GS2017-13

Sedimentary facies variability of the Upper Ordovician Williams Member in the Williston Basin, southern Manitoba: lithostratigraphic implications

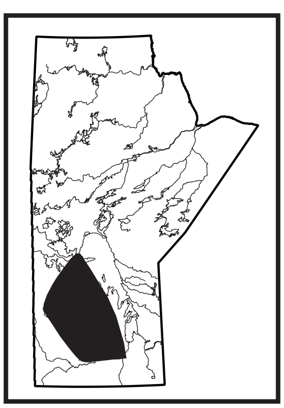
by C.Y.C. Zheng[1], M.G. Mángano[1] and L.A. Buatois[1]

[1] Department of Geological Science, University of Saskatchewan, 114 Science Place, Saskatoon, SK S7N 5E2

In Brief:

- The Williams Member is refined and placed into the Stony Mountain Formation
- Long-range correlations are challenging, with two depositional environments and correlation options proposed

Citation:
Zheng, C.Y.C., Mángano, M.G. and Buatois, L.A. 2017: Sedimentary facies variability of the Upper Ordovician Williams Member in the Williston Basin, southern Manitoba: lithostratigraphic implications; *in* Report of Activities 2017, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 148–157.



Summary

The Upper Ordovician Williams Member is analyzed based on the study of seven stratigraphic cores in the subsurface of Manitoba. Two remarkably different sedimentary facies, representing tidal flat and nearshore complex environments, have been traditionally included in this member. Confusion regarding the use of this member also generates debate on its placement at the top of the Stony Mountain Formation or the base of the lower Stonewall Formation. In this report, the Williams Member is redefined to include only the deposits of the last stage Stony Mountain Formation with two suggested correlations: 1) the member is limited to the nearshore deposits in southwestern Manitoba, or 2) the member includes tidal flat deposits toward the north and nearshore deposits toward the south. In addition, the tidal flat deposits situated above the Stony Mountain Formation should not be assigned to the Williams Member and should be included in the lower interval of the Stonewall Formation.

Introduction

The Upper Ordovician succession in the Williston Basin is characterized by the basal sandstone unit of the Winnipeg Formation, with overlying epeiric carbonate-anhydrite cycles that compose the Red River, Stony Mountain and Stonewall formations. A disconformity situated at the top of the Stonewall Formation marks a prolonged hiatus separating the Ordovician from the Silurian (Demski et al., 2015). Different subdivisions of these epeiric sea deposits have been adopted not only between Saskatchewan and Manitoba, but also in outcrop and subsurface due to a complex facies pattern. For instance, the Stony Mountain Formation was divided, from base to top, into the Hartaven, Gunn and Gunton members in Saskatchewan (Kendall, 1976). In Manitoba, the formation was divided into the Gunn, Penitentiary, Gunton and Williams members based on type sections in the outcrop belt (Elias et al., 2013b), whereas the formation was divided into the Hartaven, Gunn/Penitentiary and Gunton members in the subsurface of southwestern Manitoba (Nicolas and Barchyn, 2008). There is disagreement between these subdivisions. Specifically, the Williams Member, in places capped by the basal Stonewall anhydrite, was placed at the base of the lower Stonewall Formation in the subsurface of southwestern Manitoba (Bezys and Bamburak, 2004; Nicolas and Barchyn, 2008). However, the member was first proposed for the uppermost part of the Stony Mountain Formation based on outcrops in the Stonewall quarry (Smith, 1963; Cowan, 1971). The decision to move the Williams Member into the Stonewall Formation was based on detailed stratigraphic investigations conducted jointly by the Manitoba Geological Survey (MGS), Saskatchewan Geological Survey and the Geological Survey of Canada (R. Bezys, pers. comm., 2017), and even though a formal publication of that decision is not available, the stratigraphic reassessment is mentioned in Martiniuk (1992) and Norford et al. (1998). A recent study placed the upper contact of the member at a disconformity in the Stonewall quarry, suggesting its inclusion in the uppermost interval of the Stony Mountain Formation as well (Elias et al., 2013b).

The purpose of this study is to provide a preliminary assessment of the sedimentary facies variability of the Williams Member in the subsurface, aiming to clarify its definition and distribution, based on seven stratigraphic cores in southern Manitoba (Figure GS2017-13-1, Table GS2017-13-1).

Stratigraphic setting

In the Williston Basin, Late Ordovician sedimentation began with a large-scale marine transgression from the southeast. This punctuated transgression led to the deposition of shoreface sandstone to offshore mudstone of the Winnipeg Formation (Kreis, 2004; Dorador et al., 2014). Detailed lateral facies correlation at this stratigraphic level is complicated due to complex stratal architectures resulting from a series of topographic depressions on the underlying Cambrian

