A. Contributed Papers - Southern

The Early Silurian *Virgiana* Brachiopod Beds in the Northeastern Williston Basin, Manitoba and Saskatchewan

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1. Introduction

Virgiana was a large-shelled pentamerid brachiopod that flourished throughout North America and much of Siberia for a short time during the Early Silurian (middle-late Rhuddanian). *Virgiana decussata* from the Williston and Hudson Bay basins is easily distinguishable because its shells are the largest and bear the most numerous costae among all *Virgiana* species. In the Williston and the Hudson Bay basins, shells of *Virgiana decussata* are abundant, commonly preserved as shell beds in the basal parts of Fisher Branch and Severn River formations. The species was first described by Whiteaves (1891, 1906) and Kindle (1915) on the basis of specimens collected from the Grand Rapids area near the Saskatchewan River mouth. Stearn (1956) noted a much wider distribution of the species in the Fisher Branch Formation along the outcrop belt of Manitoba.

Biostratigraphic importance of the *Virgiana decussata* beds in Manitoba was recognized by Kindle (1914), who identified the "*Virgiana* zone" in the Paleozoic outcrop belt of Manitoba. This zone was used to mark the stratigraphic "Unit B" of Baillie (1951) and the Fisher Branch Formation of Stearn (1956).

In many drill hole cores stretching from the Winnipeg to the Grand Rapids area, the *V. decussata* beds are common and have been used as a marker for the basal Silurian slightly above the Ordovician-Silurian boundary (Bannatyne, 1988; Bezys, 1991; Bezys and McCabe, 1996).

In Saskatchewan, the earliest report on the occurrence of *Virgiana* in Silurian strata dates back to Richardson (1823), who collected brachiopod shells from the Cumberland House area. These were identified as *Pentamerus aylesfordii* by Sowerby and *Pentamerus knightii* by Davidson, and regarded as *Pentamerus decussatus* by Whiteaves (1891). However, in his study of the Ordovician and Silurian stratigraphy of east central Saskatchewan, Kupsch (1952) did not succeed in locating the *Virgiana* locality in the Cumberland House area. Except for these early reports, the presence of *Virgiana* in Lower Silurian outcrops of north-central Saskatchewan has not been convincingly documented. In drill hole cores, however, *Virgiana* occurs in a number of wells (Haidl, 1992; Norford, 1998; Norford *et al.*, 1998).

Elsewhere, *Virgiana decussata* has been recovered from the basal part of the Severn River Formation in the Hudson Bay Lowlands. As the *Virgiana* beds represent a marker for the first of four major marine transgressions in the Llandovery (Johnson *et al.*, 1995) and the same species occurs in the Williston and Hudson Bay basins, a detailed study of the stratigraphic range and geographic distribution of *V. decussata* is critical for biostratigraphic correlation and paleogeographic reconstruction of the two basins.

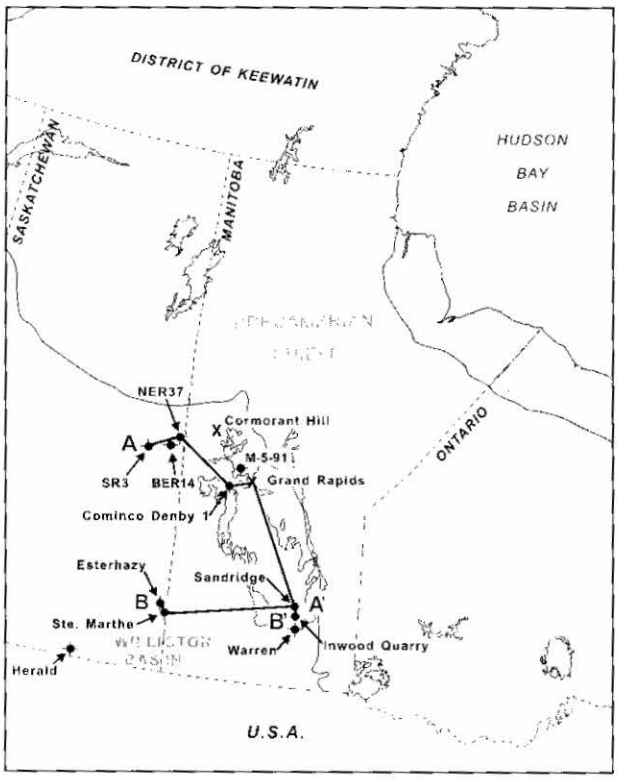

Figure 1 - Regional map showing the locations of selected studied wells and the Grand Rapids section. Also shown are locations of the two stratigraphic cross sections illustrated in Figures 5 and 6.

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The subsurface and outcrop occurrences of *V. decussata* in the Hudson Bay Basin, as summarized by Jin *et al.* (1993), were used by Norford *et al.* (1998) as an important reference marker in their study of the Ordovician-Silurian boundary interval in Saskatchewan and Manitoba. It is the purpose of this paper to provide a comparable survey of the species in core and outcrop sections of the Williston Basin.

