.1 to 184.0	85.56:12.66	5.9
ASD-4	Lot 15-16, Parish of Headingley	786	197	28	28	34	98	177.9	177.9 to 185.4	94.78:3.55	7.5
ASD-5	SE8-35-11-1EPM	790	169	45	–	45	75	150	157.5 to 159.6	93.40:5.91	2.1
ASD-6	Lot 6-7, Parish of St. Francois Xavier	787	231	65	65	83	137	220.4	220.5 to 229.0	93.77:4.88	8.5
ASD-7	SE1-33-11-2PM	790	136	13	–	13	57	113.2	118.6 to 121.0	97.36:1.25	2.4
ASD-8	Lot 23-24, Parish of St. Francois Xavier	785	274	45	100[1]	117	179	259.5	259.5 to 263.6	96.36:1.45	4.1
ASD-9	Lot 61-62, Parish of St. Charles	780	131	35	–	–	67[1]	103.3	110.8 to 112.7	88.46:10.82	1.9
ASD-10	Lot 17-18, Parish of Headingley	785	215	?	?	?	?	204.8	204.8 to 210.4	87.99:9.56	5.6
ASD-11	NE11-22-11-1EPM	786	175	37	–	37	?	163	163.0 to 170.2	90.95:6.55	7.2
ASD-12	SE5-30-11-2EPM	783	137	22	–	22	62	118.3	123.1 to 127.0	92.24:6.11	3.9
CC-1	Fort Whyte Plant	769	254	54	–	–	–	54	Limestone eroded		
CC-2	NW15-19-11-2EPM	780	80	30	–	–	30		Base of hole in Gunn		
CC-3	NE14-24-11-1EPM	789	124	24	–	24	34	104	Limestone reported	No analysis	
CC-4	NE14-23-11-1EPM	786	79	60	–	60	79?		Base of hole in Penitentiary?		
CC-5	NE14-22-11-1EPM	785	81	39	–	39	78		Base of hole in Penitentiary		
CC-6	NW5-22-11-1EPM	787	56	16	16	23			Base of hole in Gunton		

CC-7	Lot 85, Parish of St. Charles	781	80	30	–	30	66		Base of hole in Penitentiary		
CC-8	SE9-9-2EPM	778	67	44	–	–	44		Base of hole in Penitentiary		
CC-9	4-10-10-2EPM	772	90	(90 +)	–				Base of hole in drift		
CC-10	Lot 56, Parish of St. Charles	780	60	(60 +)	–				Base of hole in drift		
CC-11	NW4-36-9-1EPM	780	130	50	–	–	50	120	120 to 130?	No analysis	
CC-12	9-32-9-2EPM	777	90	(90 +)	–				Base of hole in drift		
CC-13	NE8-3-10-2EPM	768	112	62	–	–	–	62	Limestone eroded		
CC-14	Lot 50, Parish of Headingley	787	126	26	26	39	?		Base of hole in Gunn		
CC-15	SE1-34-11-2EPM	774	63	28	–	–	28	55	55 to 63	94.11:3.99	8.0
CC-16	Lot 53-54, Parish of Headingley	790	112	22	22	?			Base of hole in Gunn?		
CC-17	Lot 53-54, Parish of Headingley	790	99	17	17	?			Base of hole in Penitentiary		
CC-18	SE1-1-13-2EPM	764	55	50	–	–	–	50	Limestone eroded		
CC-19	SE1-10-12-2EPM	771	68	30	–	–	30	59.5	59.5 to 68	96.38:2.30	8.5
CC-20	SW4-23-12-2EPM	767	50	35	–	–	35	42	42.5 to 50	91.58:4.50	7.5
CC-21	NE16-15-13-2EPM	769	46	41	–	–	–	41	Limestone eroded		
Sun #7	SW4-19-11-1EPM	786	851	30	30	80	130	208	208 to ? 220	98.86:0.11	5 to ?12
M-2-69	3-14-13-2EPM	830	99	0	–	–	0	78	78 to 81	94.45:5.29	3.0

Note: [1] Holes ASD-8 and ASD-9 intersected Jurassic strata from depths of 45 to 100 feet and 35 to 67 feet respectively.

[2] Tops are as reported for Penitentiary or Gunn Member; the contact is somewhat gradational and may not be consistently picked; for the area involved, average thicknesses are Gunton, 52 feet; Penitentiary, 24 feet; and Gunn, 70 feet.

TABLE 14. Upper limestone unit, Fort Garry Member; Inland Cement Industries Limited drill holes ASD-1 to ASD-12

Hole No. / Footage	ASD-1[1] 113.5-115.5	ASD-1 115.5-117.5	ASD-1 117.5-119.5	ASD-2 182.8-184.8	ASD-3 178.1-180.0	ASD-3 180.0-182.0	ASD-3 182.0-184.0	ASD-4 177.9-179.4	ASD-4 179.4-181.4
CaO	54.95	55.13	55.37	53.66	47.27	47.27	49.22	53.99	54.54
MgO	1.00	2.29	2.01	1.76	6.43	6.83	4.92	0.80	0.80
Insoluble	0.99	0.90	1.03	0.65	0.66	0.61	0.53	1.05	0.65
$CaCO_3$	98.08	98.40	98.83	95.78	84.36	84.36	87.85	96.37	97.35
$MgCO_3$	0.84	0.48	0.42	3.69	13.45	14.29	10.30	1.67	1.67
Total	99.91	99.78	100.28	100.12	98.47	99.26	98.68	99.09	99.67
Thickness (feet)	2.0	2.0	2.0	2.0	1.9	2.0	2.0	1.5	2.0

Hole No. / Footage	ASD-4 181.4-183.4	ASD-4 183.4-185.4	ASD-5 155.4-157.5	ASD-5 157.5-159.6	ASD-6 220.5-222.6	ASD-6 222.6-224.7	ASD-6 224.7-226.8	ASD-6 226.8-229.0	ASD-7 115.5-116.7
CaO	51.22	52.89	48.79	52.33	52.89	52.61	52.19	52.46	53.16
MgO	2.98	1.99	6.11	2.83	2.19	2.29	2.78	2.09	2.19
Insoluble	1.20	0.70	0.63	0.42	0.86	0.62	0.47	1.52	0.38
$CaCO_3$	91.42	94.39	87.08	93.40	94.39	93.89	93.15	93.64	94.88
$MgCO_3$	6.24	4.16	12.78	5.91	4.57	4.78	5.82	4.37	4.58
Total	98.86	99.25	100.49	99.73	99.82	99.29	99.44	99.53	99.84
Thickness (feet)	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.2	1.2

Hole No. Footage	ASD-7[2] 116.7-118.6	ASD-7 118.6-121.0	ASD-8 259.5-261.6	ASD-8 261.6-263.6	ASD-9 110.8-112.7	ASD-10[3] 204.8-210.4	ASD-11 163-167	ASD-11 167-170.2	ASD-12 123.1-129.0
CaO	32.67	54.55	53.99	53.99	49.56	49.30	50.81	51.14	51.68
MgO	19.31	0.60	0.60	0.80	5.17	4.57	3.38	2.82	2.92
Insoluble	1.16	1.03	1.30	1.32	0.28	2.25	2.03	2.62	1.30
$CaCO_3$	58.31	97.36	96.36	96.36	88.46	87.99	90.69	91.27	92.24
$MgCO_3$	40.39	1.25	1.25	1.67	10.82	9.56	7.07	5.90	6.11
Total	99.86	99.64	98.91	99.35	99.56	99.80	99.79	99.79	99.65
Thickness (feet)	1.9	2.4	2.1	2.0	1.9	5.6	4.0	3.2	3.9

Analyses for holes ASD-1 to ASD-9 are by Inland Cement Industries Limited, and for holes ASD-10 to ASD-12 by Manitoba Mines Branch Analytical Laboratory.

[1] For detailed location, see Table 13; the holes are plotted in Figure 4.

[2] The analysis represents an interbedded dolomite.

[3] Detailed analyses for holes ASD-10 to ASD-12 are listed in Table 15.

TABLE 15. Detailed chemical analyses, upper limestone unit, Fort Garry Member

Hole No. / Footage	ASD-10 204.8-210.4	ASD-10 204.8-206.3	ASD-11 163-167	ASD-11 167-170.2	ASD-12 123.1-127.0	CC-15 53-61	CC-19 64-72.5	CC-20 42.5-50	M-2-69 78-81	LSM-11 192-197
SiO_2	0.65	0.49	0.50	0.96	0.25	1.34	1.10	1.74	0.67	0.50
Al_2O_3	0.31	0.08	0.18	0.22	0.14	} 0.54	} 0.34	} 0.94	0.21	0.31
Fe_2O_3	0.45	0.29	0.38	0.31	0.39				0.29	0.20
CaO	49.30	54.41	50.81	51.14	51.68	52.73	54.00	51.31	52.92	53.07
MgO	4.57	1.16	3.38	2.82	2.92	1.91	1.10	2.15	2.53	2.15
Na_2O	0.09	0.02	0.05	0.05	0.04	–	–	–	0.01	0.02
K_2O	0.06	0.06	0.05	0.10	0.03	–	–	–	0.08	0.03
P_2O_5	Nil	Nil	Nil	Nil	Nil	–	–	–	Nil	Nil
S	0.03	0.02	0.04	0.06	0.08	–	–	–	0.02	n.d.
LOI	44.35	43.79	44.40	44.13	44.10	43.00	43.04	42.30	44.01	43.86
Total	99.80	100.32	99.79	99.79	99.65	99.52	99.58	99.38	100.75	100.14
$CaCO_3$	87.99	97.11	90.69	91.27	92.24	94.11	96.38	91.58	94.45	94.72
$MgCO_3$	9.56	2.43	7.07	5.90	6.11	3.99	2.30	4.50	5.29	4.50
Thickness	5.6 feet	1.5 feet	4 feet	3.2 feet	3.9 feet	8 feet	8.5 feet	7.5 feet	3.0 feet	5.0 feet

ASD-10, Inland Cement drill hole, Lot 17-18, Parish of Headingley.
ASD-11, Inland Cement drill hole, NE l.s. 11, sec. 22, tp. 11, rge. 1EPM.
ASD-12, Inland Cement drill hole, SE l.s. 5, sec. 30, tp. 11, rge. 2EPM.
CC-15, Canada Cement drill hole, SE corner, sec. 34, tp. 11, rge. 2EPM.
CC-19, Canada Cement drill hole, SE corner, sec. 10, tp. 12, rge. 2EPM.
CC-20, Canada Cement drill hole, SW corner, sec. 23, tp. 12, rge. 2EPM.
M-2-69, Manitoba Mines Branch core hole, Stony Mountain, l.s. 2, sec. 14, tp. 13, rge. 2EPM.
LSM-11, Dauphin River area, SW¼ sec. 1, tp. 35, rge. 7WPM; correlation uncertain (see text).

ing in the areas of thinnest overburden, or by room and pillar mining elsewhere. The economics of recovering the limestone would be dependent on such factors as adequate reserves and thickness of high-calcium limestone, a favourable rate of cost of extraction versus production costs from present sources, a compliance with zoning regulations in this largely developed area, and the location of the deposit in relation to the cement and lime plants at Fort Whyte.

The occurrences of limestone in Ordovician and Silurian strata in *Hudson Bay Lowland* are discussed, along with occurrences in Devonian rocks, in the introduction to the Devonian section. It should be noted here that limestone has not been reported from the Silurian section in southwestern Manitoba.

DEVONIAN

Devonian formations form the bedrock surface in a belt 10 to 50 miles wide, extending from the southeast end of Lake Manitoba to the Overflowing River area at the northwest end of Lake Winnipegosis (Figure 1). Devonian strata, covered by glacial drift, also form the bedrock surface in a small area southeast of Portage la Prairie. The Devonian rocks include the Ashern, Elm Point, and Winnipegosis Formations of the Elk Point Group, and the Dawson Bay and Souris River Formations of the Manitoba Group (Baillie, 1951, 1953).

DISTRIBUTION OF LIMESTONE IN DEVONIAN FORMATIONS

To date, all high-calcium limestone produced in Manitoba has been obtained from limestone beds in the Elm Point, Dawson Bay, and Souris River Formations. Results of studies on recent drilling in the area have yielded new information on location, thickness, quality, and extent of these limestone beds. Their stratigraphic position is shown in Figure 2, in the sections for the Lake Winnipegosis, Lake St. Martin, and Lake Manitoba areas. Five main high-calcium limestone beds are present: the Elm Point Formation, upper and lower zones in the Dawson Bay Formation, and upper and lower zones within the outcrop portion of the Souris River Formation. Minor occurrences of limestone within the predominantly dolomitic Winnipegosis Formation have also been intersected. High-calcium limestone of Devonian Elm Point age has been preserved as down-faulted or slumped blocks within a crypto-explosion crater structure in the Lake St. Martin area (McCabe and Bannatyne, 1970). As the crater was formed in either the Permian or Triassic Period, the large slump blocks of limestone, although of Devonian age, are included in the (?) Permian-Triassic Lake St. Martin Series, as shown in the section in Figure 2. This Series includes also some highly brecciated limestone of undetermined age.

HUDSON BAY LOWLAND

Scattered occurrences of limestone within Paleozoic rocks have been reported from Hudson Bay Lowland in Manitoba. Recent geological surveys and exploration drilling have increased the knowledge of these strata (Nelson and Johnson, 1966; Sanford *et al.*, 1968; Cumming, 1971; and Norford, 1971).

Analysis of an Ordovician carbonate rock from Limestone Rapids on the Nelson River (Goudge, 1944, p. 85) indicated a dolomitic limestone containing 11.50 per cent $MgCO_3$ and 79.20 per cent $CaCO_3$. The scattered outcrops of Ordovician strata in the Hudson Bay Lowland consist primarily of dolomitic limestone (Cumming, 1971), and outcrops of Silurian strata consist primarily of dolomite, with intervals containing interbedded limestone and dolomitic limestone (Norford, 1971).

In 1966-1967, the Sogepet-Aquitaine Kaskattama Province No. 1 well was drilled near the delta of the Kaskattama River, 84 miles east of York Factory. Strata from early Middle Devonian to Precambrian were intersected; the Precambrian contact is present at a depth of 2,913 feet. Johnson and Nelson (1969) reported significant limestone zones in the Devonian and Ordovician sections, and limestone interbedded with dolomite in the Silurian section.

Chip samples from the Kaskattama well, from a depth of 40 feet, analyzed 98.36 per cent $CaCO_3$ and 1.90 per cent $MgCO_3$. The surficial deposits at this location (57°14'18.487" latitude, 90°10'29.408" longitude) are 23 feet thick. Johnson and Nelson (1969) describe the interval from 23 to 154 feet as buff to light grey, bioclastic, fossiliferous crystalline to finely crystalline limestone. This is the (?) Middle Devonian Kwataboahegan Formation (Norris and Uyeno, 1971), and limestone is present also in the underlying Lower Devonian Stooping River Formation. These strata are older than the Devonian strata of southwestern Manitoba, which range in age from Middle to Upper Devonian.

In summary, some high-calcium limestone is present in the Devonian strata. Limestone has been reported in the subsurface, but is apparently rare in outcrop. As the reports cited do not contain any chemical analyses, inferences as to the occurrence of high-calcium limestone in the Ordovician and Silurian outcrops are at present unwarranted.

DEPOSITIONAL HISTORY

A summary of the depositional environments of the Devonian strata of southwestern Manitoba is necessary to understand their facies relationships and the structural irregularity of their outcrop belts. A more detailed discussion is given by McCabe (1967). Structure contours, isopachs and outcrop belts for each formation are shown in the Manitoba Mines Branch Revised Stratigraphic Map Series.

Following regression of Silurian seas, a period of erosion continued until late-Lower or Middle Devonian time. Then subsidence, associated with development of the Elk Point Basin extending from southwestern Manitoba through southern Saskatchewan to northern Alberta, was the dominant influence on the nature of the Devonian strata (Figure 5A).

Red dolomitic shale and local basal breccia beds of the Ashern Formation were deposited on the eroded Silurian surface. The Ashern is overlain by carbonate rock of the Winnipegosis Formation, which has a complex depositional pattern (Figure 5B). In the subsurface, south of Lake Manitoba, a thin shelf-type carbonate is present along the rim of the Elk Point Basin. To the north and west, a fringing bank, increasing in thickness from 40 to over 160 feet, formed along the edge of the basin. In the outcrop belt, the north edge of the fringing bank is in the vicinity of The Narrows of Lake Manitoba. Northwest from The Narrows area, within the deeper part of the Elk Point Basin, the Winnipegosis Formation is composed of 40 to 60 feet of inter-reef dolomite, with apparently randomly interspersed patch and pinnacle reefs 200 to 350 feet in thickness. In the Dawson Bay area at the northwest end of the outcrop belt, reef thickness exceeds 350 feet. The outcrop belt of the Devonian strata represents a radial section of the basin.

Thus the Winnipegosis Formation comprises reef, inter-reef, fringing bank, and shelf carbonates, most of which are completely dolomitized. However, in the area east of Lake Manitoba, the carbonate rocks range from partially dolomitized limestone to high-calcium limestone. This limestone facies is named the Elm Point Formation, and is apparently a definable unit only in the outcrop area extending from Oak Point to Waterhen Lake (Figure 1). It is partially to highly dolomitized along the west edge of the outcrop belt south of Dog Lake, and at Waterhen Lake.

In the deeper parts of the Elk Point Basin, deposits of halite, anhydrite, dolomite, and potash salts formed in an evaporite environment during or following the reef development in the Winnipegosis Formation. These deposits comprise the Prairie Evaporite. They occur only in the subsurface, but originally, they covered a much larger area. Specifically, the Winnipegosis Formation, in the area extending from The Narrows of Lake Manitoba to Dawson Bay, is considered to have been overlain by salt which has subsequently been removed by solution (McCabe, 1971, p. 176). The overlying unit of red shale, the Second Red Bed, may represent, in part, insoluble residue resulting from solution of the salt beds.

Deposition of the Prairie Evaporite was followed by a marine transgression. The red shale and argillaceous limestone, comprising the Second Red Bed, were deposited during the early stages of this transgression, and were followed by beds of the Middle Devonian Dawson Bay and Upper Devonian Souris River Formations. These formations comprise shale-carbonate sequences formed during several sedimentary cycles in a predominantly normal marine environment. Evaporites were formed farther west in Saskatchewan; their eastern limits of deposition are not known but they may well have extended into Manitoba.

Solution of whatever Prairie Evaporite salt beds were once present in the outcrop belt area, has resulted in draping of Dawson Bay and Souris River strata over underlying Winnipegosis reef structures (Figure 5C). Solution of Dawson Bay and Souris River eva-

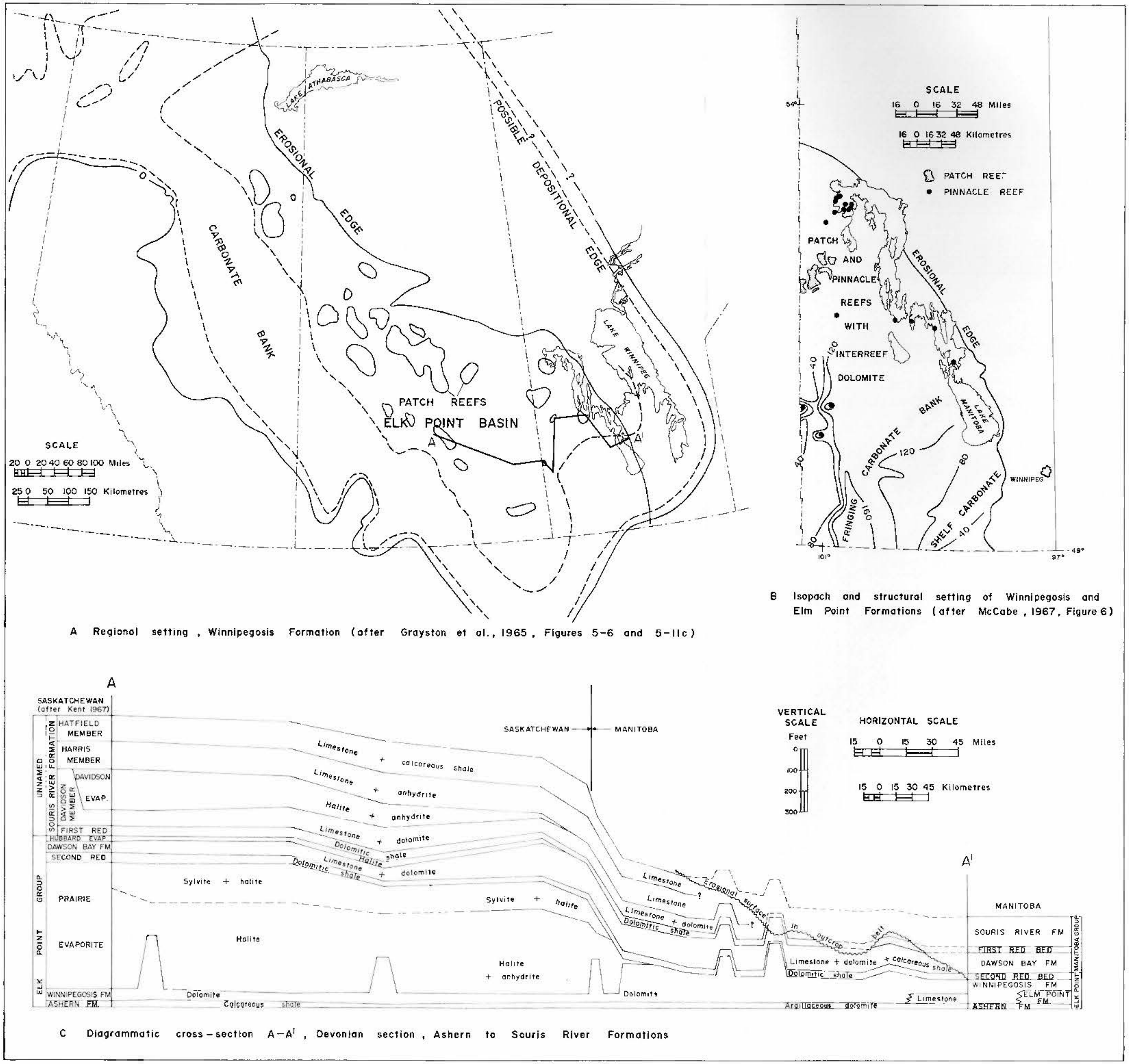

Figure 5: Regional relations of Devonian strata in southwestern Manitoba and eastern Saskatchewan

porites, if present in Manitoba, would have resulted in local disturbance of overlying strata. An irregular outcrop pattern for these formations has developed, and abnormally narrow outcrop belts occur in areas where domal structures have been truncated by subsequent erosion. These features are important factors in evaluation of high-calcium limestone deposits of the area. Depositional conditions of the Dawson Bay and Souris River Formations are discussed in more detail in the sections describing those formations.

ELM POINT FORMATION

The Elm Point Formation, composed primarily of mottled high-calcium limestone, is an eastern facies of the basal part of the dolomitic Winnipegosis Formation. The formation was defined by Kindle (1914) and mapped in detail by Baillie (1951). McKennitt (1961) described the subsurface stratigraphy. Detailed descriptions of industrial mineral operations utilizing the limestone, as well as numerous chemical analyses, were reported by Goudge (1944). The limestone is illustrated in Plate 3, samples 6, 7 and 8.

Outcrops are present east of Lake Manitoba from Oak Point to Waterhen Lake (Figure 1). In this report, the previous work of Goudge (1944) and Baillie (1951) has been supplemented with a great deal of new data obtained from:

i) Manitoba Soil Survey maps (preliminary and published reports);
ii) water well records, on file at the Manitoba Water Resources Branch in Winnipeg;
iii) assessment work reported by individuals or companies;
iv) additional field descriptions of outcrops and new quarries;
v) drill core obtained from the Manitoba Mines Branch core hole program and other government drilling programs;
vi) regional isopach and structure contour maps.

In the following sections the formation is described in detail from south to north.

Area south of Lake Manitoba

South of Lake Manitoba, the rocks of the Devonian Elk Point Group are covered by strata of Jurassic and younger age. Studies of subsurface data (McKennitt, 1961) indicate the Elm Point limestone lithology in the area south from the outcrop belt is of irregular and limited distribution, and the occurrences cannot be traced as a continuous unit.

Near Curtis, in township 11, ranges 5 and 6WPM (Figure 1), core holes intersected strata of the Dawson Bay and Winnipegosis Formations, but the holes were not deep enough to determine whether or not the Elm Point Formation is present. Thus, although Elm Point limestone may be present in this area, the depth to the limestone limits the possibilities of extraction.

Oak Point area

A small quarry 2 miles north of Oak Point, in l.s. 4, sec. 18, tp. 18, rge. 4WPM (Figure 6), was operated by David Bowman as a source of magnesian limestone, prior to 1924. The stone was used for low magnesia lime and for crushed stone. The property is at present held by The Winnipeg Supply and Fuel Company Limited. The quarry has been described by Goudge (1944), and Baillie (1951). Goudge reported analyses, made by Canada Cement Company Limited, on an 11-foot section, reproduced in Table 16. The quarry is irregularly shaped and approximately 4,000 square feet in area. It is reported to be 12 feet deep, but has been filled with water for many years to within 4 to 5 feet of the top of the exposed limestone. Part of the crusher and the remains of one of the former Keystone draw-kilns are located on the south edge of the quarry (Plate 4).

The rock exposed in the upper 4.5 feet is thin bedded (1 inch to 3 inches) mottled magnesian limestone, composed of brownish biosparite in a partially dolomitized buff biomicrite matrix. Undulations in the bedding planes are related to the alternation of biosparite in the thicker part and biomicrite matrix in the thinner part of each bed. The two most prominent sets of vertical joints are oriented 115 and 170 degrees azimuth.