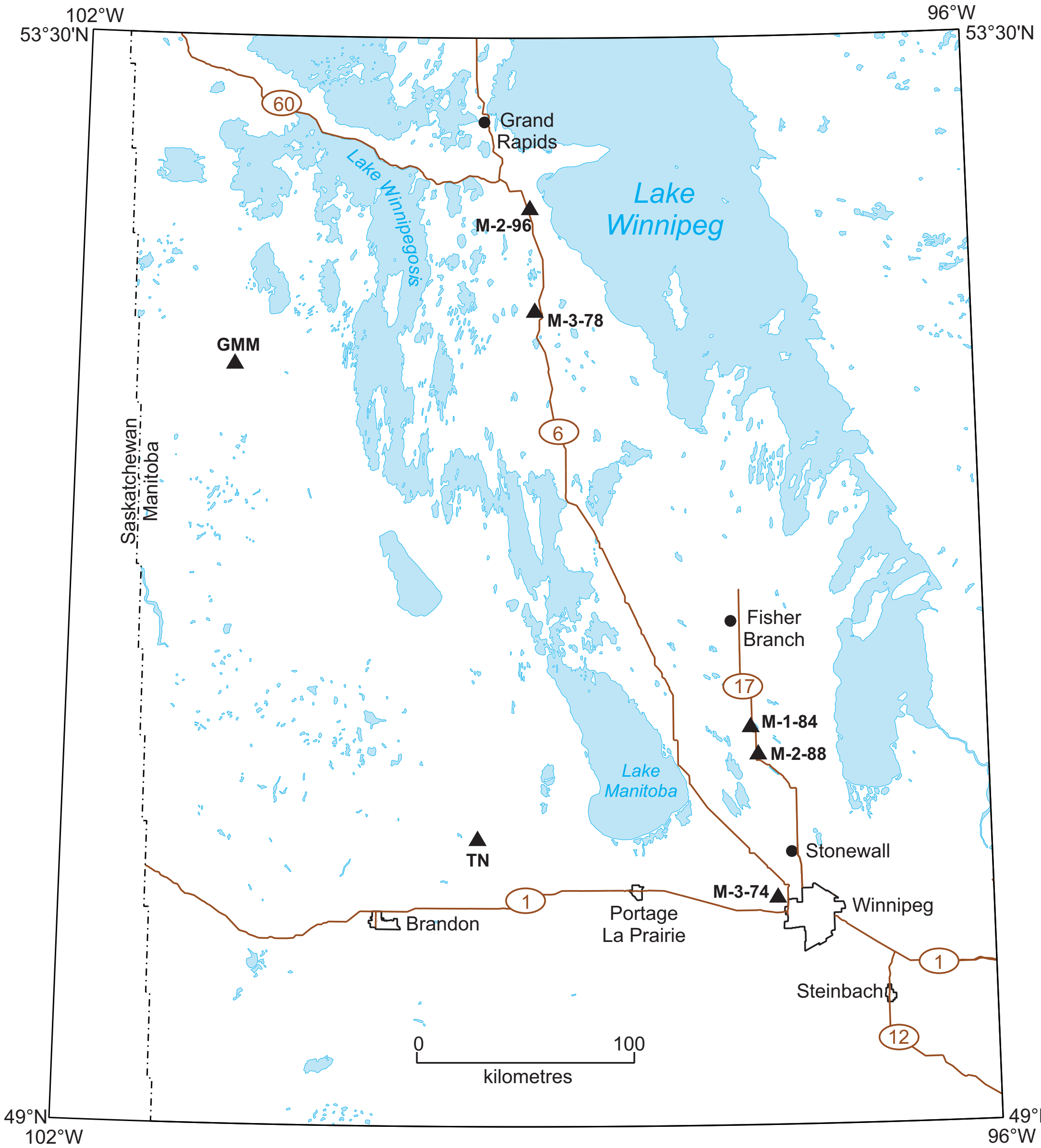


Figure GS2017-13-1: *Location map of the seven stratigraphic cores (black triangles) studied in southern Manitoba. Abbreviations: GMM, Gulf Minerals Minitonas; TN, Tudale Neepawa.*

Table GS2017-13-1: Details of well locations and cored intervals for the seven stratigraphic cores studied in southern Manitoba.

Drillhole	Location	Core interval
M-3-78	12-07-40-10W1*	73.6–98 m
M-3-74	01-21-11-01E1	2.0–27.7 m (6.6–90.9 ft.)
M-2-96	03-28-44-11W1	11.0–37.0 m
M-2-88	04-11-18-01W1	40.0–56.8 m
M-1-84	04-15-19-01W1	17.00–42.65 m
Tudale Neepawa	15-29-14-14W1	534.0–562.7 m (1752–1846 ft.)
Gulf Minerals Minitonas	03-29-36-25W1	381.0–402.3 m (1250–1320 ft.)

*L.S. 12, Sec. 7, Twp. 40, Rge. 10, W 1st Mer.

Deadwood Formation (Vigrass, 1971; Potter, 2006). Subsequent Late Ordovician sedimentation in the Williston Basin is characterized by carbonate-evaporite tripartite cycles. These cycles typically contain fossiliferous wackestones at the base, grading into parallel-laminated mudstone, and capped by anhydrite beds (Kent and Christopher, 1994; Norford et al., 1994). The Red River Formation records the first two cycles, whereas the Stony Mountain Formation and the lower interval of the Stonewall Formation together record the third cycle (Figure GS2017-13-2; Kendall, 1976). These cycles are variably preserved across the basin. The complete succession is preserved in a basin-centre position in southeastern Saskatchewan, whereas in Manitoba the capping anhydrites are commonly absent (Nicolas and Barchyn, 2008). Depositional trends in the Red River and Stony Mountain formations show a similar overall pattern in the Williston Basin, exhibiting the thickest strata in southern Manitoba and thinning toward the north (Bezys and Bamburak, 2004; Nicolas and Barchyn, 2008). Furthermore, subsurface correlations in the basin demonstrate continuous southwest-trending strata with minor lithological changes, and indicate depositional and erosional thinning of stratigraphic units from the southeast toward the northwest (Norford et al., 1994). In contrast, although the thickness and lithology of the Stonewall Formation are uniform throughout the outcrop belt (Bezys and McCabe, 1996), subsurface correlations of the formation exhibit a thinning trend toward the outcrop belt in the north and east (Nicolas and Barchyn, 2008). Subsequent erosion highly constrained the present distribution of these Ordovician carbonate successions. In the Williston Basin, erosion on the Transcontinental, Severn, Peace River and Sweetgrass–North Battlefield arches removed parts of the underlying deposits in the east, northeast, northwest and west of the basin, respectively (Norford et al., 1994). The widespread Ordovician epeiric carbonate deposits were correlated from northern Mexico to northern Greenland and from eastern Quebec to eastern Alaska, with the maximum distribution marked by the Red River–Stony Mountain coral province (Ross et al., 1982; Elias, 1991; Elias et al., 2013a).

