

New perspective on the stratigraphic architecture of the middle member of the Bakken Formation, Williston Basin, North Dakota

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ABSTRACT

The Bakken Formation (late Devonian – Mississippian) forms a “complete” hydrocarbon system in the subsurface of the Williston Basin (USA and Canada). The formation has four members: a basal sand-rich Pronghorn member, overlain successively by a lower black shale member, a productive middle carbonate and siliciclastic member, and an upper black shale member. The Bakken Formation is bounded below and above by the Three Forks and the Lodgepole formations respectively. However, the facies architecture of the middle member is poorly understood with various models proposed (e.g. Hlava et al., 2012; Novak and Egenhoff, 2017; Tidholm, 2019).

This study employed detailed logging and facies analysis, supplemented with micropetrographic and well-log analysis of fifty-six drilled cores to deduce the most likely stratigraphic architecture of the middle member of the Bakken Formation. The cores are from the North Dakota portion of the Williston Basin, USA.

The middle Bakken comprised six facies deposited in a tidally-influenced shelf system. The six facies are bounded by seventh facies, the black shales of the lower and upper Bakken. A key finding is the occurrence of stromatolite facies in the upper part of the middle Bakken, notably near the basin center which can be correlated laterally across the study area. Sequence stratigraphic analysis revealed three large-scale packages (lower, middle, and upper) within the middle Bakken. The lower package is a skeletal lag-based fossiliferous mudstone to bioturbated siltstone capped by rhythmic, laminated siltstone/sandstone facies, interpreted as lower offshore-subtidal-intertidal deposits. The middle package comprises scour-based, massive and cross-bedded sandstone with ooids, and are interpreted as indicative of shoals within the subtidal-intertidal zone. The upper package includes scour-based, cyclically arranged microbial carbonates of algal-laminated-domal stromatolitic bindstone subfacies which grade upward into skeletal mud-wackestone/packstone with intercalated skeletal lags, interpreted as subtidal facies. The stacking patterns reflect shallowing upward to deepening upward patterns. The middle Bakken member correlates over 200 km from North Dakota into southeastern Saskatchewan, Canada. An abrupt deepening is indicated by a sharp upper contact with the upper Bakken shale.

The entire Bakken Formation denotes a repeated regressive-transgressive cycle represented by five systems tracts: LST-TST, HST, second LST, and second TST. Laterally extensive facies tracts suggest a stable shelf during Mississippian period. The upward shallowing to deepening facies trend in the North Dakota portion supports distal deposition, while southeastern Saskatchewan, reportedly lacking a second LST (Zhang et al., 2016), suggests proximal bypass zone.

The stratigraphic model for the Bakken Formation supports regressive-transgressive control influenced by factors related to the carbonate factory and less syndepositional tectonics based on identified tracts and facies. The upward shallowing-deepening facies trend in the upper part of the middle Bakken indicates low accommodation and a variation in sediment supply accompanied by an episodic increase in sedimentation rates, which likely translated into observed predictable stromatolite development. Integrating this model with seismic and geomechanical investigations can guide horizontal drilling targets and the predictions of suitable zones for microbial-enhanced oil recovery strategies within the correlated section.