# [PS]Ichnology and the Characterization of Brackish-Water Paleoenvironments Within the Lower Cretaceous Mannville Group of West-Central Saskatchewan and East-Central Alberta, Canada*

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## Abstract

Preliminary ichnological-sedimentological study from 51 cored wells of the Lower Cretaceous (Early to mid-Albian) Mannville Group (Sparky, Waseca and McLaren Formations) in east-central Saskatchewan and west-central Alberta yield ten recurring facies that reflect conditions of reduced and fluctuating salinity, typical of brackish-water settings. The successions display physical sedimentological features dominated by abundant organic-rich mudstone drapes of probable fluid-mud origin, synaeresis cracks, soft-sediment deformation, carbonaceous detritus, normally graded mudstones and wave, current and combined-flow ripples. Facies are generally heterolithic, attesting to autocyclic fluctuations in depositional processes.

Ichnologically, bioturbation intensities range widely (BI 0-5) and facies are characterized by abundant diminutive ichnogenera comprising low-diversity (locally monogeneric) trace fossil suites. Common ichnogenera include *Gyrolithes*, *Teichichnus*, *Planolites*, *Palaeophycus*, *Cylindrichnus*, *Skolithos*, *Thalassinoides*, *Chondrites* and *Lingulichnus*. Rare but important elements include *Asterosoma*, *Lockeia*, *Phycosiphon*, *Rosselia* and *Rhizocorallium*. Most suites consist of mixtures of elements characteristic of both the *Skolithos* Ichnofacies and the *Cruziana* Ichnofacies. Persistent ichnogenera constitute facies-crossing elements that record permanent to semi-permanent dwellings of deposit-feeding infauna. Additional behaviours include navichnia (sediment-swimming structures) and fugichnia (escape structures), consistent with rapid and episodic deposition of sand as well as mud (e.g., via flocculation). Variations in bioturbation intensity primarily attest to marked changes in sedimentation rates.

The integration of ichnological and sedimentological datasets indicates that deposition occurred within brackish-water embayments, bay-head deltas, tidal flats, and coastal plain environments. Variations in trace fossil diversities and the introduction of less markedly

facies-crossing ichnogenera (e.g., *Asterosoma* , *Phycosiphon*, and *Rhizocorallium*) may suggest that elevated salinities occurred periodically within the study area.

## Selected References


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# Ichnology and the Characterization of Brackish-Water Paleoenvironments Within the Lower Cretaceous Mannville Group of West-Central Saskatchewan and East-Central Alberta, Canada

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## ABSTRACT

Preliminary ichnological-sedimentological study from 51 cored wells of the Lower Cretaceous (Early to mid-Albian) Mannville Group (Sparky, Waseca, and McLaren formations) in west-central Saskatchewan and west-central Alberta yield ten recurring facies that reflect conditions of reduced and fluctuating salinity, typical of brackish-water settings. The successions display physical sedimentological features dominated by abundant organic-rich mudstone drapes of probable fluid-mud origin, syneresis cracks, soft-sediment deformation, carbonaceous detritus, normally graded mudstones, and wave, current and combined-flow ripples. Facies are generally heterolithic, attesting to autogenic fluctuations in depositional processes.

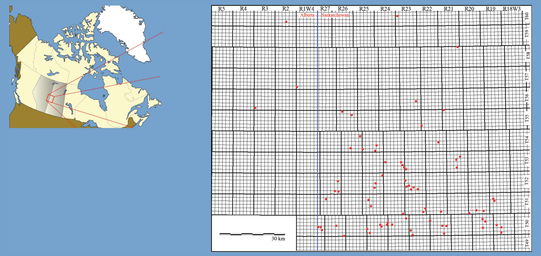
Ichnologically, bioturbation intensities range widely (BI 0-5), and facies are characterized by abundant diminutive ichnogenera comprising low-diversity (locally monogeneric) trace fossil suites. Common ichnogenera include *Gyrolithes*, *Teichichnus*, *Planolites*, *Palaeophycus*, *Cylindrichnus*, *Skolithos*, *Thalassinoides*, *Chondrites*, and *Lingulichnus*. Rare but important elements include *Asterosoma*, *Lockeia*, *Phycosiphon*, *Rosselia*, *Helminthopsis*, Terebellina and *Rhizocorallium*. Most suites consist of mixtures of elements characteristic of both the *Skolithos* Ichnofacies and the *Cruziana* Ichnofacies. Persistent ichnogenera constitute facies-crossing elements that record permanent to semi-permanent dwellings of deposit-feeding infauna. Additional behaviours include navichnia (sediment-swimming structures) and fugichnia (escape structures), consistent with rapid and episodic deposition of sand as well as mud (e.g., via flocculation). Variations in bioturbation intensity primarily attest to marked changes in sedimentation rates.