In the subsurface of southwestern Manitoba, the Stony Mountain Formation was subdivided, from base to top, into the Hartaven, Gunn/Penitentiary and Gunton members. The Stonewall Formation was subdivided into the lower Stonewall Formation, which contained the basal Williams Member, and the upper Stonewall Formation. In places, the Gunton anhydrite and the basal Stonewall anhydrite capped the Gunton Member and the Williams Member, respectively (Figure GS2017-13-3; Nicolas and Barchyn, 2008). Although the precise lithostratigraphic position of the Williams Member is still ambiguous, this member serves as a transition between the underlying Gunton Member and the overlying lower Stonewall Formation.

The Williams Member was first characterized within the standard section at the Winnipeg Supply and Fuel Company quarry (Stonewall quarry) near the town of Stonewall and at that time it was included in the Stony Mountain Formation (Smith, 1963; Cowan, 1978). The member consists of argillaceous, mottled, dense arenaceous dolomite with coarse, well-rounded, frosted and pitted, quartz sand grains abundant

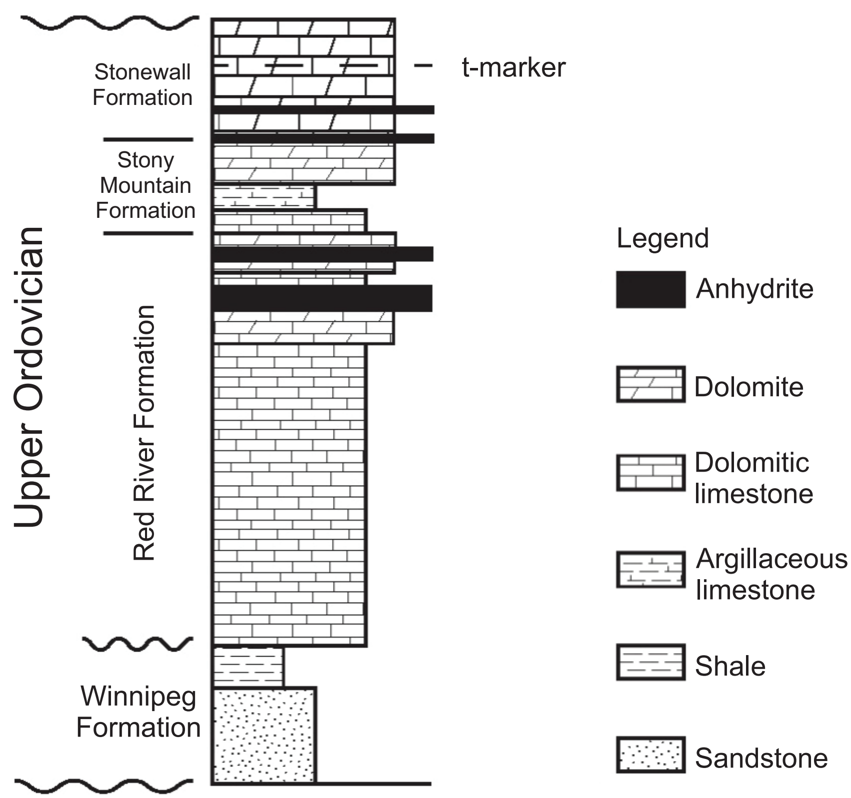


Figure GS2017-13-2: *The Upper Ordovician succession in the Williston Basin (modified from Kendall, 1976).*

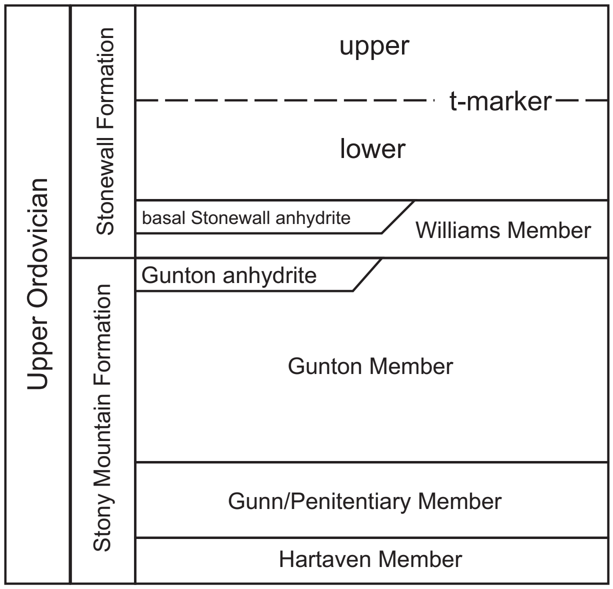


Figure GS2017-13-3: *Stratigraphy of the Upper Ordovician Williston Basin in the subsurface of Manitoba (modified from Nicolas and Barchyn, 2008).*

toward the base. In places, there is laminated to crossbedded and conglomeratic dolostone. This unit is recessive, pinching out toward the north, with the only other exposure around Fisher Branch (Smith, 1963; Cowan, 1978; Glass, 1990). Recent carbon-isotope profiling of the type section supported placing the formational boundary between the Williams Member of the Stony Mountain Formation and the overlying Stonewall Formation at a sharp, irregular contact (Elias et al., 2013b) located at a stratigraphically higher position than the original contact assigned by Smith (1963). This contact is indicative of a period of subaerial exposure and significant erosion, occurring after deposition of the bed that contains rounded, sand-size carbonate clasts and frosted quartz grains and before deposition of the overlying dolostone. Furthermore, the Williams Member was suggested to have been deposited during the final regressive stage of the Stony Mountain Formation (Elias et al., 2013b). On the other hand, at outcrops in the Grand Rapids uplands the Williams Member consists of planar-laminated to crossbedded dolostone, in places containing fine, subrounded quartz sand grains, with a subaerially exposed upper contact at the top of a thrombolitic interval. Therefore, the member was suggested to be part of the Stony Mountain Formation, having been formed under a tidal flat to restricted lagoon environment during a regression (Stewart, 2012; Elias et al., 2013b).