In the ditch northwest of the quarry, mottled limestone is exposed over an area of 250 feet by 10 feet. The soil survey map of the Teulon area (Pratt *et al.*, 1961) indicates that bedrock is near surface in a ½ mile by ¼ mile area surrounding the quarry. The

TABLE 16. Elm Point Formation: Oak Point quarry; data from Goudge (1944)

Depth from surface (feet)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	Average
SiO_2	3.00	1.92	4.00	3.09	4.06	4.00	2.94	3.00	1.96	1.80	1.84	3.46
$Fe_2O_3 + Al_2O_3$	0.72	0.92	0.74	0.94	0.96	1.00	1.04	1.00	0.96	0.72	0.94	0.90
CaO	50.76	50.68	49.34	49.94	47.01	50.91	51.81	51.81	52.19	52.79	52.41	50.88
MgO	3.06	3.06	4.39	3.74	6.48	4.24	3.60	2.88	2.52	2.43	2.88	3.58
LOI	41.00	41.10	41.00	40.86	40.37	39.18	39.93	40.97	42.00	42.22	41.90	40.96
Total	99.08	98.22	99.47	99.38	99.42	99.33	99.68	99.66	99.63	99.96	99.97	99.78
$CaCO_3$	90.60	90.45	88.06	89.13	83.90	90.86	92.47	92.47	93.15	94.22	93.54	90.81
$MgCO_3$	6.40	6.40	9.18	7.82	13.55	8.87	7.52	6.02	5.27	5.08	6.02	7.49

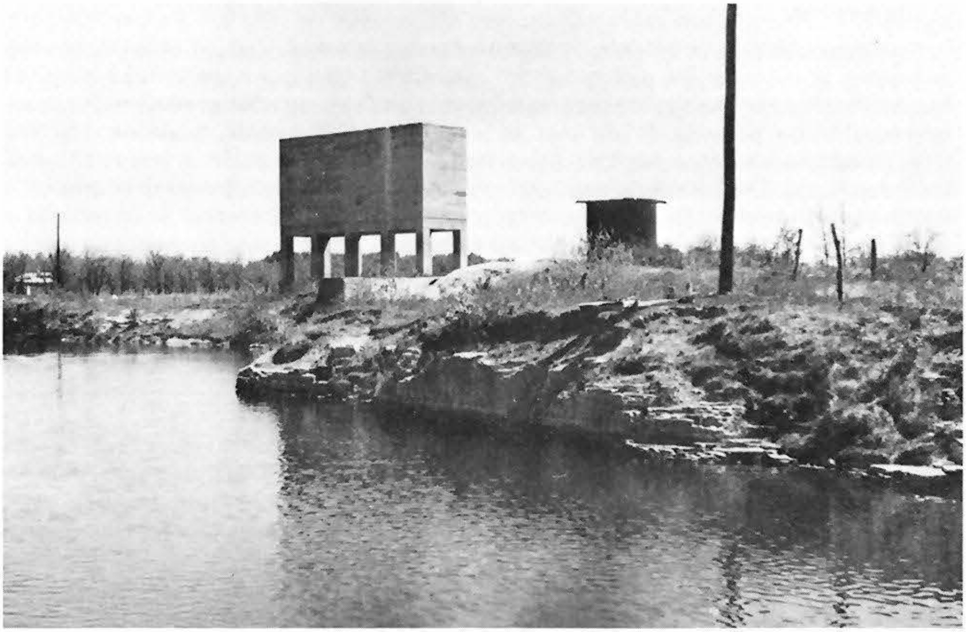

PLATE 4. Quarry at Oak Point in thin bedded Elm Point Formation, showing remains of crushing plant and kiln.

quarry is on the northeast portion of a slight topographic rise.

In drill hole FRED 69-1, southwest of the Oak Point quarry, the upper 15 feet was reported to consist of 3 feet of glacial drift and 12 feet of limestone. Below the level of the quarry floor, limestone was cored from 15 feet to 25 feet, at which depth the Ashern Formation was intersected. Detailed analyses of this core (Table 17) indicate, on average, a slightly lower magnesium carbonate content, and significantly lower SiO_2 and combined Fe_2O_3 and Al_2O_3 contents, compared with the quarry section described by Goudge (Table 16). The drilling results indicate a total thickness of 22 feet of Elm Point Formation in the area of the Oak Point quarry.

TABLE 17. Elm Point Formation, Oak Point; Drill hole FRED 69-1; l.s. 4, sec. 18, rge. 4WPM

Hole No. Footage	69-1 15-20	69-1 20-25	Average 15-25
SiO_2	2.1	1.0	1.55
Al_2O_3	0.3	0.3	0.3
Fe_2O_3	0.15	0.16	0.16
CaO	50.3	52.2	51.25
MgO	3.48	2.75	3.12
Na_2O	0.03	0.03	0.03
K_2O	0.21	0.13	0.17
P_2O_5	0.03	0.01	0.02
S	0.04	0.18	0.11
LOI	43.12	43.75	43.44
Total	99.75	100.55	100.15
$CaCO_3$	89.78	89.63	89.54
$MgCO_3$	7.28	5.75	6.52
Thickness	5 feet	5 feet	10 feet

Lily Bay area

An extensive area in which the Elm Point Formation either outcrops or is near surface is present in the northern part of tp. 20, rge. 6WPM, and the southern half of tp. 21, rge. 6WPM (Figures 6 and 7). Considerable exploration has been done by cement companies interested in the potential of this area as a source of high-calcium limestone. The area is 55 miles closer to Winnipeg than Steep Rock (95 miles total distance versus 150 miles for Steep Rock). The area of greatest potential is situated 7 to 9 miles west of Deerhorn.

Based on recent data, an area of approximately 12 square miles is considered to be underlain by 12 to 56 feet of Elm Point Formation, under a thin cover of glacial drift. The magnesia content of the limestone within this area ranges from 0.50 to 5.00 per cent.

Manitoba Mines Branch core hole M-2-70, one mile west of Lily Bay intersected 16 feet of magnesian limestone overlying 24.5 feet of high-calcium limestone, overlying the Ashern Formation. Detailed analyses are listed in Table 18.

Canada Cement Lafarge Ltd.; exploration program and Lily Bay quarry

An exploration drill program was carried out in the Lily Bay area (Figure 7) by Canada Cement Lafarge Ltd. Analyses for selected holes from the 1958 drill program (Table 19) were made available by courtesy of J. Selwyn. An examination of these analyses, along with that of Manitoba Mines Branch core hole M-2-70, indicates that the limestone varies

TABLE 18. Elm Point Formation, Manitoba Mines Branch core hole M-2-70, 175 feet west of southeast corner l.s. 1, sec. 5, tp. 21, rge. 6WPM

Footage	0-5	5-10	10-16	16-21	21-26	26-31	31-36	36-40.5
SiO_2	1.10	1.24	1.26	1.16	0.98	1.55	0.96	0.81
Al_2O_3	0.20	0.23	0.22	0.20	0.13	0.23	0.13	0.11
Fe_2O_3	0.19	0.19	0.23	0.19	0.24	0.28	0.22	0.21
MgO	3.05	3.70	2.85	1.83	1.81	1.95	2.06	2.08
CaO	51.88	50.57	51.92	53.06	53.06	52.24	52.87	53.30
Na_2O	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.07
K_2O	0.13	0.18	0.19	0.17	0.14	0.27	0.14	0.08
P_2O_5	0.00	0.01	0.03	0.02	0.00	0.00	0.01	0.00
LOI	43.57	43.82	43.59	43.47	43.54	43.01	43.62	43.75
S	0.09	0.10	0.08	0.10	n.d.	0.09	n.d.	n.d.
Total	100.24	100.07	100.40	100.24	99.93	99.65	100.04	100.41
$CaCO_3$	92.60	90.26	92.67	94.70	94.70	93.24	94.36	95.13
$MgCO_3$	6.38	7.74	5.96	3.83	3.79	4.08	4.31	4.35
Thickness	5 feet	5 feet	6 feet	5 feet	5 feet	5 feet	5 feet	4.5 feet

PLATE 5. Lily Bay quarry, Canada Cement Lafarge Ltd.; 30 feet of the Elm Point mottled limestone is exposed.

in quality. In hole 58-3-58, for example, 35 feet of magnesian limestone was intersected (average 90.58% $CaCO_3$, 7.04% $MgCO_3$); in hole 58-3-16, high-calcium limestone comprised 56 feet of the section (average 94.87% $CaCO_3$, 3.10% $MgCO_3$).

Canada Cement Lafarge Ltd. began production of high-calcium limestone in August 1971, from a quarry in the NW¼ sec. 33, tp. 20, rge. 6WPM, one mile west of Lily Bay. By October 1971, the quarry was approximately 140 feet square, and exposed 30 feet of thin-bedded mottled limestone of the Elm Point Formation (Plate 5). Mottling is pronounced in the upper 10 feet, and is accentuated by the contrast between the brown limestone mottles and the light yellowish grey matrix in which the magnesia content is concentrated. The lower 20 feet has a less pronounced mottling. The water table was intersected at a depth of 28 feet. On the east wall of the quarry, films of red clay are present along some bedding planes, but layers of red shale were not observed.

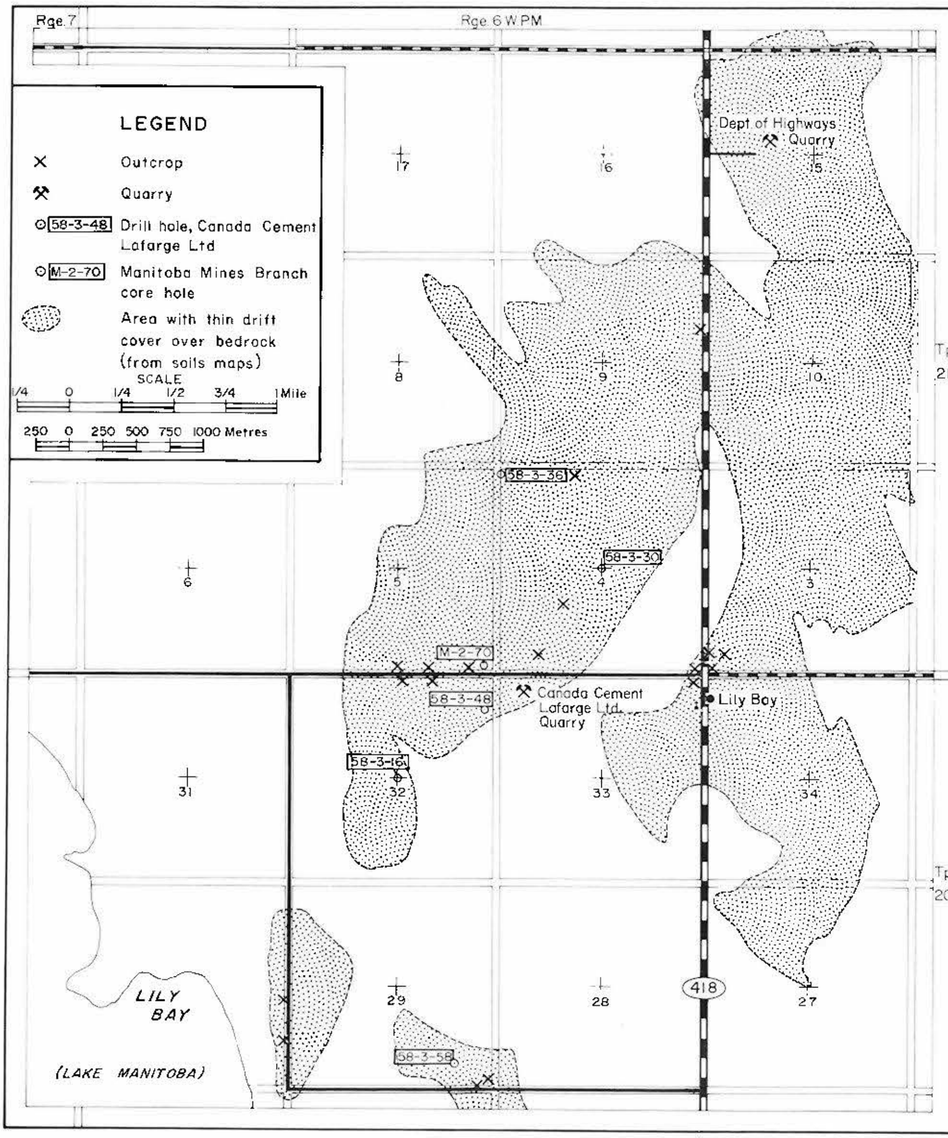

Figure 7: Lily Bay area: drill hole locations and outcrops, Elm Point Formation

TABLE 19. Elm Point Formation, Lily Bay area; analyses courtesy of J. Selwyn, Canada Cement Lafarge Ltd.

Hole No.					Hole 58-3-58				
Footage	3-7	7-11	11-15	15-19	19-23	23-27	27-31	31-35	35-38
SiO_2	1.46	1.96	2.10	1.40	1.62	2.22	2.30	1.54	1.56
R_2O_3[1]	0.40	0.30	0.50	0.36	0.30	0.40	0.48	0.34	0.42
CaO	49.30	51.22	50.48	52.80	51.52	50.55	50.55	50.55	49.50
MgO	4.70	2.74	3.29	2.00	2.82	3.29	3.29	3.65	4.89
LOI	43.64	43.16	43.20	43.04	43.14	42.90	42.96	43.40	43.38
Total	99.50	99.48	99.57	99.60	99.50	99.36	99.58	99.48	99.75
$CaCO_3$	87.99	91.42	90.10	94.24	91.95	90.22	90.22	90.22	88.35
$MgCO_3$	9.83	5.73	6.88	4.18	5.90	6.88	6.88	7.63	10.23
Thickness	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	3 ft.

Hole No.								Hole 58-3-16							
Footage	5-9	9-13	13-17	17-21	21-25	25-29	29-33	33-37	37-41	41-45	45-49	49-53	53-57	57-61	61-62
SiO_2	1.20	1.16	0.74	0.80	1.08	1.28	1.78	1.50	1.42	1.20	1.90	2.28	1.00	0.84	0.72
R_2O_3[1]	0.30	0.32	0.20	0.36	0.30	0.50	0.60	0.28	0.40	0.28	0.36	0.48	0.44	0.50	0.88
CaO	54.61	53.70	54.21	53.55	54.39	52.19	51.15	52.42	53.10	53.55	52.87	52.72	53.25	52.49	43.95
MgO	0.50	1.33	1.00	1.46	0.69	2.42	2.98	1.96	1.33	1.17	1.30	1.23	1.20	2.21	8.55
LOI	43.10	42.96	42.90	43.00	42.88	42.90	42.78	43.30	43.24	43.44	42.48	42.60	43.30	43.60	44.80
Total	99.71	99.47	99.05	99.17	99.34	99.29	99.29	99.46	99.49	99.64	98.91	99.31	99.19	99.64	98.90
$CaCO_3$	97.47	95.84	96.75	95.58	97.08	93.15	91.29	93.56	94.77	95.58	94.36	94.09	95.04	93.68	78.44
$MgCO_3$	1.05	2.78	2.09	3.05	1.44	5.06	6.23	4.10	2.78	2.45	2.72	2.57	2.51	4.62	17.88
Thickness	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	1 ft.

Hole No.						Hole 58-3-48					
Footage	2-6	6-10	10-14	14-18	18-22	22-26	26-30	30-34	34-38	38-42	42-46
SiO_2	0.92	1.24	1.78	1.50	3.04	1.72	1.66	1.60	2.30	1.48	1.22
R_2O_3[1]	0.32	0.28	0.40	0.38	0.76	0.32	0.34	0.40	0.46	0.40	0.44
CaO	53.02	51.97	50.79	50.49	51.89	52.60	52.75	52.53	51.40	52.23	52.15
MgO	2.05	2.50	3.04	4.37	2.57	1.80	1.78	1.98	2.49	2.22	2.49
LOI	43.38	43.68	43.16	42.88	40.94	43.80	43.10	43.12	42.90	43.36	43.04
Total	99.69	99.67	99.16	99.62	99.20	99.52	99.63	99.63	99.55	99.69	99.34
$CaCO_3$	94.63	92.75	90.65	90.11	92.61	93.88	94.15	93.76	91.74	93.22	93.08
$MgCO_3$	4.29	5.23	6.36	9.14	5.38	3.7[illegible]	3.72	4.14	5.21	4.64	5.21
Thickness	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.

Hole No.				Hole 58-3-30					Hole 58-3-36		
Footage	5-9	9-13	13-17	17-21	21-25	25-29	29-30	4-8	8-12	12-16	16-1
SiO_2	1.94	1.44	2.18	2.90	1.26	1.32	3.34	1.94	1.50	1.06	1.76
R_2O_3[1]	0.42	0.58	0.76	0.60	0.52	0.42	1.36	0.62	0.40	0.46	1.06
CaO	52.37	54.46	52.05	51.97	53.63	51.22	30.51	51.90	53.10	52.88	43.69
MgO	1.10	0.62	1.91	1.61	1.30	3.28	18.83	2.08	1.55	1.89	8.53
LOI	42.50	42.70	42.40	42.12	42.40	43.04	44.72	42.78	42.50	43.06	42.12
Total	98.69	99.80	99.30	99.20	99.11	99.28	98.76	99.32	99.05	99.35	97.16
$CaCO_3$	93.47	97.20	92.90	92.76	95.72	91.42	54.45	92.63	94.77	94.38	77.98
$MgCO_3$	2.30	1.30	3.99	3.37	2.72	6.86	39.38	4.35	3.24	3.95	17.84
Thickness	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	4 ft.	1 ft.	4 ft.	4 ft.	4 ft.	3 ft.

[1] $R_2O_3 = Al_2O_3 + Fe_2O_3$

Hole 58-3-58: 250′ W and 600′ N of SW corner l.s. 1, sec. 29, tp. 20, rge. 6WPM; overburden, 3 feet; elev. 829.1 feet.
Hole 58-3-16: centre of sec. 32, tp. 20 rge. 6WPM; overburden, 5 feet; elev. 835.3 feet.
Hole 58-3-48: 200′ W and 800′ S of NE corner, l.s. 16, sec. 32, tp. 20, rge. 6WPM; overburden, 2 feet; elev. 841.2 feet.
Hole 58-3-30: centre of sec. 4, tp. 21, rge. 6WPM; overburden, 5 feet; elev. 842.1 feet.
Hole 58-3-36: NW corner l.s. 13, sec. 4, tp. 21, rge. 6WPM; overburden, 4 feet; elev. 832.6 feet.

PLATE 6. Location of measured section, south wall of Department of Highways quarry; note variation in mottling. The lighter areas have a higher MgO content than the darker mottles.

Department of Highways quarry

A quarry was opened in 1970 by the Manitoba Department of Highways at l.s. 11, sec. 15, tp. 21, rge. 6WPM, 2½ miles north of Lily Bay (Figure 7). A total of 70,000 tons of Elm Point limestone was removed for use as crushed stone for highway construction. The quarry is 175 feet long, 125 feet wide, and 17 feet deep, and is dry. It shows some unique features of the lithology of the Elm Point Formation as described in a section measured on the south wall of the quarry (Table 20), and shown in Plate 6.

The quarry beds dip gently to the south, at slightly more than one degree. The upper beds have the appearance of being 7 to 12 inches thick, but break readily into slabby layers 1 to 3 inches thick; the lower beds do not split as readily. The two most prominent

TABLE 20. Measured section of Elm Point limestone, Department of Highways quarry, l.s. 11, sec. 15, tp. 21, rge. 6WPM

		Thickness in feet
Top soil:	Variable; 3 to 8 inches	
Unit 4c:	Limestone, magnesian; high contrast mottling, brown and buff; 30 to 40% brown mottles with drusy coating on bedding planes and fractures	1.2
Unit 4b:	Limestone, magnesian; strongly contrasted mottling, chocolate brown and light buff; brown mottling variable from 35 to 55%; medium bedded, 5 to 8 inches, but breaks into thin flaggy beds, 1 to 2 inches thick; secondary calcite; fossiliferous: brachiopods, crinoid stems noted	4.3
Unit 4a:	Limestone, magnesian; 35 to 45% brown mottles; 2 to 4-inch beds; vugs up to ½ inch; some iron staining	1.2
Unit 3:	Limestone (marker bed in quarry); predominantly brown limestone in almost continuous layer; crinoid stems, gastropods noted; light brown finely crystalline matrix; 65 to 85% brown limestone; some secondary iron oxide pellets, up to ¼-inch in diameter	1.2
Unit 2:	Limestone, magnesian; strongly mottled, 25 to 30% brown mottles in buff micritic matrix; beds 3 to 6 inches thick	5.4
Unit 1:	Limestone, magnesian; as above; beds 7 to 12 inches thick	5.0
	Total limestone	18.3

TABLE 21. Elm Point Formation, Department of Highways quarry, l.s. 11, sec. 15, tp. 21, rge. 6WPM

Unit Footage, from surface	Unit 4 0.0-6.7	Unit 3 6.7-7.9	Unit 2 7.9-13.3	Unit 1 13.3-18.3
SiO_2	1.05	0.53	0.89	1.19
Al_2O_3	0.30	0.10	0.30	0.50
Fe_2O_3	0.18	0.15	0.11	0.15
CaO	49.32	52.49	50.10	49.82
MgO	5.00	2.71	4.33	4.38
Na_2O	0.04	0.02	0.02	0.02
K_2O	0.14	0.06	0.11	0.15
P_2O_5	0.00	0.00	0.00	0.00
S	0.02	0.06	0.06	0.06
LOI	44.16	44.03	44.27	43.97
Total	100.2	100.15	100.2	100.25
$CaCO_3$	88.03	93.68	89.42	88.92
$MgCO_3$	10.46	5.67	9.06	9.16
Thickness	6.7 feet	1.2 feet	5.4 feet	5.0 feet

joint sets are almost vertical and strike 60 degrees and 130 degrees azimuth.

The distribution of the mottling is irregular (see Table 20), and makes selection of an average sample for chemical analysis difficult. A weighted, random sample of each bed within the analyzed intervals was selected and each sample was crushed and quartered for chemical analysis (Table 21).

Area north of Lily Bay

The variable magnesia content in the Elm Point limestone in this area (Figure 6) is shown by partial analyses from two outcrops. An analysis of a few inches of a buff, faintly mottled micritic limestone from a ditch outcrop in l.s. 9, sec. 9, tp. 21, rge. 6WPM, 1.65

miles north of the Lily Bay corner, indicated it is of high-calcium quality (54.08% CaO, 1.27% MgO, and 43.80% LOI; recalculated: 96.52% $CaCO_3$ and 2.66% $MgCO_3$). Mottled brown and yellowish buff biomicrite, exposed in a low ridge in SE¼ sec. 21, tp. 22, rge. 7WPM, 4.5 miles northwest of Pine View, is a magnesian limestone (50.70% CaO, 3.90% MgO, and 44.10% LOI; recalculated: 90.49% $CaCO_3$ and 8.16% $MgCO_3$).

Dog Lake-Ashern area

Numerous outcrops of the Elm Point Formation are present in the Dog Lake-Camper-Ashern-Moosehorn Bay area (Figure 8). Drift cover in the area is generally thin. Manitoba Soils Survey maps (Pratt *et al.*, 1961; and Mills and Smith, 1971) were particularly useful in locating a number of previously unreported outcrops. Outcrops occur either as small knolls or domes, up to a few thousand feet across, or as flat pavement-type exposures in ditches or in fields under a thin soil cover. Drilling would be required to determine thickness of limestone remaining in any particular location. Thickness of limestone near Dolly Bay is probably greater than in the eastern part of the area.

Partial analyses of some of the numerous outcrops examined are listed in Table 22. They indicate quality of the rock ranges from dolomitic limestone to high-calcium limestone.

TABLE 22. Partial analyses, Elm Point Formation, Dog Lake—Dolly Bay area

Sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CaO	47.53	50.46	52.81	55.70	54.46	50.06	54.04
MgO	6.63	3.95	1.67	0.35	0.25	4.86	1.77
LOI	44.47	43.69	43.30	43.93	42.95	44.44	44.34
Total	98.65	98.1	98.8	100.0	97.65	99.35	100.15
$CaCO_3$	84.83	90.06	94.26	99.41	97.20	89.35	96.45
$MgCO_3$	13.87	8.26	3.49	0.73	0.52	10.16	3.70

(1) 2.5 miles south of Camper; l.s. 16, sec. 32, tp. 23, rge. 6WPM.
(2) 2 miles east of Dog Lake; l.s. 5, sec. 3, tp. 24, rge. 7WPM.
(3) 2 miles north of Dog Lake; l.s. 13, sec. 26, tp. 24, rge. 8WPM.
(4) 1.5 miles east of Dolly Bay; l.s. 16, sec. 34, tp. 24, rge. 9WPM.
(5) 1.5 miles southeast of Moosehorn Lake; l.s. 3, sec. 15, tp. 25, rge. 8WPM.
(6) South of Moosehorn Bay; SW sec. 24, tp. 25, rge. 9WPM.
(7) South of Moosehorn Bay; l.s. 3, sec. 23, tp. 25, rge. 9WPM.

Spearhill area

A circular outlier of the Elm Point Formation occurs at Spearhill on a topographic rise. The highest point is 50 feet above the surrounding plain. The hill, some 80 acres in extent, is centred in SE¼ sec. 22, tp. 27, rge. 7WPM, and is located 6 miles northeast of the closest outcrop of the Elm Point Formation (Figure 8).

Spearhill quarry: Steel Brothers Canada Ltd.

The limestone is quarried as a source of chemical lime and limestone by Steel Brothers Canada Ltd. A detailed description of the quarry was reported by Goudge (1944), and Baillie (1951) described the lithology and structure. An analysis of the fold structures exhibited in the southern part of the quarry was made by Wardlaw *et al.* (1969).

The rock is predominantly mottled high-calcium limestone, with variations in the intensity of the mottling throughout the quarry (Plate 7). However, ridges of impure limestone have been left protruding above the quarry floor, as well as one reported occurrence of dolomite that Baillie (1951) suggested may represent a dolomitic reef facies of the Elm Point Formation. The impure limestone has a low magnesia content, but it contains more silica, iron oxides, and alumina than is desirable for use in lime production. Various analyses of the

PLATE 7. Spearhill quarry, Steel Brothers Canada Ltd.; northeast and east walls, showing 15 feet of the Elm Point Formation.

TABLE 23. Analyses of Elm Point Formation, Spearhill quarry

Sample	(1)	(2)	(3)	(4)
SiO_2	1.18	5.26	0.74	0.81
Al_2O_3	0.25	0.42	0.81	0.23
Fe_2O_3	0.20	0.70	0.06	0.16
CaO	54.74	51.32	54.17	55.27
MgO	0.19	0.94	0.16	0.25
Na_2O	n.d.	n.d.	n.d.	0.08
K_2O	n.d.	n.d.	n.d.	0.12
MnO	n.d.	n.d.	0.024	n.d.
P_2O_5	0.02	0.02	0.025	0.04
S	Nil	0.01	n.d.	0.04
TiO_2	n.d.	n.d.	Trace	n.d.
CO_2	43.18	41.30	42.68	n.d.
LOI	n.d.	n.d	n.d	43.61
Total	99.76	99.97	98.51	100.6
$CaCO_3$	97.71	91.60	96.68	98.65
$MgCO_3$	0.40	1.96	0.33	0.52
Thickness	15 feet	?	?	15 feet

(1) "Spearhill: Fifteen feet of Elm Point limestone in face of quarry;" from Goudge (1944, p. 61).
(2) "Spearhill: Yellow mottled limestone from a reef-like mass in the quarry;" from Goudge (1944, p. 61).
(3) Analysis of "the limestone at the quarry", from Baillie (1951, p. 66); analysis by Manitoba Mines Branch.
(4) Spearhill quarry, east wall, as of July 1971; 15.0-foot section.

quarry rocks are listed in Table 23. A distinctive feature of this Elm Point limestone is its very low magnesia content.

At the south end of the quarry, the limestone beds dip slightly southward, although minor undulations are common. The floor of the quarry is relatively uneven, having the appearance of almost continuous low domes. The underlying rock, wherever checked, is a reddish to orange silty argillaceous rock, gradational to the Ashern Formation. The irregular quarry floor contrasts sharply with the generally flat floor of the Canada Cement Lafarge Ltd. quarry at Steep Rock.

The origin of the folds in the Elm Point strata and of the domal structures on the floor of the quarry is problematic. It is possible that the knoll, being an outlier of the Elm Point Formation lying over incompetent beds of the Ashern Formation was subjected to glacial ice-thrusting during Pleistocene time, as suggested by Wardlaw *et al.* (1969). In some areas, for example along the east wall of the 1971 working face, faulting was noted. Beds on the south side are down-faulted, and dip as much as 26 degrees to the north. Other possible causes of the folds and domes are the presence of reef structures in the underlying Silurian strata (although these would tend to be covered by the Ashern Formation and the relief subdued), or the occurrence of low reef structures in the basal part of the Elm Point Formation, as suggested by Baillie (1951).