This study is based on the examination of 44 cores in Manitoba and Saskatchewan and a re-examination of the type locality of *V. decussata* near the mouth of the Saskatchewan River at Grand Rapids (Figure 1 and Table 1).

Table 1 - Occurrences of** Virgiana decussata **in the subsurface of Manitoba and Saskatchewan.

Well Name	Well Location	UTM Northing	UTM Easting	*Virgiana* in Fisher Branch (Interlake) (m)	Upper Stonewall marker (m)	t-marker(s) (m)
Manitoba Wells						
Warren M-1-86	13-31-13-1W1	5555900	600485	32.76 - 37.65	40.7 - ??	42.5 - 44.5
Inwood Quarry M-2-88	4A-11-18-1W1	5597720	606100	25.3	29.7 - 30.7	35.5 - 37.0
Inwood Quarry M-4-69	4B-11-18-1W1	5597775	606150	19.6 - 21.1	21.1 - 26.0	27.5 - 30.8
Sandridge M-32-91	7-3-19-1W1	5606440	604950	15.7	17.3 - 18.5	ND[1]
Sandridge M-18-91	1-10-19-1W1	5607360	605670	6.0 and 12.7	13.8 - 15.3	ND[1]
Sandridge M-16-91	5A-10-19-1W1	5607600	604250	8.0	11.9 - ??	13.6 - 14.4
Sandridge M-25-91	5B-10-19-1W1	5608080	604410	3.2 and 10.4	10.9 - 12.8	ND[1]
Sandridge M-27-91	7-10-19-1W1	5607750	604920	11.4 - 11.8	11.8 - 13.3	18.0 - 19.0
Sandridge M-20-91	8-10-19-1W1	5608170	605660	6.9 - 7.3	7.3 - 8.5	14.3 - 14.6
Sandridge M-21-91	9-10-19-1W1	5608560	605560	5.6	6.0 - 7.5	14.3 - 14.6
Sandridge M-24-91	13-10-19-1W1	5608920	604420	6.0 - 7.0	7.0 - 8.4	13.0 - 14.1
Poplarfield M-35-92	5-4-22-1W1	5635840	601660	17.9	18.3 - 19.6	ND[1]
Broad Valley M-3-88	8-14-23-3W1	5648675	586375	43.2 - 50.0	50.0 - 51.4	55.5 - 57.0
Sturgeon Gill Road M-3-91	13A-7-52-12W1	5925398	485198	20.61 - 20.73	not picked	24.64 - 24.79
Sturgeon Gill Road M-4-91	13B-7-52-12W1	5925398	485198	20.6 - 20.94	20.9 - 21.9	24.55 - 24.95
Grand Rapids Core Hole 403	1-28-48-13W1	5890400	480600	12.5 - 14.3	14.3 - 14.5	17.2 - 17.8
Footprint Lake N M-1-95	13-5-50-13W1	5904550	477860	18.9 - 20.4	20.4 - ??	23.8 - 26.1
Footprint Lake M-1-89	8-7-50-13W1	5905525	477575	30.0	30.0 - ??	34.1 - 36.2
10 Mile Road M-2-89	12-19-51-13W1	5919232	475095	34.2 - 34.8	34.8 - 35.8	38.34 - 40.32
N Sturgeon Gill Road M-8-95	9-4-52-13W1	5923540	479900	24.68	not picked	28.3 - 28.85
N Sturgeon Gill Road M-4-95	10-8-52-13W1	5925330	477780	33.3	33.6 - ??	36.9 - 39.0
Cat Trail M-3-89	3-17-52-13W1	5926000	477275	36.6 - 38.1	38.1 - 40.4	42.0 - 43.8
Honeymoon Lake M-3-93	5-24-52-13W1	5931175	480213	26.8 - 28.3	28.3 - 28.98	31.44 - 32.7
West Honeymoon Lake M-9-95	1-32-52-13W1	5930900	478250	33.8	not picked	38.4 - 39.0
Microwave Road M-5-89	11-8-53-13W1	5934950	477520	37.4 - 38.4	38.4 - 39.3	41.6 - 43.1
Little Limestone Lake South M-4-94	7-29-54-13W1	5948885	477816	34.9 - 35.4	35.4 - 36.8	not picked

Table 1 (continued) - Occurrences of* Virgiana decussata *in the subsurface of Manitoba and Saskatchewan.