The integration of ichnological and sedimentological datasets indicates that deposition occurred within brackish-water embayments, bay-head deltas, tidal flats, and coastal plain environments. Variations in trace fossil diversities and the introduction of less markedly facies-crossing ichnogenera (e.g., *Asterosoma*, *Phycosiphon*, and *Rhizocorallium*) may suggest that elevated salinities occurred periodically within the study area.

## METHODOLOGY

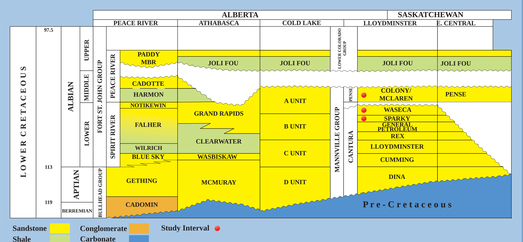
Data for this project was collected through the detailed examination of 51 cored wells of the Lower Cretaceous (Early to mid-Albian) Mannville Group (Sparky, Waseca, and McLaren formations). The cored intervals were evaluated for trace fossils, sedimentary structures, lithological features, and stratigraphic surfaces in order to assign interpretations of facies relationships, facies associations, and depositional environments. Ichnological appraisal includes ichnogenera identification, trace fossil size, bioturbation intensity, distribution of burrowing, and ethological interpretation.

## STUDY AREA

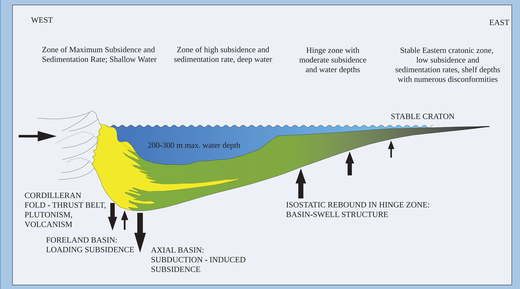



The study area is located in West-Central Saskatchewan and East-Central Alberta, Canada, shown in the above figures.The figures illustrate the geographical research area and core distributions employed from the eastern margin of the basin (Mannville Group).

## STRATIGRAPHIC CHART




Stratigraphic position of the Mannville Group within the Eastern Alberta and Saskatchewan (modified after Christopher, 1997).




Foreland development of the Western Canadian Sedimentary Basin (Leckie & Smith,

## BRACKISH-WATER ICHNOLOGICAL MODEL

1) a reduction in the number and diversity of animal species that consist mainly of marine rather than freshwater organisms.

2) pronounced size reduction of fauna compared to their fully marine counterparts, , leading to generally smaller sized trace fossils in the facies.

3) facies characterized by opportunistic colonization particularly of event of beds.

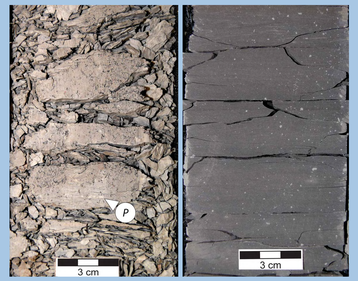
4) abundance of trophic generalists leads to suites dominated by facies-crossing ichnogenera.

5) brackish-water environments support large biomasses; most facies are burrowed to varying intensities.

6) vertical and horizontal ichnofossils are juxtaposed at the bed scale, dominated by forms that are common to both *Skolithos* and *Cruziana* ichnofacies.

