

Depositional Setting of the Upper Devonian – Lower Mississippian Bakken Formation of Subsurface Saskatchewan: Integrating Sedimentologic and Ichnologic Data

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Summary

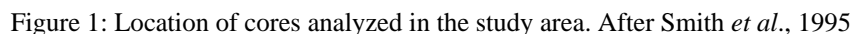
The Upper Devonian – Lower Mississippian Bakken Formation of the Williston Basin (Canada) is one of the most significant hydrocarbon reservoirs in southeastern Saskatchewan and represents an ideal hydrocarbon system, comprising the source rock, reservoir rock, and cap rock all within the same formation. The Bakken Formation is subdivided into three members: the lower and upper members both consisting of shelf black-shale, and the sandy-silty middle member. Based on an integrated sedimentologic and ichnologic analysis a new paleoenvironmental interpretation is proposed for the Bakken Formation. In contrast with previous studies which suggest fully marine conditions for the entire Middle Member, ichnologic evidence reveals deposition under brackish-water conditions for the middle part of the Middle Member. The lower and the upper part of the Middle Member present high bioturbation index and relatively high ichnodiversity corresponding to the “distal” *Cruziana* ichnofacies, reflecting fully marine conditions. In contrast, the middle part of the Middle Member is characterized by a low bioturbation index and ichnodiversity, which in addition to the appearance of synaeresis cracks and structures suggestive of tidal influence support the hypothesis of brackish-water conditions during deposition of this interval. The recognition of marginal-marine brackish deposits in the Bakken Formation, has a high impact on the reservoir geometry and the facies distribution, allowing a better prediction of the prospective areas, both for oil exploration and production.

Introduction

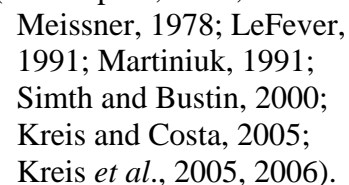
Previous sedimentologic studies conducted on the Bakken Formation suggest open-marine environments for the three members of the Bakken Formation. However, based on a new sedimentologic and ichnologic analysis of cores in southeastern Saskatchewan, a different paleoenvironmental interpretation is proposed, suggesting deposition of the Middle Member occurred under two different regimes, fully marine and brackish-water conditions.

Due to the strong influence that environmental variables such as salinity, oxygen, and food supply have on benthic organisms, ichnology is a powerful tool for paleoenvironmental reconstructions, providing information that is not commonly recorded in the original sedimentary fabric.

The study is based on core analysis from the Bakken Formation in southeastern Saskatchewan. Fifty one core wells have been slabbled and described so far in Saskatchewan, representing 970 meters. Of these, thirty seven are located in the study area in southeastern Saskatchewan.



Deposition of the Bakken Formation took place during the Late Devonian and Early Mississippian, as suggested by conodont biostratigraphy (Hayes, 1985; Karma, 1991). The unit is restricted to the subsurface of the Williston Basin in North Dakota, Montana, Manitoba and Saskatchewan (Christopher, 1961;



The Bakken Formation has been subdivided into three units based on lithology: a lower black-shale member; a middle siltstone, fine-grained calcareous siltstone, sandstone, or interbedded sandstone and siltstone with mud drapes, and an upper black-shale member, similar to the lower one.

