

# **An Overlooked Devonian Sequence — Sea-Level Changes During Middle Bakken Member Deposition, and the Importance of Clastic Dykes in the Lower Bakken Shale, North Dakota, USA\***

**Sven Egenhoff<sup>1</sup>**

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<sup>1</sup>Geosciences, Colorado State University, Fort Collins, Colorado, United States ([Sven.Egenhoff@colostate.edu](mailto:Sven.Egenhoff@colostate.edu))

## **Abstract**

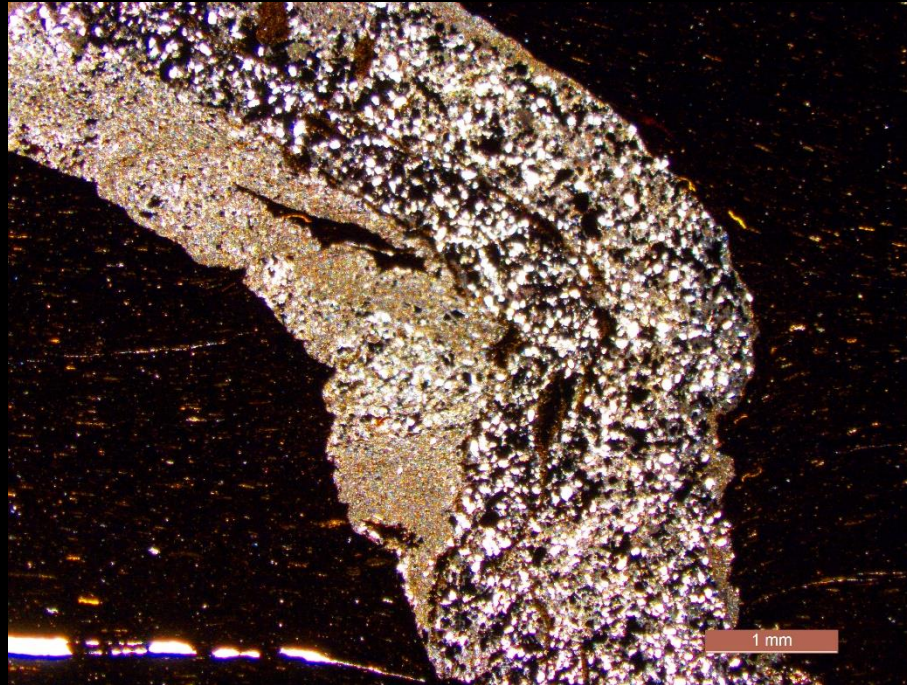
The main target for hydrocarbons in the Williston Basin of North Dakota, USA, is the middle Bakken member that represents a mixed carbonate-siliciclastic ramp system, sandwiched between the two organic-rich lower and upper Bakken member shales. For extracting oil from the middle Bakken member, this unit with low porosities has to be fractured, and the fracture behavior depends heavily on the composition of the unit. Current sedimentological models envision the entire Bakken Formation to represent one large fluctuation of sea-level with the two shales reflecting the transgressions and highstands, and the mixed siliciclastic-carbonate middle member the lowstand. However, the transition from the lower shale to the middle mixed carbonate-siliciclastic member does not represent a gradual coarsening as for that interval, but contains several carbonate units that are mudstones to packstones, and all of these carbonates contain glauconite to varying degrees. These partly coarse-grained carbonates are present in many of the cores close, but not directly in the basin center in North Dakota. The carbonate packstones require a significant drawdown of sea-level to be deposited around the center of the basin. In a mixed carbonate-siliciclastic system, however, carbonates without much siliciclastic content can only form if the siliciclastic input is turned off which is typical for transgressions, as is the presence of glauconite. It therefore seems reasonable to assume that sea level fell at the boundary of the lower to middle Bakken member transition, deposited packstones during the initial transgression, and subsequently fine-grained carbonates with glauconite during the later transgression. This scenario would also explain the presence of both carbonates and siliciclastics sedimentary dykes in the lower Bakken shales: while sea-level was experiencing a fall and subsequent rise, earthquakes lead to the rupture of the shales, and the fill reflects the sediment overlying these dykes at the time of their formation – coarse siliciclastics during the sea-level fall, and carbonates during the rise of sea-level. So both the thin layer of carbonates as well as the fill of the clastic dykes in the lower Bakken shale member document a drawdown of sea level during middle Bakken member deposition that is otherwise not reflected in the sedimentary record.

## References Cited

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# An overlooked Devonian sequence –

sea-level changes during middle Bakken member deposition,  
and the importance of clastic dykes in the lower Bakken shale,  
North Dakota, USA