## SUMMARY OF DEPOSITIONAL FACIES DESCRIPTIONS

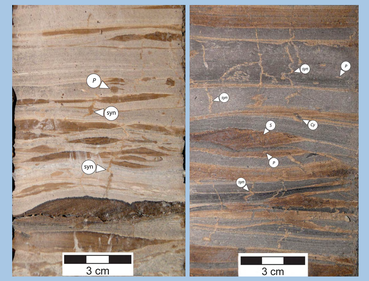
| | FACIES | LITHOLOGY | PHYSICAL SEDIMENTARY STRUCTURES | BIOGENIC STRUCTURES | BIOTURBATION INTENSITY | DEPOSIONAL PROCESSES | DEPOSITIONAL SETTING |
|---|---|---|---|---|---|---|---|
| Facies 1: Mudstone | 1a: Fissile Mudstone | Thick dark gray to black mudstone, locally laminated fine-grained sandstone/siltstone interlaminated. Shale 98%, sandstone/siltstone 2%. | Rare oscillation ripple lamination. | *Chondrites*, *Planolites*, navichnia | 0-2 | Mudstone deposited through suspension settling or as flocculated mud; sediment mobilized by oscillatory flow. | Various depositional settings, abandoned channel, chenier plain. |
| | 1b: Burrowed silty mudstone | Mixture of mudstone, fine-to very fine-grained sandstone and siltstone; mudstone 70%, sandstone/siltstone 30%. | Rare preservation of physical sedimentary structures, locally oscillation ripples, micro-HCS (thin-bedded low-angle undulatory parallel lamination). | *Teichichnus*, *Planolites*, *Palaeophycus*, *Asterosoma*, *Helminthopsis*, *Phycosiphon*, *Gyrolithes*, *Cylindrichnus*, *Skolithos*, *Chondrites*, fugichnia, navichnia | 2-5 | Mudstone deposited via suspension suspension sediment settling; as flocculated mud, sandstone deposited by oscillatory flow. | fully marine deposition below storm wave base or settings sheltered from storms, slow continuous deposition, oxygenated conditions. |
| | 1c: Pinstripe mudstone | Dark gray or black mudstone with very thin interbedded siltstone or very fine- grained sandstone. | Pinstripe lamination, normal grading, synaeresis cracks. | *Planolites*, *Cylindrichnus*, *Skolithos*, *Teichichnus*, *Gyrolithes*, navichnia | 0-2 | Mudstone deposited through suspension settling or as mud; sediment mobilized by oscillatory flow. | Various depositional settings, Possible hyperpycnal and/or hypopycnal conditions. |
| Facies 2: Facies 2: Mudstone dominated heterolithics | 2a: Lenticular-bedded mudstone | Gray, sideritic silty mudstone with very fine to fine grained rippled sandstone, locally bioturbated. Mudstones > 70% | Oscillation ripple cross-lamination, convolute bedding, normally graded beds, sharp contacts. | *Planolites*, *Skolithos*, *Cylindrichnus*, *Teichichnus*, navichnia | 0-2 | Alternation between traction transport and suspension sediment deposition. | Various depositional settings, common in shallow, subtidal to intertidal environments. |
| | 2b: Burrowed mudstone and sandy siltstone | Heterolithic, interbedded mudstone and very fine-to fine-grained sandstone. Mudstones > 70% | Oscillation ripple cross-lamination, local micro-HCS, synaeresis cracks, normal grading. | *Planolites*, *Skolithos*, *Gyrolithes*, *Teichichnus*, *Thalassinoides*, *Palaeophycus*, *Rosselia*, *Rhizocorallium*, *Terebellina*, *Chondrites*, fugichnia, navichnia | 1-5 | Mudstone deposited through suspension settling or as flocculated mud, sediment mobilized by oscillatory flow. Clay shrinkage from salinity fluctuations. | Deposition within fair weather wave base. Fluctuating salinity, low rate of sedimentation, and periodic event sedimentation |
| Facies 3: - Subequal sandstone and mudstone heterolithics | 3a: Sporadically to moderately burrowed interbedded sandstone and mudstone | Heterolithic mudstone and sandstone; sharp contacts, locally bioturbated. Sandstone/mudstone proportions approximately subequal | Oscillation ripple, very rare current ripples, sand filled synaeresis cracks. | *Planolites*, *Skolithos*, *Gyrolithes*, *Cylindrichnus*, *Chondrites*, *Teichichnus*, navichnia, ?Arenicolites fugichnia. | 0-2 | Mudstone deposited by suspension settling or as flocculated mud; sandstone deposited by unidirectional flow and oscillation, salinity-induceSand clay shrinkage. | Deposited above storm wave base but below fairweather wave base, fluctuating salinity. |
| | 3b: Moderately to pervasively burrowed interbedded sandstone and mudstone. | Heterolithic mudstone and sandstone; contacts are bioturbated. Sandstone/mudstone proportions approximately subequal | Rare oscillation and current ripples. | *Planolites*, *Cylindrichnus*, *Skolithos*, *Teichichnus*, *Palaeophycus*, *Thalassinoides*, *Rosselia*, *Chondrites*, *Asterosoma*, *Gyrolithes*, navichnia, fugichnia. | 2-4 | Mudstone deposited by suspension settling or as flocculated mud, sandstone deposited by unidirectional flow and oscillation. | Deposited above storm wave base but below fairweather wave base, slower deposition than F3a |