Steep Rock area

The Elm Point Formation is at or close to the surface in much of a 30-square mile area centred around Steep Rock (Figure 8). The type section of the Elm Point Formation is exposed in cliffs on the east shore of Lake Manitoba, 4 miles south of the village. The formation in that area has a maximum known thickness of 53 feet (J. Selwyn, personal communication). The limestone has a well developed mottling with small amounts of iron oxides concentrated in the greyish brown mottles. Stain tests show small amounts of dolomite crystals finely disseminated in the yellowish buff matrix, indicating incipient dolomitization.

Steep Rock quarry: Canada Cement Lafarge Ltd.

The Elm Point Formation is exposed in the Canada Cement Lafarge Ltd. quarry at Steep Rock (Frontispiece). The quarry is located mainly in NW¼ sec. 34, tp. 28, rge. 10WPM (Figure 8). Up to 50 feet of mottled limestone has been reported in the quarry. It occurs in beds 3 to 11 inches thick, and is fossiliferous in places. In general, the limestone appears to be flat-lying, but some low, broad domes are present.

Numerous partial analyses of the limestone have been reported by Goudge (1944), and an analysis by Baillie (1951) is included in Table 24. From the analyses reported by Goudge (1944), it is evident that the rock is a fairly uniform high-calcium limestone. The average of 49 analyses from the lower 20 feet of the formation below the 1944 level of the quarry floor indicated 2.07 per cent SiO_2, 0.34 per cent Fe_2O_3 plus Al_2O_3, 95.59 per cent $CaCO_3$, and 1.33 per cent $MgCO_3$. The average of two samples representing the upper 26 feet of the limestone exposed in the quarry, is 1.15 per cent SiO_2, 0.22 per cent Fe_2O_3, 0.30 per cent Al_2O_3, 95.49 per cent $CaCO_3$, and 2.59 per cent $MgCO_3$.

The basal two to three feet of Elm Point Formation, overlying the Ashern Formation, is varicoloured and argillaceous, with a high magnesia content; it is not quarried. The Elm Point Formation thins to the east, as a result of regional westward dip and of increased glacial erosion to the east. The 1971 working face at the east end of the quarry ranged from 32 to 38 feet in height, reflecting differences in depth of glacial erosion. A large area has been stripped of overburden on the south and east sides of the quarry. Vertical joints strike 34 degrees and 145 degrees azimuth.

Large cone-shaped solution caverns have been encountered in a few places in the quarry, and these extend from surface almost to the quarry floor. The caverns contain smooth textured clays of green, orange and brown hues, that in places enclose clusters of pyrite crystals, marcasite nodules, and well preserved crinoid stems. The age of the clays is uncertain, but they are believed to have been deposited at some time within the post-Devonian to early Cretaceous interval. The normally even bedding of the limestone is disturbed around these caverns, suggesting collapse of overlying unsupported beds into the caverns.

Faulkner quarry: Steel Brothers Canada Ltd.

The Winnipeg Supply and Fuel Company Limited opened a new quarry in 1969, 4 miles west of Faulkner and 2 miles southeast of Steep Rock (Figure 8).The quarry has

TABLE 24. Elm Point Formation, Steep Rock area and Basket Lake area

Sample Footage from surface	Steep Rock quarry	Faulkner quarry Unit 3 0-6	Faulkner quarry Unit 2 6-12	Faulkner quarry Unit 1 12-16.5	Faulkner	Elm Point	Basket Lake hill	P.R. 328
SiO_2	1.26	0.81	0.72	0.77	–	–	1.00	–
Al_2O_3	0.61	0.20	0.20	0.20	–	–	0.27	–
Fe_2O_3	0.06	0.18	0.20	0.18	–	–	0.17	–
CaO	54.79	53.85	53.89	53.80	52.70	55.23	54.57	54.57
MgO	0.25	1.05	1.53	1.21	2.38	0.30	0.50	0.35
Na_2O	–	0.02	0.04	0.03	–	–	0.03	–
K_2O	–	0.10	0.09	0.09	–	–	0.12	–
P_2O_5	0.021	0.01	0.01	Nil	–	–	0.02	–
MnO	0.024	–	–	–	–	–	–	–
TiO_2	Trace	–	–	–	–	–	–	–
S	–	0.03	0.02	0.02	–	–	0.02	–
LOI	43.01	43.48	43.55	43.52	43.74	43.57	43.43	43.33
Total	100.055	99.75	100.25	99.82	98.8	99.1	100.13	98.25
$CaCO_3$	97.80	96.11	96.18	96.02	94.06	98.57	97.40	97.40
$MgCO_3$	0.52	2.20	3.20	2.53	4.98	0.63	1.05	0.73
Thickness	—	6 feet	6 feet	4.5 feet	–	–	–	–

Steep Rock quarry: NW¼ sec. 34, tp. 28, rge. 10WPM; from Baillie (1951, p. 65).
Faulkner quarry: l.s. 11, sec. 23, tp. 28, rge. 10WPM; measured section, south wall.
Faulkner, 3 miles south: l.s. 1, sec. 9, tp. 28, rge. 9WPM; outcrop.
Elm Point, 2 miles east: l.s. 1, sec. 10, tp. 28, rge. 10WPM; outcrop.
Basket Lake: outcrop samples from top of hill and floor of gravel pit; sec. 19, tp. 33, rge. 11WPM.
P.R. 328: outcrop north of road in SW¼ sec. 18, tp. 32, rge. 11WPM.

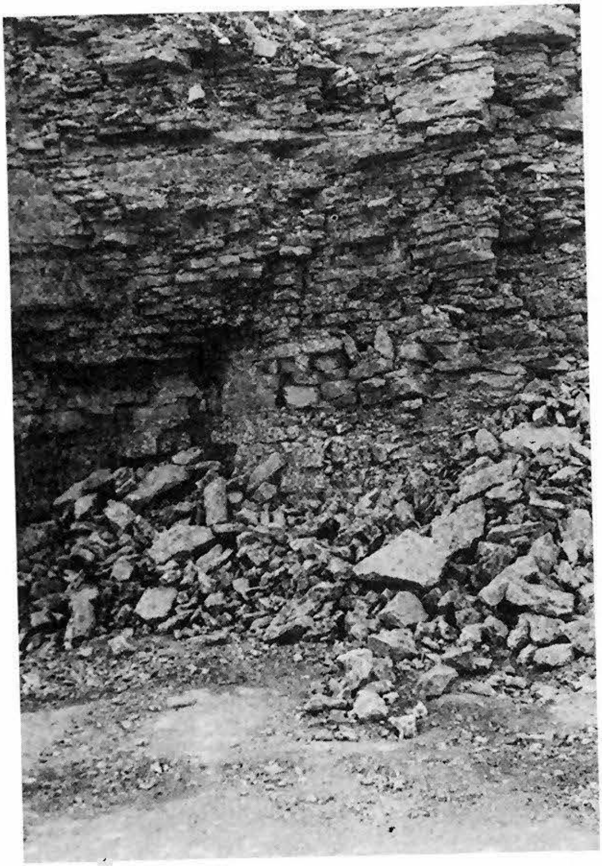

PLATE 8. Location of 18.5-foot measured section of southwest face of the Faulkner quarry, Steel Brothers Canada Ltd.; rock hammer at centre of photo indicates scale.

been operated by Steel Brothers Canada Ltd. since 1972.

The Elm Point limestone is exposed in several outcrops and is present under a thin soil and drift cover over a wide area in the vicinity of the quarry. In 1971, an 18.5-foot section was measured (Table 25) along the southwest face of the quarry; the basal two feet are concealed by rubble. The rock is the typical brown and buff mottled high-calcium limestone of the Elm Point Formation (Plate 8). It has been used in both of the company's lime plants, at Spearhill and at Fort Whyte.

TABLE 25. Measured section, Faulkner quarry

		Thickness in feet
Overburden:	0 to 6 inches	
Unit 3:	Limestone, mottled; medium brown mottles in buff matrix; matrix forms approximately 50% of rock; calcitic drusy crust noted on undulating bedding planes; thin bedded, 1 inch to 3 inches	6
Unit 2:	Limestone, mottled; as above, except thicker bedded, 4 inches to 9 inches, in lowest 1.7 feet of section; this lower part is more massive, with subconchoidal fracture; over-all mottling of this section is not as pronounced because of darker buff colour of matrix	6
Unit 1:	Limestone, mottled; sharp contrast in mottling; light buff matrix, with patches of orange staining; beds 4 inches to 6 inches thick	4.5
	Total exposed section	16.5

A few zones were noted in which the usual buff matrix of the limestone is stained a bright orange. These zones are up to 15 feet wide at the surface, and extend irregularly downward 8 to 10 feet. A solution cavity 6 feet in diameter, filled with varicoloured clay (green, orange, mauve, white, and grey) mixed with abundant sand and some sandstone, was noted on the west wall of the quarry, 5 feet below the top of the face.

Channel samples from the south face of each of the three units listed in Table 25 were analyzed (Table 24). The floor of the quarry shows slight undulations with a maximum relief of 2 to 3 feet. Two major fracture sets were measured at 180 degrees and 275 degrees azimuth; both sets are nearly vertical.

Other exposures, Steep Rock area

As shown on the soils map for the Grahamdale area (Mills and Smith, 1971), and in Figure 8, the Elm Point limestone is at or close to the surface in a large area around Steep Rock. The soil type in the area (Narcisse complex), consists of 6 to 20 inches of stony till overlying limestone bedrock. Sections 1 to 4 in township 29, range 10WPM as well as all the land area of tp. 28, rge. 10WPM, are believed to be underlain by the Elm Point Formation. The thickness of limestone will be dependent on the depth of the drift cover, and the regional dip of the formation, which is estimated to be 12 to 15 feet per mile.

Elm Point limestone was noted as far east as l.s. 1, sec. 9, tp. 28, rge. 9WPM, 3 miles south of Faulkner, where the rock consists of 1½-inch to 2-inch beds of mottled limestone in which the partially dolomitized matrix is stained dark orange. A partial chemical analysis (Table 24) indicates it is a high-calcium limestone. Samples from a broad outcrop area of fossiliferous, mottled limestone in l.s. 1, sec. 10, tp. 28, rge. 10WPM, east of Elm Point, were analyzed (Table 24), and show a high purity. At least 50 feet of Elm Point limestone is present in this area. Large reserves are reportedly present in the Elm Point-Steep Rock Point area to the northwest. The thickness of limestone present in the general area of the Faulkner quarry is about 30 feet.

Basket Lake-Waterhen Lake area

In the area extending from Portage Bay on Lake Manitoba northwest to Waterhen Lake (Figure 1), only a few outcrops are known. However, access in this area is limited, and the area has not been thoroughly explored.

In an area of approximately 3 square miles, extending from Basket Lake southward to Highway 328 (Figure 9), rock either outcrops or is present under a thin cover of soil. One square mile of this area immediately south of Basket Lake consists of a large hill of limestone, with relief of up to 45 feet. Limestone samples were obtained from the top of the hill, from the east slope a few feet below the top, from an outcrop in the floor of a gravel pit at a level about 15 feet below the top, and from an outcrop ridge along Provincial Road 328. Chemical analyses are listed in Table 24. The limestone is of high purity, and differs from the typical Elm Point Formation in that mottling is barely visible, and the rock is extremely tough. It is a greyish yellow, finely crystalline to micritic limestone, with abundant calcite crystals in places.

An occurrence of Elm Point Formation on an island at the north end of Waterhen Lake is reported by Norris and Uyeno (1971), and probably represents a facies transitional to the Winnipegosis Formation.

On Pelican Bay, Lake Winnipegosis, 57 feet of high-calcium limestone was intersected in Mines Branch core hole M-2-73, in l.s. 9, sec. 33, tp. 43, rge. 21WPM. The hole ended in limestone, which is correlated with the Elm Point Formation.

Lake St. Martin area

High-calcium limestone, some of which has been correlated with the Devonian Elm Point Formation, is preserved within the Lake St. Martin crypto-explosion crater structure. This 14-mile diameter circular structure, centred in sec. 33, tp. 32, rge. 8WPM (Figure 9) is believed to have been formed either as a result of volcanic explosion or by impact of a meteorite in Permian or Triassic time. The details of the structure have been described by McCabe and Bannatyne (1970).

The limestone sections are interpreted as slumped or down-faulted blocks of Ordovician to Devonian formations that were present in the area at the time of crater formation. Carbonate rocks have been noted in outcrop east of Gypsum Lake, and occur below a shallow drift cover within the western rim of the crater, and underlying 200 feet of a volcanic-like rock near the southeastern edge of the crater. All known carbonate occurrences lie within one mile or less of the postulated rim of the crater.

The original depth of the crater, following uplift of a central shock-metamorphosed block of Precambrian rock, was at least 1,000 feet and possibly considerably more. The crater was filled with fall-back breccia and covered in part by a volcanic-like rock of trachyandesite composition that solidified from a molten state. The (?) Permian-Triassic Lake St. Martin Series, as defined by McCabe and Bannatyne (1970), includes the fall-back breccia, granite breccia, carbonate breccia, carbonate slump blocks, and the trachyandesite. Microfaunal studies have confirmed that some of the limestone slump blocks are of similar age to Devonian Elm Point Formation (T. T. Uyeno, personal communication). The Lake St. Martin Series was covered at one time by red beds and gypsum deposits of Jurassic or Jura-Triassic age, most of which have been removed by subsequent erosion, especially from the southern half of the crater. The gypsum is quarried north of Gypsumville.

Limestone is known to outcrop within the crater at only one locality, 1.5 miles east of Gypsum Lake. A clearing 400 feet by 250 feet exposes limestone under little or no soil cover. Some of the rock is brecciated, occurring as buff limestone fragments in a reddish limestone banded matrix. Generally, the limestone is thin bedded and flaggy, and the clearing has much limestone rubble scattered throughout. The analysis (Table 26) indicates it is a slightly argillaceous high-calcium limestone. A thickness of only about two feet is exposed. Microfaunal studies indicate an Ordovician age for this limestone (T. T. Uyeno, personal communication).

Drill hole LSM-1, drilled on an outcrop knoll of the trachyandesite rock near the south shore of The Narrows of Lake St. Martin, intersected 214 feet of the melt rock, 11 feet of granitic breccia, and 71 feet of carbonate breccia to the bottom of the hole at a depth of 296 feet. All the rocks are included in the St. Martin Series. The carbonate breccias exhibit a high degree of fracturing, and include intervals of argillaceous limestone, calcareous shale, and dolomite. In the upper 10 feet of the zone, from a depth of 225 to 235 feet, some thin layers of granitic breccias occur with the carbonates. Although high-calcium limestone beds are present (e.g. 96.38% $CaCO_3$ and 2.03% $MgCO_3$, at 239 feet), the interval from 239 to 257 feet has an average $MgCO_3$ content of 5.63 per cent (Table 26). The age of the beds in this section is not known; the lithology does not resemble that of Paleozoic limestones that outcrop in southwestern Manitoba.

Drill hole LSM-14, 3 miles northwest of Gypsumville, is of particular interest because only 29 feet of drift overlies limestone. The uppermost 18 feet of bedrock is high-calcium limestone (Table 26), in part fractured. The remainder of the core in this hole, from 47 to 199 feet, consists of zones of fractured or brecciated limestone and dolomite, interbedded with some shale beds and zones of mixed limestone, dolomite, and shale breccia.

One of the thickest sections of high-calcium limestone in Manitoba was cored between depths of 70 and 150 feet in drill hole LSM-6, 2 miles southwest of Gypsumville. This location lies a short distance inside the postulated rim of the crater. Glacial drift and soil are 42 feet thick. The interval from 42 to 70 feet consists of interbedded limestone, dolomitic limestone and dolomite. In contrast to the brecciated or fractured nature of the previous occurrences, this interval shows fine horizontal laminations, with little evidence of disturbance. The interval from 70 to 150 feet also appears undisturbed, and consists of mottled yellowish brown and greyish yellow micritic high-calcium limestone. The limestone is identical in appearance to the Elm Point Formation, and studies of conodont fauna by T. T. Uyeno (personal communication) have confirmed the Elm Point age. The interval from 70 to 85 feet is an almost pure limestone, containing 99.07 per cent $CaCO_3$; the average carbonate content of the entire 80-foot interval is 96.24 per cent $CaCO_3$ and 1.70 per cent $MgCO_3$ (Table 26). This 80-foot interval may represent the only complete section of the high-calcium limestone facies of the Elm Point Formation in Manitoba. Within the main outcrop belt itself, the upper beds have been eroded to an unknown depth and westward from the outcrop belt, the limestone grades laterally to dolomite. The location

TABLE 26. Limestone in Lake St. Martin Series, Lake St. Martin crater structure

Hole No. Footage	5-25-33-8WPM (outcrop)	LSM-1 239	LSM-1 239-248	LSM-1 248-257	LSM-14 29-38	LSM-14 38-47	LSM-6 70-85	LSM-6 85-95	LSM-6 95-110	LSM-6 110-130	LSM-6 130-150	LSM-6 70-150
SiO_2	3.24	1.15	2.76	2.22	2.8	1.37	0.16	0.43	1.21	1.24	1.17	0.92
Al_2O_3	0.67	0.30	0.69	0.72	0.3	0.16	0.02	0.03	0.35	0.27	0.22	0.21
Fe_2O_3	0.63	0.40	0.33	0.31	0.18	0.32	0.10	0.22	0.52	0.16	0.16	0.23
CaO	52.46	54.0	52.35	52.50	54.27	53.4	55.51	54.46	51.32	54.20	54.55	54.04
MgO	0.88	1.10	2.62	2.76	0.20	1.72	0.28	0.80	2.54	0.42	0.33	0.81
Na_2O	0.05	Nil	0.07	0.07	Trace	Trace	0.02	0.21	0.03	0.08	0.03	0.06
K_2O	0.34	0.07	0.02	0.01	0.20	0.13	0.01	0.06	0.18	0.17	0.15	0.10
P_2O_5	0.05	0.01	0.08	0.05	0.01	0.04	0.05	0.04	0.05	0.09	0.08	0.08
S	0.04	n.d.	0.02	0.01	0.03	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
LOI	42.16	43.24	41.56	41.56	42.74	43.50	43.78	43.52	42.85	43.16	43.19	43.28
Total	100.5	100.27	100.5	100.2	100.75	100.65	99.90	99.50	98.84	99.54	99.70	99.57
$CaCO_3$	93.63	96.38	93.43	93.70	96.86	95.31	99.07	97.20	91.60	96.73	97.36	96.45
$MgCO_3$	1.84	2.03	5.48	5.77	0.42	3.60	0.57	1.67	5.31	0.88	0.69	1.69
Thickness	–	1 foot	9 feet	9 feet	9 feet	9 feet	15 feet	10 feet	15 feet	20 feet	20 feet	80 feet

Outcrop: 1.5 miles east of Gypsum Lake: NW l.s. 5, sec. 25, tp. 33, rge. 8WPM; elevation: 835 feet.
LSM-1: SE¼ sec. 16, tp. 32, rge. 7WPM; elevation: 820 feet.
LSM-14: SW l.s. 4, sec. 4, tp. 33, rge. 9WPM; elevation: 820 feet.
LSM-6: SE¼ sec. 16, tp. 32, rge. 9WPM; elevation: 810 feet.

of this limestone, 20 miles to the northeast of the main outcrop belt, suggests that a thicker section, possibly of a purer limestone, was deposited in this part of the Elm Point Basin. In any event, the high purity of the limestone, its known thickness,and the possibility of finding areas with shallow drift cover, indicate that the region within the crater rim warrants further exploration.

Summary of Elm Point Formation

Outcrops of the Elm Point Formation are restricted to relatively small, isolated areas, ranging from less than one square mile to larger areas covering 10 to 15 square miles, as in the Lily Bay and Steep Rock areas. Between the known exposures along the defined outcrop belt, available water well data indicate that the Elm Point Formation has been partially or completely eroded, as has the underlying Ashern Formation.

Analyses of limestone samples from the outcrop belt indicate a decrease in magnesia content from Oak Point northward to Basket Lake and Lake St. Martin. Areas of erratic magnesia distribution are present in the Lily Bay area and in part of the Dog Lake area. These variations may be related in part to the facies change from Elm Point limestone to Winnipegosis dolomite.

WINNIPEGOSIS FORMATION

The Winnipegosis Formation (originally named Winnipegosan by Tyrrell, 1893), consists primarily of dolomite, as described in the introductory section to the Devonian formations. Known occurrences of magnesian and high-calcium limestone within the Winnipegosis Formation are listed in Table 27. Three aspects of the formation warrant further discussion in regard to the occurrence of high-calcium limestone.

Elm Point-Winnipegosis facies relationship

As noted in the previous section, the magnesia content of the limestone of the Elm Point Formation varies erratically in the area from Dog Lake south to Oak Point. The changes can be related to both an increased amount of matrix present surrounding limestone mottles, and to different degrees of dolomitization of the matrix. An increased degree of dolomitization is shown in the Lily Bay quarry, the Oak Point quarry, and the Department of Highways quarry north of Lily Bay. Average $MgCO_3$ contents are 5.19 (Hole 58-3-48), 7.01 and 9.38 per cent respectively.

Outcrop relations in the Dolly Bay area, noted by Baillie (1951), suggest that Winnipegosis dolomite overlies Elm Point Formation limestone; drilling would be required to determine the thickness and quality of the Elm Point Formation in that area.

In the Overton area, Mines Branch core hole M-4-70 intersected a dolomitized section along the western edge of the outcrop belt of the Elm Point Formation. The carbonate rock consists of a matrix which is completely dolomitized except for disseminated fossil fragments composed of calcite. The mottled areas are limestone, but are smaller and more

TABLE 27. Limestone occurrences, Winnipegosis Formation

M-4-70 4-14-23-8W	Partially dolomitized limestone (magnesian limestone)
M-1-72 16-26-24-10W	Partially dolomitized limestone (magnesian limestone)
Husky Baden No. 2 4-33-44-26W	Dolomitic limestone, limestone fragments in dolomitic matrix, thin bed of high-calcium limestone
Salt Point Dawson Bay	Crystalline limestone, in part laminated; 4 to 7 feet thick
M-6-70 9-16-30-17W	3 feet of limestone containing patches and layers of dolomite, at top of Winnipegosis
M-10-72 8-17-45-25W	9.5 feet of high-calcium organic limestone, in part laminated; partial analysis: 94.81% $CaCO_3$ and 2.68% $MgCo_3$

lensoid than in typical Elm Point limestone. The mottles are confined to the lower part of the section; in the upper part, secondary calcite is present.

Farther west, Mines Branch core hole M-1-72 was drilled at the site of a Winnipegosis Formation reef structure 2 miles south of Richard Point. Winnipegosis dolomite is present to a depth of 88 feet, beneath which a mottled magnesian limestone, equivalent to the Elm Point Formation, was intersected to a depth of 154 feet where it is underlain by the Ashern Formation. A representative sample of the Elm Point interval analyzed 88.62 per cent $CaCO_3$ and 10.65 per cent $MgCO_3$.

The above data suggest that the Elm Point limestone is progressively dolomitized westward from the outcrop belt in the Oak Point to Overton area, and that only the lower part of the Winnipegosis Formation is involved in the facies change to Elm Point limestone.

Winnipegosis reef structures

Pinnacle and patch reefs occur in the area between The Narrows of Lake Manitoba and Dawson Bay (Figure 5). These reefs form the core of domal and anticlinal ridge structures in the overlying Dawson Bay and Souris River Formations, probably as the result of solution of inter-reef salt beds. The presence of these structures affects the outcrop distribution of high-calcium limestone zones in the Dawson Bay and Souris River Formations.

Limestone beds at the top of the Winnipegosis Formation

In the area extending from the town of Winnipegosis to Red Deer Lake (Figure 10), a limestone zone immediately below the Winnipegosis Formation-Second Red Bed contact has been reported in some outcrops and has been intersected in three cored holes, two of which are shown in Figure 10. In other drill holes, the zone is absent.

Laminated high-calcium limestone was intersected at a depth of 150 feet in Mines Branch core hole M-6-70, 8 miles southeast of Winnipegosis in l.s. 9, sec. 16, tp. 30, rge. 17WPM. Three feet of limestone containing patches and layers of dolomite directly underlie the Second Red Bed. As only 1.0-foot and 0.5-foot sections of possible high-calcium limestone are present, the sections were not analyzed.

Baillie (1951, p.23) noted that along the north side of Salt Point, in the Dawson Bay area, Winnipegosis dolomite grades upward through an impure, slightly argillaceous dolomitic limestone, to a yellowish white, crystalline, in part laminated, limestone, about 4 to 7 feet thick. He considered the limestone to be part of the reef or "bioherm" structure. The limestone is overlain by shale of the Second Red Bed.

In Mines Branch core hole M-10-72, west of the Highway 10 bridge at Red Deer River (Figure 10), banded organic limestone is present at the top of the Winnipegosis Formation. The contact with the Second Red Bed occurs at a depth of 62 feet. The interval from 62 to 71.5 feet analyzed 94.81 per cent $CaCO_3$ and 2.68 per cent $MgCO_3$ and is thus a high-calcium limestone. A calcareous zone lying above a reef structure was intersected in the Husky Baden No. 2 well, 4 miles southeast of Red Deer Lake, in l.s. 4, sec. 33, tp. 44, rge. 26WPM. The Winnipegosis Formation is present from a depth of 353 to 437 feet, with the interval from 353 feet to 362 feet consisting of interbedded dolomitic limestone, fragments of limestone in a dolomitic matrix (some contorted, with minor pyrite), and one bed of high-calcium limestone. The limestone distribution is erratic, however, and is of high-calcium quality over an interval of only a few feet.

This limestone zone is worth noting as, in field exploration, it could be mistaken for other limestone zones within the Devonian section. The zone apparently is persistent in the Dawson Bay area. The reason for the lack of dolomitization is an unsolved problem.

DAWSON BAY FORMATION

The Middle Devonian Dawson Bay Formation was defined by Baillie (1953) to include strata from the base of the Second Red Bed to the top of a widespread reefoid and stromatoporoid zone, underlying the First Red Bed. The formation is the lower unit of the Manitoba Group.

The main outcrop belt of the Dawson Bay Formation extends for a distance of 180 miles from Kinosota, on the west shore of Lake Manitoba, northwest to Overflowing River (Figure 1). In a small area southeast of Portage la Prairie, the lower part of the formation forms the bedrock surface on a paleotopographic high which is covered by more than 150 feet of glacial deposits.

An upper and a lower zone of high-calcium limestone, some of high purity, are present within the formation. The only production has been from a small quarry southeast of Winnipegosis, in SE¼ sec. 29, tp. 30, rge. 17WPM. The occurrences of limestone is selected core holes along the outcrop belt are shown in Figure 10.