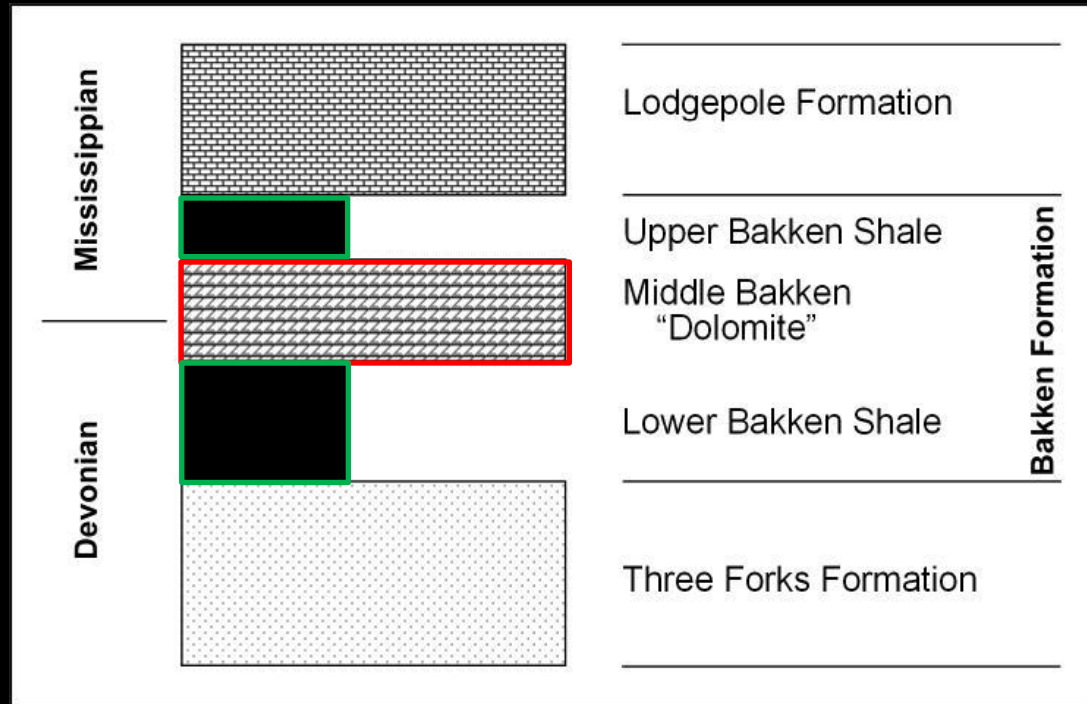


Sven Egenhoff

Colorado State University, Fort Collins, CO



# Scientific problem



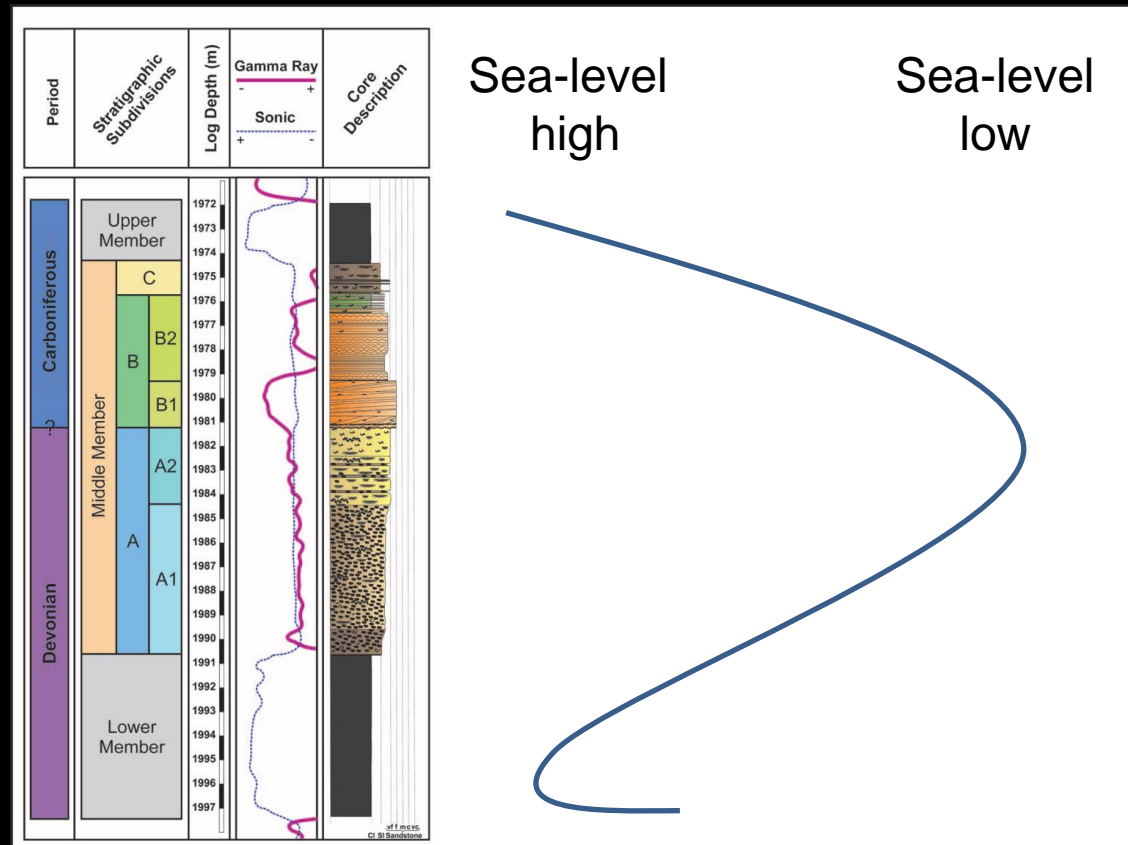
- General sediment architecture Bakken: Devonian-Mississippian, **Middle Bakken** = main reservoir (conventional?)
- Shales: **source rocks** for Bakken and over-/underlying units

# Problem

- Model - Bakken deposition = one sea-level fluctuation on very low-inclined slope
- Highstands = shales
- Lowstands = sandstones (and siltstones)