Well Name	Well Location	UTM Northing	UTM Easting	*Virgiana* in Fisher Branch (Interlake) (m)	Upper Stonewall marker (m)	t-marker(s) (m)
William Lake NE M-1-94	7-34-56-13W1	5970496	479610	20.2 - 20.7	20.7 - 23.6	25.3 - 26.0
Capstan Point M-4-89	5-34-48-14W1	5892605	471309	?? - 47.17	47.17 - 47.6	51.5 - 53.8
North Dike Road M-1-96	13-24-50-14W1	5909450	474500	36.6	36.6 - ??	40.5 - 42.0
Cook's Cave SE Grand Rapids M-6-91	15-18-51-14W1	5917738	466222	39.1 - 39.5	39.5 - 40.25	43.02 - 45.02
Cook's Cave North M-1-93	4-20-52-14W1	5927723	467033	49.0 - 49.74	49.74 - 51.5	53.55 - 55.76
Reedy Lake Lineament East M-5-95	11-25-54-14W1	5949459	474227	30.08 - 30.58	30.58 - 31.33	34.14 - 35.28
Reedy Lake Lineament West M-6-95	11-25-54-14W1	5949489	474124	30.2 - 30.7	30.7 - ??	34.4 - 35.6
William Lake M-12-90	7-21-55-14W1	5957370	468362	27.3 - 29.9	32.2 - 33.0	35.2 - 36.0
Cook's Cave South M-5-91	14-23-51-15W1	5919340	462537	43.8 - 45.1	45.3 - 46.0	49.23 - 50.24
Davidson Lake M-10-90	11-16-55-15W1	5956124	458392	39.9 - 40.2	not picked	44.4 - 45.2
Cominco Denby-1	12-25-47-17W1	5881425	445725	71.8 - 72.1	73.1 - 73.5	77.6 - 78.7
Saskatchewan Wells						
PCS Mining Ste. Marthe[2]	1-14-17-30W1	5593978[3]	748247[3]	1183.75 - 1183.95	1184.75 - 1186.55	upper[4]: 1190.54 - 1191.46 lower[4]: 1192.38 - 1193.6
Hudson Bay Namew Lake NER 36	4-8-59-30W1	5996603[3]	700739[3]	15.2 - 15.3	15.3 - 17.2	18.7 - 19.3
Hudson Bay Namew Lake NER 37	13-23-58-31W1	5991002[3]	698816[3]	25.6 - 26.1	26.2 - 27.7	30.3 - 30.6
IMC Esterhazy K-1 3SWD[2]	16-26-20-33W1	5626306[3]	714862[3]	1181.81 - 1182.03	1185.0 - 1186.52	upper: 1189.84 - 1191.0 lower: 1192.02 - 1192.8
Cominco BER14	7-3-58-3W2	5984000	672750	35.0 - 35.3	36.3 - 38.7	41.5 - 42.3
Cominco SR3	9-36-57-8W2	5981463	628000	51.91 - 51.96	52.12 - 53.57	56.99 - 57.26

Notes:

1 not drilled deep enough
2 core depths adjusted to log depths
3 extended Zone 13 UTM co-ordinates
4 not cored

2. *Virgiana decussata* Beds at the Type Locality

Whiteaves' (1891) description of *V. decussata* was based on the specimens collected by Tyrrell (1892) from the south bank of the Saskatchewan River at the foot of the Grand Rapids. Kindle (1915) was the first to provide a detailed description of the *Virgiana*-bearing section at the Grand Rapids type locality, although he failed to locate the *Virgiana* beds on the south bank of the river. Both Tyrrell (1892) and Kindle (1915) recorded one *Virgiana* bed and placed it at 3.35 m (11 ft) above the base of the Grand Rapids section.

During the 1998 field trip (JJ and GG) to Grand Rapids, a section on the south bank of the Saskatchewan River was measured, right below the Wayside Park, and two *Virgiana* beds were found (Figure 2). The lower *Virgiana* bed is a densely packed coquina with an average thickness of 30 cm, and contains a mixture of disarticulated valves, conjunct shells, and shells preserved in life position (Figure 3A to 3C). This corroborates Johnson and Lescinsky's (1986) finding of *Virgiana* clusters in life position from the Fisher Branch Formation. The shell bed is underlain by a 30 cm thick dolowackestone rich in

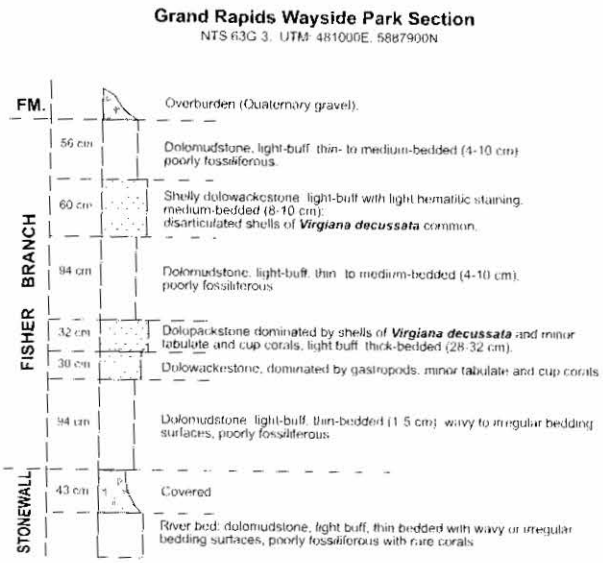

Figure 2 - Outcrop section on south bank of the Saskatchewan River, just below the Wayside Park picnic site, Grand Rapids. Note the occurrences of two* Virgiana *beds.