Stratigraphy

The Dawson Bay Formation can be divided into four distinct and correlatable lithologic units: A) basal red shale, the "Second Red Bed"; B) a lower carbonate unit of argillaceous limestone or dolomite, and high-calcium brachiopod biomicrite; C) a middle calcareous shale unit, with some argillaceous limestone; D) an upper carbonate unit of dolomite and, in places, high-calcium stromatoporoid limestone. The general lithology is illustrated in the Lake Manitoba and Lake Winnipegosis sections in Figure 2, and, in more detail, in Figure 10.

The Second Red Bed (A) unconformably overlies the Winnipegosis Formation and is composed of dolomitic shale. It forms a useful stratigraphic marker bed. Few outcrops of this unit are known. The colour varies from red in the Kinosota-Rorketon-Lake Manitoba Narrows area, to greenish grey in the Winnipegosis-Volga area, and to variegated shades of olive, brown, light grey as well as red in the Dawson Bay area. Thickness of the unit ranges from 30 to 40 feet.

Overlying the basal shaly unit is a carbonate unit (B) consisting of dolomite overlain by dolomitic limestone that grades upward to high-calcium limestone. This "Dawson Bay lower limestone zone" consists of micrite and highly fossiliferous brachiopod biomicrite. The maximum known thickness of this zone is 40 feet, in the Volga area. Minor variations in both lithology and thickness were noted throughout the outcrop belt. One characteristic of these limestone beds is the occurrence of small blebs or crescent-shaped purplish red patches of iron-stained limestone, related to pyrite grains and fossil fragments within micritic limestone. These patches, together with the orange tinge of the micrite, impart a distinctive appearance to this unit. The limestone is illustrated in Plate 3, sample 9, and Plate 9, sample 10.

Overlying the limestone is a thick bed of calcareous shale (C) with interbedded fossiliferous argillaceous limestone. Where intersected in the Dawson Bay-Mafeking area, the unit is at least 45 feet thick and is predominantly bluish grey and highly calcareous. In the Volga area, the unit is 35 to 40 feet thick and is predominantly purplish red; in places it is abundantly fossiliferous.

Overlying the middle shaly unit of the Dawson Bay Formation is an upper carbonate section (D) consisting of a distinctive brown saccharoidal dolomite overlain by cream to white high-calcium limestone. In most occurrences this "Dawson Bay upper limestone zone" is a coral-stromatoporoid biolithite, possibly biohermal in places. Where exposed in a quarry 6 miles southeast of Winnipegosis (Figure 1), it is an almost chemically pure limestone consisting of rounded masses of stromatoporoid. The limestone is illustrated in Plate 9, samples 11 and 12. The lithology of the upper carbonate section in Manitoba is variable, and in some areas the limestone beds are absent. Evaporite beds overlie this carbonate section in the subsurface in Saskatchewan (Figure 5C), but the original eastward extent of the evaporite strata is not known.

The Dawson Bay strata represent shelf carbonates and associated biostromal and possible reef deposits. The cyclic sequence of lithologies, as described above, probably reflects a change from subaerial to shallow marine, to deep marine conditions, followed

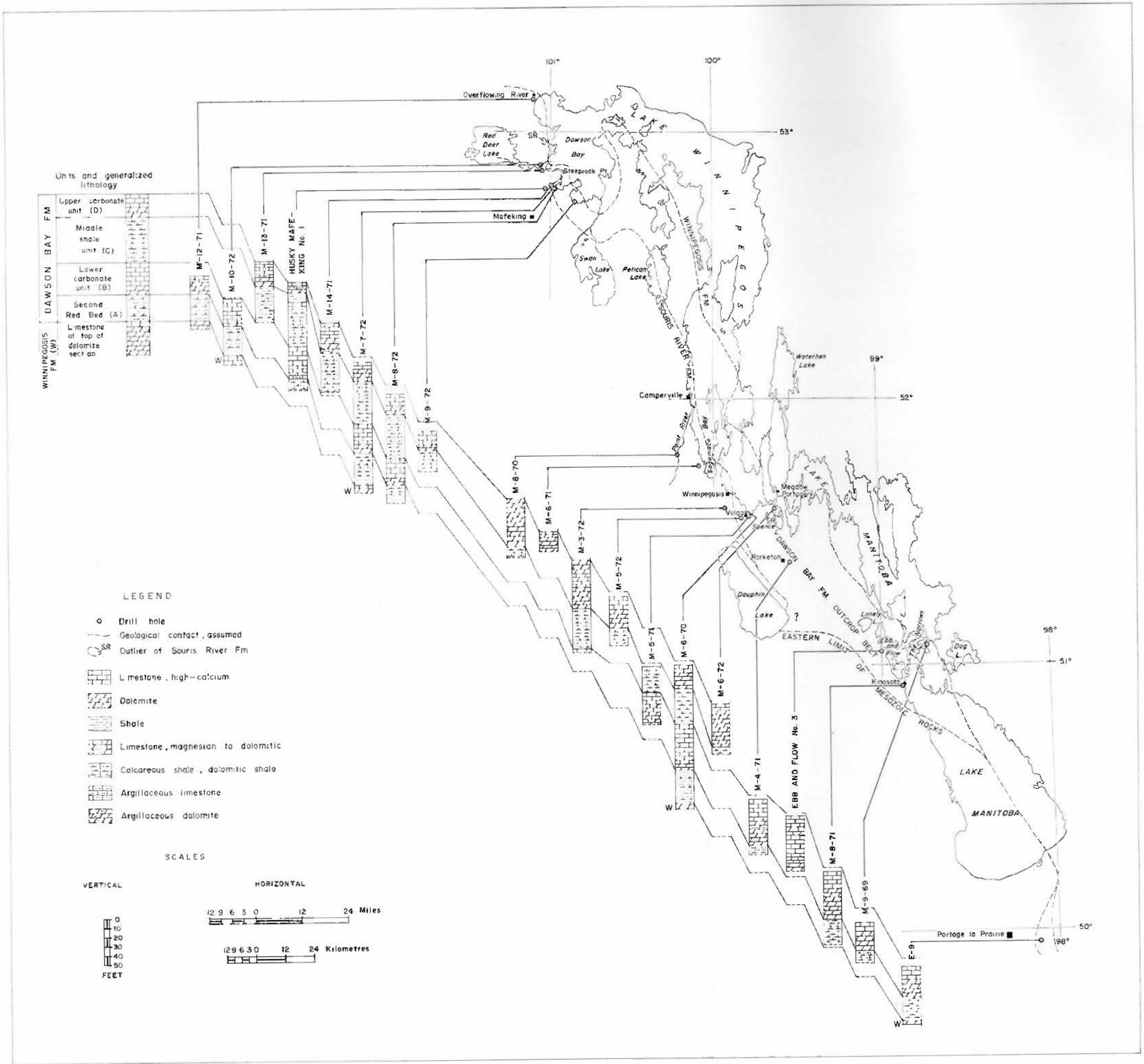

Figure 10: Correlation of the Dawson Bay Formation: Lake Manitoba-Lake Winnipegosis area

by gradual shallowing and restriction of the circulation, possibly by stromatoporoid banks, until evaporitic conditions were established. The lower shale zone (Second Red Bed) may represent both a residual shale from solution of salt beds, and an increase in clastic detritus caused by slight positive tectonic movements in the basin margin areas. Baillie (1953, p. 56) has postulated that shale zones following evaporite conditions may be formed during the transitional change from an evaporitic to a normal marine environment. Because of the faunal extinction during evaporitic conditions, biochemical precipitation of limestone would be at a minimum. A notable feature of the Dawson Bay strata is widespread distribution of similar lithologies, indicating uniform and stable conditions over broad areas of the Manitoba Shelf.

Occurrences of high-calcium limestone in the Dawson Bay Formation are described for separate areas of the outcrop belt in the following sections.

Curtis area, southeast of Portage la Prairie

In 1961, Westroc Industries Limited drilled 4 holes in the area of township 11, ranges 5 and 6WPM, near Curtis (Figure 1). One hole was abandoned in glacial drift at a depth of 186 feet. The other 3 holes intersected Devonian strata on a paleotopographic high. In the area to the north, west, and south, the Paleozoic strata are covered by red beds of the Jurassic Amaranth Formation.

Dolomitic limestone beds, up to 15 feet in thickness, were intersected in the basal part of the lower carbonate unit (B) of the Dawson Bay Formation. The limestone is a light buff to pale purplish micrite, underlain by 18 feet of buff, finely crystalline dolomite. The section is separated by 34 feet of the Second Red Bed from dolomite of the Winnipegosis Formation. An analysis of 13 feet of limestone from drill hole E-9 (Table 28) indicates a gradual change from dolomitic limestone to the underlying dolomite. It is possible that better quality limestone is present at a higher stratigraphic level.

TABLE 28. Dawson Bay Formation, lower limestone zone; Westroc Industries Limited hole E-9; east side of Lot 37, Parish of High Bluff

Hole No. Footage	E-9 152-160	E-9 160-165
SiO_2	3.88	1.70
Al_2O_3	1.24	0.63
Fe_2O_3	0.41	0.33
CaO	44.77	44.91
MgO	6.87	8.54
Na_2O	0.04	0.04
K_2O	0.59	0.32
P_2O_5	0.06	0.04
S	0.14	0.10
LOI	42.18	43.95
Total	100.18	100.55
$CaCO_3$	79.91	80.16
$MgCO_3$	14.37	17.86
Thickness	8 feet	5 feet

Explanation of PLATE 9: High-calcium limestones of Manitoba (II)

Devonian Dawson Bay Formation

Lower limestone zone (continued)

10) *Hole M-6-70, Centennial Beach, Lake Winnipegosis*
Limestone, abundant well preserved brachiopod shells. Upper part light brownish grey biomicrite, with bioclasts in a light buff micritic matrix; reddish and purplish streaks associated with minute grains of pyrite. Lower part is a brown biosparite.

Upper limestone zone

11) *Hole M-5-72: 9 feet; southwest of Volga*
Limestone, stromatoporoidal biolithite, layered and finely laminated; light greyish brown. Formed of coalescing masses of stromatoporoid; minor lenses and stringers of calcite.

12) *Hole M-9-72: 3 feet; east of Bell River*
Limestone, finely crystalline, mottled white and yellowish brown. White areas are sparry to drusy calcite-lined vugs, partially or completely filled. Matrix is finely crystalline, and does not contain any obvious organic material.

Devonian Souris River Formation

Point Wilkins Member

13) *Hole M-10-71: 87 feet; north of Mafeking*
Limestone, slightly mottled biopelmicrite, light creamy buff. Abundant well preserved fossils and bioclasts, mainly brachiopods and gastropods; darker lenses are of translucent calcite containing small black disseminated grains. Subdued mottling caused by patches of slightly darker pelletoid material in a sparry calcite matrix, scattered through the light buff micritic matrix.

14) *Hole M-10-71: 90 feet; north of Mafeking*
Limestone, mottled biomicrite, with abundant recrystallized bioclasts, mainly from brachiopods. Buff mottles of biomicrite, in a light buff biomicrite matrix; irregular distribution of mottles, in part related to bioclasts. No macroscopic pellets visible. Minor stylolitic parting.

Upper limestone zone

15) *Hole M-7-70: 19.5 feet; northwest of Winnipegosis*
Limestone, mottled, micritic to very finely crystalline in shades of orange buff, yellowish grey, purplish grey, and buff. Vugs lined with sparry and drusy calcite. Minor content of bioclasts.

16) *M-7-70: 21 feet; northwest of Winnipegosis*
Limestone, stromatoporoidal organic, finely laminated; a biolithite. On right side, brownish buff, clean; on the left, buff, with pyrite in blebs and as disseminations oriented along the laminations. Narrow band of clear calcite along contact, with orange iron oxide-stained limestone to the left. In lower right corner, limestone allochems in sparry calcite matrix.

Jurassic Reston Formation

17) *Turtle River, south of Ste. Rose du Lac (outcrop sample)*
Limestone, smooth, slightly argillaceous, light buff micrite. Virtually featureless, with some poorly preserved brachiopod shells. Slightly curved to rounded shallowly pitted planes, related to the fossils. Some very fine grained minute specks of pyrite; a few patches of slightly lighter colour.

18) North of Morden (outcrop sample)

Limestone, crystalline; a medium grained biosparite. Inoceramus shells with prismatic calcite, and as bioclasts in matrix. Much of the matrix is composed of acicular calcite crystals, possibly disaggregated Inoceramus prisms. Dark brown to brownish red streaks and specks; iron stained calcite crystals; scattered reddish brown phosphatic organic remains.

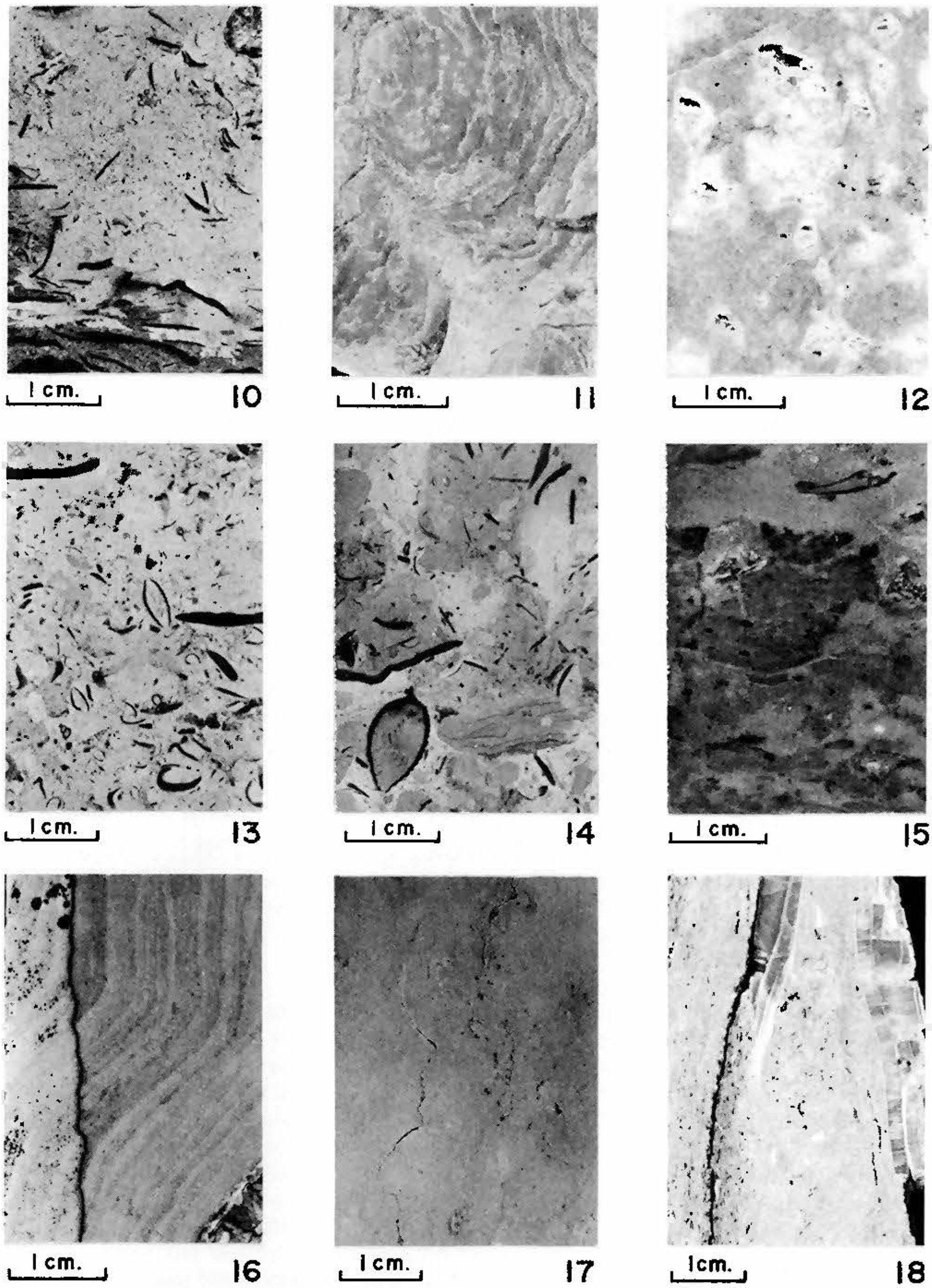

PLATE 9. High-calcium limestones of Manitoba (II)

The Narrows, Lake Manitoba

The lower limestone zone of the Dawson Bay Formation is extensively exposed in The Narrows area between Nina Lake and Wapah, and also southwest of Reykjavik (Figure 11).

Evidence from drill holes, combined with the distinctive brachiopod biomicrite lithology, is sufficient to indicate that most of the outcrops of limestone in this area represent the lower limestone zone. Because of the irregular distribution of the Dawson Bay Formation, caused by draping over Winnipegosis reef structures (Figure 11), more drilling will be necessary to determine the precise stratigraphic position of some occurrences.

The limestone is generally of high-calcium quality and is very finely crystalline to microcrystalline. In places the limestone is somewhat argillaceous, and is characterized by purplish streaks associated with fossils. The fossils are mainly brachiopods (Atrypa species predominant), along with pelecypods, gastropods, and trilobites. Fossil content ranges from sparse to abundant, and some layers of shell limestone or coquina are present. Preservation of the frill structures of winged Atrypa, indicative of quiet water deposition, was noted in two localities. One locality is 1.8 miles east of The Narrows in l.s. 5, sec. 13, tp. 24, rge. 10WPM; the other locality is on the mainland southwest of Manitoba Island.

East of The Narrows (Figure 11), Mines Branch hole M-9-69, in NW¼ l.s. 8, sec. 13, tp. 24, rge. 10WPM, intersected 44 feet of the Dawson Bay Formation, the top 9 feet of which is high-calcium limestone (Table 29). Outcrops of highly fossiliferous brachiopod biomicrite occur for ¾ mile along Provincial Road 235 in section 13 (Table 30, analysis 1). In a quarry ¼ mile east of The Narrows bridge, a Winnipegosis reef core is exposed; flanking beds dip as steeply as 26 degrees (site of hole M-3-70).

Farther south, a small outcrop southwest of Dog Lake is the easternmost outcrop known of the Dawson Bay Formation. It consists of a small exposure of slightly argillaceous limestone (Table 30, analysis 2) near the north end of a topographic rise in l.s. 12, sec. 11, tp. 23, rge. 9WPM (Figure 11).

North of The Narrows, Baillie (1951, p. 49) reported a 14-foot exposure of the Dawson Bay Formation at the north end of Manitoba Island. Very pale orange to pinkish grey argillaceous limestone comprises the upper 12.5 feet of the section. Below a covered interval one foot thick, 10 inches of pale orange dolomite is exposed at the base of the outcrop.

On the mainland, southwest of Manitoba Island, limestone outcrops intermittently along an extensive bedrock ridge with little or no soil cover. The ridge extends over a distance of 1 mile, from l.s. 12, sec. 28, to l.s. 12, sec. 27, in tp. 24, rge. 10WPM (Figure 11). The rock consists of thin-bedded, buff to purplish orange biomicrite (Table 30, analysis 3). Some highly fossiliferous beds contain winged Atrypa with well preserved frills. The rock is a mottled purplish grey micrite, with reddish mottles and stained patches (Table 30, analysis 4), and probably underlies the biomicrite. All the outcrops described are part of the Dawson Bay lower limestone zone.

In the Wapah area, 3 to 4 miles southwest of The Narrows (Figure 11), exposures of the Winnipegosis Formation, the Second Red Bed, and the Dawson Bay Formation were noted. Dolomite, believed to be of the Winnipegosis Formation, is exposed in the west ditch of the road, in the south central part of sec. 13, tp. 24, rge. 11WPM. Red shale is present in the shoulder of the road, above ditch level, for a distance of 500 feet, and probably represents an outcrop of the Second Red Bed.

Several outcrops of Winnipegosis dolomite occur along the road through the B. Brandson farm, 1 to 1.5 miles southwest of Wapah (Figure 11). Farther to the southwest, in l.s. 1, sec. 11 and l.s. 16, sec. 2, of tp. 24, rge. 11WPM, is an extensive outcrop area of purplish biomicrite of the lower limestone zone. Purplish fossiliferous limestone, with patches or red, orange, and yellow, is exposed in the floor of a gravel pit in NE¼ sec. 2, tp. 24, rge. 11WPM; it is overlain by highly fossiliferous argillaceous limestone. In a test pit on the northwest side of the gravel pit, a 6- to 8-inch bed composed of shell material is both overlain and underlain by highly fossiliferous limestone. These beds overlie the argillaceous limestone. In another small test pit, 150 feet northwest of the quarry, thin-bedded, 2- to 4-inch, buff, non-fossiliferous limestone strikes 350 degrees azimuth and dips 5 degrees to the east. A 1.5-foot section was sampled (Table 30, analysis 5).

TABLE 29. Dawson Bay Formation, east of The Narrows, Lake Manitoba; Manitoba Mines Branch core hole M-9-69; l.s. 8, sec. 13, tp. 24, rge. 10WPM

Hole No. Footage	M-9-69 0-4.5	M-9-69 4.5-9.0
SiO_2	3.41	3.43
Al_2O_3	0.88	0.77
Fe_2O_3	0.33	0.26
CaO	52.9	52.7
MgO	0.48	0.65
Na_2O	0.03	0.03
K_2O	0.40	0.43
P_2O_5	0.10	0.10
S	0.07	0.05
LOI	41.91	41.92
Total	100.5	100.35
$CaCO_3$	94.46	94.06
$MgCO_3$	1.00	1.36
Thickness	4.5 feet	4.5 feet

TABLE 30. Dawson Bay Formation, partial analyses; The Narrows of Lake Manitoba area

Sample	1	2	3	4	5	6	7	8
CaO	54.27	52.67	53.76	53.06	52.56	54.39	54.18	52.78
MgO	0.20	0.71	0.40	0.71	1.22	0.15	0.40	0.61
LOI	42.67	42.22	42.57	42.37	42.53	42.79	42.90	42.05
Total	97.15	95.60	96.75	96.14	96.31	97.35	97.48	95.44
$CaCO_3$	96.86	94.01	95.95	94.70	93.81	97.03	96.70	94.20
$MgCO_3$	0.42	1.49	0.84	1.49	2.55	0.31	0.84	1.28

1) 1.8 miles east of The Narrows; l.s. 5, sec. 13, tp. 24, rge. 10WPM.
2) Southwest of Dog Lake; l.s. 12, sec. 11, tp. 23, rge. 9WPM.
3) 1.5 miles west of Manitoba Island; N½ sec. 28, tp. 24, rge. 10WPM.
4) 0.4 mile southwest of Manitoba Island; l.s. 11, sec. 17, tp. 24, rge. 10WPM.
5) Test pit, 1.5-foot section sampled; NE¼ sec. 2, tp. 24, rge. 11Wpm.
6) 5.6 miles southwest of Reykjavik; l.s. 6, sec. 36, tp. 24, rge. 11WPM.
7) 3 miles southwest of Reykjavik; l.s. 9, sec. 16, tp. 25, rge. 11WPM.
8) 500 feet southeast of sample 7; l.s. 5, sec. 15, tp. 25, rge. 11WPM.

Another test pit immediately to the east is higher in the section, and exposes 1 foot of mottled, purplish-streaked microcrystalline limestone, with calcite-lined vugs. All these beds are part of the Dawson Bay lower limestone zone.

Dense biomicrite with some secondary calcite is exposed 5.6 miles south of Reykjavik (Table 30, analysis 6), and is correlated with the Dawson Bay lower limestone zone.

A domal structure is present 3 miles southwest of Reykjavik, in E½ sec. 16 and N½ sec. 15, tp. 25, rge. 11WPM (Figure 11). At the crest of a topographic rise is a wide area of outcrop of packed biomicrite, which is apparently flat-lying (Table 30, analysis 7). About 500 feet to the southeast, greyish brown non-fossiliferous micrite, with purplish red flecks, dips at a low angle to the northeast (Table 30, analysis 8). On the northwest side of the rise, vuggy brown fossiliferous dolomite beds dip at a low angle to the northwest. The dolomite is probably part of the lower carbonate unit of the Dawson Bay Formation, but its position has not been verified. Baillie (1951) reported an outcrop of the Winnipegosis Formation about ¼ mile north of this structure.

Lake Manitoba to Dauphin area

Only three outcrop areas are known in that portion of the outcrop belt of the Dawson Bay Formation extending from Lake Manitoba to Dauphin Lake. These are at Kinosota, on the Ebb and Flow Indian Reserve, and south of Lonely Lake (Figure 11).

At Kinosota, dense orange and purplish microcrystalline limestone with curved streaks of red iron oxide occurs as a pavement type outcrop in a ditch 5,500 feet north of the Kinosota Post Office, and outcrops along the road allowance between lot 18 (R. M. Moar) and lot 19 (E. F. Garrioch). The second occurrence is in a clearing 200 feet by 1,000 feet, with little or no soil cover. Drill hole M-8-71 was located near the eastern edge of this clearing, and intersected 18 feet of faintly mottled buff to purplish high-calcium micritic limestone (Table 31). The limestone is underlain by 33 feet of mottled buff to purplish dolomite. Below this interval, 26 feet of red argillaceous dolomite and dolomitic shale of the Second Red Bed was intersected. The micritic limestone readily takes an attractive polish. The strata exposed at Kinosota are thought to occur near the middle of the Dawson Bay lower limestone zone, stratigraphically below the biomicrite zone exposed elsewhere in the Lake Manitoba area.

TABLE 31. Dawson Bay Formation, Kinosota; Manitoba Mines Branch core hole M-8-71, lot 18-19, Manitoba House Settlement

Hole No. Footage	M-8-71 0-6	M-8-71 6-12	M-8-71 12-18
SiO_2	2.78	2.38	2.51
Al_2O_3	0.75	0.64	0.72
Fe_2O_3	0.26	0.27	0.40
CaO	53.98	53.50	51.14
MgO	0.10	0.25	2.43
Na_2O	0.02	0.04	0.02
K_2O	0.36	0.34	0.36
P_2O_5	0.04	0.05	0.05
S	0.05	0.05	0.06
LOI	42.31	42.33	42.90
Total	100.55	99.85	100.59
$CaCO_3$	96.34	95.49	91.28
$MgCO_3$	0.21	0.52	5.08
Thickness	6 feet	6 feet	6 feet

At Ebb and Flow Indian Reserve No. 52, Baillie (1951) mapped an outcrop of the "Manitoba Group". In 1970, the Western Minerals Section of the Department of Indian Affairs and Northern Development carried out a drill program to assess the limestone potential of the reserve. The writer is indebted to J. D. Godard for permission to include results of this program, which are summarized in Table 32. Glacial drift ranges in thickness from less than 1 foot to more than 90 feet. Limestone from 10 to 54.5 feet thick was intersected in three holes, and is underlain by dolomite and red shale. The limestone section in hole No. 3, from a depth of 3.5 to 45 feet, was analyzed (Table 33). High-calcium limestone, 17.5 feet thick is underlain by 24 feet of magnesian and dolomitic limestone. As the Second Red Bed was intersected in hole No. 4, this section is part of the lower carbonate unit of the Dawson Bay Formation.

Northwest of the Ebb and Flow Indian Reserve, flat ditch outcrops of Dawson Bay limestone are present on either side of Provincial Road 235, south of Lonely Lake (Figure 11). The rock is a thin-bedded, highly fossiliferous, pale brown cryptocrystalline limestone.