Burchette & Wright 1990

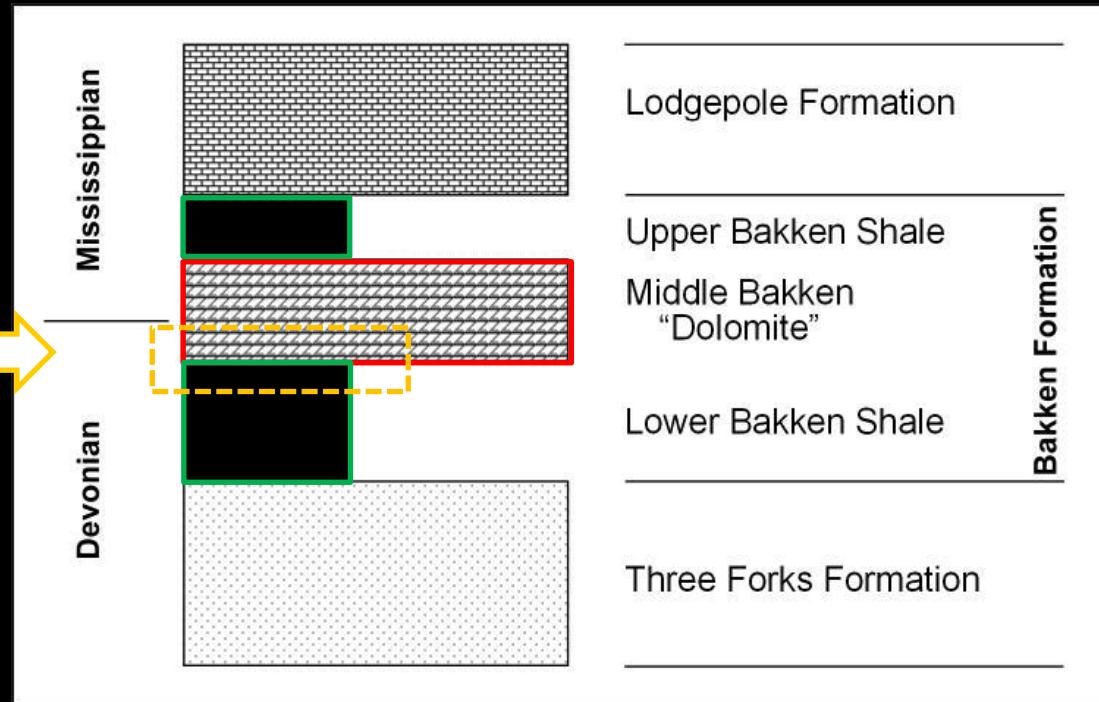
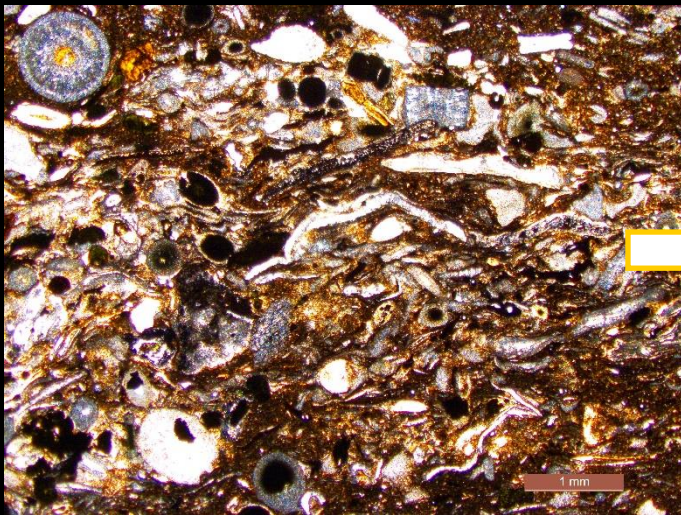


Angulo & Buatois 2012



# Problem

- But: new sedimentological observations that do not fit this model - packstones and glauconite at base of middle Bakken; too coarse/normaly characteristic for transgressions (starvation) → both difficult to explain with current model

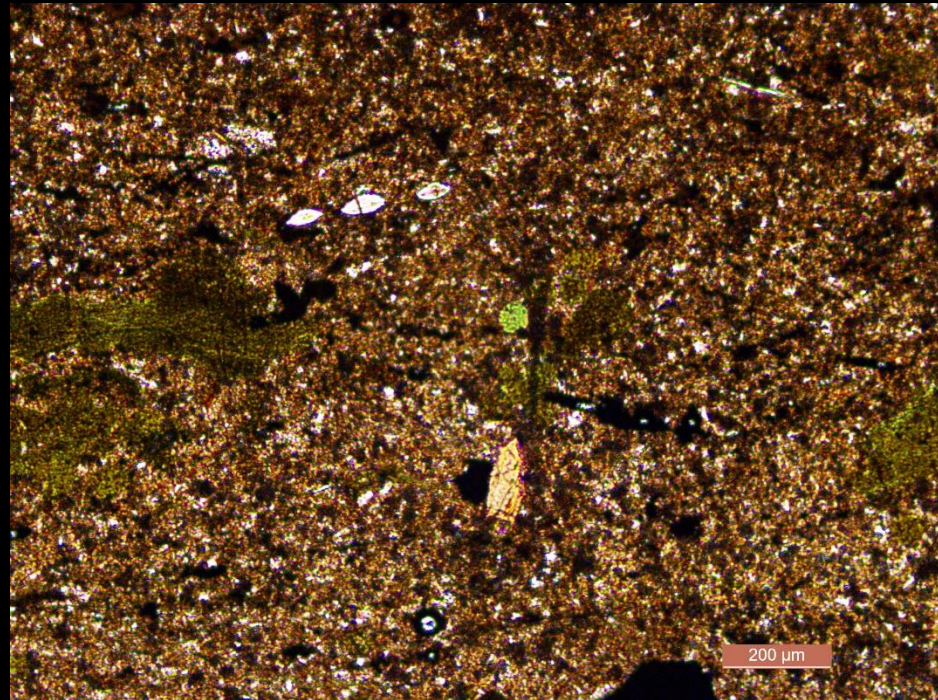


# Facies

- How do sediment at interface lower-middle Bakken look like?
- Three facies, not all present in all locations