Discrepancies also occurred during subsurface investigations. In the subsurface, the Williams Member has an argillaceous marker bed defining the upper contact of the Stony Mountain Formation across southwestern Manitoba and southern Saskatchewan (Cowan, 1971; Kendall, 1976). Kendall (1976) suggested that the equivalent beds of the upper Williams Member in Saskatchewan have a conformable contact with the overlying lower Stonewall Formation, but unconformably rests on the underlying beds of the lower Williams Member. Therefore, Kendall (1976) discarded the Williams Member and put the lower equivalent beds into the Gunton Member and the upper equivalent beds into the overlying lower Stonewall Formation. In the subsurface of southwestern Manitoba, early subsurface investigations placed the member at the top of the Stony Mountain Formation (McCabe, 1978, 1979, 1984, 1988; Bannatyne, 1988). However, later core descriptions and subsurface studies in southwestern Manitoba relocated these strata within the lower Stonewall Formation (Norford et al., 1998; Bezys and Bamburak, 2004; Nicolas and Barchyn, 2008). In addition, the member was assigned to inconsistent positions in the successions.

Sedimentary facies variability

The sedimentary facies were examined in seven cores (Figure GS2017-13-1) with detailed study of trace fossils to help decipher the depositional environment. Assessing sedimentary facies variability in these strata is crucial to achieving a better correlation. Whereas previous studies focused on body fossils (Young et al., 2007; Stewart, 2012; Elias et al., 2013b), trace fossil analysis has proven useful for facies delineation in overall muddy environmental settings, where body fossils are scarce and severe dolomitization hampers detailed microfacies analysis. Various degrees of bioturbation are assessed following the bioturbation index (BI) scheme established by Taylor and Goldring (1993). Although dolomitization is pervasive in all sections, the lithological description below follows Dunham's (1962) classification of carbonate rocks.

In this study, two remarkably different deposits were included in the Williams Member in the subsurface at various locations in southern Manitoba: 1) the parallel-laminated mudstone predominated toward the northwest (cores M-3-78 [L.S. 12, Sec. 7, Twp. 40, Rge. 10, W 1st Mer., abbreviated 12-07-40-10W1], M-2-96 [03-28-44-11W1], GMM [Gulf Minerals Minitonas; 03-29-36-25W1]), and 2) arenaceous dolostone, parallel-laminated mudstone and mottled wackestone sharply underlain by parallel-laminated mudstone dominated toward the southeast (cores M-3-74 [01-21-11-01E1], M-1-84 [04-15-19-01W1], TN [Tudale Neepawa; 15-29-14-14W1]). The dense dolostone in the M-2-88 [04-11-18-01W1] core has an unusually low sand content and the reason for its unusual preservation will be the subject of future study.

Parallel-laminated mudstone

These deposits consist of parallel-laminated carbonate mudstone intercalated with crosslaminated to crossbedded grainstone (Figure GS2017-13-4a). An alternation of very fine sand-size and mud-size carbonate produces the centimetre-scale laminations. Body fossils and trace fossils are absent within the laminated intervals (BI 0). Locally, moulds of dissolved fossils occur, forming thin sheets (3–5 cm; Figure GS2017-13-4b). Sparsely bioturbated (BI 2), 5–10 cm thick intervals are intercalated within parallel-laminated intervals and contain monospecific suites of *Phycosiphon* (Figure GS2017-13-4c) and *Chondrites*. The grainstone is composed of medium- to