TABLE 32. Summary of drill holes; Ebb and Flow Indian Reserve No. 52, courtesy of J. D. Godard

Hole No.	Location l.s.	sec.	tp.	rge.	Elevation (feet a.s.l.)	Drift thickness (feet)	Bedrock lithology (footage)
1	3	2	24	12WPM	855	76+	(abandoned in drift)
2	8	1	24	12WPM	825		(hole not drilled)
3	3	7	24	11WPM	840 ?	3.5	3.5-48.0 limestone; 48.0-55 dolomitic limestone; 55-63.6 dolomite
4	11	7	24	11WPM	827	1	1-32.2 limestone; 32-47.4 dolomite; 47.4-51 brownish red dolomitic shale
5	11	32	23	11WPM	820	90+	(abandoned in drift; artesian water)
6	6	5	24	11WPM	820	80+	(abandoned in drift)
7	12	6	24	11WPM	823	29	29-31.8 limestone; 31.8-39.0 dolomite; 39.0-49.0 dolomite, argillaceous

TABLE 33. Lower limestone zone, Dawson Bay Formation; Ebb and Flow Indian Reserve No. 52

Hole No.	Ebb and Flow No. 3 hole				
Footage	3.5-11	11-21	21-30	30-38.9	41.4-45
SiO_2	3.9	2.75	6.0	3.05	5.15
Al_2O_3	0.47	0.31	0.70	0.38	0.71
Fe_2O_3	0.35	0.26	0.64	0.47	0.29
CaO	51.85	52.81	45.11	49.48	40.99
MgO	0.98	1.15	5.45	3.66	9.86
Na_2O	0.01	0.00	0.02	Trace	0.05
K_2O	0.42	0.33	0.67	0.38	0.18
P_2O_5	0.08	0.05	0.15	0.15	0.12
S	0.04	0.03	0.03	0.02	0.05
LOI	41.75	42.68	41.38	42.58	42.55
Total	99.85	100.35	100.15	100.15	99.95
$CaCO_3$	92.54	94.26	80.51	88.31	73.16
$MgCO_3$	2.05	2.41	11.40	7.65	20.62
Thickness	7.5 feet	10.0 feet	9.0 feet	8.9 feet	3.6 feet

Note: Core was not recovered from 38.9 to 41.4 feet.

A partial analysis of a composite sample from the ditch outcrops indicates the rock is a magnesian limestone (51.29% CaO, 2.84% MgO, and 43.07% LOI, equivalent to 91.54% $CaCO_3$ and 5.94% $MgCO_3$). Although the stratigraphic position of this limestone within the Dawson Bay Formation is not certain, the occurrence of purplish mottles and abundant brachiopods suggest that it can be correlated with the lower limestone zone. A local resident reported that the rock extends over a few acres to the north of the road in which the drift cover is generally less than 10 feet thick.

Rorketon-Toutes Aides-Crane River area

The area described comprises the eastern half of that shown in Figure 12. Only a few low domal outcrops or pavement-type ditch outcrops are present, except in the area south of Onion Point on Lake Manitoba. Most of the limestone outcrops are considered to be part of the Dawson Bay lower limestone zone, either on the basis of drill results or because of distinctive lithology. However, the occurrence of Winnipegosis reefs, and of domal structures in the Dawson Bay Formation, suggest that limestone of the Dawson Bay upper limestone zone, or even the Souris River Formation, could be present. Drill results in the area to the west have shown that, in some locations, stratigraphic position cannot be determined from outcrop studies alone. The stratigraphic position of an outcrop along Provincial Road 481, northeast of Toutes Aides, is not known.

East of Rorketon, pavement-type outcrops of limestone occur in ditches and scattered through a meadow in the southwestern part of l.s. 3, sec. 17, tp. 28, rge. 15WPM (Figure 12). The rock is a tough, light brown to orange-brown finely crystalline to microcrystalline limestone containing well preserved fossils (predominantly brachiopods) and patches of calcite crystals. Manitoba Mines Branch core hole M-4-71 intersected 24 feet of brown to buff biomicrite, 26 feet of argillaceous dolomitic limestone and dolomite, and 28 feet of red shale of the Second Red Bed. Analyses of the upper 24 feet of biomicrite (Table 34), indicate the rock is a high-calcium limestone. The silica content of 1.60 to 2.25 per cent is characteristic of the Dawson Bay limestone zone.

TABLE 34. Dawson Bay Formation, Rorketon area; Hole M-4-71; SW¼ l.s. 3, sec. 17, tp. 28, rge. 15WPM

Hole No.	Manitoba Mines Branch core hole M-4-71		
Footage	0-8	8-16	16-24
SiO_2	1.6	2.5	2.25
Al_2O_3	0.4	0.75	0.6
Fe_2O_3	0.24	0.44	0.30
CaO	53.9	52.55	52.05
MgO	0.47	0.86	1.37
Na_2O	0.02	0.02	0.02
K_2O	0.26	0.39	0.38
P_2O_5	0.00	0.03	0.03
S	0.01	0.02	0.02
LOI	42.9	42.25	42.55
Total	99.8	99.8	99.55
$CaCO_3$	96.20	93.79	92.90
$MgCO_3$	0.98	1.80	2.87
Thickness	8 feet	8 feet	8 feet

Approximately 10.5 miles east of Rorketon, numerous small limestone outcrops occur in NW¼ sec. 15, tp. 28, rge. 14WPM (Figure 12). One outcrop is probably a domal structure as the thin bedded limestone is flat-lying on top, but dips 4 degrees to the north on the northwestern slope. The limestone (Table 35, analysis 1) is a fairly tough, buff biomicrite, with abundant brachiopods, some crinoids and gastropods. The frilled wings of some of the brachiopods have been preserved. Purplish patches and reddish flecks are common, and the rock is correlated with the Dawson Bay lower limestone zone. The preliminary soils map (Mills, 1970) indicates rock outcrop, or rock under a thin soil cover, occurs in sections 22, 23, 25, 26, and 27, tp. 28, rge. 14WPM (Figure 12). These areas are relatively inaccessible, and were not examined.

Micritic limestone, with reddish patches, is exposed 8 miles north of Rorketon (Table 35, analysis 2).

TABLE 35. Dawson Bay Formation, lower limestone zone; Rorketon-Toutes Aides-Crane River area

Sample	1	2	3	4
CaO	55.17	53.97	54.60	54.25
MgO	0.20	0.35	0.10	0.35
LOI	43.24	42.77	42.90	42.87
Total	98.61	97.09	97.60	97.45
$CaCO_3$	98.47	96.33	97.45	96.83
$MgCO_3$	0.42	0.73	0.21	0.73

1) 10.5 miles east of Rorketon; NW¼ sec. 15, tp. 28, rge. 14WPM.
2) 8 miles north of Rorketon; l.s. 13, sec. 23, tp. 29, rge. 16WPM.
3) Southwest of Onion Point; SW¼ sec. 6, tp. 31, rge. 14WPM.
4) Southwest of Onion Point; SE¼ sec. 6, tp. 31, rge. 14WPM.

In the Onion Point-Toutes Aides area fossiliferous, reefoid dolomite of the Winnipegosis Formation occurs in several places within the outcrop belt of the Dawson Bay Formation. Between Crane River and Toutes Aides, several domal outcrops of the Dawson Bay Formation probably reflect the presence of underlying Winnipegosis reefs. Baillie (1951, p. 48) reported one such dome in sec. 13, tp. 30, rge. 15WPM, on the south shore of Steeprock Lake.

Two large domal outcrops of limestone occur southwest of Onion Point, in SE¼ and SW¼ sec. 6, tp. 31, rge. 14WPM (Figure 12). Both are topographic rises, the crests of which are open grassy areas with abundant outcrops. In SW¼, section 6, the rock is a dense buff to grey fossiliferous limestone (Table 35, analysis 3) occurring in thin, slabby and brittle layers. Essentially the same bed covers most of the dome, and follows the erratic topographic slope. Dips of up to 4 degrees in various directions were measured. A different layer of rock is exposed in SE¼ of section 6. It is a finely crystalline brownish limestone, with purple streaks and mottles (Table 35, analysis 4). On the weathered surface, the rock has a brecciated appearance. The rock is thin bedded, brittle, fossiliferous, and dips at a low angle to the northeast.

At Onion Point, Baillie (1951, p. 48) described a 10-foot cliff of high-calcium limestone extending along the shore for 100 yards. An analysis of limestone from the west shore of Onion Point showed 95.58 per cent $CaCO_3$ and 1.28 per cent $MgCO_3$ (Wells, 1905, p. 55).

The soils map (Mills, 1970) indicates that more than 15 square miles in the area south from Onion Point is underlain by rock outcrop or rock with a soil cover of less than 30 inches (Figure 12). Rock types sampled there include high-calcium limestone and dolomite. Reefoid dolomite is part of the Winnipegosis Formation; other dolomite is probably part of the Dawson Bay Formation (e.g. bedded dolomite in outcrops immediately northeast of Steeprock Lake). The area has not been mapped in detail. A good trail extends from the southeast corner sec. 1, tp. 30, rge. 15WPM, along the east side of Steeprock Lake, to Onion Point. Several other trails, which are visible on aerial photographs, provide access to other parts of the area. The distribution of Dawson Bay limestone beds within the area is erratic, and depends on the occurrence and height of reef structures in the underlying Winnipegosis Formation.

On the basis of lithology, and because of their proximity to Winnipegosis dolomite, the sampled high-calcium limestone outcrops in the Rorketon-Toutes Aides-Crane River area are correlated with the lower limestone zone of the Dawson Bay Formation. Partial analyses (Table 35) indicate the limestone is of good quality. (Recent mapping of H. R. McCabe, personal communication, indicates the Dawson Bay upper limestone zone outcrops 1.5 miles east of Steeprock Lake).

Dauphin Lake to Lake Winnipegosis

Numerous outcrops of the Dawson Bay Formation occur in the area extending from Spence Lake southwest to Dauphin Lake and north to Lake Winnipegosis. Figure 12 shows the known outcrops, as well as areas of thin soil cover, as indicated on the preliminary soils map (Mills, 1970). Field studies and diamond drilling have outlined in part the two main Dawson Bay limestone zones. However, because the outcrop pattern has been complicated by the draping of beds over underlying reef structures, more detailed mapping and additional drilling is required to fully evaluate the limestone reserves and to determine the stratigraphic position of some of the beds. To illustrate this point, Manitoba Mines Branch core hole M-6-72, northwest of Spence Lake, confirmed the presence of Souris River strata (page 83) in an area previously thought to be underlain by Dawson Bay strata.

An almost complete section of the Dawson Bay Formation was intersected in Mines Branch hole M-6-70, drilled on the northeast slope of an outcrop ridge at Centennial Beach, Lake Winnipegosis. The hole intersected 150 feet of Dawson Bay strata, including the Second Red Bed (Table 36), and 25 feet of the Winnipegosis Formation; the section is shown in Figure 10.

TABLE 36. Dawson Bay Formation; Manitoba Mines Branch core hole M-6-70; l.s. 9, sec. 16, tp. 30, rge. 17WPM

Footage	Lithology	Thickness (feet)
0 - 8	Upper limestone zone; clean stromatoporoid limestone	8
8 - 25.5	Dolomite, buff to light brown	17.5
25.5- 63.5	Middle shale horizon, calcareous, fossiliferous	38
63.5-106	Lower limestone zone; biomicrite, abundant brachiopods; slightly argillaceous in lower half	42.5
106 -113.5	Dolomite, dark yellowish brown; transitional zone at top	7.5
113.5-150	Second Red Bed, red dolomitic shale, to argillaceous dolomite	36.5

Because of the irregular pattern of the outcrop belts, the limestone zones are described in order of stratigraphic position, rather than by geographic area. All locations mentioned are shown in the western half of Figure 12.

Lower limestone zone

The lower limestone zone intersected in hole M-6-70 is characterized by a relatively high silica content (Table 37). The upper 20 feet averages 95.31 per cent $CaCO_3$, 1.28 per cent $MgCO_3$, and 2.67 per cent SiO_2. The lower 20 feet has a significantly higher silica content, and averages 89.67 per cent $CaCO_3$, 1.13 per cent $MgCO_3$, and 6.53 per cent SiO_2. Some chert nodules occur in this section. This zone is correlated with the sections from Rorketon (Table 34, hole M-4-71) and Kinosota (Table 31, hole M-8-71), as shown in Figure 10.

Two other Mines Branch core holes in the Volga area, M-7-71, drilled on a knoll 300 yards west of Paradise Beach, and M-5-71, located 2 miles to the southeast (Figure 12), intersected the lower limestone zone. Hole M-7-71 intersected 30 feet of brownish grey biomicrite and dense micrite (Table 37). In hole M-5-71 buff biomicrite of high-calcium quality occurs at a depth of 30 to 39.5 feet; from 39.5 feet to 61 feet, the limestone contains variable amounts of dolomite, and is not of high-calcium quality.

The lower limestone zone is characterized by abundant brachiopods in a micrite matrix, and purple streaks and flecks. Where these features are well developed, the limestone

TABLE 37. Dawson Bay Formation, lower limestone zone; Manitoba Mines Branch core holes M-6-70 and M-7-71

Hole No. Footage	M-6-70 66-71	M-6-70 71-76	M-6-70 76-81	M-6-70 81-86	M-6-70 86-91	M-6-70 91-96	M-6-70 96-101	M-6-70 101-106	M-7-71 0-10	M-7-71 10-20	M-7-71 20-30
SiO_2	3.76	2.58	2.58	1.77	4.38	6.35	6.50	8.89	1.60	2.40	4.97
Al_2O_3	0.30	0.23	0.24	0.30	0.40	0.51	0.54	0.81	0.47	0.70	1.48
Fe_2O_3	0.25	0.20	0.17	0.18	0.28	0.40	0.41	0.61	0.18	0.25	0.62
CaO	52.88	53.54	53.63	53.54	52.39	50.72	50.08	47.78	54.32	53.35	50.11
MgO	0.58	0.56	0.75	0.53	0.53	0.56	0.58	0.49	0.66	0.76	1.21
Na_2O	0.05	0.03	0.05	0.04	0.03	0.05	0.20	0.12	0.03	0.02	0.04
K_2O	0.32	0.25	0.24	0.27	0.41	0.67	0.69	0.90	0.21	0.30	0.58
P_2O_5	0.04	0.00	0.00	0.00	0.03	0.03	0.08	0.04	Nil	0.02	0.04
LOI	42.48	42.89	43.04	42.79	42.07	41.16	41.19	40.39	0.05	0.09	0.30
S	n.d.	n.d.	0.11	0.13	0.13	0.14	0.19	0.23	43.08	42.42	40.66
Total	100.66	100.28	100.81	99.55	100.65	100.59	100.46	100.26	100.60	100.32	100.01
$CaCO_3$	94.38	95.56	95.72	95.56	93.51	90.53	89.38	85.28	96.95	95.22	89.44
$MgCO_3$	1.21	1.17	1.57	1.11	1.11	1.17	1.21	1.02	1.38	1.59	2.53
Thickness	5 feet	5 feet	5 feet	5 feet	5 feet	5 feet	5 feet	5 feet	10 feet	10 feet	10 feet

Hole M-6-70: l.s. 9, sec. 16, tp. 30, rge. 17WPM, Centennial Beach, Lake Winnipegosis.
Hole M-7-71: l.s. 16, sec. 20, tp. 30, rge. 17WPM, west of Paradise Beach, Lake Winnipegosis.

zone can be identified, e.g. in a ridge west of Spence Lake (Table 38, analysis 1). Other outcrops of limestone from this zone occur south and west of Lawrence Lake (Table 38, analyses 2 and 3). Where the distinguishing features are not present, it is difficult to assign the outcrop to a specific zone, e.g. the flat pavement outcrop of finely crystalline cream to buff non-fossiliferous slightly friable limestone 2 miles southwest of McCann Lake.

TABLE 38. Dawson Bay Formation, partial analyses; Dauphin Lake to Lake Winnipegosis area

Sample	1	2	3	4	5	6	7
CaO	53.83	54.04	54.50	55.73	54.74	54.32	54.34
MgO	0.56	1.01	0.51	0.25	0.15	1.41	0.86
LOI	42.81	43.35	43.01	43.82	43.05	44.01	43.21
Total	97.20	98.40	98.02	99.80	97.94	99.74	98.41
$CaCO_3$	96.08	96.45	97.27	99.47	97.70	96.95	96.99
$MgCO_3$	1.17	2.11	1.07	0.52	0.31	2.95	1.80

a) Lower limestone zone
1. Ridge 1.25 miles west of Spence Lake; l.s. 3, sec. 4, tp. 30, rge. 16WPM.
2. South of Lawrence Lake; l.s. 3, sec. 8, tp. 30, rge. 16WPM.
3. West of Lawrence Lake; l.s. 8, sec. 18, tp. 30, rge. 16WPM.

b) Upper limestone zone
4. Ridge 0.75 mile southwest of Volga P.O.; l.s. 9, sec. 7, tp. 30, rge.17WPM.
5. 0.75 mile west of McCann Lake; l.s. 15, sec. 32, tp. 29, rge. 17WPM.
6. 0.5 mile southwest of 5; SW¼ l.s. 13, sec. 32, tp. 29, rge. 17WPM; ? upper limestone.
7. Mines Branch core hole M-6-72; depth: 59.8 to 63.5 feet; l.s. 10, sec. 22, tp. 30, rge. 16WPM.

TABLE 39. Dawson Bay Formation, upper limestone zone

Hole No. Footage	M-6-70 0-8	Quarry 0-8	M-6-71 99-121.9	M-5-72 0-6	M-5-72 6-13
SiO_2	0.48	0.15	0.94	0.33	0.17
Al_2O_3	0.84	0.05	0.18	0.06	0.04
Fe_2O_3	0.06	0.05	0.24	0.03	0.07
CaO	54.17	55.91	52.94	55.50	55.74
MgO	0.40	0.20	2.36	0.42	0.40
Na_2O	0.15	0.05	Trace	0.01	0.01
K_2O	0.10	0.02	0.07	0.02	0.02
P_2O_5	Nil	0.01	0.02	0.01	Nil
S	n.d.	0.03	0.03	0.01	0.03
LOI	43.27	43.98	43.85	43.79	44.00
Total	99.47	100.45	100.65	100.18	100.58
$CaCO_3$	96.68	99.79	94.49	99.06	99.48
$MgCO_3$	0.83	0.42	4.94	0.88	0.84
Thickness	8 feet	8 feet	22.9 feet	6 feet	7 feet

Mines Branch core hole M-6-70; l.s. 9, sec. 16, tp. 30, rge. 17WPM.
Channel sample, east wall of quarry; l.s. 2, sec. 29, tp. 30, rge. 17WPM.
Mines Branch core hole M-6-71; l.s. 1, sec. 21, tp. 32, rge. 19WPM.
Mines Branch core hole M-5-72; l.s. 9, sec. 7, tp. 30, rge. 17WPM.

Upper limestone zone

The outcrop ridge at Centennial Beach contains abundant stromatoporoids and is part of the Dawson Bay upper limestone zone. Mines Branch core hole M-6-70 intersected 8 feet of this zone (Table 39).

The upper, stromatoporoidal limestone is well exposed in a quarry, 0.75 mile west of Paradise Beach, in l.s. 2, sec. 29, tp. 30, rge. 17WPM. It is located in an area in which the soil cover is thin or absent. The quarry measures 40 feet by 80 feet, and is 8 feet in depth. A channel sample taken from the east wall of the quarry (Plate 9) indicates the limestone is almost chemically pure (99.79% $CaCO_3$, 0.42% $MgCO_3$, out of an analytical total of 100.45%). The content of other elements is remarkably low (Table 39). The limestone is off-white in colour, and consists almost entirely of rounded masses, up to 12 inches in diameter, of well preserved stromatoporoids, identified as *Actinostroma* sp. by Baillie (1951).

PLATE 10. Stromatoporoid masses in east wall of quarry in sec. 29, tp. 30, rge. 17WPM; upper limestone zone of the Dawson Bay Formation.

Mines Branch core hole M-6-71, 10 miles northwest of Winnipegosis (Figure 13), was drilled deep enough to intersect the upper stromatoporoid limestone zone of the Dawson Bay Formation. The limestone zone is thicker, but less pure (Table 39), than in the quarry described above.

The stromatoporoid zone is characterized by its high purity and distinctive fauna, and has been recognized in several outcrops, denoted 'S' in Figure 12. The outcrop in l.s. 9, sec. 7, tp, 30, rge. 17WPM is in the form of a low dome, 150 feet by 400 feet, rising 10 feet above the road level. Mines Branch core hole M-5-72 intersected 13 feet of high-purity limestone. The outcrop and core consist of highly fossiliferous stromatoporoidal and coralline limestone (Table 38, analysis 4 and Table 39). A bedding plane near the north end of the outcrop strikes 335 degrees and dips 3 degrees east. An outcrop of similar rock, 0.75 mile west of McCann Lake, was sampled (Table 38, analysis 5). One-half mile farther southwest, in l.s. 13 of sec. 32, tp. 29, rge. 7WPM, outcrops of buff to pinkish orange finely crystalline limestone and of brown micrite were noted. This rock has a significantly higher $MgCO_3$ content (Table 38, analysis 6). Although its stratigraphic position is uncertain, it could immediately underlie the stromatoporoidal limestone. The upper limestone zone was intersected also in Mines Branch core hole M-6-72, north of Spence Lake (Table 38, analysis 7), under 60 feet of Souris River strata.

The data described in this section indicate that abundant reserves of high-calcium limestone, some of exceptional purity, are present in this area. The Winnipeg Supply and Fuel Company Limited drilled seven holes in 1969 during an exploration program in this area.

Pelican Rapids-Steeprock River area

Lower limestone zone

Along the southwest shore of Dawson Bay, from the vicinity of the Steeprock River eastwards to near Pelican Rapids (Figure 13), the landscape is characterized by an almost continuous series of large domal structures that expose beds of the Dawson Bay Formation. These structures were examined by Baillie (1951) along the shoreline, where erosion has removed parts of the domes, revealing the rock sequence. In the present study, this area was examined by way of a road extending from Steeprock River to the Pelican Rapids Indian Reserve No. 65A. The road crosses or passes close by, at least ten pronounced dome or ridge structures. In most places, only a few feet of section are exposed, as virtually the same bed covers the entire surface of the structure. Almost all the rocks exposed contain abundant fossil fragments, predominantly brachiopod shells, in a micritic matrix. In places, non-fossiliferous beds are exposed. Samples from two of the dome structures correlated with the lower limestone zone were analyzed (Table 40, analyses 1 and 2).

TABLE 40. Dawson Bay Formation; Pelican Rapids-Steeprock River area

Sample	1	2	3
CaO	53.76	54.46	55.80
MgO	0.10	0.20	0.15
LOI	42.26	42.88	43.87
Total	96.12	97.55	99.82
$CaCO_3$	95.95	97.20	99.59
$MgCO_3$	0.21	0.42	0.31

1. Lower limestone zone; l.s. 8, sec. 33, tp. 43, rge. 24WPM.
2. Lower limestone zone; l.s. 13, sec. 5, tp. 44, rge. 24WPM.
3. Upper limestone zone; l.s. 5, sec. 25, tp. 43, rge. 24WPM.

Immediately south of the mouth of Steeprock River (Figure 13A), an easily accessible dome has had approximately one-third of its mass removed by erosion, exposing medium-bedded light buff limestone, which is highly fossiliferous in some beds. Drill hole M-8-72, one-quarter mile northwest of this dome, intersected 13 feet of the Dawson Bay upper limestone zone and 18 feet of the Dawson Bay lower limestone zone (Table 41). Baillie (1951, p. 38) described a nearby dome, one-half mile north of the mouth of the Steeprock River, in which 1 foot of Winnipegosis Formation was exposed at the base of a cliff, below Dawson Bay limestone and shale. The lower limestone zone was intersected also in Husky Mafeking No. 1 hole (Figure 13A), south of the junction of Highway 10 and the Steeprock River-Pelican Rapids road. Analyses of a 24-foot section are listed in Table 41. In both M-8-72 and Husky Mafeking No. 1, the upper part of the lower zone is high in SiO_2 and Al_2O_3, and consists of light grey and buff argillaceous biomicrite.

Upper limestone zone

Mines Branch core hole M-14-71 (Figure 13A) was collared in limestone of the Point Wilkins Member of the Souris River Formation. The Dawson Bay upper limestone zone

TABLE 41. Dawson Bay Formation, lower limestone zone; Manitoba Mines Branch core hole M-8-72 and Husky Mafeking No. 1

Hole No.	M-8-72	M-8-72	M-8-72	Husky Mafeking No. 1		
Footage	70-76	76-84	84-90	207.5-216	216-225	225-231.5
SiO_2	8.50	1.55	3.66	8.82	1.75	2.62
Al_2O_3	2.36	0.37	1.06	2.53	0.50	0.81
Fe_2O_3	0.85	0.14	0.42	0.99	0.17	0.42
CaO	47.34	53.6	51.82	47.57	54.61	53.08
MgO	1.36	1.13	1.11	0.85	0.30	0.75
Na_2O	0.07	0.03	0.04	0.05	0.02	0.02
K_2O	0.95	0.18	0.37	1.02	0.23	0.25
P_2O_5	0.27	0.01	0.10	0.06	0.03	0.01
S	0.03	0.03	0.10	0.03	0.04	0.10
LOI	38.56	43.08	41.45	38.08	42.77	41.96
Total	100.29	100.12	100.13	100.00	100.42	100.02
$CaCO_3$	84.99	95.67	92.49	84.90	97.47	94.73
$MgCO_3$	2.84	2.36	2.32	1.78	0.63	1.57
Thickness	6 feet	6 feet	6 feet	8.5 feet	9 feet	6.5 feet

Mines Branch core hole M-8-72; SW l.s. 5, sec. 13, tp. 44, rge. 25WPM.
Husky Mafeking No. 1 hole; l.s. 5, sec. 16, tp. 44, rge. 25WPM.

was intersected at a depth of 127.2 feet to 144.7 feet. This zone contains abundant stromatoporoids, and is a high-calcium limestone of high purity (Table 42). Below this zone 15.3 feet of dolomite and argillaceous calcareous dolomite was intersected, overlying 42.7 feet of the middle calcareous shale unit of the Dawson Bay Formation.

The stromatoporoidal limestone zone outcrops also on a ridge in the central part of sec. 14, tp. 44, rge. 25WPM on the Pelican Rapids road (Figure 13A). In core hole M-7-72, 9 feet of limestone was intersected; it contains only a minor amount of stromatoporoid. In core hole M-8-72, 0.7 mile to the east (Figure 13A) 13 feet of high purity limestone from the upper limestone zone (Table 42) was intersected.

Most of the domes southeast of the Steeprock River bridge expose beds of the Dawson Bay lower limestone zone. However, two outcrops of the upper limestone zone are known. One of these outcrops, 1.3 miles east of the Bell River (Figure 13), was drilled and 15 feet of limestone was recovered in Mines Branch core hole M-9-72 (Table 42). The most easterly known outcrop along the road, in l.s. 5, sec. 25, tp. 43, rge. 24WPM, consists of a mottled brown and white crystalline limestone (Table 40). Rock of identical lithology is present immediately underlying the stromatoporoidal limestone in core hole M-13-71, north of the Dawson Bay Forestry Tower, and thus this outcrop is correlated with the Dawson Bay upper limestone zone.