## Facies 1: glauconite mudstone

- Mudstone matrix
- Glauconite, conodonts, some shell debris, phosphate
- Orientation random

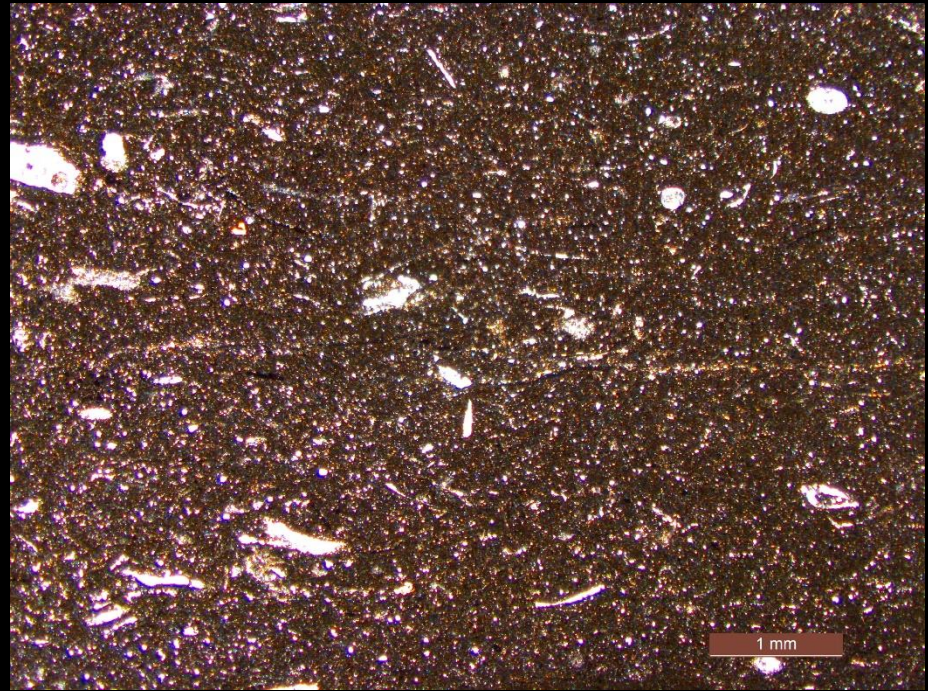




# Facies

## Facies 2: carbonate wackestone

- Carbonate shell debris (brachiopods, echinoderms) and quartz grains
- Matrix carbonate with some clay content
- Particle orientation random → highly bioturbated (*Phycosiphon* isp.)