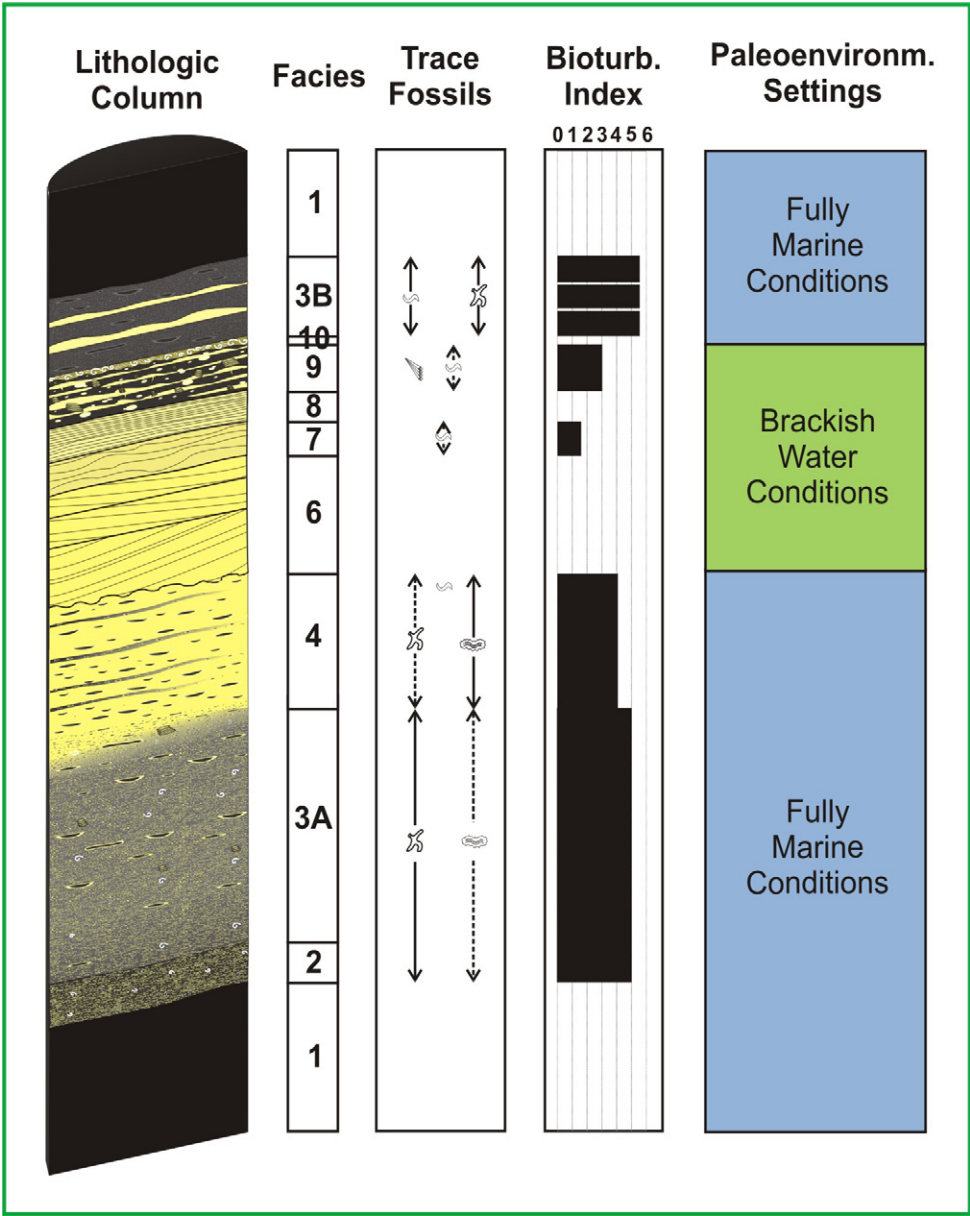
Figure 2: Stratigraphic Chart. Based on Karma, 1991

Sedimentary Facies and Trace Fossils

Ten sedimentary facies were defined based on their sedimentologic and ichnologic characteristics on the Bakken Formation. For detailed descriptions of these facies see Angulo *et al.*, 2008.

Paleoenvironmental Interpretation

Two paleoenvironmental settings have been interpreted based on sedimentologic and ichnologic core analysis of the Bakken: fully marine and brackish water. The fully marine regime includes the shelf-black



shales of the lower and upper member (facies 1), and the offshore-highly bioturbated siltstone and sandstone of the lower and upper portion of the Middle Member and is characterized by “distal” *Cruziana* ichnofacies, where dominant elements are *Nereites missouriensis* and *Phycosiphon*, while subordinate ichnotaxa are *Asterosoma* and *Planolites*, and rare components are *Teichichnus* and *Chondrites*. The brackish regime is interpreted for the sandstone and thinly laminated mudstone and sandstone present in the middle part of the Middle Member. Low to moderate degree of bioturbation, an ichnofauna characterized by small size and low ichnodiversity from a depauperate *Cruziana* ichnofacies, where dominant elements are *Planolites* and *Teichichnus*, appearance of synaeresis cracks and structures suggestive of tidal influence, are evidence of the brackish-water conditions.

Figure 3: Idealized Stratigraphic Log of the Bakken Formation

Conclusions

Integration of ichnology within conventional sedimentologic analysis constitutes a powerful tool for paleoenvironmental reconstructions. In contrast with previous models which suggest fully marine conditions for the whole Middle Member (offshore and shoreface deposits), the ichnologic analysis of cores of the

Bakken Formation reveals a much more complex succession of sedimentary environments for this unit, comprising not only offshore, offshore-transition, and shoreface deposits under fully marine conditions, but also marginal-marine deposits under brackish-water conditions.

Certainly, further studies need to be done to provide a more accurate characterization of the sedimentary environments that prevailed during deposition of the Bakken Middle Member. A better understanding of the sedimentary environments and a more accurate sedimentologic model for the Bakken Formation, would have a high impact in the geometry and facies distribution of the prospective rocks in the area, both, for exploration and production purposes.

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