Part of the upper limestone unit was intersected in Mines Branch core hole M-10-71, at the junction of Highway 10 and the Pelican Rapids road. It is separated from the First Red Bed by a 1.4-foot interval of brecciated rock and buff dolomite. Only the top 3.1 feet of the zone, consisting of buff, irregularly banded, fragmented limestone was recovered, from 159.4 to 162.5 feet (Table 42). In Husky Mafeking No. 1 hole, 0.7 mile south of M-10-71, a 6-foot section of the upper limestone zone is present, immediately underlying the First Red Bed.

The above analyses indicate the high-purity stromatoporoidal limestone that occurs in the Dauphin Lake-Lake Winnipegosis area is present in equivalent thickness, but slightly lower purity, in the Steeprock River area.

Red Deer River-Overflowing River area

The Dawson Bay Formation forms the bedrock surface in the area from the Dawson Bay Forestry Tower ridge northward to the Overflowing River (Figure 13), except for an outlier of the Souris River Formation at the junction of Highway 10 and Dawson Bay road. At the Forestry Tower ridge, the Souris River Formation is present, whereas dolomite of

TABLE 42. Dawson Bay Formation, upper limestone zone; Manitoba Mines Branch core holes M-14-71, M-10-71, M-8-72, and M-9-72

Hole No. / Footage	M-14-71 127.2-135	M-14-71 135-140.5	M-14-71 140.5-144.7	M-14-71 127.2-144.7 (Average)	M-10-71 159.4-162.5	M-8-72 0-13	M-9-72 0-8	M-9-72 8-15
SiO_2	2.30	1.05	0.87	1.57	1.74	0.30	0.20	1.32
Al_2O_3	0.16	0.30	0.26	0.23	0.12	0.16	0.04	0.24
Fe_2O_3	0.21	0.22	0.27	0.22	0.04	0.09	0.19	0.21
CaO	54.26	55.06	54.54	54.58	55.10	55.67	54.66	53.54
MgO	0.30	0.10	0.70	0.33	0.15	0.45	1.08	1.38
Na_2O	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
K_2O	0.08	0.07	0.07	0.07	0.10	0.03	0.03	0.08
P_2O_5	0.02	0.04	0.02	0.03	Nil	Nil	Nil	Nil
S	0.05	0.05	0.07	0.06	0.03	0.01	Nil	Nil
LOI	42.84	43.29	43.42	43.13	43.13	43.90	43.86	43.31
Total	100.23	100.09	100.24	100.23	100.40	100.62	100.07	100.09
$CaCO_3$	96.84	98.27	97.34	97.41	98.34	99.36	97.56	95.56
$MgCO_3$	0.63	0.21	1.46	0.69	0.31	0.94	2.26	2.89
Thickness	7.8 feet	5.5 feet	4.2 feet	17.5 feet	3.1 feet	13 feet	8 feet	7 feet

Hole M-14-71: SW l.s. 4, sec. 23, tp. 44, rge. 25WPM.
Hole M-10-71: l.s. 4, sec. 21, tp. 44, rge. 25WPM.
Hole M-8-72: l.s. 5, sec. 13, tp. 44, rge. 25WPM.
Hole M-9-72: l.s. 16, sec. 27, tp. 43, rge. 24WPM.

TABLE 43. Dawson Bay Formation and First Red Bed; Red Deer River–Overflowing River area
Manitoba Mines Branch core holes M-13-71, M-10-72 and M-12-71

Hole No. Footage	M-13-71 0-3.3*	M-13-71 17-23.5	M-13-71 23.5-34.0	M-10-72 0-9	M-10-72 9-18	M-10-72 18-26.5	M-12-71 0-6.4
SiO_2	4.90	0.48	0.89	2.51	3.10	3.40	1.20
Al_2O_3	1.26	0.15	0.36	0.44	0.54	0.68	0.32
Fe_2O_3	0.38	0.05	0.24	0.19	0.20	0.39	0.16
CaO	51.72	55.80	54.88	53.43	53.89	52.80	54.43
MgO	0.51	0.30	0.56	0.76	0.12	0.50	0.56
Na_2O	0.02	Trace	Trace	0.02	0.02	0.02	0.08
K_2O	0.43	0.04	0.08	0.22	0.26	0.29	0.16
P_2O_5	0.01	Nil	Nil	0.05	0.01	0.01	0.05
S	0.01	0.02	0.06	0.01	0.03	0.14	0.03
LOI	40.95	43.70	43.26	42.57	42.27	41.74	43.46
Total	100.19	100.54	100.35	100.20	100.44	99.97	100.45
$CaCO_3$	92.31	99.59	97.95	95.36	96.18	94.24	97.15
$MgCO_3$	1.07	0.63	1.17	1.59	0.25	1.05	1.17
Thickness	3.3 feet	6.5 feet	10.5 feet	9 feet	9 feet	8.5 feet	6.4 feet

*The analysis from M-13-71, 0 to 3.3 feet, is from limestone within the First Red Bed.
Mines Branch core hole M-13-71: l.s. 7, sec. 8, tp. 45, rge. 25WPM; upper limestone zone.
Mines Branch core hole M-10-72: NW l.s. 8, sec. 17, tp. 45, rge. 25WPM; lower limestone zone.
Mines Branch core hole M-12-71: l.s. 12, sec. 7, tp. 48, rge. 25WPM; lower limestone zone.

the Winnipegosis Formation outcrops 2.6 miles north of Overflowing River.

The outcrops and the results from three Manitoba Mines Branch core holes (Figure 10) are described in order from south to north. The stratigraphic positions of the sections, and analyses of the limestone zones are described.

The First Red Bed, the basal unit of the Souris River Formation, is exposed in the floor of a gravel pit immediately north of the Dawson Bay Forestry Tower ridge. Mines Branch core hole M-13-71, located on the north side of the pit, intersected 17 feet of the First Red Bed, including a 3.3-foot bed of limestone. Below this interval, 17 feet of the Dawson Bay upper limestone zone was intersected (Table 43). The upper 7 feet of the zone consists of clean, pale buff limestone containing some stromatoporoids; the lower 10 feet consists of a fine to medium crystalline vuggy limestone, in part mottled brown and white.

Outcrops in the Red Deer River area have been described by Baillie (1951, p. 38-40). A limestone section 12 feet thick outcrops on the north bank, 100 yards west of the Red Deer River bridge. Goudge (1944, p. 74) reported this section analyzed 2.02 per cent SiO_2, 0.81 per cent Al_2O_3, 96.12 per cent $CaCO_3$, and 0.77 per cent $MgCO_3$. Mines Branch core hole M-10-72 (Figure 13A), located on the outcrop northwest of the bridge, intersected the Dawson Bay lower limestone zone from surface to a depth of 26.5 feet (Table 43), overlying the Second Red Bed. The zone consists of a light greyish buff biomicrite with some light buff micrite beds, and a one-inch layer of stromatoporoid at a depth of 9.8 feet. Other outcrops along the Red Deer River (Figure 13A) are considered to be within the lower part of the Dawson Bay Formation.

A domal structure is transected by Provincial Highway 10, at a point 2.3 miles north of the Red Deer River bridge. A smaller dome is exposed in the east ditch, 120 feet farther north. A section measured at the larger of the two domes is given in Table 44. An analysis of the upper 14.4-foot section of limestone, probably from the Dawson Bay lower limestone zone, is listed in Table 45, analysis 1.

TABLE 44. Geological section, domal structure in l.s. 1, sec. 28, tp. 45, rge. 25WPM; Dawson Bay Formation

	Thickness (feet)
Limestone, light grey to buff, medium bedded; weathers to flaggy beds; generally sparse fossil fragments; a few thin fossiliferous layers	7.6
Limestone, fossil fragments in micrite	0.8
Limestone, buff to grey, micritic; sparse fossil fragments; 1 inch shaly bed 3 feet above base	6.0
Limestone, buff, micritic with fossil fragments; stylolitic partings; fossils concentrated in lower 1 inch	1.1
Limestone, mottled buff and bluish; sublithographic; beds 2 inches to 7 inches; vugs lined with iron oxide	1.9
Limestone, argillaceous, and calcareous shale; orange to reddish	2.5
Limestone, argillaceous; light brown to yellowish; friable	3.0
Rubble cover to base of section	2.5
Total	25.4

In an earlier examination of this exposure, shortly after the road cut was blasted, 2.3 feet of brown to dark red shale, possibly part of the Second Red Bed, was noted at the base of the outcrop. This part of the section is now covered with rubble.

Several other outcrops, believed to be of the lower limestone zone, were noted along Highway 10, in township 46, range 25WPM. Two outcrops in section 9 consist of greenish grey argillaceous limestone, in which some well preserved fossils were noted. Tentatively identified types include Atrypa, Spinatrypa, and Productid brachiopods, tetracorals, and trilobites. In both outcrops the fossils occur loose on the outcrop surface, where they have been washed out of their shaly matrix. The limestone from the most northerly outcrop, in l.s. 14, is greenish grey and argillaceous, but of good high-calcium quality (Table 45,

TABLE 45. Partial analyses, lower limestone zone, Dawson Bay Formation; Red Deer River–Overflowing River area

Sample	1	2	3
CaO	54.60	54.32	54.25
MgO	0.35	0.25	0.5
LOI	43.16	42.84	42.69
Total	98.11	97.41	97.44
$CaCO_3$	97.45	96.95	96.83
$MgCO_3$	0.73	0.52	0.31

1. Dome north of Red Deer River bridge; l.s. 1, sec. 28, tp. 45, rge. 25WPM; upper 14.4 feet.
2. Highway 10, 1.3 miles south of Dawson Bay Road; l.s. 14, sec. 9, tp. 46, rge. 25WPM.
3. Highway 10, 1.5 miles northeast of Dawson Bay Road; S½ sec. 27, tp. 46, rge. 25WPM.

analysis 2). An outlier of the Souris River Formation, described under that formation, outcrops at the junction of Highway 10 and the Dawson Bay Road. Farther north, in section 27, small flat ditch outcrops expose a few inches of light grey biomicrite that weathers orange-brown (Table 45, analysis 3).

Mines Branch core hole M-12-71 was collared in the most northerly known outcrop of the Dawson Bay Formation, at a microwave tower site 1.3 miles south of the Overflowing River bridge. The top 6.4 feet of buff biomicrite (Table 43) is correlated with the lower limestone zone of the Dawson Bay Formation.

Shores and islands of Lake Winnipegosis

Numerous occurrences of limestone in the Dawson Bay Formation occur along the shores and islands of Lake Winnipegosis. These outcrops have been described in detail in reports by Tyrrell (1893), Goudge (1944), and Baillie (1951). As most of them are in remote localities, or of small size, only brief descriptions are included in Table 46.

Summary

Two zones of high-calcium limestone have been identified in the Dawson Bay Formation (Figure 10). A lower zone consists of buff brachiopod biomicrite overlying micrite, and has distinctive orange and purple streaks and flecks. It has a high silica content, generally between 2.5 and 4.5 per cent, but ranging from 1.5 to 8.8 per cent. It is remarkably uniform in lithology and is of high-calcium quality throughout the outcrop belt extending from Kinosota to Overflowing River, a distance of 180 miles. The zone ranges from 20 to 40 feet in thickness, and numerous areas could be quarried. Very large reserves are present.

An upper zone of stromatoporoidal limestone is present in most, but not all, of the pertinent cored intervals from south of to northwest of Lake Winnipegosis. Numerous outcrops of this zone occur in the Volga area, and some in the area north of Mafeking. A moderate tonnage of high-calcium limestone with a minimum of impurities could be quarried. Known thicknesses of better quality stone range from 3 to 13 feet.

SOURIS RIVER FORMATION

General stratigraphy

The Upper Devonian Souris River Formation, formally named by Sandberg and Hammond (1958), consists of several shale-carbonate-evaporite cycles. The uppermost cycles, which include evaporite beds, occur in the subsurface; only the lower part of the formation is present in the outcrop belt (Figures 5C, 12 and 13). Outcrops are known in three areas: i) the Spence Lake-Winnipegosis-Point River area; ii) the Swan Lake area; and iii) the

TABLE 46 Other reported occurences of limestone in the Dawson Bay Formation, shores and islands of Lake Winnipegosis

Location	Mode of occurrence	References
Charlie Island, Lake Winnipegosis tp. 30, reg. 17WPM	Island 1½ mi. × ½ mi., mainly less than 15 feet above lake level; outcrops on east and west shores and near centre. Analysis of 5-foot section: 96.52% $CaCO_3$; 1.18% $MgCO_3$; 1.30% SiO_2.	Baillie (1951, p. 47); Goudge (1944, p. 75)
Charlie Point, Lake Winnipegosis tp. 30, rge. 17WPM	High-calcium limestone reported in a number of domal structures 400 yards in diameter, rising 25 to 30 feet above lake level. Analysis: 96.45% $CaCO_3$; 0.86% $MgCO_3$, 1.52% SiO_2.	Baillie (1951, p. 47); Goudge (1944, p. 75)
Snake Island, Lake Winnipegosis tp. 31, rge. 17WPM	Island is 1¼ miles long and up to ¼ mile wide; it rises 25 feet above lake level. Upper 15 feet: 95.18% $CaCO_3$, 2.17% $MgCO_3$, 1.58% SiO_2; underlying 4 feet is magnesian limestone (7.01% $MgCO_3$).	Baillie (1951, p. 46); Goudge (1944, p. 75)
Weston Point, and island ½ mile to the west; tp. 34, rge. 18 WPM	In eroded domes; 11 feet of limestone along east side of the point, and up to 12 feet of limestone on the island.	Baillie (1951, p. 44)
South Manitou Island, Lake Winnipegosis tp. 35, rge. 18WPM (now named Devils Island)	Composed largely of high-calcium limestone.	Baillie (1951, p. 44); Goudge (1944, p. 71)
Pelican Bay, Lake Winnipegosis tp. 43, rge. 21WPM	Up to 7 feet of limestone in cliffs that extend 300 feet along the shore.	Baillie (1951, p. 42)
Whiteaves Point, Dawson Bay, Lake Winnipegosis tp. 45, rge. 23WPM	At least 10 feet of (?) Dawson Bay high-calcium limestone in north part of a ½-mile long cliff; south part is Winnipegosis dolomite. Limestone analysis: 96.37% $CaCO_3$; 0.78% $MgCO_3$; 1.66% SiO_2.	Goudge (1944, p. 75)

Mafeking-Steeprock Point (Dawson Bay) area. Southwest of the outcrop belt in Manitoba, the formation is overlain by Mesozoic and younger strata (Figure 1).

The depositional environments of the Souris River strata are essentially a continuation of the cyclic normal marine to evaporite conditions that existed during deposition of the Dawson Bay Formation. Variations in thickness and lithology of the units suggest local fluctuations in sedimentation conditions within the Manitoba Shelf area. As in the Dawson

Bay Formation, draping of beds over Winnipegosis reef structures has resulted in a complex distribution of the various units within the outcrop belt (Figures 12 and 13).

The lithology of the formation and the correlations of cored intersections are shown in Figure 14. The formation consists of the basal First Red Bed, a zone of interbedded limestone and shale (unnamed), high-calcium limestone of the Point Wilkins Member as defined by Baillie (1951), a zone of dolomite and minor shale (unnamed), and an upper zone of crystalline and stromatoporoidal limestone (unnamed).

The basal "First Red Bed"* is variable in thickness and lithology. In the Point River-Winnipegosis area, it consists of light grey to pale buff shale and is 5 to 40 feet thick. In the Dawson Bay area, it is predominantly red shale, and is 32 to 38 feet thick. A 3.3-foot bed of limestone (Table 43) is present in the lower part of the red bed section.

Overlying the First Red Bed in the Winnipegosis area is a layer predominantly of dolomite, 7 to 23 feet or more in thickness. The equivalent interval in the Dawson Bay area consists of 21 to 30 feet of argillaceous limestone and high-calcium limestone, interbedded with thin shale layers.

The Point Wilkins Member consists of about 50 feet of organic limestone in the Winnipegosis area, and of 70 feet of micritic limestone in the Dawson Bay area. In the intervening area, available data suggests the member is of variable lithology, although some correlations are uncertain. West of Sagemace Bay, the equivalent section is composed of dolomite, including some reefoid facies. In the Point River area, the member consists of oölitic and highly organic limestone, some of which is partially dolomitized. Limestone from the Point Wilkins Member is illustrated in Plate 9, samples 13 and 14.

Overlying the Point Wilkins Member in the Winnipegosis area is a 30-foot interval consisting of dolomite, in part with a brecciated texture, and of red shale in a bed up to 10 feet thick. The equivalent interval in the Dawson Bay area consists of 30 feet of predominantly dolomitic strata, with minor slightly calcareous dolomite interbeds.

In the Winnipegosis area, 30 feet of high-calcium limestone overlies the dolomite-red shale section. The limestone is a pale yellowish grey micrite containing stromatoporoids, and represents the youngest Souris River strata known in the outcrop belt. Stromatoporoidal limestone in an equivalent stratigraphic position outcrops in at least three localities in the Dawson Bay area. The limestone is illustrated in Plate 9, samples 15 and 16.

The high-calcium limestone occurrences in the Souris River Formation are described in detail in the following sections.

Spence Lake-Winnipegosis-Point River area

The outcrop belt of the Souris River Formation, based on presently available data, extends from south of Winnipegosis to the Point River area (Figure 13). An outlier of unknown extent is present north of Spence Lake (Figure 12). Other outliers may be present in the region shown in Figure 12, but the outcrop near Spence Lake is the only occurrence identified to date (1972).

High-calcium limestone is present in the Point Wilkins Member at Spence Lake, at Winnipegosis, and at Point River. A dolomitic facies, containing a 10-foot zone of high-calcium limestone, is known from the area five miles east of Point River. The upper high-calcium limestone zone is exposed in the quarry 1.5 miles northwest of Winnipegosis, and in outcrops along the Mossy River at Winnipegosis.

Limestone of high purity outcrops 1.5 miles north of Spence Lake in NE¼ sec. 22, tp. 30, rge. 16WPM (Figure 12). Analysis of an outcrop sample showed 99.23 per cent $CaCO_3$ and 0.42 per cent $MgCO_3$. Mines Branch core hole M-6-72 intersected 7 feet of high-calcium limestone (Table 47) overlying dolomite and the First Red Bed (Figure 14), indicating the limestone is part of the Point Wilkins Member. This outlier of the Souris River Formation lies 10 miles east of the main outcrop belt. Its full extent is not known, but the upper Dawson Bay stromatoporoidal limestone outcrops 3.5 miles to the south, 0.75 mile west of Spence Lake, suggesting the outlier may extend to the south. As consid-

*In some geological reports (e.g. Grayston *et al.*, 1964) the First Red Bed is included as the upper unit of the Middle Devonian Dawson Bay Formation.

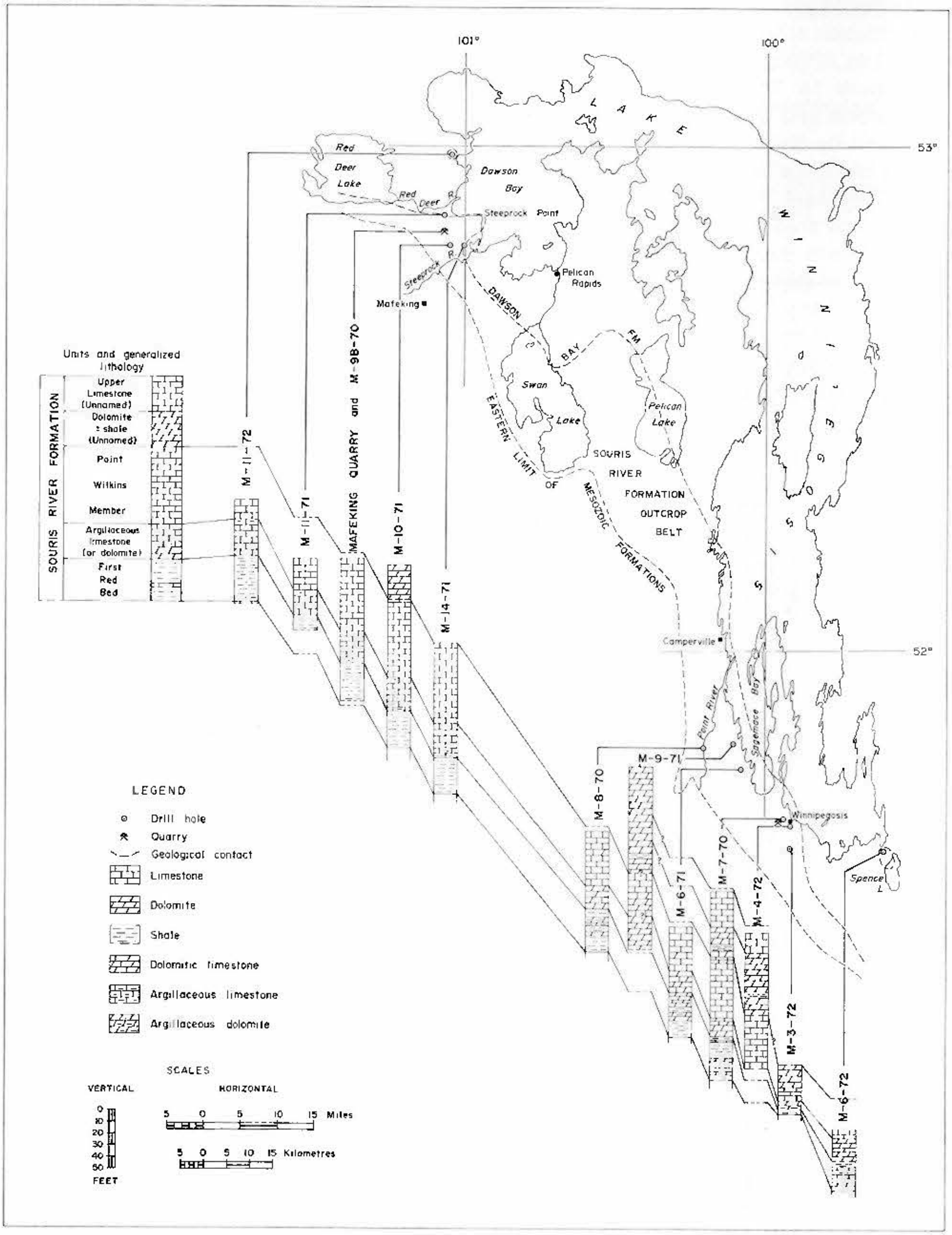

Figure 14: Correlation of the Souris River Formation in the Winnipegosis-Dawson Bay area

erable structural relief is present, it is possible that similar outliers may occur within the outcrop belt of the Dawson Bay Formation.

A small outcrop of the Souris River Formation occurs 3.5 miles south of Winnipegosis (Figure 12). Mines Branch core hole M-3-72 intersected mainly dolomite, and the First Red Bed is poorly developed. Only thin interbeds of high-calcium limestone were intersected, suggesting an anomalous section is present.

Other outcrops of the Souris River Formation are present along the Mossy River, at the town of Winnipegosis (Figure 12). East of the Mossy River bridge, a domal structure

TABLE 47. Souris River Formation, Spence Lake and Winnipegosis areas

Hole No. Footage	M-6-72 0-7	Mossy River outcrop	M-4-72 0-8.5	Winnipegosis quarry
SiO_2	2.15	1.30	1.85	0.96
Al_2O_3	0.26	0.65	0.50	0.39
Fe_2O_3	0.09	0.33	0.30	0.07
CaO	53.78	54.11	53.89	54.89
MgO	0.91	0.38	0.63	0.18
Na_2O	0.01	-	0.02	-
K_2O	0.12	-	0.21	-
P_2O_5	0.06	0.05	0.06	0.01
S	Nil	0.03	0.02	Nil
LOI	42.86	42.90	42.95	43.31
Total	100.25	99.75	100.45	99.81
$CaCO_3$	95.99	96.59	96.18	98.00
$MgCO_3$	1.90	0.80	1.32	0.38
Thickness	5 feet recovered	8 feet	8.5 feet	6 feet

Mines Branch core hole M-6-72: l.s. 10, sec. 22, tp. 30, rge. 16WPM; Point Wilkins Member.

Mossy River outcrop: from Goudge (1944, p. 75): "Eight feet of Manitoban limestone from the bank of Mossy River"; SE¼ sec. 10, tp. 30, rge. 18WPM.

Mines Branch core hole M-4-72: l.s. 2, sec. 10, tp. 31, rge. 18WPM; upper limestone zone.

Winnipegosis quarry: from Goudge (1944, p. 75): "Six feet of Manitoban limestone in quarry of Winnipeg Supply and Fuel Co., Ltd."; in l.s. 14, sec. 9, tp. 31, rge. 18WPM; upper limestone zone.

is exposed. The beds at the east end of the outcrop dip 15 degrees towards the east. At the west end of the outcrop, minor fault displacement of the beds is evident. Goudge (1944) reported an analysis of 8 feet of high-calcium limestone (Table 47). He noted also the occurrence of patches of reddish and yellow magnesian limestone that analyzed 1.98 per cent Fe_2O_3, 81.59 per cent $CaCO_3$, and 7.01 per cent $MgCO_3$.

Mines Branch hole M-4-72 was drilled on an outcrop, on the western side of Mossy River, 750 feet northeast of the Mossy River bridge. Although 114 feet of the Souris River Formation was intersected, true stratigraphic thickness is uncertain as the strata dip as much as 45 degrees. Sixteen feet of limestone from the upper zone is present; an analysis of the upper 8.5 feet is given in Table 47. A 6-inch bed of dolomite is present within the zone. Core recovery from the lower 7.5 feet of the zone was too low to warrant analysis, but stain tests indicate it consists mainly of high-calcium limestone. The interval from 16 feet to 68 feet consists of dolomite, some of which is brecciated, and some interbedded red and pale green shale. Limestone of the Point Wilkins Member was intersected from a depth of 68 feet to the bottom of the hole at 114 feet. The zone is cavernous in part, with sand in the cavities. As only 24 feet of core were recovered from the Point Wilkins interval, it was not analyzed. Stain tests indicate the limestone is of high-calcium quality.

The available evidence from the Winnipegosis area suggests that considerable structural disturbance has occurred probably as a result of "salt solution" and draping of beds over reef structures.