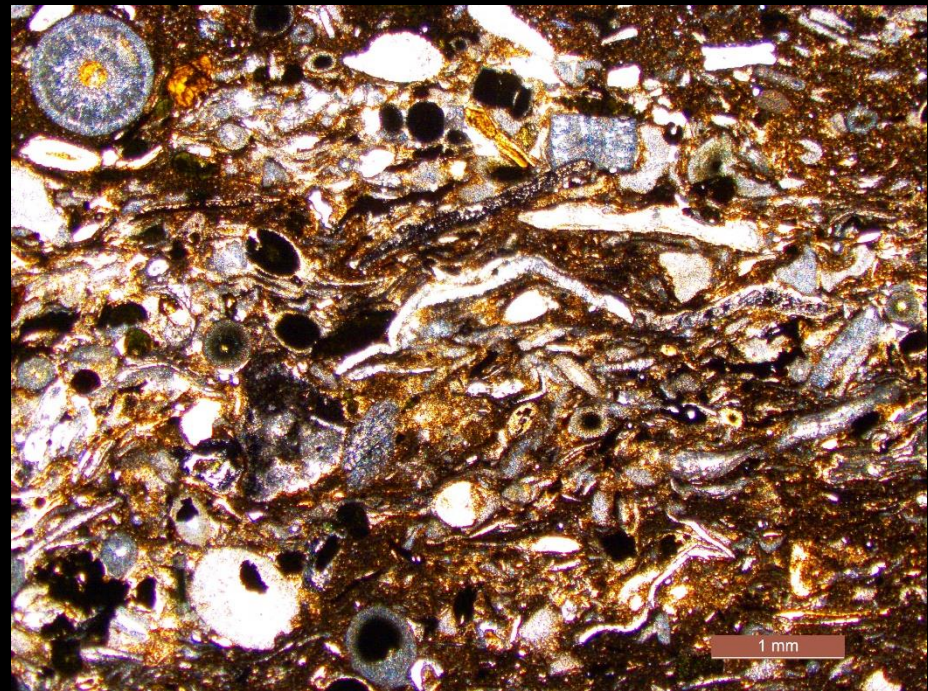




# Facies

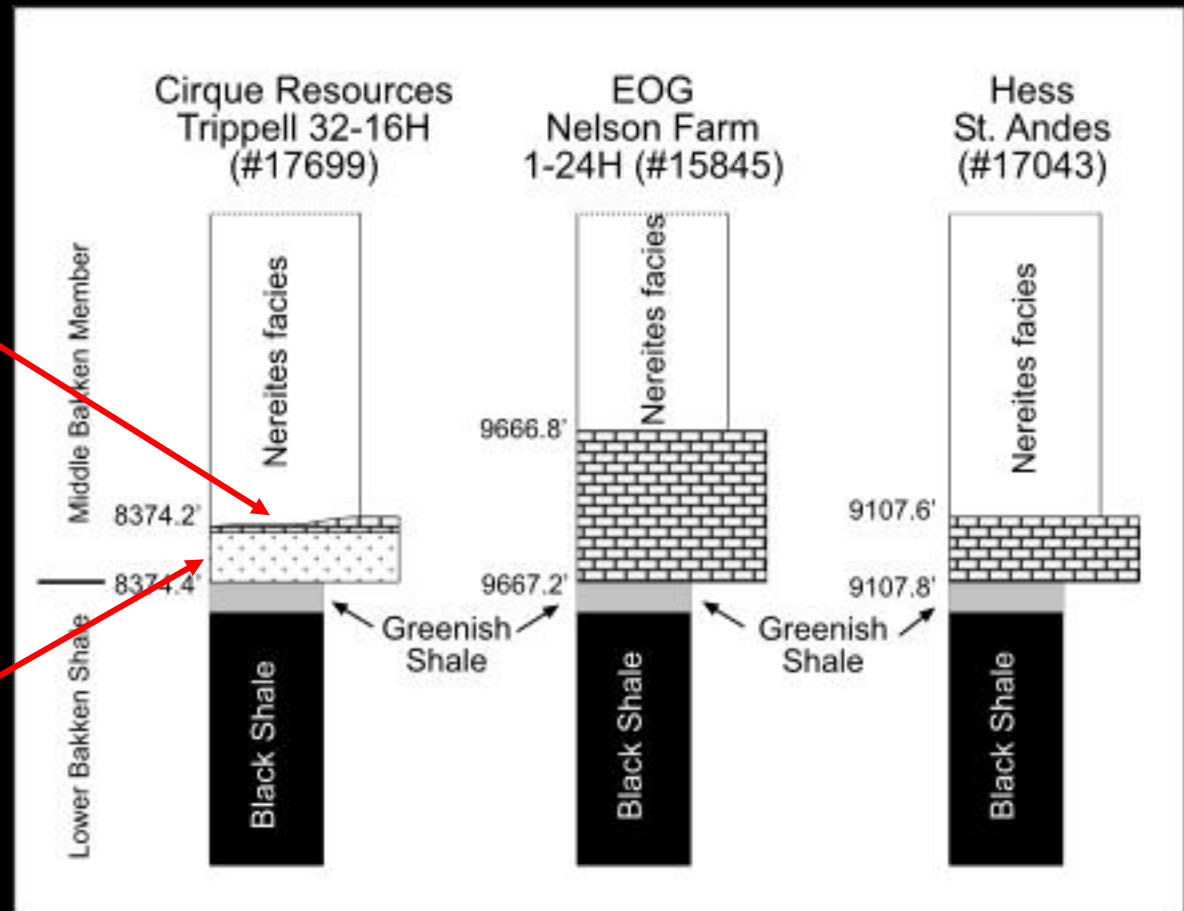
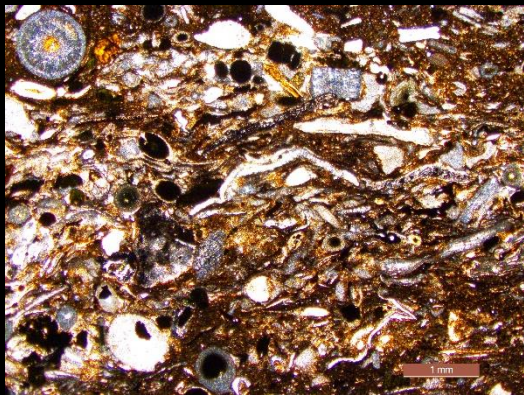
## Facies 3: carbonate packstone

- Carbonate shell debris (brachiopods, echinoderms, trilobites), some phosphate, rare glauconite
- Matrix carbonate (with some clay)
- Particle orientation roughly parallel to bedding