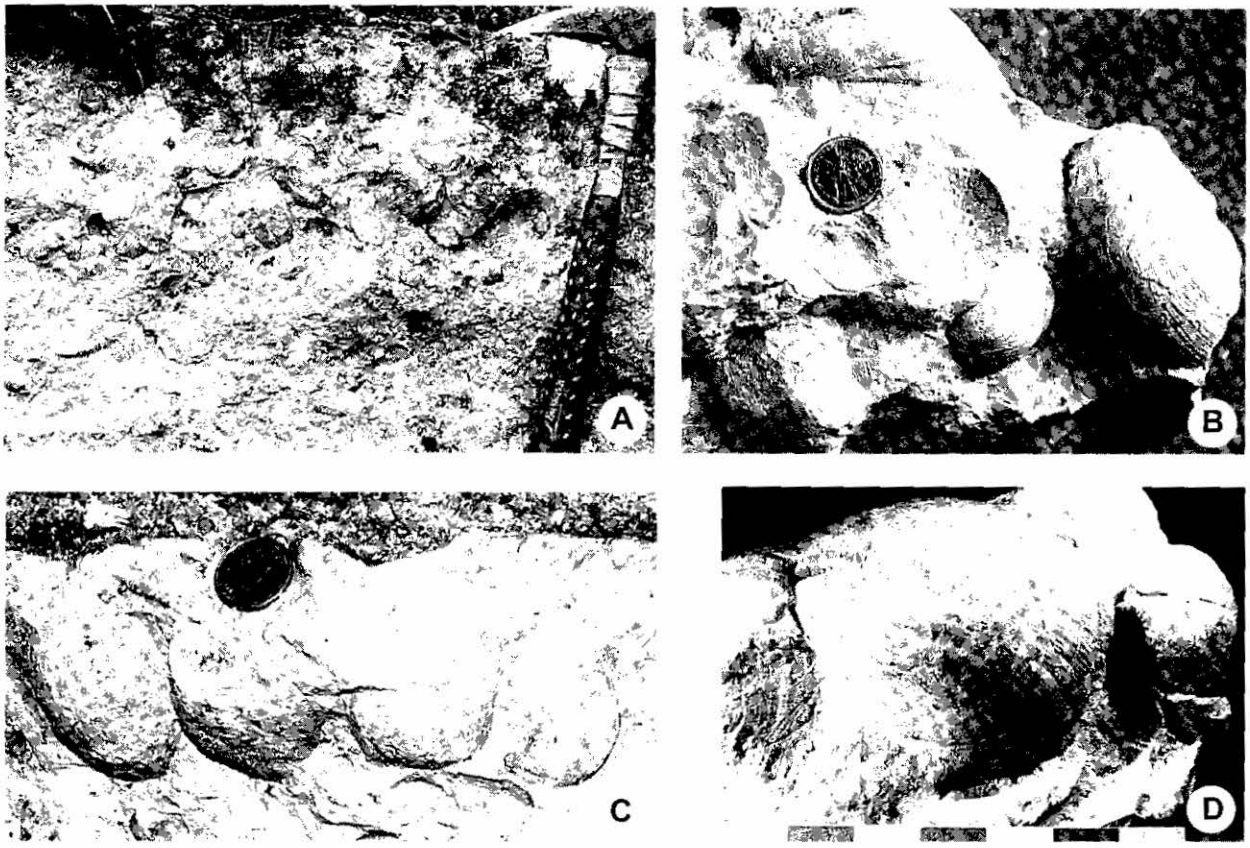

Figure 3 - A) to C) Lower* Virgiana *bed at the Grand Rapids Wayside Park Section (refer to Figure 2). A) shelly dolopackstone with complete shells and disarticulated valves of* V. decussata*; B) nearly complete, conjunct shells of* V. decussata *showing characteristic fine ribbing and posterior ovarian pits (dime for scale); C) nearly complete, conjunct shells of* V. decussata *preserved in life position (dime for scale); and D) coquinitic dolopackstone with well-preserved* V. decussata *from the basal Severn River Formation, near Churchill, Hudson Bay Lowlands (scale bar in centimetres).

gastropods and small tabulate and solitary rugose corals. Below is a barren to poorly fossiliferous unit 94 cm thick above a covered 43 cm thick interval, which probably correlates with the Upper Stonewall marker bed. In the subsurface, the marker is typically a reddish brown, olive green, or bluish grey, argillaceous dolomudstone at the top of the Stonewall Formation. It tends to be recessive-weathering compared to the cleaner, harder, dolowackestone and dolopackstone above.

The shells in the upper *Virgiana* bed are considerably less densely packed and more fragmentary. Reddish-brown iron staining is more prominent in the upper *Virgiana* bed than in the lower one. The upper *Virgiana* bed is separated from the overburden of Quaternary glacial till by a 60 cm thick, poorly fossiliferous dolomudstone unit and from the lower by a 94 cm thick poorly fossiliferous dolomudstone. Our observation supports Johnson and Lescinsky's report of two distinct *Virgiana* beds in the Fisher Branch Formation. Traditionally, only a single *Virgiana* zone was recognized (Kindle, 1915; Stearn, 1956), which created correlation problems within the Fisher Branch Formation. The *Virgiana* bed of poorly preserved shells in outcrops near Narcisse (Stearn, 1956, p17) is most likely correlative to the upper *Virgiana* bed, which typically contains fragmentary shells in the Grand Rapids outcrops.