An abandoned quarry 1.5 miles northwest of the town of Winnipegosis (l.s. 14, sec. 9, tp. 31, rge. 18WPM) exposes 7.2 feet of high-calcium limestone (Figure 12). The quarry is held by Steel Brothers Canada Ltd. The previous owner, The Winnipeg Supply and Fuel Company Limited, carried out an exploration drilling program in 1969 in the quarter section south and west of the quarry area. The quarry, located on the crest of a ridge, is approximately 100 feet in diameter. The section, which is now weathered and partly overgrown, was described by Baillie (1951, p. 45) as follows:

"Unit		Feet
2.	Limestone, yellowish grey (5Y8/1), in poorly defined beds 1 inch to 2 inches thick. The lower 3 feet is dense and unfossiliferous but grades upwards to a more fossiliferous rock with much clastic material. Rounded masses, as much as 1 foot in diameter, of finely crystalline hard limestone that show concentric laminations, are present in places...	4.3
1.	Limestone, yellowish grey (5Y7/2), dense, in even thin beds. The beds become thinner towards the top of the unit. Slight change in texture and colour give a laminated appearance. The top of this unit forms the quarry floor and small mounds as much as 3 feet in diameter protrude 3 to 5 inches above the quarry floor. The mounds are tough and hard and have slight vugular porosity. An irregular layered appearance suggests algal origin. The top beds of this unit have a weathered appearance and contain dessication figures. Exposed...	2.8
	Total thickness of sections...	7.1 feet"

An analysis of a 6-foot section of the limestone, reported by Goudge (1944), is reproduced in Table 47. Goudge reported that small masses of soft yellowish magnesian limestone occurred in the deepest part of the quarry. These were separated from the cream coloured, white-weathering high-calcium limestone and discarded. A drainage ditch along the south side of Highway 20 has been excavated in bedrock immediately north of the abandoned quarry, and exposes up to 4 feet of smooth, dense micritic, fossiliferous limestone similar to Baillie's (1951) Unit 2. McCammon (1960) placed the quarry beds in the "Stromatoporoid Zone", the uppermost unit in the outcrop belt. This is the "upper limestone zone" of the Souris River Formation.

Manitoba Mines Branch core hole M-7-70 (Figure 12) was collared in an outcrop 1.5 miles northwest of Winnipegosis (SE¼ sec. 16, tp. 31, rge. 18WPM) and approximately 600 feet northeast of the abandoned quarry described above. The hole intersected 29.5 feet of the upper high-calcium limestone zone of the Souris River Formation (Table 48). It is a pale yellowish grey micrite, with stromatoporoids. Several brecciated zones are present, in which fragments of limestone are enclosed in a soft micritic matrix. Small dolomitic fragments and thin zones of brecciated shale occur erratically in this zone, and could cause problems if the section were quarried.

The upper limestone zone is underlain by 30.5 feet of dolomite, with minor interbedded limestone. Below the dolomite, high-calcium limestone of the Point Wilkins Member was cored from a depth of 60 to 106 feet (Table 48). It is correlated with the section from 68 to 114 feet intersected in hole M-4-72, described above. In the Winnipegosis area the Point Wilkins Member is primarily an organic limestone containing pellets or oolites, finely laminated algal masses, and well preserved corals in a sparry calcite matrix.

West of Sagemace Bay (Figure 13), the Souris River Formation was cored in Mines Branch hole M-6-71. About 95 feet of the formation was intersected, including about 54 feet of the First Red Bed. Core recovery was only 40 per cent in the lower 60 feet of this interval. Two intervals of high-calcium micritic limestone, from 10.0 to 18.5 feet, and from 27.7 to 36.5 feet, occur within the section correlated with the Point Wilkins Member (Table 49). Stain tests indicate the Point Wilkins strata between 18.5 and 27.7 feet are partially to completely dolomitized. The interval between the Point Wilkins and First Red Bed differs significantly from the equivalent interval in the Mafeking area, described below, in that the carbonate portion in this area is primarily dolomite, and in the Mafeking area it is argillaceous limestone.

Six miles northwest of M-6-71, outcrops of the Souris River Formation occur in the vicinity of Point River, along Provincial Road 271 (Figure 13). An oolitic limestone is exposed west of Point River. Mines Branch core hole M-8-70 located east of Point River intersected highly organic limestone from surface to a depth of 45 feet (Table 49); these beds are tentatively correlated with the Point Wilkins Member. The analyses indicate the strata from 17 to 27 feet are magnesian limestone. The Point Wilkins Member in this area is cavernous, and core recovery was about 50 per cent.

Mines Branch core hole M-9-71, 14 miles south of Camperville (Figure 13), intersected dolomite from surface to total depth of 154 feet, except for high-calcium limestone from

TABLE 48. *Souris River Formation; Manitoba Mines Branch core hole M-7-70, SE¼ sec. 16, tp. 31, rge. 18WPM.*

Zone	Upper limestone zone			Point Wilkins Member				
Footage	0-10	10-20	20-29.5	60-70	70-80	80-90	90-100	100-106
SiO_2	1.17	2.24	2.62	1.12	1.85	2.51	1.89	10.0
Al_2O_3	0.69	0.69	0.64	0.29	0.34	0.53	0.45	0.84
Fe_2O_3	0.10	0.13	0.17	0.09	0.07	0.09	0.06	0.08
CaO	53.79	53.15	51.86	54.45	54.16	53.64	54.08	49.25
MgO	0.42	0.48	1.20	0.42	0.36	0.37	0.33	0.60
Na_2O	0.02	0.04	0.02	Nil	0.10	0.05	0.05	0.05
K_2O	0.15	0.25	0.30	0.08	0.15	0.35	0.05	0.05
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOI	42.69	42.13	41.94	43.28	42.79	42.25	42.84	39.23
Total	99.03	99.11	98.75	99.73	99.82	99.79	99.75	99.6
$CaCO_3$	96.00	94.86	92.56	97.18	96.66	95.74	96.52	87.90
$MgCO_3$	0.88	1.00	2.51	0.88	0.75	0.77	0.69	1.25
Thickness	10 feet	10 feet	9.5 feet	10 feet	10 feet	10 feet	10 feet	6 feet

TABLE 49. Point Wilkins Member; Winnipegosis–Point River area Manitoba Mines Branch core holes M-6-71, M-8-70, and M-9-71

Hole No. Footage	M-6-71 10.0-18.5	M-6-71 27.7-36.5	M-8-70 0-7	M-8-70 7-17	M-8-70 17-27	M-8-70 27-37	M-8-70 37-45	M-9-71 90-99
SiO_2	0.99	0.78	0.38	1.68	0.68	0.28	0.27	0.49
Al_2O_3	0.28	0.23	0.13	0.41	0.19	0.07	0.12	0.09
Fe_2O_3	0.13	0.12	0.12	0.36	0.33	0.12	0.18	0.08
CaO	55.24	55.31	55.74	52.57	51.80	55.31	55.53	55.46
MgO	0.40	0.45	0.15	1.97	3.29	0.61	0.30	0.30
Na_2O	0.01	0.01	0.04	0.09	0.04	0.03	0.03	0.02
K_2O	0.11	0.10	0.04	0.06	0.04	Trace	0.06	0.06
P_2O_5	0.01	0.02	0.04	0.04	Nil	0.04	0.04	Nil
S	0.02	0.03	0.04	0.04	0.04	0.04	0.05	0.04
LOI	43.55	43.57	43.87	43.28	44.07	43.97	43.78	43.74
Total	100.75	100.62	100.55	100.5	100.5	100.45	100.35	100.3
$CaCO_3$	98.59	98.72	99.48	93.83	92.45	98.72	99.11	98.99
$MgCO_3$	0.84	0.94	0.31	4.12	6.88	1.28	0.63	0.63
Thickness	8.5 feet	8.8 feet	7 feet (6′ rec.)	10 feet (5′ rec.)	10 feet (5′ rec.)	10 feet (4′ rec.)	8 feet (4′ recov.)	9.0 feet

Mines Branch core hole M-6-71: l.s. 1, sec. 21, tp. 32, rge. 19WPM; Sagemace Bay.
Mines Branch core hole M-8-70: l.s. 13, sec. 34, tp. 32, rge. 20WPM; Point River.
Mines Branch core hole M-9-71: l.s. 1, sec. 5, tp. 33, rge. 19WPM; 14 miles south of Camperville.

90 to 99 feet (Table 49). Because of the extensive dolomite, the section was thought at first to be possibly part of the Winnipegosis Formation (McCabe and Bannatyne, 1971). However, a closer comparison with available core has shown that limestone is present as thin interbeds between 99 and 128 feet. The interval from 90 to 128 feet is tentatively correlated with the Point Wilkins Member (Figure 14). The major part of the member has been partially or completely dolomitized in this area (H. R. McCabe, personal communication). The upper limestone zone is not present in M-9-71. Fossiliferous dolomite, including finely laminated masses, at a depth of 42 to 62 feet may be the dolomitized equivalent of the upper limestone zone, but correlations are uncertain.

Significant changes in the degree of dolomitization and basic changes in lithology occur in the Souris River Formation between the Mafeking area and the Point River-Sagemace Bay area. Further drilling is required to refine geological correlations. Stratigraphic and paleontological studies currently in progress by H. R. McCabe, Manitoba Mines Branch and A. W. Norris and T. T. Uyeno, Geological Survey of Canada, should help to clarify stratigraphic relations of these Devonian strata.

Swan Lake area

Outcrops of Souris River Formation occur in Swan Lake area, 30 to 40 miles northeast of the town of Swan River. Outcrops on Rose Island, in Swan Lake (Figure 13) are described by Baillie (1051, p. 51) as follows:

> "Near the north end of Swan Lake, yellowish grey dense limestone with the mottling typical of the Point Wilkins limestone, is exposed in cliffs. On the northwest end of Rose Island a section 10 feet thick was measured. The rock is brecciated in places and breaks easily into fragments. Minopyrite is present."

Tyrrell (1893) reported similar limestone outcropping on the three adjacent islands.

An outcrop in NE¼ sec. 7, tp. 40, rge. 23WPM, eleven miles south of Rose Island, is described by Baillie (1951, p. 53) as follows:

> "About 350 feet east of Swan River and a few miles from its mouth, a section nine feet thick is exposed in the northwest side of a low dome. The lower 4 feet is composed of pale yellowish orange coarsely crystalline limestone in well-defined beds 1 inch to 2 inches thick. This limestone is overlain by 5 feet of pale yellowish orange coarsely crystalline porous brecciated limestone in poorly defined beds 5 inches thick."

TABLE 50. Souris River Formation, Swan Lake area; from Wells (1905)

Sample	1	2	3
Insoluble	3.25	0.65	1.70
Al_2O_3 / Fe_2O_3	0.74	0.22	0.30
CaO (calculated)	53.23	54.85	54.24
MgO (calculated)	0.57	0.43	0.43
SO_3	Trace	0.04	0.04
H_2O	0.03	0.03	0.04
CO_2 (calculated)	42.41	43.52	43.04
Total	100.23	99.74	99.79
$CaCO_3$ (reported)	95.01	97.90	96.81
$MgCO_3$ (reported)	1.20	0.90	0.90
Thickness		...not reported...	

1. "Fine grained, compact, rather soft, fossiliferous Upper Devonian limestone, collected by J. B. Tyrrell, 1889, from Hog Island, Swan Lake."
2. "Grey, compact, rather soft, fossiliferous Upper Devonian limestone collected by J. B. Tyrrell, 1889, from Rosebush Island (Rose Island), Swan Lake."
3. "Fossiliferous, similar to No. 2, collected by J. B. Tyrrell, 1889, from Station 89, Swan Lake."

Baillie correlated this outcrop with strata overlying the Point Wilkins Member in the vicinity of the junction of Highway 10 and the Steeprock River-Pelican Rapids road.

Chemical analyses of samples of limestone from the Swan Lake area, collected by Tyrrell, were reported by Wells (1905). The analyses are reproduced in Table 50.

Tyrrell (1893) reported two outcrops on the eastern side of the delta of Swan River. The most northerly consists of slightly argillaceous limestone of the Dawson Bay Formation. The outcrop two miles to the south consists of a low anticline of Souris River strata similar to those at Rose Island. The area is not easily accessible by road.

Mafeking-Steeprock Point area (Dawson Bay area)

A significant area of outcrop of the Souris River Formation is present to the north and northeast of Mafeking (Figure 13A). The area from the junction of Highway 10 and the Steeprock River-Pelican Rapids road, east to the mouth of the Steeprock River, north to Steeprock Point and west to the Dawson Bay Forestry Tower, probably is underlain either by limestone of the Point Wilkins Member, or by dolomite and limestone higher in the Souris River Formation. This area of 20 square miles contains large reserves of high-calcium limestone of good quality. Drift cover is absent or thin, except in the central part of the area where outcrops are not discernible on aerial photographs. Because of the structural complexity of this area, detailed examination of each outcrop is required to determine the presence of limestone and its stratigraphic position. In recent years, most of the Point Wilkins Member has been exposed in the Inland Cement Industries Limited quarry 10 miles north of Mafeking, and complete sections have been recovered in core holes drilled by the Manitoba Mines Branch. In general, the Point Wilkins Member consists of a mottled buff micrite and biomicrite throughout this area.

The Souris River Formation is exposed in an 80 to 90-foot cliff at Steeprock Point. This point, formerly named Point Wilkins, is called Steeprock Point on all topographic maps issued since 1960. The uppermost 48 feet of this section, consisting of dense high-calcium limestone, was designated by Baillie (1951, p. 41) as the type section of the Point Wilkins Member. It is underlain by 24.3 feet of argillaceous limestone with shaly partings, and 11 feet of red to grey calcareous shale of the First Red Bed. Analyses, reported by Goudge (1944, p. 75), are reproduced in Table 51.

The Mafeking quarry, in secs. 29 and 32, tp. 44, rge. 25WPM, was opened in 1956 by Inland Cement Industries Limited, following an exploratory drilling program that indicated

TABLE 51. Limestone analyses, Steeprock Point (Point Wilkins); from Goudge (1944)

Sample	1	2
SiO_2	1.00	9.42
Al_2O_3	0.25	2.08
Fe_2O_3	0.17	0.43
CaO	54.54	47.22
MgO	0.25	0.72
P_2O_5	0.04	0.05
S	Trace	0.01
LOI	43.09	39.49
Total	99.34	99.42
$CaCO_3$	97.30	85.88
$MgCO_3$	0.53	1.50
Thickness	40 feet	30 feet

1. "Point Wilkins: top 40 feet of cliff"; Goudge, p. 75.
2. "Point Wilkins: next 30 feet of argillaceous limestone, in same cliff"; Goudge, p. 75.

the occurrence of up to 67 feet of high-calcium limestone. The rock is transported about 275 miles by rail, via Hudson Bay Junction, to the company's Portland cement plant in Regina.

PLATE 11. Panoramic view of east wall of Mafeking quarry, Inland Cement Industries Limited. Units 1 to 11 of the Souris River Formation, dipping northward, are exposed in the lower bench; units 12 to 16 are exposed in the upper face.

A detailed examination of the quarry was made in 1971, and the exposed section, from the top of the First Red Bed to near the top of the Point Wilkins Member, was divided into 16 units (Plate 11 and Table 52). These units can be identified and traced throughout the quarry, and the structure within the quarry can be readily determined (Plate 1). Flexures of broad amplitude occur throughout the quarry. Correlation of some distinctive units was made with outcrops in the surrounding area, and with core from Manitoba Mines Branch core hole M-10-71, 2 miles south of the quarry (Figure 13A), in which a complete section of the Point Wilkins Member and of the lower part of the Souris River Formation was recovered.

Two other Mines Branch core holes were drilled in the Mafeking quarry area. Hole M-9A-70 was drilled 300 feet east of Highway 10, opposite the end of the quarry rail line. It was collared in bedrock in a large area stripped of overburden. Dolomite was intersected to a depth of 8 feet, below which the Point Wilkins Member was cored from 8 to 41 feet. At 41.0 feet, a solution cavern in the limestone filled with silica sand and clay was encountered, and the hole was abandoned at 53.5 feet, within the cavern. Hole M-9B-70 was drilled, with permission of Inland Cement Industries Limited, from the quarry floor. The lower part of the Souris River Formation was intersected to 27 feet, and the First Red Bed from 27 feet to 59 feet, the total depth of the hole. The hole was abandoned when artesian water was encountered.

The quarry section has been divided into 61.0 feet of the Point Wilkins Member and 27.2 feet of the lower Souris River Formation. A detailed section from the quarry area is listed in Table 52. Analyses are given for comparable units from the Point Wilkins Member in core hole M-10-71, and for the lower units in core hole M-9B-70 in the quarry floor. Detailed analyses for M-10-71 are listed in Table 53, and for M-9B-70, in Table 54. The geological section is a combined section, from the south and east walls of the lower bench, and the east wall of the upper bench of the quarry (Plate 11). On the basis of the correlation made with hole M-10-71, the upper surface of unit 16, as measured in the quarry, is about 6 feet below the top of the Point Wilkins Member. The lower contact of the Point Wilkins Member is placed at the base of unit 7. Sampled intervals in M-9B-70, made prior to quarry mapping, do not correspond exactly with the geological units, as indicated in Table 52.

Because of the large reserves of high-calcium limestone believed to occur within this area, it is described in considerable detail. Five Manitoba Mines Branch core holes (Figures 13 and 13A), other than the two holes at the Mafeking quarry, supplied the data presented below. The stratigraphic sequence is shown in Figure 2, and correlations between core holes are shown in Figure 14.

Mines Branch core hole M-10-71 was collared in an outcrop on the floor of a gravel pit, near the junction of Highway 10 and the Steeprock River-Pelican Rapids road (Figure 13A). In this drill hole, which is near the southwestern edge of the Souris River outcrop

TABLE 52. Geological section, Mafeking quarry, Inland Cement Industries Limited; correlated with Manitoba Mines Branch core hole M-10-71

Unit	Lithology	Thickness (feet) Quarry	Thickness (feet) Core hole M-10-71	M-10-71 analysis % $CaCO_3$: % $MgCO_3$
Overburden	Glacial boulder till	Thin	0	
	Point Wilkins Member			
Unit 16	Limestone, yellow grey to yellowish brown, mottled, thick-bedded to massive; very fine grained to microcrystalline	11.1	11.0	97.19:1.02
Unit 15	Limestone; mottled, as in unit 16; prominent horizontal break 5.5 feet above base; 0.1′ dense marker bed at top	8.7	8.8	98.01:0.88
Unit 14	Limestone; mottled; iron staining accentuates mottling on weathered surface; 0.2′ dense marker bed at top	3.9	3.7	97.43:0.75
Unit 13	Limestone; mottled, lighter colour along fractures; 0.6′ marker bed of unmottled microcrystalline fossiliferous limestone at top	9.1	9.0	96.50:1.53
Unit 12	Upper 1.1′ limestone, light brown, microcrystalline, incipient mottling; central 0.9′ breccia, limestone fragments in 10 to 20% micrite matrix, with secondary calcite; lower 1.6′ is a distinctive bed of biomicrite, marked by concentric algal growths (oncolites)	3.6	3.8	95.76:1.88
Unit 11	Upper 0.2′ intraformational breccia layer; 4.4′ limestone, micrite, sparry calcite stringers; 0.8′ limestone, small gastropods, fossil fragments at base, pyrite nodules to ¾″; 1.8′ limestone, buff, thin bedded	7.2	7.1	95.33:1.72
Unit 10	Limestone, mottled, dense, thick bedded; 0.7′ to 2.3′; 0.1′ breccia zone with pyrite 1.2′ above base	6.9	6.0	95.33:1.82
Unit 9	Limestone, mottled, microcrystalline; fragmental in upper part, brachiopods and fossil fragments in lower part; basal 0.5′ breccia	4.3	3.6	96.13:1.51
Unit 8	Shale, green, with rounded limestone pebbles, 0.2′ (unit 8A) at top; limestone, buff biomicrite; 0.2′ layer of intraformational breccia 0.9′ above base	2.5	5.5 (Units 7 and 8)	96.47:0.31 (Units 7 and 8 combined)
Unit 7	Limestone, buff biomicrite, irregularly mottled; 0.7′ layer of purplish platy shale, with green and red patches, at base	3.8		
	Lower part of Souris River Formation	Quarry	Core hole M-9B-70	M-9B-70 analysis % $CaCO_3$: % $MgCO_3$
Unit 6	Limestone, argillaceous, brownish buff; beds 0.4′ to 0.8′, thinner at base; abundant fossils, weathers red	9.5	5.9	95.31:0.61 (upper 6′ of Unit 6)
Unit 5	Limestone, buff, greenish streaks, microcrystalline; beds 0.3′ to 1.8′; calcite streaks with pyrite rims; purplish streaks, in part rimming fossils	6.0	7.4	88.44:0.90 (lower 3.5′ of Unit 6, plus Unit 5)
Unit 4	Limestone, argillaceous, mottled, fossiliferous buff, with purplish streaks; thin layers of olive shale	1.2	8.6 (Units 2, 3 and 4)	90.04:0.92 (Units 2, 3, and 4 combined)
Unit 3	Limestone, light brown, microcrystalline; fossil fragments, secondary calcite	4.0		
Unit 2	Argillaceous limestone, brown patches; variations in thickness and in clay content	1.0		
Unit 1	Limestone, argillaceous, brown, very fine grained; in quarry, rubble covered at base	5.5	4.4	84.42:2.36
	First Red Bed			
	Shale, red		32 +	

TABLE 53. Chemical analyses, Point Wilkins Member; Manitoba Mines Branch core hole M-10-71

Footage Unit	30-36 above 16	36-41.5 upper 16	41.5-47 lower 16	47-51.5 upper 15	51.5-55.8 lower 15	55.8-59.5 unit 14	59.5-64 upper 13	64-68.5 lower 13	68.5-72.3 unit 12	72.3-79.4 unit 11	79.4-85.4 unit 10	85.4-89.0 unit 9	89-94.5 unit 8 & 7	30-94.5 Average
SiO_2	1.79	1.39	1.32	0.98	1.13	1.25	1.91	1.12	1.54	2.14	1.85	1.85	1.88	1.59
Al_2O_3	0.45	0.43	0.42	0.32	0.37	0.40	0.53	0.32	0.48	0.67	0.58	0.33	0.53	0.49
Fe_2O_3	0.30	0.16	0.17	0.05	0.12	0.17	0.24	0.26	0.16	0.23	0.17	0.44	0.22	0.21
CaO	53.28	54.35	54.56	54.95	54.84	54.59	53.69	54.44	53.65	53.41	53.41	53.86	54.05	54.04
MgO	1.15	0.58	0.39	0.41	0.43	0.36	0.74	0.72	0.90	0.82	0.87	0.72	0.15	0.65
Na_2O	0.03	0.04	0.03	0.03	0.02	0.05	0.04	0.02	0.01	0.03	0.02	0.03	0.02	0.03
K_2O	0.14	0.17	0.14	0.10	0.11	0.15	0.20	0.13	0.16	0.20	0.25	0.15	0.19	0.16
P_2O_5	0.05	0.01	0.01	Nil	0.01	0.01	0.04	0.02	0.02	0.03	0.02	0.01	0.02	0.02
S	Nil	0.04	0.04	0.04	0.04	0.02	0.01	Nil	0.05	0.15	0.05	0.36	0.02	0.06
LOI	42.97	43.31	43.24	43.46	43.34	43.27	42.81	43.32	43.02	42.67	42.78	42.40	42.84	43.02
Total	100.16	100.48	100.32	100.34	100.41	100.27	100.21	100.35	99.99	100.35	100.00	100.15	99.92	100.27
$CaCO_3$	95.09	97.00	97.38	98.08	97.88	97.43	95.83	97.17	95.76	95.33	95.33	96.13	96.47	96.45
$MgCO_3$	2.41	1.21	0.82	0.86	0.90	0.75	1.55	1.51	1.88	1.72	1.82	1.51	0.31	1.36
Thickness	6 feet	5.5 feet	5.5 feet	4.5 feet	4.3 feet	3.7 feet	4.5 feet	4.5 feet	3.8 feet	7.1 feet	6.0 feet	3.6 feet	5.5 feet	64.5 feet

TABLE 54. Lower part of Souris River Formation; core hole M-9B-70; Mafeking quarry; l.s. 3, sec. 32, tp. 44, rge. 25WPM

Footage	0.7-6.6	6.6-14.0	14.0-22.6	22.6-27.0
SiO_2	2.65	8.22	6.5	10.44
Al_2O_3	0.35	1.18	0.62	1.17
Fe_2O_3	0.09	0.34	0.16	0.31
CaO	53.4	49.55	50.45	47.3
MgO	0.29	0.43	0.44	1.13
Na_2O	0.03	0.06	0.06	0.06
K_2O	0.29	0.59	0.48	0.73
P_2O_5	0.03	Nil	Trace	0.02
S	0.03	0.03	0.03	0.03
LOI	42.55	39.33	40.42	38.1
Total	99.7	99.75	99.15	99.3
$CaCO_3$	95.31	88.44	90.04	84.42
$MgCO_3$	0.61	0.90	0.92	2.36
Thickness	5.9 feet	7.4 feet	8.6 feet	4.4 feet
Core recovered	5.9 feet	5 feet	5 feet	4 feet

Note: Divisions do not correspond exactly to the units measured in the quarry (see Table 52). The top of this section is at or immediately below the base of the Point Wilkins Member.

TABLE 55. Souris River Formation limestone, partial analyses; Mafeking-Steeprock Point area

Sample	1	2	3	4	5	6
CaO	55.52	55.24	54.06	55.10	54.46	55.03
MgO	0.35	0.15	0.40	0.30	0.30	0.45
LOI	43.84	43.18	42.49	43.26	43.03	43.49
Total	99.71	98.57	96.95	98.66	97.79	98.97
$CaCO_3$	99.09	98.59	96.86	98.34	97.20	98.22
$MgCO_3$	0.73	0.31	0.84	0.63	0.63	0.94

1. Stromatoporoid zone, above Point Wilkins Member; l.s. 2, sec. 21 tp. 44, rge. 25 WPM.
2. Mines Branch core hole M-14-71; SW l.s. 4, sec. 23, tp. 44, rge. 25WPM; depth: 0. to 21.5 feet; Point Wilkins Member.
3. M-14-71; depth: 21.5 to 42 feet; Point Wilkins Member.
4. M-14-71; depth: 42 to 69 feet; Point Wilkins Member.
5. Point Wilkins Member, brecciated, near top; l.s. 10, sec. 32, tp. 44, rge. 25WPM.
6. Above Point Wilkins Member; l.s. 7, sec. 5, tp. 45, rge. 25WPM.

belt, 157 feet of the Souris River Formation was cored, including 33 feet of the First Red Bed. The uppermost 30 feet consists of mottled yellow to buff microcrystalline dolomite, including thin beds of limestone, fragmented rock, and brecciated dolomite cemented with calcite. These beds comprise the dolomite unit between the upper limestone zone and the Point Wilkins Member (Figure 14). At the base of this unit is a 3-foot bed of distinctively mottled grey and yellowish buff limestone. The underlying Point Wilkins limestone can be readily correlated with the units from the Mafeking quarry (see Table 52), and samples for chemical analyses were selected on the basis of the unit boundaries. Numerous outcrops are present, for a distance of 0.8 mile, from west of the junction eastward to the edge of a topographic rise. The strata exposed are limestone of the Point Wilkins Member, the overlying dolomite, and, at the eastward edge, a stromatoporoid limestone (Table 55, analysis 1). The latter is of high-purity, and is stratigraphically equivalent to the upper limestone zone exposed in the quarry northwest of Winnipegosis.

Core hole M-14-71 was collared in a bedrock ridge, 200 feet north of the Steeprock River-Pelican Rapids road, and 2 miles east of core hole M-10-71 (Figure 13A). The hole intersected 127 feet of Souris River Formation, including 30 feet of the First Red Bed. Of direct economic importance is the fact that almost the total thickness of the Point Wilkins Member was intersected. The outcrop beds must be very close to the top of the unit, if the member maintains its thickness throughout the area, as a thickness of 69 feet of high-calcium limestone was cored (Table 55, analyses 2, 3 and 4). An outcrop 0.8 mile to the southeast and approximately 15 feet topographically lower, represents the stromatoporoid zone in the upper part of the Dawson Bay Formation; the unit was cored in Mines Branch hole M-7-72.