# Facies arrangement

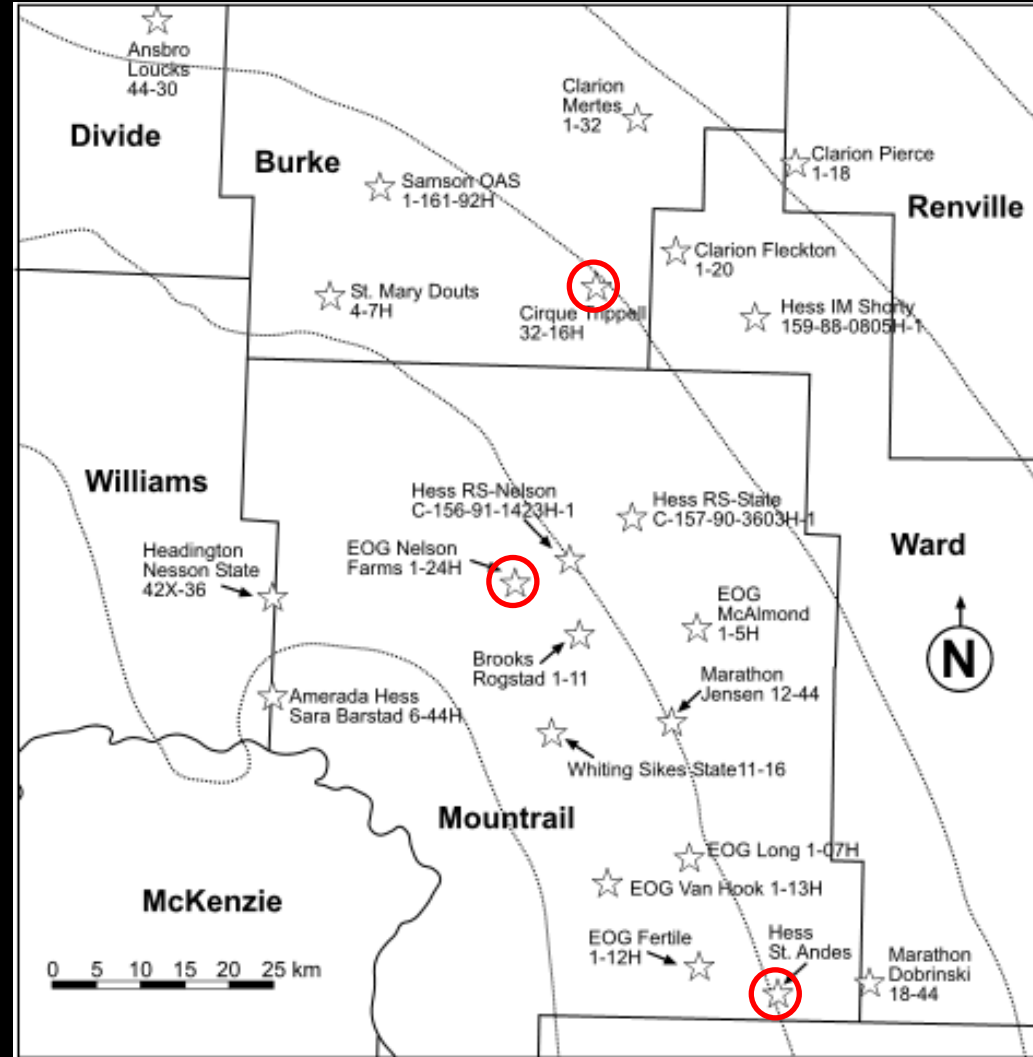
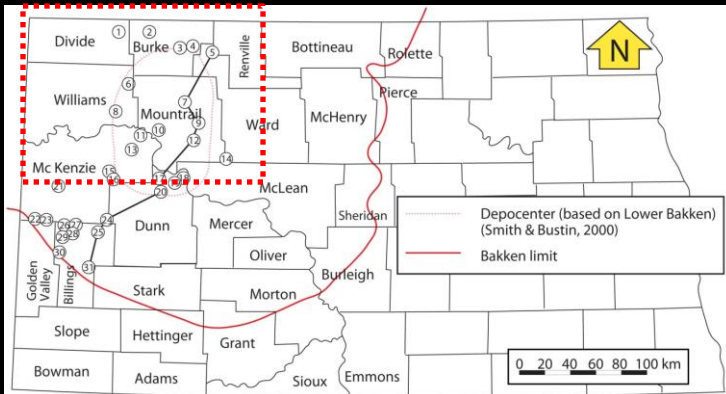
- Arrangement of facies and thickness varies, but: generally coarsening-upwards
- Lack of silt- and sand-size siliciclastics, only carbonates preserved (and glauconitic mudstones)





# Facies distribution

- These facies occur in at least 20 cores in NW North Dakota
- Recognized throughout basin, close to depocenter and towards margins
- So how do the facies get there?





# Revised model

- Bakken: mixed carbonate-siliciclastic system
- "Pure" carbonates only when siliciclastic input is shut off
- Transgression → no input → carbonate deposition; fits well with the glauconite

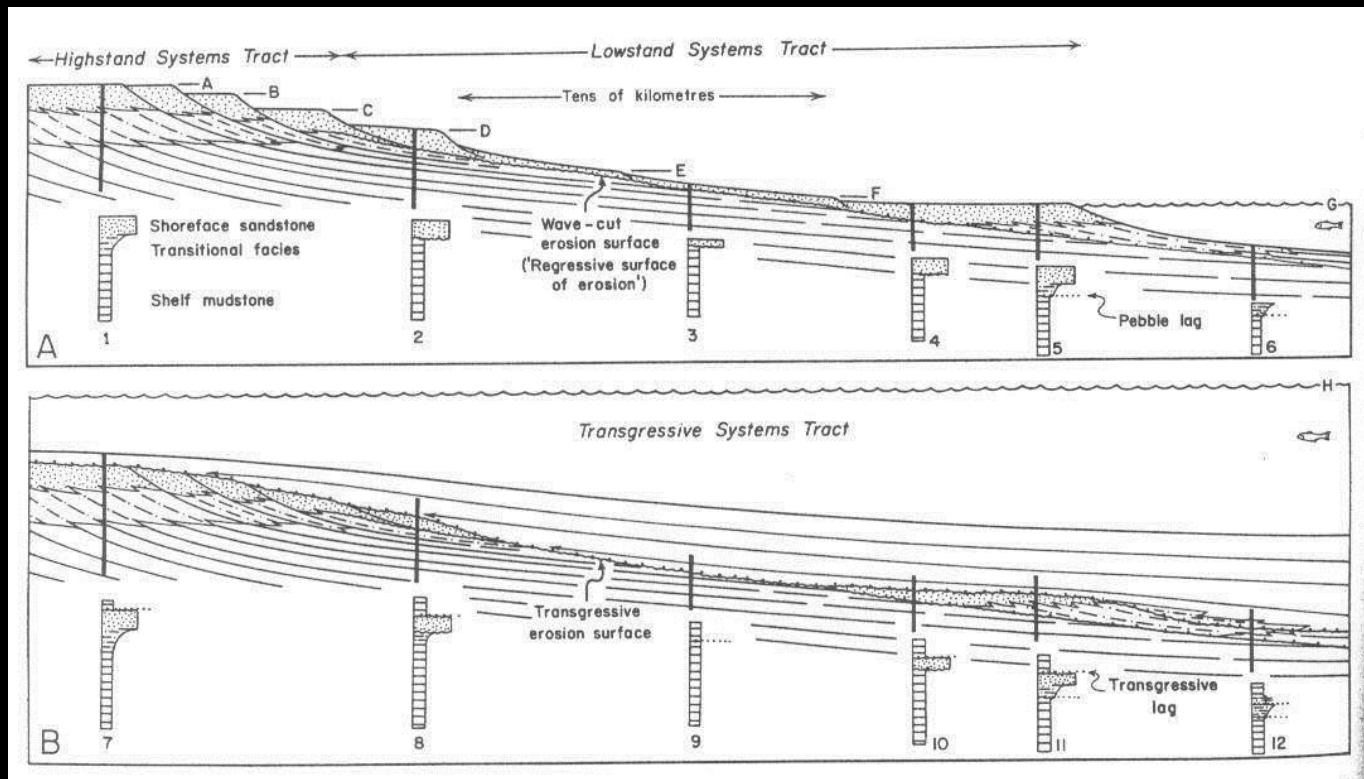


Questar MHA 1-18A



# Revised model

- But: if transgression at lower-middle Bakken boundary → need of a regression first
- Revised model based on Canadian Cretaceous (Plint 1988)