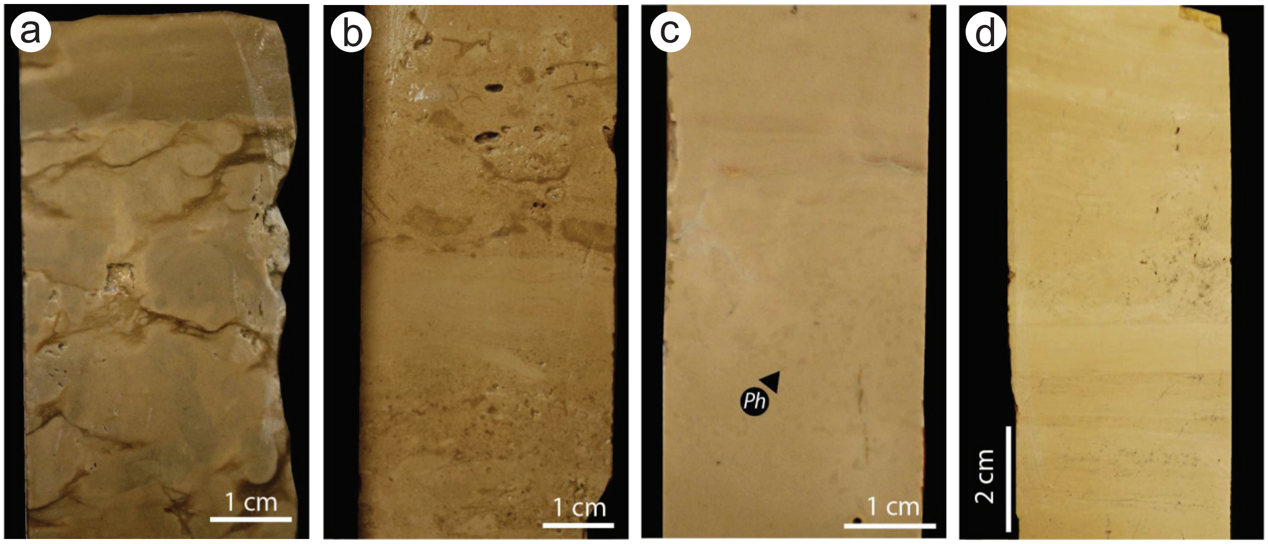


Figure GS2017-13-4: *Sedimentary facies of the parallel-laminated mudstone:* ***a)*** *sharp, basal contact of the parallel-laminated mudstone resting on top of nodular, mottled wackestone; depth 33.3 m in core M-2-96;* ***b)*** *bioclasts forming thin sheets (<5 cm) intercalated within the parallel-laminated mudstone; depth 12.2 m (40 ft.) in core M-3-74;* ***c)*** *a thin interval (BI 2–3) containing* Phycosiphon *(Ph) represents the establishment of short-term subtidal conditions between tidal flat progradations; depth 46 m in core M-2-88; and* ***d)*** *the upper part of this core interval contains crosslamination, whereas the bottom of the core interval contains planar-lamination; vugs are possibly remnants of dissolved bioclasts; depth 21.3 m (70 ft.) in core M-3-74. Top direction of the core is at the top of photo.*

fine-grained sand-size peloids and is characterized by scoured bases commonly with a basal lag underlying the low-angle crosslamination. Bioturbation is absent (BI 0) in this interval (Figure GS2017-13-4d).

Similar to the upper Red River Formation, some authors ascribed the parallel-laminated mudstone to intertidal and supratidal settings (Roehl, 1967; Kendall, 1976; Clement, 1985; Derby and Kilpatrick, 1985; Ruzyla and Friedman, 1985). However, the lack of evaporites and structures indicative of subaerial exposure may argue against a supratidal setting (Ginsburg et al., 1977). The scarcity of fossils, together with the presence of monospecific trace fossil suites, suggests restricted conditions. Whereas the producers of *Phycosiphon* and *Chondrites* would have colonized the sediment under subtidal conditions during refreshing events, the laminated intervals represent intertidal deposits formed during restricted conditions that prevented bioturbation. In contrast, the interbedded, cross-laminated grainstone records high energy sand shoals (Gonzalez and Eberli, 1997). In this case, nonbioturbation may have resulted from rapid deposition. Stewart (2012) suggested that the Williams Member in the Grand Rapids uplands was deposited under the shallowest and most restricted conditions in the Stony Mountain Formation, possibly in tidal flat and restricted lagoon environments.

Arenaceous dolostone, parallel-laminated mudstone and mottled wackestone

These deposits consist of a complex array of facies, ranging from arenaceous dolostone, parallel-laminated mudstone to mottled wackestone. In places, where bedding is well developed, the succession consists of basal medium- to fine-grained sandstone (up to tens of centimetres thick) intercalated with argillaceous dolostone, sharply overlain by parallel-laminated mudstone to mottled wackestone with a capping, thin, red-stained, argillaceous dolostone layer. The sandstone interval is rarely bioturbated (Figure GS2017-13-5a). Body fossils are absent. Sedimentary structures are remarkably rare and restricted to a few medium-grained sandstone beds, showing crossbedding and parallel lamination. The mottled wackestone is moderately to intensely bioturbated (BI 3–4), and characterized by *Thalassinoides*-like structures. Some sparse fenestrae in the mottled wackestone may be voids left by dissolved centimetre-scale skeletal remains (Figure GS2017-13-5b). Alternatively, in places where bedding was not well developed, deposits are characterized by arenaceous dolostone locally blackened by pyrite crystals (Figure GS2017-13-5c). Sand content varies at different locations, with visible quartz grains occurring locally. Crosslaminated to planar-laminated, medium-grained sandstone layers intercalate within this interval. Body fossils and trace fossils are usually absent. Certain intervals of arenaceous dolostone were stained by the red argillaceous layers intercalated within the successions.

As noted above, the parallel-laminated mudstone represents tidal flat deposits. The mottled wackestone with *Thalassinoides*-like structures has been interpreted as recording deposition in shallow subtidal settings (Kendall, 1977; Myrow, 1995; Zenger, 1996; Jin et al., 2012). Generally, shallow-marine, restricted conditions are characterized by the lack of macrofossils (Elias et al., 2013b) together with sparsely preserved bioturbation. Therefore, the *Phycosiphon* producer may have colonized during short-term refreshings likely related to flooding events, whereas the occurrence of *Thalassinoides*-like