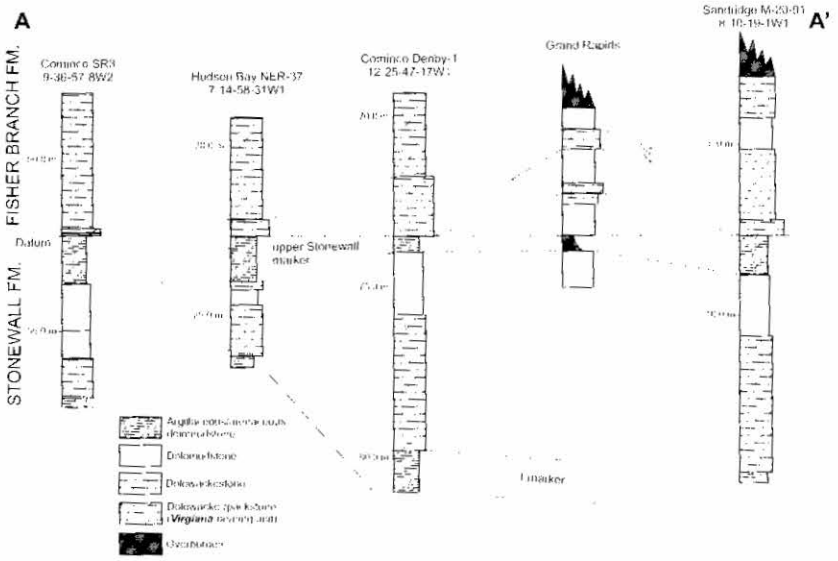

Figure 4 - Cross section A-A' through north-central Saskatchewan and Manitoba, showing stratigraphic distribution of Virgiana beds, Upper Stonewall Marker, and t-marker.

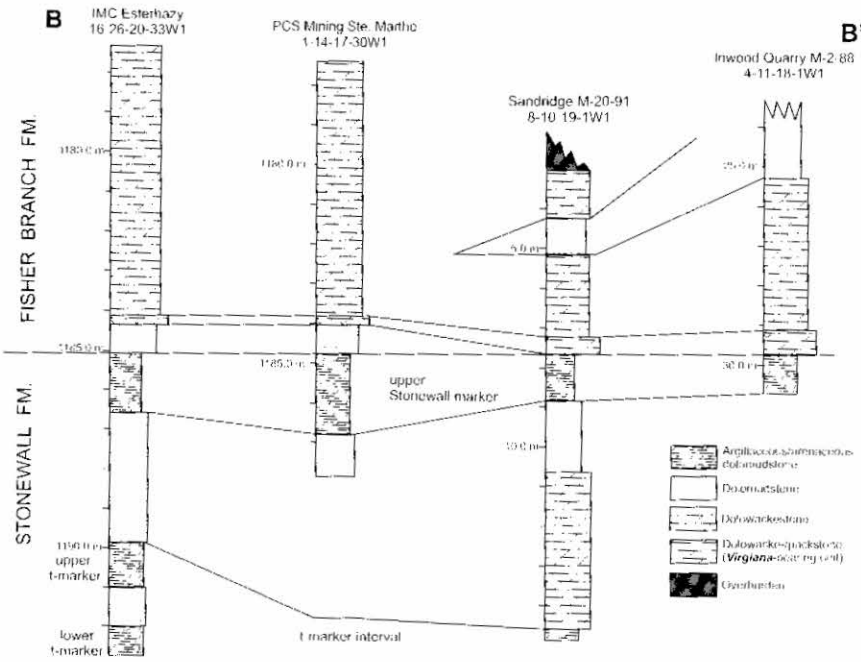

Figure 5 - Cross section B-B' through southern Saskatchewan and Manitoba, showing stratigraphic distribution of Virgiana beds, Upper Stonewall Marker, and t-marker interval.

3. *Virgiana decussata* in the Subsurface of Southern Manitoba

Examination of cored sections indicates that *Virgiana decussata* occurs within a 2 to 3 m interval at the base of the Fisher Branch Formation over a large area of the northeastern Williston Basin, from southern Manitoba to the Cumberland Lake area of north-central Saskatchewan (Figures 4 and 5). The Fisher Branch Formation is well defined in the subsurface of Manitoba, bounded in most places by the U_1 marker bed (Figures 6, 7, and 8H) at the top and the Upper Stonewall marker bed (Figure 8B) immediately below its base. Only in a few wells has *Virgiana* been observed to occur in significant numbers in the upper part of the Fisher Branch Formation, such as in M-1-86 drill hole (13-31-13W1, see Norford *et al.*, 1998).