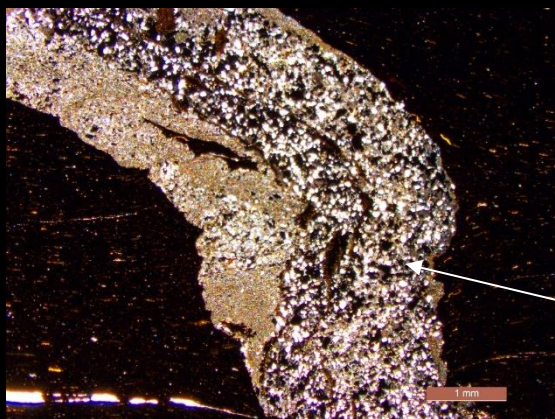


Plint 1988

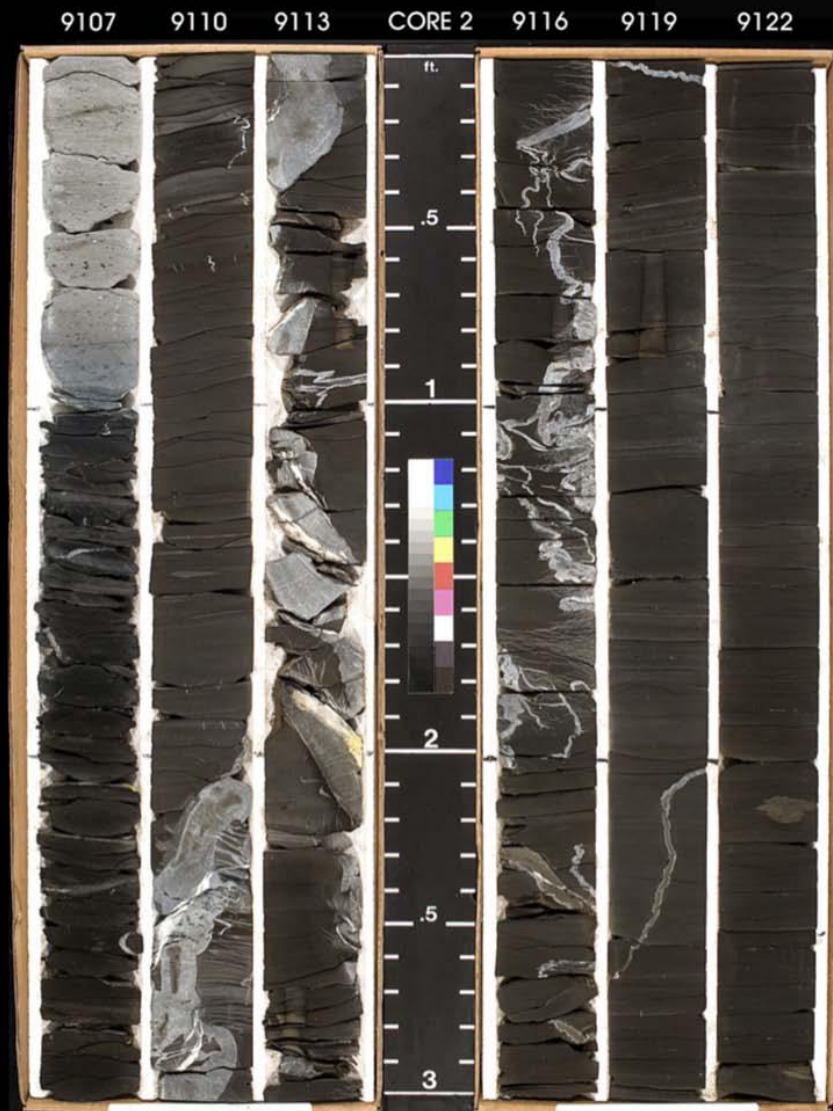


# Discussion

- If system first prograded and subsequently retrograded → where are the progradational siliciclastics?
- Clastic dykes in lower Bakken; filled with carbonates and siliciclastics