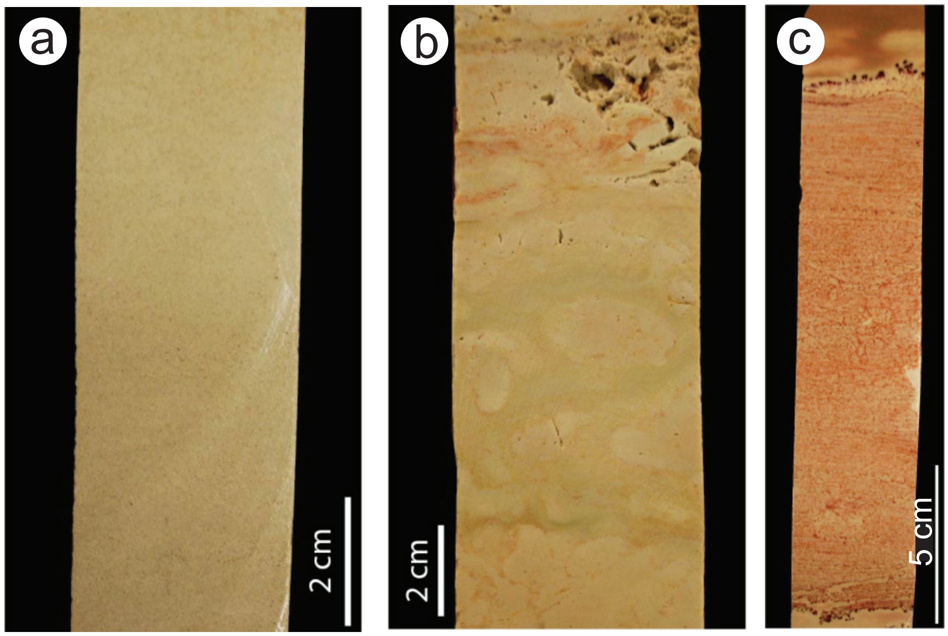


Figure GS2017-13-5: *Sedimentary facies of the arenaceous dolostone and mottled wackestone:* ***a)*** *a medium- to fine-grained sandstone layer (10 cm thick) intercalated within the arenaceous dolostone interval; depth 15.7 m (51.4 ft.) in core M-3-74;* ***b)*** *mottled wackestone; the nodular appearance results from the presence of burrows attributed to* Thalassinoides*; the upper part of the core interval contains vugs of body fossils; depth 10.4 m (34 ft.) in core M-3-74;* ***c)*** *planar-laminated to crosslaminated arenaceous dolostone, containing high sand content; black dots are pyrite crystals; depth 16.5 m (54 ft.) in core M-3-74. Top direction of the core is at the top of photo.*

burrows represents more open marine conditions. The whole succession, recording all the subenvironments interpreted above, is <10 m thick. This significant vertical change in sedimentary facies suggests a highly complex facies mosaic, probably representing a nearshore environment that encompassed a wide variety of subenvironments. Further evidence of a relative sea-level fall is provided by the capping arenaceous dolostone in the type section, which was interpreted to be the result of a period of subaerial exposure (Elias et al., 2013b).

Discussion

It can be surmised that confusion regarding the precise placement of the Williams Member originates from the application of different definitions. Specifically, in core M-2-96, the parallel-laminated mudstone, representing tidal flat deposits (depth 28.0–33.3 m), was included in the Williams Member and placed within the lowermost Stonewall Formation (R.K. Bezys and K. Horsman, unpublished core description, 1996; Figure GS2017-13-6). On the other hand, very different facies in core M-3-74, comprising vuggy, mottled, argillaceous dolostone intercalated with arenaceous dolostone representing nearshore deposits (depth 6.5–18 m [21.3–59.1 ft.]), were also placed within the lowermost Stonewall Formation (H.R. McCabe, unpublished core description, 1974; Figure GS2017-13-6). H.R. McCabe (unpublished core description, 1974) initially assigned the Stonewall Formation–Stony Mountain Formation contact to depth 12.6 m (41.3 ft.) but later moved it to depth 18.0 m (59.1 ft.; Figure GS2017-13-6).

Correlation problems lie not only in the different nature of these deposits, but also in the fact that significant diachronism is involved. A single thin dolomitic mudstone bed containing angular clasts of the same lithology as the underlying facies underlies the Williams Member in core M-3-74. These types of contacts commonly cap the tidal flat deposits toward the northwest, specifically at depths 388.6 m (1275 ft.) and 79.7 m in cores GMM and M-3-78, respectively. The underlying successions of the Stony Mountain Formation become dominated by the mottled, nodular wackestone at these places. Also, this contact is believed to mark the fragmental, sharp top of the Williams Member at depth 28.0 m in core M-2-96. Thin, shaly layers invariably mantled these contacts toward the northwest, and are comparable to the marker bed at the top of the Stony Mountain Formation in the subsurface of Saskatchewan (Kendall, 1976). These strata are analogous to equivalent strata in the Big Horn Dolomite in Wyoming, where similar contacts represent subaerial exposure at the termination of the parasequences of the Horseshoe Mountain Member (Holland and Patzkowsky, 2012). It is possible that intervals between three thin shaly marker beds situated higher in the sequence, in places mixed with patterned dolomite, record parasequences overlying the Stony Mountain Formation in southern Manitoba (Figure GS2017-13-7b, c). These possible parasequences could have been formed during a transition from a greenhouse climate to an icehouse climate preceding the Hirnantian glaciation (Holland and Patzkowsky, 2012). Coincidently, three to four informally assigned, reddish-stained marker beds characterize the lower Stonewall Formation in the subsurface of southern