| Facies 4: Sandstone dominated heterolithics | 4a: Interbedded mudstones and rippled sandstones. | Heterolithic mudstone and sandstone. Dark mudstone drapes of cm to mm scale, organic detritus; sandstones cm to dm scale (> 60%) | Oscillation ripple cross-lamination synaeresis cracks, micro-HCS, mudstone drapes, convolute bedding, normally graded beds. | *Planolites*, *Skolithos*, *Gyrolithes*, *Cylindrichnus*, *Chondrites*, fugichnia, navichnia | 0-2 | Mudstone deposited mainly from suspension settling, oscillatory flow, possible hyperpycnal and hypopycnal conditions. Clay shrinkage from salinity fluctuations. | fair weather and rare storm conditions. Fluvial sediment input in the coastal regime. |
| | 4b: Interbedded bioturbated mudstone and rippled sandstones | Heterolithic mudstone and sandstone. Dark mudstone drapes cm to mm scale, organic detritus; sandstones cm to dm scale (> 60%) | Oscillation ripple cross-lamination synaeresis cracks, micro-HCS, mudstone drapes, convolute bedding, normally graded beds | *Planolites*, *Skolithos*, *Gyrolithes*, *Cylindrichnus*, *Chondrites*, *Teichichnus*, *Palaeophycus*, *Lockeia*, *Thalassinoides*, fugichnia, navichnia. | 2-4 | Mudstone deposited from suspension, sandstone entrained by waves. Clay shrinkage from salinity fluctuations. | Fair weather and rare storm waves. Variable water salinities, possible fluvial sediment input. |
| Facies 5: Wavy and planar parallel laminated sandstone | | fine-grained sandstone, organic detritus, local mudstone drapes. | Wavy parallel lamination. | *Skolithos*, *Cylindrichnus*, *Chondrites*, fugichnia | 0-2 | Sediment mobilized by waves. | Sediment deposited above fairweather wave base. |
| Facies 6: Low-angle undulatory parallel laminated sandstone | | very fine-grained, erosionally amalgamated sandstone, rare mudstone drapes. | HCS, SCS, oscillation ripple cross-lamination. | fugichnia | 0-1 | Erosional amalgamation, produced by storm waves. | HCS and SCS, deposited under strictly oscillatory storm conditions. Sediment deposited above fairweather wave base or below fairweather wave base but above storm wave base. |
| Facies 7: Bioturbated sandstone | | fine-grained sandstone with some interstitial mud and bioturbated fabric, alternating with thin, sharp based laminated sand beds. | Locally HCS and oscillation ripples | Dominated by biogenically mottled fabric; *Planolites*, *Skolithos*, *Palaeophycus*, *Asterosoma*, *Chondrites*, ?*Arenicolites*. | 0-5 | Sediment mobilized by oscillatory waves. Fairweather beds sandy and extensively burrowed, indicating shoaling waves; storm overprint to generate laminated to burrowed bedding. | Sediment deposited above fairweather wave base, influenced by wave and storm conditions with slow and continual accumulation. |
| Facies 8: Massive (apparently structureless) sandstone | | Fine-to medium-grained , well sorted sandstone. | Apparently structureless sand, local siderite nodules, shale partings, and carbonaceous material. | No trace fossils identified | 0 | May have been deposited very rapidly without formation of bedforms and hence stratification, or sit saturation may obscure existing structures. | Various depositional settings. |
| Facies 9: Current ripple to trough-cross stratified sandstone | | Fine-to Lower coarse-grained, sandstone, abundant organic detritus, well to moderate sorting | Trough cross-beds, current and combined flow rippled sandstone, mushroom rip up clasts. | *Skolithos*, *Cylindrichnus*, *Planolites*, fugichnia | 0-2 | Sediment transported by unidirectional currents | Current dominated environment with high sedimentation rates and high to moderate energy hydrodynamic regime. |
| Facies 10: Coal | | Coal, crushly bedded to massive, rare plant debris, locally high clay and sand contents. | Locally associated with roots. | No trace fossils identified | 0-1 | Subaerial exposure | Marginal marine environments, terrestrial peat swamp environment. |