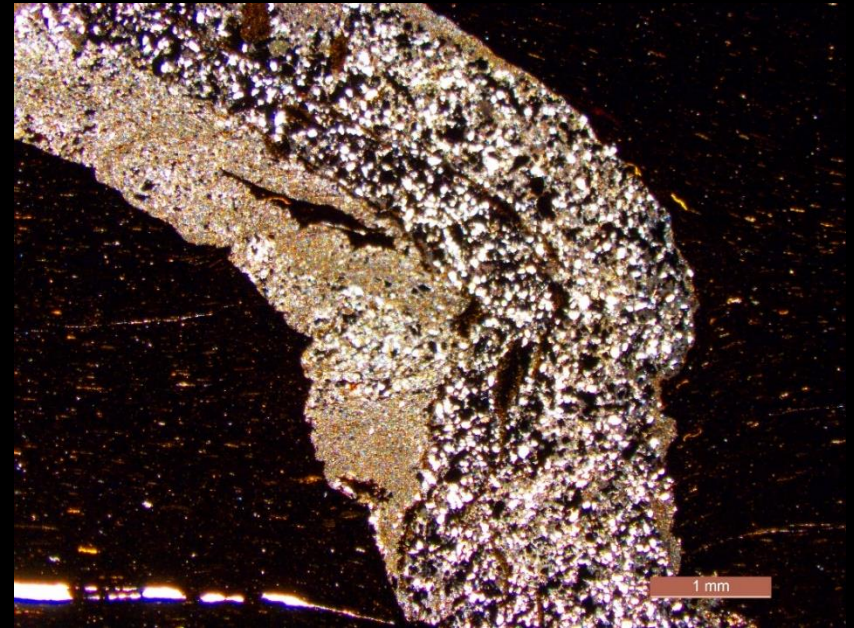
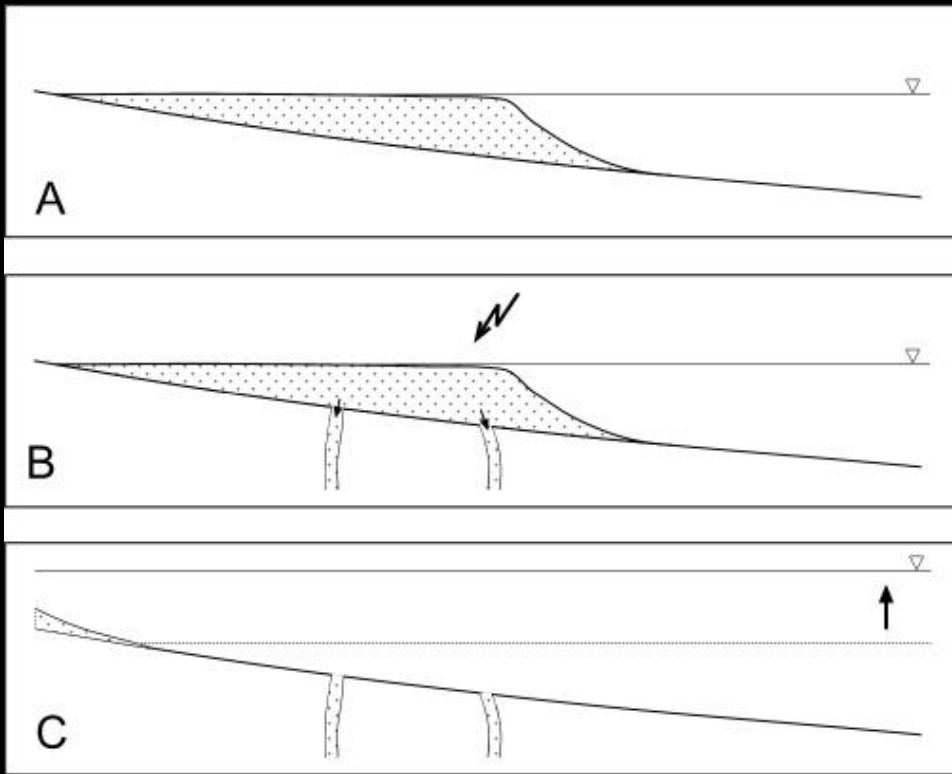
Sand grains





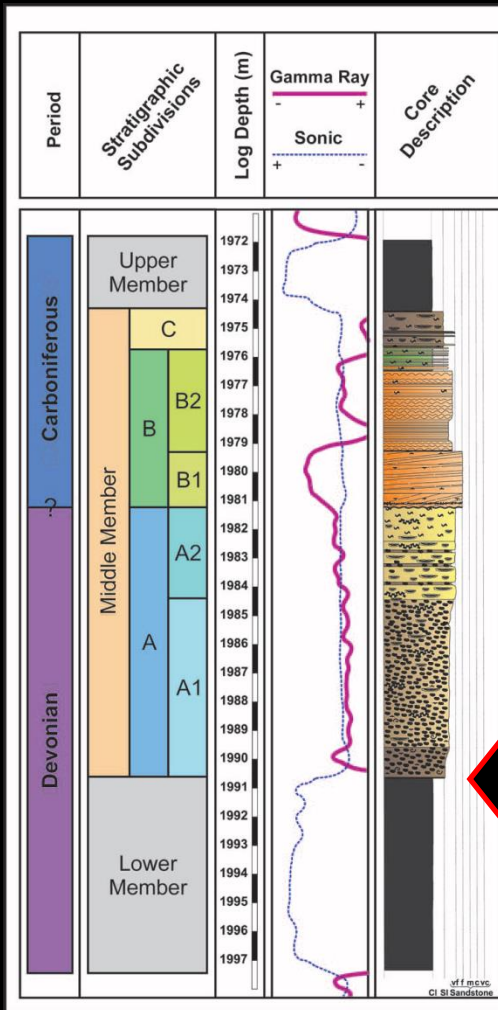
# Discussion

- During regression → clastics prograded into basin center
- Earthquake → dykes formed, clastics were injected
- Sea-level rise → clastics eroded + pushed landwards



# Implications for sequence stratigraphy:

- Modification of original model - probably two sequences



Sea-level

+ -

TST

LST

FSST

HST

TST

LST & FSST

Several sequences?

Deposition of sand  
Forming injectites



# Conclusions

- Transition lower - middle Bakken Formation: Centimeter-thick carbonate unit(s) widespread; consist of 3 wacke- to packstone facies + glauconite mudstones
- Likely reflect sea-level transgression after lowstand prior to deposition of middle Bakken member
- Clastic dykes in lower member are the only remnants of prograding clastics during initial lowstand
- Overall: Bakken deposition reflects two fluctuations of sea-level, not one