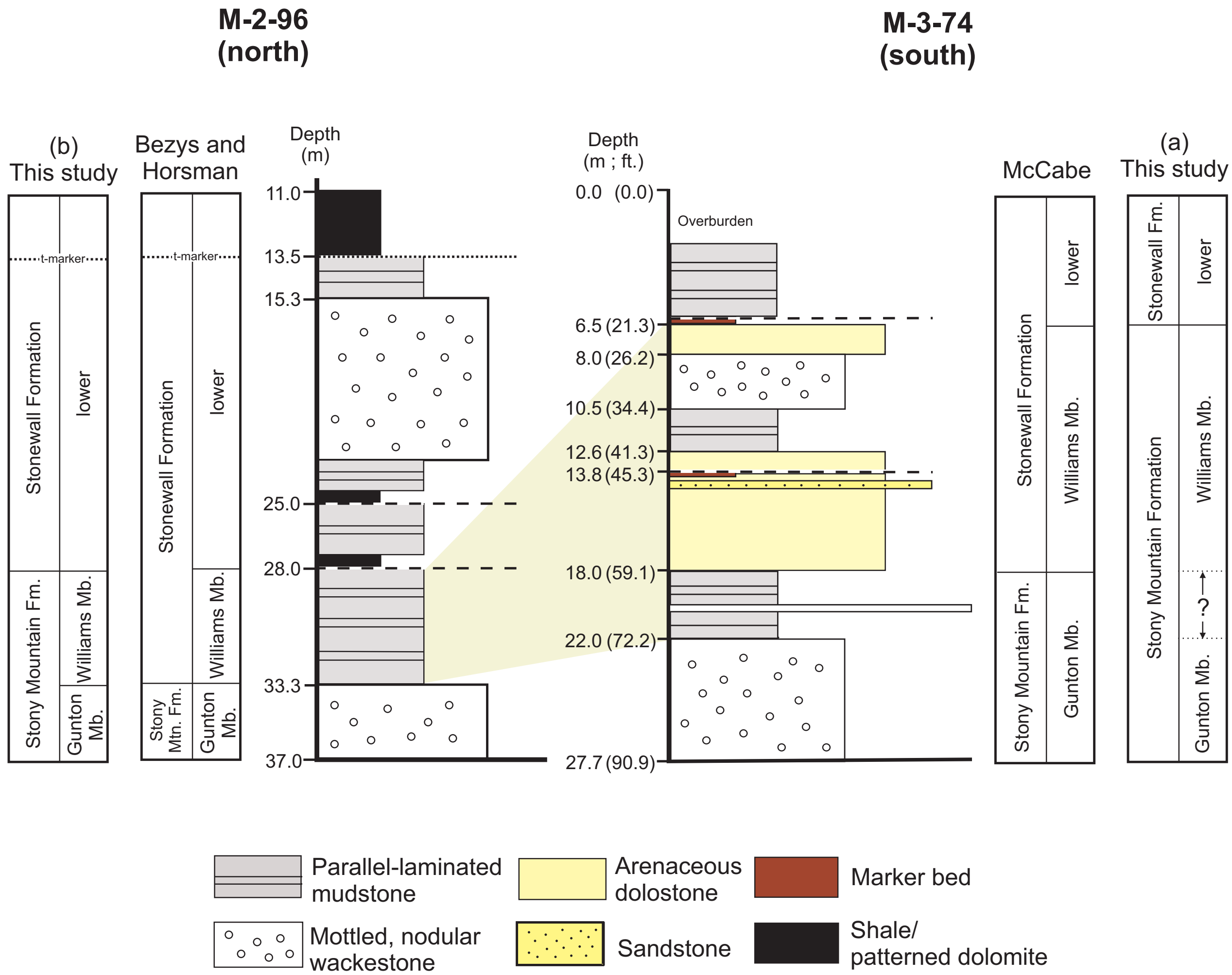


Figure GS2017-13-6: *Correlation between cores M-2-96 and M-3-74, showing previous subdivisions assigned to the two cores and alongside are the two possible revised subdivisions (labelled a and b) recommended from this study. The beige shaded area marks one revised correlation (b) of the Williams Member of the Stony Mountain Formation. The long dash lines mark shaly marker beds in core M-2-96 and reddish-stained marker beds in core M-3-74. Bezys and Horsman from unpublished core descriptions (1996) and McCabe from unpublished core descriptions (1974). Abbreviation: Mtn., Mountain.*

Manitoba (Figure GS2017-13-7a). In early investigations, the Williams Member was assigned to the intervals overlying the contacts at places where the Williams Member was considered to be the dolomite with shale interbeds, and overlying the contact, at 73.6–79.7 m in M-3-78, was placed in the Stony Mountain Formation (McCabe, 1978). Later identification of the upper Stony Mountain Formation contact and the capping marker bed is believed to be the reason for moving the Williams Member to within the lower Stonewall Formation (Norford et al., 1998).

The type section of the Williams Member in the Stonewall quarry is representative of the member in southern Manitoba, and Smith (1963) suggested deposition was continuous from the Gunton Member to the Williams Member. However, problems arose correlating the members toward the northwest, where the transitional intervals between the Gunton Member and the lower Stonewall Formation become dominated by parallel-laminated mudstone, representing tidal flat deposits with no sand influx. The authors agree with Elias et al. (2013b) that the Williams Member should be included in the upper part of the Stony Mountain Formation. Therefore, identifying the upper contact or marker bed of the Stony Mountain Formation is crucial. In addition, the parallel-laminated mudstone with shaly interbeds situated above the upper contact of the Stony Mountain Formation should not be assigned to the Williams Member.

The strata in the 6.5–18.0 m (21.3–59.1 ft.) depth interval in M-3-74 is comparable to the Williams Member section in the Stonewall quarry, and the Stonewall Formation–Stony Mountain Formation contact identified in the quarry is suggested to be placed at the top of the interval in M-3-74. In M-2-96, the upper contact of the Stony Mountain Formation is placed at a depth of 28.0 m. The Williams Member should not be assigned to the parallel-laminated mudstone with shaly interbeds situated