**Facies 1a: Fissile Mudstone**

Facies 1a consists of massive dark gray to black mudstone, locally laminated. Very fine-grained sandstone and siltstone comprise 3% to 5% of the facies, locally shows normal grading, and contains oscillation ripples. Bioturbation intensities range from BI 0-1. Trace fossils include *Planolites* (P), *Chondrites* (Ch), and navichnia (mantle-and-swirl structures).

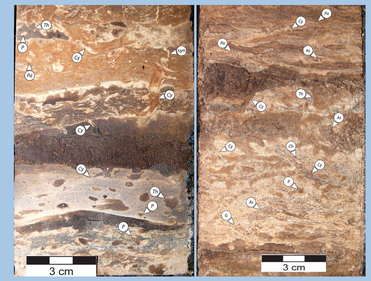
The mudstones have been deposited through suspension settling or as flocculated mud, with the silt and sand transported by oscillatory waves, and the graded beds indicating sediment emplacement by sudden, waning-energy density under flows. Low bioturbation intensities are probably the result of high sedimentation rates. Marine conditions are supported by the presence of diminutive *Chondrites*.




**Facies 2a: Lenticular-Bedded Mudstone**

Facies 2a comprises composite bedsets made up of dark gray to black mudstone interbedded with abundant oscillation-rippled siltstone and sandstone stringers. Bioturbation intensities are low and range between BI 0-2. This weakly burrowed character distinguishes it from Facies 2b. Biogenic structures are typically diminutive, and suites show low diversity. Trace fossils include *Planolites* (P), *Skolithos* (S), *Cylindrichnus* (Cy), *Teichichnus* (T), fugichnia (fu), and navichnia (na).

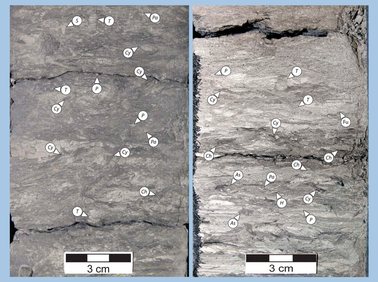
Facies 2a is interpreted to have been deposited due to autogenic alternations between traction sediment reworking by waves and suspension sediment deposition of flocculated clay. Low-diversity trace fossil suites, diminutive ichnogenera, and a predominance of facies-crossing elements suggest an environment in which water salinities were persistently brackish. Facies 2a corresponds to brackish-water bays, bay-head deltas.




**Facies 3b: Moderately to Pervasively Burrowed Interbedded Sandstone and Mudstone**

Facies 3b is sedimentologically similar to Facies 3a, but is more pervasively burrowed. Bedding contacts are bioturbated and only locally sharp. Bioturbation intensities range from BI 2-4. Trace fossils include *Planolites* (P), *Cylindrichnus* (Cy), *Skolithos* (S), *Teichichnus* (T), *Palaeophycus* (Pa), *Thalassinoides* (Th), *Rosselia* (R), *Chondrites* (Ch), *Asterosoma* (As), *Gyrolithes* (G), navichnia (na), and fugichnia (fu).

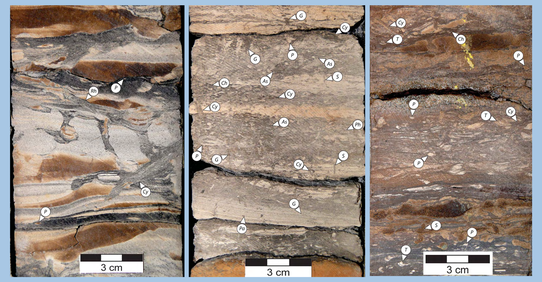
The elevated bioturbation indicates generally slower rates of deposition than typical of Facies 3a. Higher diversity suites and the absence of monogeneric suites suggest that salinities were generally higher and/or varied less markedly. Facies 3b corresponds to shallow bay settings that were subject to less pronounced depositional stresses. Such bays are generally less restricted, and/or have fewer fluvial channels draining into their landward margins.




**Facies 1b: Burrowed Silty Mudstone**

Facies 1b consists of up to 70% mudstone with intercalated layers of fine-grained sandstone/siltstone. Bioturbation intensities within the facies commonly reach BI 5, but locally decrease down to BI 2, where primary sedimentary structures are preserved. Trace fossils include *Teichichnus* (T), *Planolites* (P), *Palaeophycus* (Pa), *Asterosoma* (As), *Helminthopsis* (H), *Phycosiphon* (Ph), *Gyrolithes* (G), *Cylindrichnus* (Cy), *Skolithos* (S), *Chondrites* (Ch), fugichnia, and navichnia.

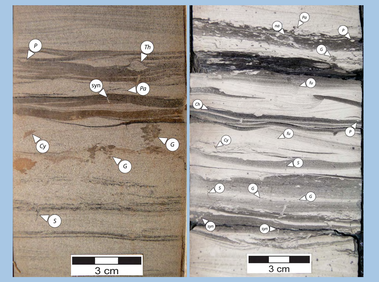
Facies 1b is interpreted to have been deposited in a well-oxygenated and more normal marine setting, probably lying below fairweather wave-base and largely sheltered from storms.