In most wells, the *Virgiana* coquinitic bed of densely packed and relatively well preserved shells is about 40 to 60 cm thick and located within the basal 150 cm of the Fisher Branch Formation

(Figures 8C to 8E). It is apparently correlative to the basal *Virgiana* bed at the Grand Rapids section (see Figures 2 and 7). *Virgiana* shells are more scattered in the 2 m interval immediately above the basal shell bed (e.g. M-20-91) and a second shell bed may be present in some wells (e.g. M-18-91, M-25-91). Small favositid tabulate and solitary rugose corals are associated with the shell bed but are usually rare. In some wells, corals become more common immediately above the 1.5 m thick *Virgiana* interval (Figure 8F and G). A summary of the *Virgiana* occurrences in the subsurface of Manitoba can be found in Table 1.

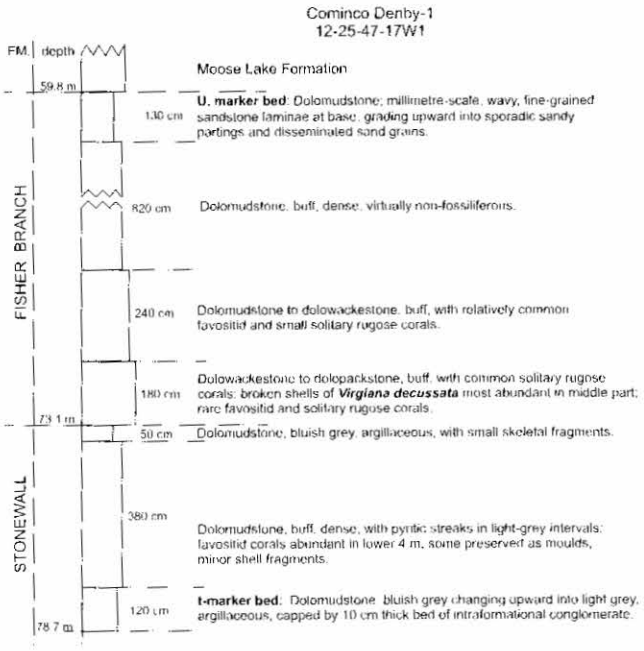

Figure 6 - Part of the cored section from well 12-25-47-17W1, from the t-marker to the U_1 Marker. Only one Virgiana zone is recognized.

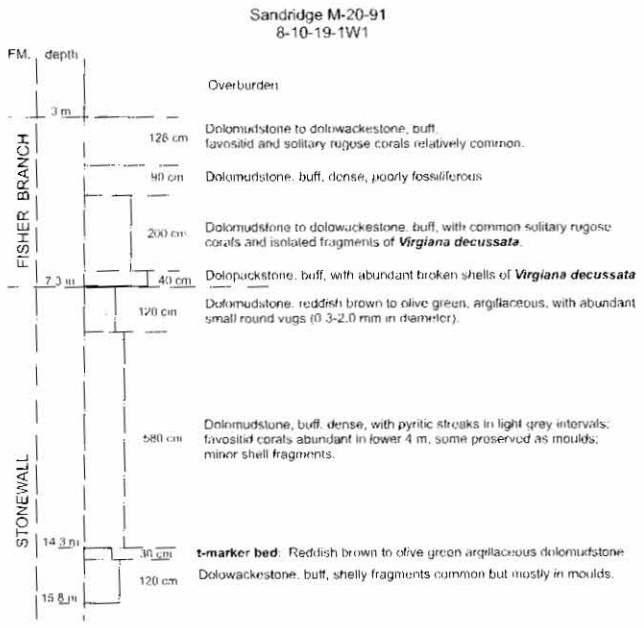

Figure 7 - Part of the cored section from well 8-10-19-1W1. Note the thicker interval between the t-marker and the Virgiana zone, as compared with that in the northerly wells.

4. *Virgiana decussata* in the Subsurface of East-central Saskatchewan

In general, the *Virgiana* shell bed is less well developed in Saskatchewan than in Manitoba. Except for a putative early report, no new material of *Virgiana* has been collected from outcrop in Saskatchewan. At present, *Virgiana* has been identified in six drill hole cores, but no coquinas have been observed. Compared to the Manitoba occurrences, the shells in the Saskatchewan wells are sparse and confined to intervals less than 50 cm thick. A list of the known *Virgiana* occurrences in the subsurface of Saskatchewan is given in Table 1.

5. Virgiana Beds and the t-marker Bed

In Manitoba, the base of the *Virgiana* zone is about 6 to 8 m above the top of the t-marker bed within the Stonewall Formation in the southern area (Townships 18 to 23, Ranges 4 to 14), but only 3 to 4 m in the northern area (Townships 47 to 56, Ranges 5 to 34). A similar southerly increase in the vertical distance between the top of the t-marker bed and the *Virgiana* zone is apparent in the Saskatchewan wells. In the Namew Lake cores, for example, the base of the *Virgiana* zone is between 3.4 to 4.2 m above the top of the t-marker. The distance increases to about 7 m in the Esterhazy well (20-33W1).