To the south of the Mafeking quarry, dolomite and limestone outcrops in the area where the Canadian National Railway spur line approaches Highway 10 (l.s. 10, sec. 20, tp. 44, rge. 25WPM). These strata occur above the Point Wilkins Member and are described in Table 56. At the north end of the railway junction (l.s. 6, sec. 30, tp. 44, rge. 25WPM), the Point Wilkins limestone is present.

TABLE 56. Section above Point Wilkins Member, l.s. 10, sec. 20, tp. 44, rge. 25WPM

Lithology	Thickness (feet)
Limestone, tough, medium bedded; concentric algal banded structures (oncolites); strike 342 degrees azimuth, dip 7 degrees east	1.5+ (Partially covered)
Limestone, buff to brown, speckled; algal growths	1.5+ (Partially covered)
Limestone, pale buff; thin slabby beds, brittle and sonorous; sparse fossil fragments; fine banding (stromatoporoid ?) noted in upper part; strike 342 degrees azimuth, dip 11 degrees east	6.0
Dolomite, orange brown, fine saccharoidal; mottled in part; dips at low angle to south	6.0
Limestone, buff; orange to rose stained; tough, dense rock	2.0+ (Partially covered)
Total: Incompletely exposed:	17.0+

Several outcrops of the Point Wilkins Member and the overlying strata are present in the area north of the Mafeking quarry. In borrow pits 0.3 mile northeast of the Mafeking quarry, and along the old route of Highway 10 (Figure 13A), several outcrops of the Point Wilkins Member occur within a distance of several hundred feet. The uppermost layer of the member, consisting of thin slabby beds of mottled limestone, is exposed east of the centre of sec. 32, tp. 44, rge. 25WPM (Table 58, analysis 5). The overlying beds consist of orange-stained, mottled, saccharoidal dolomite. In the NE¼ of sec. 32, a large outcrop area, exposed in a borrow pit, consists of similar dolomite. This dolomite grades laterally into a red ochre mixed with dolomite, at the north end of the borrow pit.

Northwest of this area, along a trail extending from the Dawson Bay Forestry Tower to a gravel ridge 2 miles to the southwest, two outcrops of dolomite were noted in sec. 6, tp. 45, rge. 25WPM. These beds are considered correlative with the above dolomite, although drilling is required to confirm this. If these correlations are correct, then the outcrops in the area between the Mafeking quarry, the Dawson Bay Forestry Tower and the gravel pit northwest of the quarry (Figure 13A) are underlain by the entire thickness of the Point Wilkins Member.

Along Highway 10, 1.5 miles north of the Mafeking quarry, a road cut through a rock ridge exposes strata of the upper limestone zone. A measured section from this outcrop is described in Table 57. An analysis of the upper 3.5 feet of limestone (Table 55, analysis 6) indicates that it is of high purity. This limestone may be Dawson Bay Formation.

TABLE 57. Section above Point Wilkins Member, l.s. 7, sec. 5, tp. 45, rge. 25WPM

Lithology	Thickness (feet)
Limestone, buff to cream, fine to medium crystalline; abundant sparry calcite; stromatoporoid masses 4 to 8 inches in diameter, in part silicified; corals noted on weathered surface; chert patches; iron sulphide and iron oxide streaks and grains; beds 2 to 10 inches thick; lower contact ¼-inch drusy layer (Table 55, analysis 6)	3.5
Dolomite, calcitic, rosy to light brown, sucrosic; numerous calcite-lined vugs up to 1 inch in diameter; in part laminated (stromatoporoid ?); weathers to deep orange brown; beds 4 to 8 inches thick	3.2
Limestone, buff; sparry calcite in streaks and vugs	0.7
Base, rubble covered	
Total	7.4

TABLE 58. Point Wilkins Member, west side of road cut, Highway 10 at Dawson Bay Forestry Tower

Lithology	Thickness (feet)
Limestone, mottled, weathers to flaggy beds; 1 inch of shaly limestone at base	3.3
Limestone, mottled, buff, micritic; 1 inch green shale at base; prominent fracture 5.5 feet above base (correlated with Unit 14, Mafeking quarry)	8.5
Limestone, as above	3.3
Limestone, very smooth, marker bed	0.9
Limestone, as above	0.4
Total	16.4

The stromatoporoidal limestone is exposed also in the north central part of a gravel pit to the west of this outcrop, and the underlying calcitic dolomite is exposed elsewhere in the pit. The beds strike 286 degrees azimuth, and dip 8 degrees north.

Limestone of the Point Wilkins Member is exposed in a 700-foot long road cut on Highway 10, immediately east of the Dawson Bay Forestry Tower (Table 58). As noted in the table, the strata can be correlated with the upper units exposed in the Mafeking quarry. The beds are mainly horizontal, except for one monoclinal fold 100 feet from the north end. In another exposure north of the main outcrop area, the beds show a pronounced upward warp, with dips toward the east.

Six feet of high-calcium limestone of the Point Wilkins Member is exposed in the north-facing ridge at the Dawson Bay Forestry Tower. This is the site of a former quarry and processing plant where high-calcium limestone, used for poultry grit and hog-feed mix, was produced by L. K. McArdle in the 1940s.

Immediately north of this ridge, outcrops are present in several areas on the floor of a gravel pit, on both sides of the old route of Highway 10. In Mines Branch core hole M-11-71, collared in an outcrop of Point Wilkins limestone 250 feet west of the old road, 47.5 feet of Souris River Formation limestone, and 12 feet of the First Red Bed were cored. The Souris River section consists of 20.8 feet of Point Wilkins limestone, and 26.7 feet of the underlying argillaceous limestone.

East of the old road, and immediately north of the Forestry Tower, the beds of the lower part of the Souris River Formation and of the First Red Bed are intermittently exposed in ridges. The beds dip south at angles of up to 33 degrees. Approximately 50 feet of section is exposed over a horizontal distance of 300 feet. Mines Branch core hole M-13-71, collared in an outcrop of limestone near the north edge of the gravel pit, indicated that the limestone (Table 43, analysis 1) is an interbed within the First Red Bed. The top of the Dawson Bay Formation was intersected at a depth of 17 feet.

Core hole M-11-72 (Figure 14), drilled in an outcrop west of Highway 10, at the junction with the Dawson Bay road, confirmed the presence of an outlier of the Souris River Formation 8 miles north of the main outcrop belt (Figure 13). At the junction, outcrops west and east of Highway 10 expose, respectively, a light grey biomicrite (97.33% $CaCO_3$ and 0.31% $MgCO_3$) and a light brown micrite (98.47% $CaCO_3$ and 0.35% $MgCO_3$). Four feet of the biomicrite is exposed, in beds 2 to 5 inches in thickness. Patches of interformational breccia also are present. A total of 1.7 feet of the micrite, in beds 1 to 3 inches in thickness, is exposed, and it underlies the biomicrite. The beds dip 8 degrees or less to the west. This is the northernmost outcrop known of the Souris River Formation.

The upper 16 feet of core in M-11-72, from the Point Wilkins Member, was analyzed (Table 59). The limestone is of high-calcium quality and has a low silica content. The section from 16 feet to 47 feet is the lower, argillaceous limestone zone of the Souris River Formation. The First Red Bed was intersected from 47 feet to 86 feet.

TABLE 59. Outlier of Souris River Formation; Manitoba Mines Branch core hole M-11-72, l.s. 2, sec. 21, tp. 46, rge. 25WPM

Hole No. Footage	M-11-72 0-8	M-11-72 8-16
SiO_2	0.93	1.05
Al_2O_3	0.24	0.28
Fe_2O_3	0.16	0.11
CaO	54.87	54.52
MgO	0.57	0.78
Na_2O	0.01	0.02
K_2O	0.09	0.11
P_2O_5	Nil	Nil
S	0.02	0.02
LOI	43.51	43.45
Total	100.40	100.34
$CaCO_3$	97.93	97.31
$MgCO_3$	1.19	1.63
Thickness	8 feet	8 feet

Summary: Souris River Formation

In summary, sporadic occurrences of a limestone zone 30 feet above the Point Wilkins Member, have been noted in outcrop. Some of the limestone is of high purity, and is exposed in the quarry northwest of Winnipegosis. Approximately 30 feet of predominantly dolomitic rock separates this zone from the underlying Point Wilkins high-calcium limestone. Domal structures and depth of erosion control the distribution and thickness of both the dolomitic cover and the Point Wilkins limestone. Available evidence suggests large reserves of high-calcium limestone are present in the Mafeking-Steeprock Point area; the major part of the reserves are within the Point Wilkins Member, which has a maximum thickness of 70 feet.

MESOZOIC FORMATIONS

The Jurassic and Cretaceous section in Manitoba consists predominantly of marine shales with zones of evaporites, calcareous beds, sandstone, and bentonite. Thin zones of high-calcium limestone are known from the Reston and Favel Formations (Figure 2).

JURASSIC RESTON FORMATION

The Reston Formation, named by Stott (1955), is referred to also as the Jurassic Lime. It overlies the Amaranth Formation, composed of red beds, anhydrite and gypsum, and underlies the Melita Formation of mixed shale and sand. Only one outcrop area of the Reston Formation is known in Manitoba. This occurs along the Turtle River (Plate 11), in SW¼ sec. 4, tp. 24, rge. 15WPM, and exposes several feet of limestone and calcareous shale. The main limestone bed exposed is 1.7 feet in thickness, and is slightly argillaceous, but low in magnesia (Table 60, analysis 1). The limestone is illustrated in Plate 9, sample 17.

PLATE 12. Shelving ledge of Reston Formation limestone, exposed along west bank of Turtle River, 1.5 miles south of Ste. Rose du Lac.

Mines Branch core hole M-10-70, collared in an outcrop of the Melita Formation 2 miles southeast of Ste. Rose du Lac (Figure 1) in l.s. 5, sec. 22, tp. 23, rge. 15WPM, intersected limestone beds at depths of 55 to 58.5 feet (1 foot of limestone recovered) and from 92.5 to 93.5 feet. The hole ended in limestone. Analyses of the zones are listed in Table 60. The lower limestone is considered part of the Reston Formation. It is probable that the upper limestone is a limestone bed within the Melita Formation.

These analyses indicate the presence of high-calcium limestone, within the Jurassic strata, but the extent and total thickness are not known. In a recent core hole near Neepawa, 55 miles south of the Turtle River outcrop, a 20-foot bed of limestone was intersected in the Reston Formation.

TABLE 60. Limestone beds in Reston Formation

Sample	1	2	3
SiO_2	4.61	3.6	3.45
Al_2O_3	1.32	0.6	0.65
Fe_2O_3	0.75	0.42	0.19
CaO	50.43	51.45	51.8
MgO	1.25	0.79	0.82
Na_2O	0.04	0.10	0.11
K_2O	0.25	0.52	0.57
P_2O_5	0.14	0.23	0.04
S	0.09	0.10	0.26
LOI	41.25	41.31	41.35
Total	100.15	99.1	99.25
$CaCO_3$	90.01	91.83	92.45
$MgCO_3$	2.61	1.65	1.71
Thickness	1.7 feet	1 foot	1 foot

1. Outcrop in SW¼ sec. 4, tp. 24, rge. 15WPM.
2. M-10-70: l.s. 5, sec. 22, tp. 23, rge. 15WPM; 55 to 58.5 feet (1 foot of core recovered).
3. M-10-70: 92.5 to 93.5 feet.

CRETACEOUS FAVEL FORMATION

The Favel Formation, named by Wickenden (1945, p. 23), is of Upper Cretaceous age. It is underlain by carbonaceous shales of the Ashville Group and is overlain by the bentonitic, calcareous, and carbonaceous shale beds of the Vermilion River Formation. Kirk (1930) divided the Favel Formation into the Keld beds of speckled calcareous shale and oil shale, and the overlying Assiniboine beds of calcareous shale with thin limestone beds.

Wells (1905, p. 63) reported analyses of a 4-foot limestone bed exposed in the banks of Assiniboine River, 8 miles northwest of Treherne (Figure 1) in SW¼ sec. 36, tp. 8, rge. 11WPM. The analyses of an upper, grey soft limestone and a lower red, coarse-grained limestone are listed in Table 61. Small outcrops of the limestone zones within the formation are known from north of Morden, and in a low escarpment east of Riding Mountain in the Kelwood area. The most extensive outcrops of the formation are along rivers and streams cutting the slopes of Riding, Duck, and Porcupine Mountains, where thick overburden would make economic extraction difficult. The limestone beds are characterized in most places by abundant Inoceramus shells, some of which are more than 12 inches across. The limestone is illustrated in Plate 9, sample 18.

More detailed descriptions of the formation are included in reports by Leith (1929), Wickenden (1945), and Bannatyne (1970). In particular, Plate 20 in Leith (op. cit.) shows the correlation between outcrops along the Manitoba Escarpment of three separate, thin limestone zones within the Favel Formation. Leith correlates the limestone outcrop along Assiniboine River with the uppermost zone.

TABLE 61. Limestone bed in Favel Formation, Assiniboine River; from Wells (1905)

Sample	1	2
Insoluble	1.00	1.24
Fe_2O_3 / Al_2O_3	0.72	1.16
CaO	53.13	53.09
MgO	1.27	1.07
SO_3	0.13	0.14
H_2O	0.20	0.30
Undetermined (CO_2 and organic)	43.55	43.00
Total	100.00	100.00
$CaCO_3$	94.83	94.76
$MgCO_3$	2.66	2.24
Thickness	2 feet	2 feet

1. "Gray, rather soft limestone containing numerous shells; in layers 1 to 4 inches thick, immediately above (2); the whole bed is not more than 2 feet thick"; Wells (1905); from SW¼, sec. 36, tp. 8, rge. 11WPM.
2. "Reddish, compact, soft, coarse grained limestone; occurring as a bed about 2 feet thick"; Wells (1905); same locality as (1).

SUMMARY AND CONCLUSIONS

High-calcium limestone may be defined as limestone containing more than 95 per cent carbonate (calcite plus dolomite), but less than 5 per cent $MgCO_3$. Limits are set on other constituents, (e.g. silica, the alkalis, phosphorus, and sulphur), depending on the use of the limestone.

Distribution of high-calcium limestone in Manitoba, within formations of Ordovician, Devonian, Jurassic and Cretaceous ages, has been determined from examination of outcrops, quarries, and recent drill hole data. Quality of the limestone, which in places is variable, has been determined by chemical analyses and from data supplied by operating companies. Previously published results were based primarily on outcrop studies and a limited amount of information from drill holes. As the result of recently acquired data, several new areas of high-calcium limestone have been outlined in Ordovician strata, and a detailed description and correlation of the Devonian limestone zones has been attempted.

ORDOVICIAN RED RIVER FORMATION

A zone near the base of the Dog Head Member consists mainly of magnesian limestone. One 2-foot interval of high-calcium limestone was intersected at depth at Garson.

High-calcium limestone occurs at or near the top of the Selkirk Member. It is at least 7 feet thick in the Winnipeg-Birds Hill area, and is 20 feet thick northeast of Lake St. Martin. Limestone in significant thickness is not known to occur between these two areas.

Extensive investigations in the Winnipeg-Stony Mountain area have outlined a bed of high-calcium limestone up to 8.5 feet thick, but of variable thickness and quality, at the top of the Fort Garry Member. This bed can be traced into the Interlake area. A thin limestone bed within the Fort Garry Member is present in both the Lake St. Martin and Winnipeg areas.

The Ordovician limestone beds have not been commercially developed. The proximity of the limestone to Winnipeg may make it economically attractive in the future. The Selkirk Member limestone zone in the Lake St. Martin area, 20 feet thick and of high purity, is of potential interest.

DEVONIAN ELM POINT FORMATION

High-calcium limestone is quarried at four localities east of Lake Manitoba. Regional variations in the magnesia content are important in outlining areas of high-calcium limestone. In general, a decrease in magnesia content is noted from south to north in the outcrop belt. The limestone grades westward into dolomite of the Winnipegosis Formation. In the Lake St. Martin area, slumped blocks of Elm Point limestone are preserved within a 14-mile diameter crypto-explosion structure. In the Hudson Bay Lowland, high-calcium limestone has been noted in Devonian strata older than the Elm Point Formation.

DEVONIAN WINNIPEGOSIS FORMATION

Limestone zones, 2 to 10 feet thick, occur locally at the top of the formation, generally at the top of reef structures.

DEVONIAN DAWSON BAY FORMATION

An extensive area with numerous outcrops of the Dawson Bay Formation extends from Kinosota northwest to beyond Dawson Bay. Two zones of high-calcium limestone, of appreciable thickness and quality, occur in the lower and upper parts of the formation. their areal distribution has been affected by Winnipegosis reef structures and by removal by solution of salt beds from the inter-reef areas. Numerous areas of quarryable stone are available for both zones. The lower zone is up to 40 feet thick, and has been correlated over a distance of 180 miles along the outcrop belt. The upper zone consists of 3 to 13 feet of stromatoporoidal limestone, in places more than 99 per cent $CaCO_3$. One abandoned quarry is located in this zone. Future development will be dependent on proximity to existing transportation, and on location in regard to markets.

DEVONIAN SOURIS RIVER FORMATION

The Point Wilkins Member consists of up to 70 feet of high-calcium limestone in the Dawson Bay area, where it is quarried north of Mafeking. The member is underlain by 25 to 30 feet of similar limestone with thin interbeds of shale. Large reserves are present in the Dawson Bay area. The member extends southeastward to Winnipegosis and Spence Lake, but locally it has been partially to completely dolomitized.

Up to 30 feet of high-calcium stromatoporoidal limestone occurs about 30 feet above the top of the Point Wilkins Member. It is best exposed near Winnipegosis; much of this zone has been eroded in the area north of Mafeking, but remnants are present there.

MESOZOIC FORMATIONS

The Jurassic Reston Formation contains beds of high-calcium limestone, which are generally thin and interbedded with calcareous shale. Only one outcrop is known, south of Ste. Rose du Lac. More drill hole information is required to assess the economic potential of this zone. Thin beds of highly fossiliferous limestone in the Cretaceous Favel Formation outcrop over a wide area, but are lensoid and discontinuous.

SELECTED REFERENCES

A.I.M.E.

1960: Industrial Minerals and Rocks; *Amer. Inst. Mining Met. and Petrol. Eng.*, New York.

Anderson, S.B., and Haraldson, H.C.

1968: Cement-rock possibilities in Paleozoic rocks of eastern North Dakota; *N.D. Geol. Surv.* Rept. Investigation 48.

Baillie, A.D.

1951: Devonian geology of Lake Manitoba-Lake Winnipegosis area; *Man. Mines Br.*, Publ. 49-2.

1952: Ordovician geology of the Lake Winnipeg and adjacent areas; *Man Mines Br.*, Publ. 51-6.

1953: Devonian System of the Williston Basin area, Manitoba; *Man. Mines Br.*, Publ. 52-5.

Bannatyne, B.B.

1970: The clays and shales of Manitoba; *Man. Mines Br.*, Publ. 67-1.

Birse, D.J.
1928: Dolomitization processes in the Palaeozoic horizons of Manitoba; *Trans. Roy. Soc. Can.*, 3rd series, vol. 22, sec. 4: 215-221.
Boynton, R.S.
1966: Chemistry and technology of lime and limestone; *Interscience Publishers*, New York.
Colborne, G.L.
1957: Limestone, shale and clay deposits of Canada Cement Company Limited. *In*: The geology of Canadian industrial minerals deposits; *6th Commonwealth Min. Met. Cong., C.I.M.M.*: 151-152.
Cote, P.R., Jeffery, W.G., and Koepke, W.E.
1968: The industrial mineral industry in Manitoba in 1967 and forecast to 1980; *Min. Res. Br.*, Ottawa, Min. Res. Internal Rept. MRI 382/68.
Cowan, J.
1971: Ordovician and Silurian stratigraphy of the Interlake area, Manitoba. *In*: Geoscience studies in Manitoba, A.C. Turnock, ed.; *Geol. Assoc. Can.*, Spec. Paper No. 9: 235-241.
Cumming, L.M.
1971: Ordovician strata of the Hudson Bay Lowlands in northern Manitoba. *In*: Geoscience studies in Manitoba, A.C. Turnock, ed.; *Geol. Assoc. Can.*, Spec. Paper No. 9: 189-197.
Deir, A.R.
1957: Canadian mineral statistics: 1886-1956; *Dom. Bur. Stat.*, Ind. Merchandising Div., Min. Stat. Sec., Ref. Paper No. 68.
Dowling, D.B.
1900: Report on the geology of the west shore and islands of Lake Winnipeg; *Geol. Surv. Can.*, Ann. Rept., 1898, pt. F.
Foerste, A.F.
1929: The Cephalopods of the Red River Formation of southern Manitoba; *Denison Univ.*, J. Sci. Labs., vol. 24: 129-235.
Goudge, M.F.
1944: Limestones of Canada; their occurrence and characteristics, part V: Western Canada; *Mines Br.*, Ottawa, Rept. No. 811.
Grayston, L.D., Sherwin, D.F., and Allan, J.F.
1964: Middle Devonian. *In*: Geological History of Western Canada, McCrossan, R.G., and Glaister, R.P., eds.; *Alta. Soc. Petrol. Geol.*, Calgary: 49-59.
Gutschick, K.A.
1956: Canada Cement's largest kiln doubles capacity of Ft. Whyte plant; *Rock Products*, Aug. 1956, p. 94.
Hewitt, D.F.
1960: The limestone industries of Ontario; *Ont. Dept. Mines*, Ind. Min. Circ. No. 5.
Johnson, R.D., and Nelson, S.J.
1969: Sogepet-Aquitaine Kaskattama Province No. 1 well, Hudson Bay Lowland, Manitoba. *In*: Earth Science Symposium on Hudson Bay, P.J. Hood, ed.; *Geol. Surv. Can.*, Paper 68-53: 215-226.
Kent, D.M.
1967: Devonian of Manitoba and Saskatchewan. *In*: International Symposium on the Devonian System; *Alta. Soc. Petrol. Geol.*, Calgary: 781-801.
Kindle, E.M.
1914: The Silurian and Devonian section of Western Manitoba; *Geol. Surv. Can.*, Summ. Rept. 1912: 247-261.
Kirk, S.R.
1930: Cretaceous stratigraphy of the Manitoba Escarpment; *Geol. Surv. Can.*, Summ. Rept. 1929, pt. B: 112-135.
Leith, E.I.
1929: A stratigraphical study of the Coloradoan of the Manitoba Escarpment with special reference to certain of the calcareous horizons; unpubl. M.Sc. thesis, Univ. Man.
McCabe, H.R.
1967: Tectonic framework of Palaeozoic formations in Manitoba; *Trans. C.I.M.*, vol. LXX: 180-189.
1971: Stratigraphy of Manitoba, an introduction and review. *In*: Geoscience studies in Manitoba, A.C. Turnock, ed.; *Geol. Assoc. Can.*, Spec. Paper No. 9: 167-187.

McCabe, H.R., and Bannatyne, B.B.
1970: Lake St. Martin crypto-explosion crater and geology of the surrounding area; *Man. Mines Br.*, Geol. Paper 3/70.
1971: Stratigraphic and industrial minerals core hole programme. *In*: Summary of geological field work, 1971; *Man. Mines Br.*, Geol. Paper 6/71: 61-63.
McCammon, H.
1960: Fauna of the Manitoba Group in Manitoba; *Man. Mines Br.*, Publ. 59-6.
McKennitt, D.B.
1961: The Middle Devonian Elk Point Group in Manitoba; unpubl. M.Sc. thesis, Univ. Man.
Mills, G.F.
1970: Preliminary soils map, Ste. Rose du Lac area; *Manitoba Soil Survey*.
Mills, G.F., and Smith, R.E.
1971: Soils of the Grahamdale area; *Manitoba Soil Survey*, Soils Rept. No. 16.
Nelson, S.J. and Johnson R.D.
1966: Geology of the Hudson Bay Basin; *Bull. Can. Petrol. Geol.*, vol. 14, No. 4: 520-578.
Norford, B.S.
1971: Silurian stratigraphy of northern Manitoba. *In*: Geoscience studies in Manitoba, A.C. Turnock, ed.: *Geol. Assoc. Can.*, Spec. Paper No. 9: 199-207.
Norris, A.W., and Uyeno, T.T.
1971: Stratigraphy and Conodont faunas of Devonian outcrop belts, Manitoba. *In*: Geoscience studies in Manitoba, A.C. Turnock, ed.; *Geol. Assoc. Can.*, Spec. Paper No. 9: 209-223.
Pratt, L.E., Ehrlich, W.A., Leclaire, F.P., and Barr, J.A.
1961: Detailed reconnaissance soil survey of the Fisher and Teulon map-sheet areas; *Manitoba Soil Survey*, Soils Rept. 12.
Sandberg, C.A., and Hammond, C.R.
1958: Devonian System in Williston Basin and central Montana; *Amer. Assoc. Petrol. Geol. Bull.*, vol. 42, No. 10: 2293-2334.
Sanford, B.V., Norris, A.W., and Bostock, H.H.
1968: Geology of the Hudson Bay Lowlands (Operation Winisk); *Geol. Surv. Can.*, Paper 67-60.
Stonehouse, D.H.
1971: Cement; Lime and Limestone. *In*: Canadian Minerals Yearbook 1969; *Min. Res. Br.*, Ottawa, Min. Rept. 19: 139-150; 297-306.
Stott, D.F.
1955: The Jurassic stratigraphy of Manitoba; *Man. Mines Br.*, Publ. 54-2.
Tyre, R.
1965: Inland Cement opens $16 million plant; *Trade and Commerce*, Nov. 1965: 2-24.
Tyrrell, J.B.
1893: Report on northwestern Manitoba with portions of the adjacent districts of Assiniboia and Saskatchewan; *Geol. Surv. Can.*, Ann. Rept. 1890-91, pt. E.
U.S. Bureau of Mines
1970: Mineral facts and problems; *U.S. Bur. Mines*, Bull. 650.
Wallace, R.C.
1913: Pseudobrecciation in Ordovician limestones in Manitoba; *J. Geol.*, vol. 21, No. 5: 402-421.
Wardlaw, N.C., Stauffer, M.R., and Hoque, M.
1969: Striations, giant grooves, and superposed drag folds, Interlake area, Manitoba; *Can. J. Earth Sci.*, vol. 6: 577-593.
Warne, S. St. J.
1962: A quick field or laboratory staining scheme for the differentiation of the major carbonate minerals; *J. Sed. Petrol.*, vol. 32, No. 1: 29-38.
Wells, J.
1905: Preliminary report on the limestone and the lime industry in Manitoba; *Mines Br.*, Ottawa, Rept. No. 7.
Wickenden, R.T.D.
1945: Mesozoic stratigraphy of the Eastern Plains, Manitoba and Saskatchewan; *Geol. Surv. Can.*, Mem. 239.
Wicks, F.J., and Whitehead, M.B.
1965: Lime stabilization of Lake Agassiz clays; unpubl. paper presented at 1965 Annual Western Meeting of the Can. Inst. Min. Met.