**Facies 2b: Burrowed Mudstone and Sandy Siltstone**

The heterolithic units of Facies 2b comprise 70% mudstone that is commonly bioturbated. Thin, intervening siltstone and fine-grained sandstone beds contain rare oscillation ripples, small-scale hummocky cross stratification, and current ripple laminae. Bioturbation intensities vary at the bed scale from BI 1-5, but typically average BI 3-4. Ichno fossil diversities are typically low and are characterized by diminutive forms. Trace fossils include *Planolites* (P), *Skolithos* (S), *Gyrolithes* (G), *Teichichnus* (T), *Thalassinoides* (Th), *Palaeophycus* (Pa), *Rosselia* (R), *Rhizocorallium* (Rh), "Terebellina" (*Schaubcylindrichnus freyii*), *Chondrites* (Ch), fugichnia (fu), and navichnia (na).

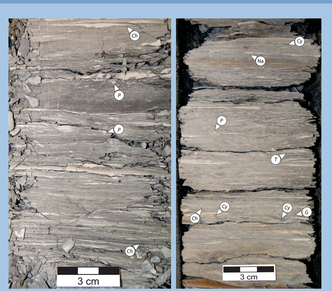
Facies 2b reflects deposition in a standing body of water within fairweather wave-base. The environment was characterized by a low (though variable) rate of deposition subject to periodic event sedimentation. Salinity appears to have fluctuated, but was generally higher than in Subfacies 2a.




**Facies 4a: Interbedded Rippled Sandstones and Mudstones**

Facies 4a consists of wavy bedded composite bedsets with oscillation-ripples sands draped with mud. Mudstones layers are thin, dark largely unburrowed, locally normally graded and may contain synaeresis cracks. Facies 4a intervals are weakly and sporadically burrowed, (BI 0-2). Trace fossil suites are of low diversity, and are generally dominated by facies-crossing structures such as *Planolites* (P), *Skolithos* (S), *Gyrolithes* (G), *Cylindrichnus* (Cy), fugichnia (fu), and navichnia (na). Ichnogenera are diminutive.

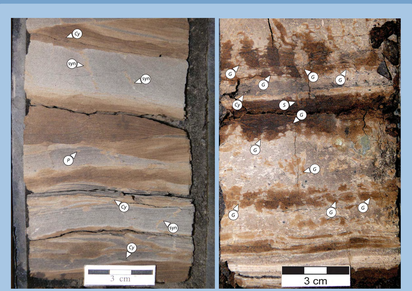
The dominance of sand and low bioturbation intensities suggest generally high sedimentation rates. Mudstone record low-energy by suspension settling and rapid clay flocculation. The domination of facies-crossing trace fossils, diminutive sizes of ichnogenera, and the presence of synaeresis cracks indicate persistently (and probably fluctuating) brackish-water conditions. Trace fossil suites are typical of salinity stressed expressions of the *Skolithos* Ichnofacies.




**Facies 1c: Pinstripe-Bedded Mudstone**

Facies 1c is characterized by abundant mm- to cm-thick, sharp-based, locally normally graded siltstone or very fine-grained sandstone layers, interlaminated with fissile mudstone. Synaeresis cracks and siderite nodules are common elements of the facies. Bioturbation intensities vary at the bed scale from BI 0-2. Trace fossils include *Planolites* (P), *Cylindrichnus* (Cy), *Skolithos* (S), *Teichichnus* (T), *Gyrolithes* (G), and navichnia.

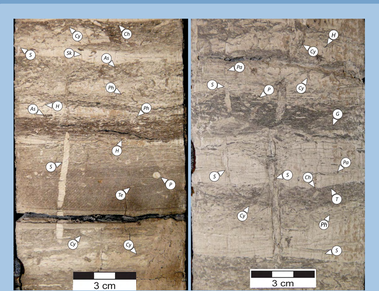
The low bioturbation intensity of the facies suggests that sedimentation rates were high. Reduced trace fossil diversities, diminutive ichnogenera, and locally common synaeresis cracks indicate that the salinities were variable, and generally reduced (i.e., brackish).




**Facies 3a: Sporadically and Weakly Burrowed Iinterbedded Sandstone and Mudstone**

Facies 3a consists of low-angle, parallel laminated to oscillation rippled sandstones intercalated with moderately bioturbated mudstone forming lenticular to wavy bedded composite bedsets.. Bioturbation intensities range from BI 0-2 and trace fossils are sporadically distributed. Ichnogenera include *Planolites* (P), *Skolithos* (S), *Gyrolithes* (G), *Cylindrichnus* (Cy), *Chondrites* (Ch), *Teichichnus* (T), *Arenicolites* (Ar), navichnia (na), and fugichnia (fu). Locally within this facies, suites are monogeneric and dominated by either *Gyrolithes*, *Cylindrichnus*, or *Planolites*.