The t-marker beds essentially consist of argillaceous dolomudstone, rich in silt- and fine sand-sized quartz grains and, in some wells (e.g. 12-25-47-17W1, 8-10-19-1W1), contain wispy laminations and intraformational conglomerates. The conglomerates tend to be best developed toward the top of the marker zone (Figure 8A). In the northern area, a single marker bed is predominantly red to olive green. In the southern area, however, a single marker bed in Manitoba and dual marker beds in Saskatchewan are distinctly grey to dark grey, with the exception of the lower t-marker in Esterhazy which is reddish brown. The colour variations probably reflect both primary composition (clay content) and diagenesis (oxidizing versus reducing conditions).

The mechanisms responsible for the transport and deposition of clastic material in these carbonate-evaporite sequences in the Williston Basin are not fully understood. Kendall (1976) interpreted the t-marker and other similar marker beds in the Upper Ordovician-Lower Silurian succession of the Williston Basin as basal lag deposits marking the beginning of transgressive cycles. Citing abundant "frosted quartz grains" as evidence, however, Johnson and Lescinsky (1986) interpreted the marker beds as deposits belonging to peak regression and subaerial exposure – marking the end of depositional cycles.

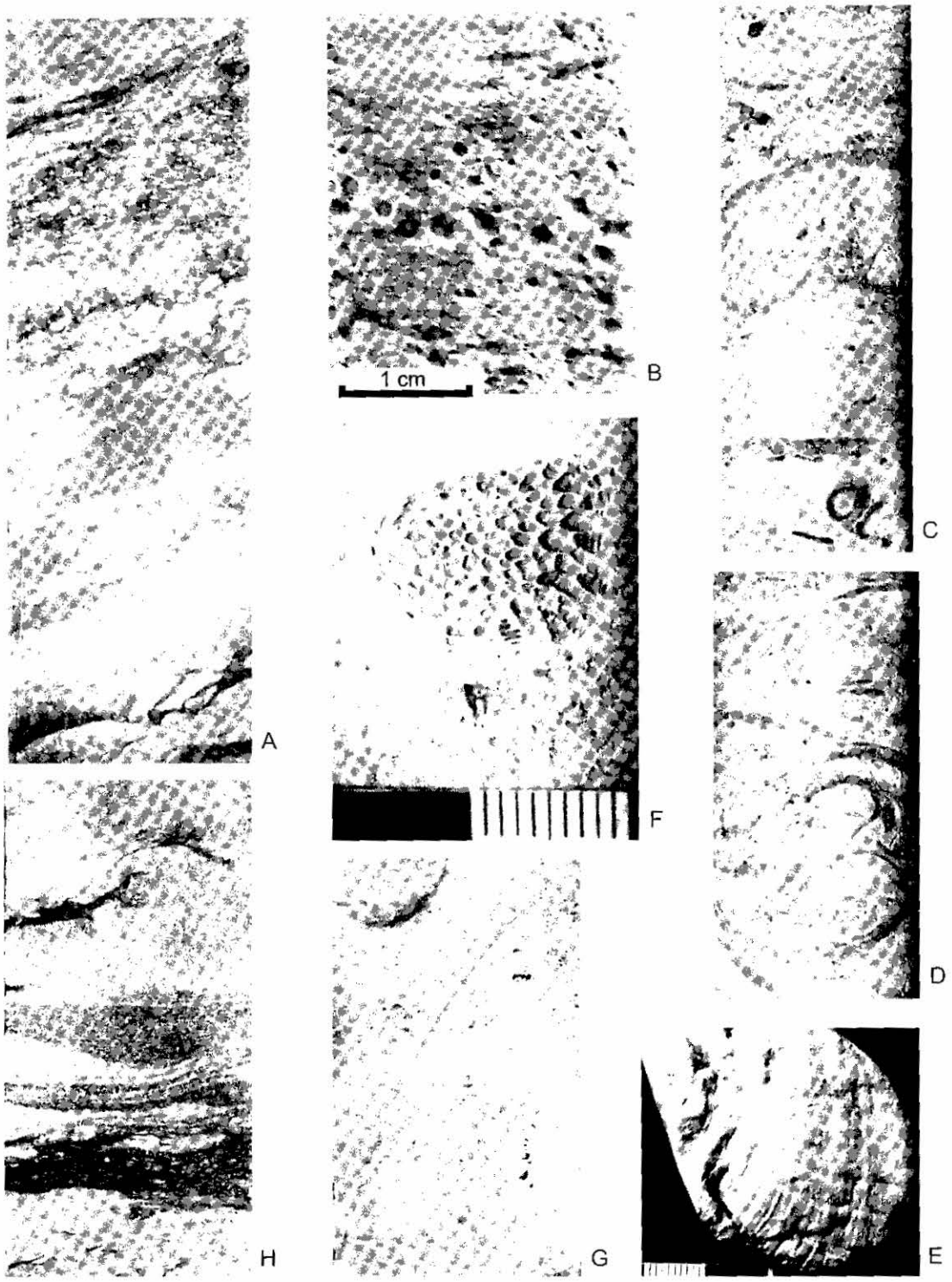

Figure 8 - Selected lithologies of the Stonewall and Fisher Branch formations. A) t-marker bed, Stonewall Formation, argillaceous dolomudstone with intraclasts and weak laminations, well 12-25-47-17W1, 84.5 m (277 ft); B) Upper Stonewall Marker, top Stonewall Formation, reddish brown argillaceous dolomudstone, with small spherical voids, well 8-10-19-1W1, 7.8 m; C to E) *Virgiana decussata* ***shell bed, basal Fisher Branch Formation, well 14-23-51-15W1, 43.8 to 44.5 m, with ventral valve at core break (43.8 m) showing fine ribbing; F)*** *Palaeofavosites* ***about 3 m above basal*** *Virgiana* ***shell bed, well 8-10-19-1W1;G) interval rich in favositid and cup corals, 74.3 m (244 ft) depth, about 3.65 m above the basal*** *Virgiana* ***bed; and H)*** U_1 ***Marker bed at the top of the Fisher Branch Formation. Note laminae and contorted beds rich in fine sand- and silt-sized quartz grains. Specimens are 2.54 cm across except in B (scale as indicated) and in E and F (detailed scale divisions in mm).***

Recently published conodont data have shown that the t-marker interval coincides with the Ordovician-Silurian boundary in Saskatchewan and Manitoba (Norford *et al.*, 1998; Nowlan and Haidl, this volume). For example, the boundary is located above a single t-marker bed in the Cormorant road-cut section, immediately above the upper t-marker in the Esterhazy well (16-26-20-33W1), within the upper t-marker bed in the Herald well (1-31–1-20W2), and immediately below a single t-marker in two Sandridge wells (1-19W2) (Norford *et al.*, 1998; Nowlan and Haidl, this volume). Further work is required to determine the depositional environments of the individual marker beds and their significance in understanding the paleogeography during the Late Ordovician–Early Silurian.