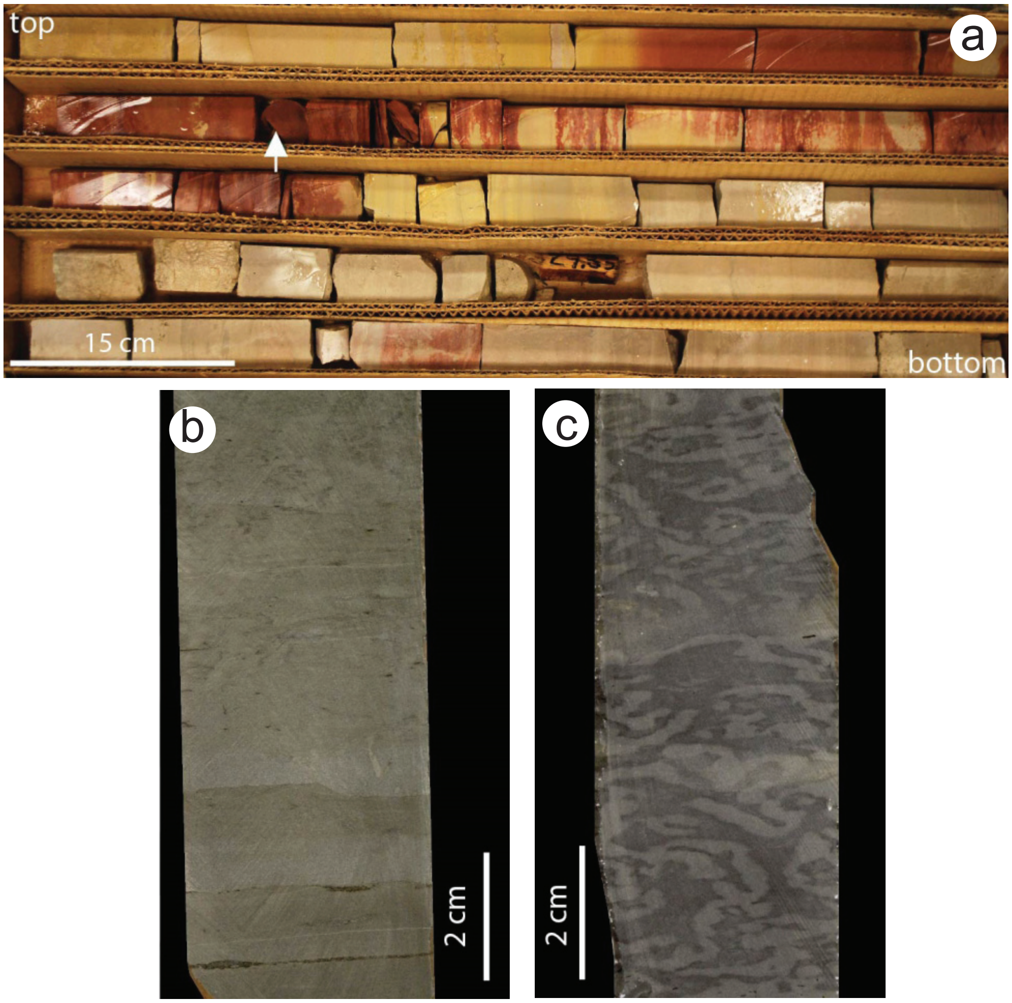


Figure GS2017-13-7: *Marker beds in the subsurface of southern Manitoba:* ***a)*** *an argillaceous, red-stained marker bed (indicated by arrow) intercalated within parallel-laminated mudstone and arenaceous dolostone in the Williams Member; depth 27.75–29.15 m in core M-1-84;* ***b)*** *a shaly layer punctuated within argillaceous dolostone caps the Stony Mountain Formation; depth 386.5 m (1268 ft.) in core Gulf Minerals Minitonas (GMM);* ***c)*** *a thin patterned dolomite layer marks the lower Stonewall Formation; depth 75.3 m in core M-3-78.*

above depth 28.0 m in M-2-96 (Figure GS2017-13-6). To address these issues, two possible stratigraphic revisions are proposed herein.

The first revision suggests that based on the characteristic sand content in the type section, the Williams Member in southern Manitoba should be limited to the intervals rich in clastic material and indicative of nearshore deposits. In this scenario, the member occurs in the south and pinches out toward the north, and is comparable to the trend in the outcrop belt. However, the distinct tidal flat deposits of the uppermost part of the Stony Mountain Formation cannot be differentiated from the underlying thick, mottled, nodular wackestone of the Gunton Member. These distinct tidal flat deposits are absent within the Gunton Member. For instance, the Williams Member of the Stony Mountain Formation is assigned to the interval at depth 6.5–18.0 m (21.3–59.1 ft.) in M-3-74 and pinches out toward the northwest. Although the 28.0–33.3 m depth interval in M-2-96 correlates to the 18.0–22 m depth interval in M-3-74, the intervals are absent within the Gunton Member (Figure GS2017-13-6, stratigraphic column a).

The second revision suggests that in the Williams Member in the subsurface of southern Manitoba the nearshore deposits in the south correlate to the tidal flat deposits in the north with a northward decrease in arenaceous content. In this case, both the tidal flat deposits and nearshore deposits would be included in the uppermost interval of the Stony Mountain Formation. In this scenario, the Williams Member is assigned to intervals of 28.0–33.3 m (Figure GS2017-13-6, stratigraphic column b) and 6.5–22.0 m (21.3–72.2 ft.; correlation shown in beige in Figure GS2017-13-6) in M-2-96 and M-3-74, respectively, and is included in the uppermost Stony Mountain Formation.

Depositional trend implications of the Williston Basin

Longman and Haidl (1996) proposed that the boundaries between members in the Willston Basin were isochronous based on a layer-cake stratigraphy and the assumption of basin-wide environmental changes. However, the apparent layer-cake stratigraphy partially originated from the loose definition of members. If the revised definitions of the Williams Member are adopted then progradational sedimentation with diachronous boundaries between facies is expected since this unit represents the maximum regressive phase of the uppermost part of the Stony Mountain Formation. Allogenic controls, especially eustatic fluctuations, undoubtedly impacted on stratal architecture, highlighting the need for high-resolution sequence stratigraphic studies, which may assist with intrabasinal correlation of key surfaces. Future studies applying sequence stratigraphic concepts to the study of these epeiric deposits may help to provide a more accurate picture of Ordovician facies distribution and depositional history for the Williston Basin.

Economic considerations

Although only two oil shows have been reported in the Stony Mountain Formation (Nicolas and Barchyn, 2008), the revised schemes proposed in this study may help to refine subsurface stratigraphy and long-range correlations. This is critical in understanding the oil pathways, which in turn help petroleum companies create exploration models they can use to build their wildcat exploration programs.

Acknowledgments

This research was funded by the American Association Petroleum Geologists Foundation Grants-in-Aid program and a SEPM student research grant to the first author, together with Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grants 311727-05/08/13 and 311726-05/08/15 to the second author and third author, respectively. Special thanks are given to M. Nicolas (Manitoba Geological Survey), who provided core information, guided the visit to the quarries and helped with this report; C. Epp (Manitoba Geological Survey), who provided enthusiastic and invaluable assistance in the Midland Sample and Core Library; and all the staff of the Midland Sample and Core Library, who assisted in preparing the core for viewing. The authors especially appreciate R. Elias' (University of Manitoba) extensive reviewing and insightful suggestions.

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