Low-diversity trace fossil suites, diminutive ichnogenera, and locally monogeneric suites suggest an environment in which water salinities were persistently and markedly brackish. Low-intensity bioturbation may indicate a combination of physico-chemical stresses and elevated deposition rates. Such settings are typical of shallow, sheltered brackish-water bays with river-sediment input along their landward margins.




**Facies 4b: Bioturbated Interbedded Rippled Sandstones and Mudstones**

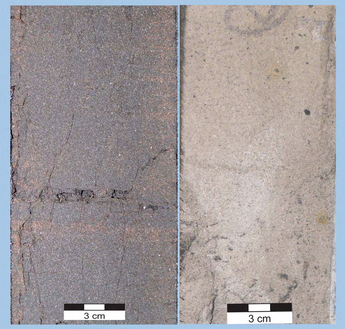
Facies 4b generally displays higher BI values compare to Facies 4a. Locally, the facies contains synaeresis cracks, soft-sediment deformation features, and normally graded mudstone drapes. Bioturbation intensities though high, are nevertheless variable, and typically range from BI 2-4 at the bed scale. Ichnogenera include *Planolites* (P), *Skolithos* (S), *Gyrolithes* (G), *Cylindrichnus* (Cy), *Chondrites* (Ch), *Teichichnus* (T), *Palaeophycus* (Pa), *Lockeia* (L), *Thalassinoides* (Th), fugichnia (fu), and navichnia (na).

The generally higher bioturbation intensities attest to reduced sedimentation rates compared to Facies 4a. The trace fossil suite contains numerous facies-crossing elements, characteristic of environmental stress, but with intercalated ichnogenera typical of higher salinity conditions. The subfacies probably indicates shallow brackish-bay environments that were less restricted, and/or were subject to reduced freshwater input along the bay margins.


**Facies 5: Planar Parallel Laminated and Oscillation Rippled Sandstone**

Facies 5 is dominated by thin zones of low-angle planar parallel laminated sandstone, interpreted as HCS and micro-HCS, with associated oscillation-ripple lamination. Rare mud interbeds drape some sand beds. Sand beds are typically erosionally amalgamated. Bioturbation intensities range from BI 0-2 at the bed scale. Trace fossils include *Skolithos* (S), *Cylindrichnus* (Cy), *Chondrites* (Ch) (in the muds), and fugichnia.

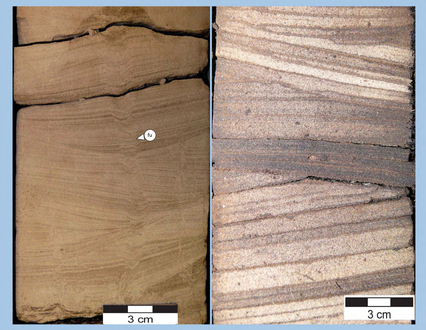
Facies 5 is interpreted to have been deposited subaqueously above fairweather wave-base where prevailing energy levels were high. Oscillatory processes (fairweather shoaling and storms) dominate the preserved expression of the facies. The trace fossil suite comprises a low-diversity, and stressed expression of the *Skolithos* Ichnofacies. Such suites are typical of higher energy sandy bays exposed to storms and wave energy, with locally turbid water columns. Probable environments include sandy bays and the delta fronts of bay-head deltas.




**Facies 8: Massive (Apparently Structureless) Sandstone**

Facies 8 comprises very fine- to medium-grained, massively bedded (apparently structureless) sandstone displaying high degrees of oil saturation and a paucity of visible sedimentary structures. Visible bioturbation is absent.

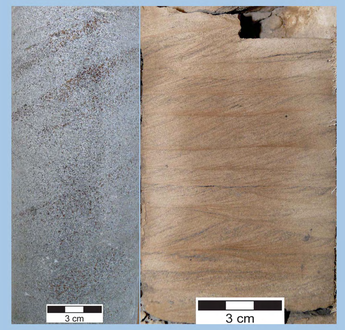
The apparently structureless character of the sandstone may be due to oil saturation which has obscured the primary physical sedimentary structures and the biogenic structures. Alternatively, the sands may have been deposited very rapidly without forming stratification.