On a broad scale, however, the t-marker interval can be regarded as a largely synchronous time line. Assuming that the basal *Virgiana* bed is also isochronous, the thicker carbonate succession between the t-marker and the *Virgiana* bed in the southern area indicates a higher rate of deposition, probably as a result of a higher rate of basin subsidence during Early Llandovery (Early Rhuddanian, pre-*Virgiana*) time.

6. Biostratigraphic and Paleogeographic Significance of the *Virgiana* Zone

To date, *Virgiana decussata* has been identified only in a relatively small northeastern corner of the Williston Basin. Detailed examination of additional cores penetrating the Silurian strata in southern Saskatchewan, North Dakota, and Montana may expand the known distribution of the genus, as our recent work has indicated that *Virgiana* can be identified even in intensely dolomitized cores. The known geographic distribution of *Virgiana* in the Williston Basin appears to parallel that in the Hudson Bay Basin, where the best-known occurrences of *Virgiana decussata* are in the Churchill area, and sporadic *Virgiana* localities can be traced northward to Southampton Island (Heywood and Sanford, 1976). No *Virgiana* has been found in the southern Hudson Bay Basin and the Moose River Basin (James Bay Lowlands; Jin *et al.*, 1993). Because *Virgiana decussata* was the first significant Early Silurian open marine shelly benthos in the Williston and Hudson Bay basins after the latest Ordovician glacio-eustatic sea level drawdown, its northerly distribution serves as strong evidence that the first major Silurian marine inundation of these two basins came from the north and that the two large intracratonic basins were well connected during the late Rhuddanian.

The *Virgiana decussata* beds in the Williston and Hudson Bay basins are regarded as correlative to the *Virgiana mayvillensis* Zone (*Coronograptus cyphus* Biozone, latest Rhuddanian) of the Anticosti Basin. In the Anticosti Basin, three Rhuddanian virgianid zones are known (Jin and Copper, 1998). The lower two zones, characterized by *V. lenticularis* and *V. barrandei* of early and mid Rhuddanian age, occur in relatively shallow-water deposits of the Becscie Formation (Jin *et al.*, 1996). The top *Virgiana* zone, represented by *Virgiana mayvillensis,* occurs in the calcareous shale and mudstone of the Merrimack Formation, which is interpreted to have been deposited during one of the two episodes in which sea level had risen to maximum within the Llandovery (Jin and Copper, in press). Such a major sea level rise in the continental-margin basin was recorded by the invasion of *Virgiana* fauna into the inland basins. The generally barren and gastropod-rich strata between the lower *Virgiana* bed and the top Stonewall Marker are most likely correlative to the *Virgiana barrandei* zone of Anticosti Island. The *Virgiana* fauna, therefore, provides import clues to the timing, direction and extent of the first Silurian marine transgression into the Williston and Hudson Bay basins.

7. Acknowledgments

This study was made possible by a University of Regina Natural and Applied Sciences Research Grant to Jisuo Jin. The Subsurface Geological Laboratory staff of Saskatchewan Energy and Mines and of Manitoba Energy and Mines provided valuable assistance in collecting subsurface data.

8. References

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