**Facies 6: Low-Angle Undulatory Parallel Laminated Sandstone**

Facies 6 consists of erosionally amalgamated, very fine-grained, low-angle undulatory parallel laminated sandstone beds. Rare oscillation rippled sandstones are locally interbedded. Bioturbation is absent or very low (BI 0-1).

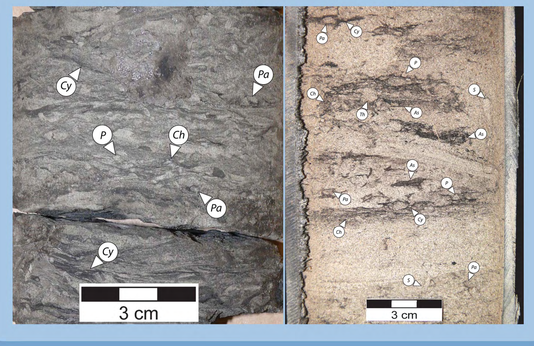
Facies 6 is interpreted as hummocky to swaley cross-stratification (HCS & SCS) deposited in a subaqueous setting, reflecting sediment emplacement during storms. Such conditions are typical of deposition above fairweather wave base in a subaqueous setting exposed to strong storm energy. Such conditions occur in open sandy bays and in storm/wave-dominated delta fronts and bay-head delta fronts.




**Facies 9: Trough-Cross Stratified and Current Rippled Sandstone**

Facies 9 encompasses fine to medium-grained sandstones that are dominated by current-generated structures. The most common structures are trough cross-stratification and current-ripple lamination. Bioturbation intensities are generally low, and vary from BI 0-2 at the bed scale. Trace fossil suites consist of *Skolithos*, *Cylindrichnus*, *Planolites*, and fugichnia.

Deposition of Facies 9 reflects conditions of quasi-steady unidirectional flow with generally high sedimentation rates, and high- to moderate-energy. The paucity of burrowing should not be taken as an indication of reduced salinity, however, as mobile bedforms such as dunes, are difficult to colonize unless they are moribund for extended periods of time. Facies 9 probably records channel environments but could also occur in proximal delta-front settings of bay-head deltas or open-coast deltas.




**Facies 7: Bioturbated Sandstone**

Facies 7 comprises fine- to medium-grained sand in which primary stratification has been disrupted due to the activity of infaunal organisms. Bioturbation intensities vary markedly at the bed scale from BI 1-5 but averages BI 3. Common ichnogenera include *Planolites* (P), *Skolithos* (S), *Palaeophycus* (Pa), *Asterosoma* (As), *Chondrites* (Ch), *Arenicolites* (Ar), and fugichnia (fu).

The sediments of Facies 7 are interpreted to have been subaqueously deposited above fairweather wave-base with slow and generally continuous accumulation of sand. Such conditions occur in sheltered open bay environments with little or no direct fluvial sediment influx.


**Facies 10: Coal**

Facies 10 comprises bedded subbituminous coal and highly carbonaceous mudstone and tend to be black to dark grey, depending upon the amount of interstitial silt and sand. This facies is locally associated with underlying rooted zones, confirming its *in situ* condition. No trace fossils are associated with this facies.

Facies 10 is interpreted to have been formed as a result of accumulation of plant material and organic matter on the coastal plain, probably as swamps, bogs and rare forested zones. The preservation of coal is commonly associated with elevated and/or rising water tables. As such, coals may mark the early onset of transgression in the coastal regime.

## CONCLUSION

Preliminary study of ichnology and sedimentology from the Lower Cretaceous (Early to Mid-Albian) Sparky, Waseca, and McLaren formations of the upper Mannville Group in west-central Saskatchewan has led to the recognition of ten recurring facies. Deposition records a predominance of oscillatory-generated structures (shoaling waves and storms), with limited current generated structures. This supports the contention of generally reduced tidal energies in the setting, and widespread dominance of subaqueous conditions. Low-diversity suites, the prevalence of facies-crossing ichnogenera and the diminutive character of ichnogenera within these facies indicate that the environment was generally subject to physico-chemical stress. The most likely stress was one of reduced and fluctuating salinity, although the magnitude of salinity reduction was spatially and temporally variable, this may be supported by the local occurrence of more marine ichnogenera (e.g., *Asterosoma*, *Phycosiphon*, *Chondrites*, *Rhizocorallium*, and *Helminthopsis*) within the succession. suggesting that elevated salinities occurred periodically within the study area.

This interpretation suggests that the facies within the study area correspond to mainly coastal margin subaqueous settings (e.g., shallow bays), with local bay-head deltas and estuaries feeding into them.

## ACKNOWLEDGEMENTS

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