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Upper Bakken shale facies architecture, and the lower to middle Bakken member transition – what you can see in core, and its applicability to drilling

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ABSTRACT:

The Bakken Formation in North Dakota, USA, is characterized by three distinct members: a middle member mixed carbonate-siliciclastic unit sandwiched between the two upper and lower member black shales. Even though known for its low porosity, the middle Bakken member is now one of the main targets for hydrocarbon exploration in the continental US, and together with the underlying Three Forks Formation contains more than 7 bbl of undiscovered oil in this small portion of the Upper Devonian to Lower Mississippian section alone.

The transition from the lower shale to the middle mixed carbonate-siliciclastic member, envisioned to constitute a simple regression, does not represent a gradual coarsening as expected. In contrast, this interval contains several centimeter-scale 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 is therefore assumed that sea level fell at the boundary of the lower to middle Bakken member transition and deposited packstones during the initial transgression. Subsequently, fine-grained carbonates with glauconite were laid down during the later transgression.

This scenario would also explain the presence of siliciclastic sedimentary dykes in the lower Bakken shales: while sea-level was experiencing a fall and subsequent rise, earthquakes lead to 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 initial middle Bakken member deposition, a lowstand that is otherwise not reflected in the sedimentary record.

The upper Bakken shale member overlying the middle Bakken unit is one of the two source rocks for the oil in the Bakken petroleum system. However, its internal sediment

architecture is largely unknown. Detailed sediment analysis of 37 cores shows that the upper Bakken shale member can be subdivided into a lower unit (interval 1) containing abundant radiolarians, high TOC values, and a significant amount of siliciclastic detritus whereas the upper part of the succession (interval 2) shows low amounts of radiolarians, low TOC values, and little silt-size detritus. It is therefore assumed that interval 1 represents the transgressive systems tract, and interval 2 the subsequent highstand systems tract. The facies analysis also shows that the sediment input must have come from the south to southwest as silt laminae are especially abundant there. The eastern margin of the basin, in contrast, is characterized by abundant clay clasts, a feature indicating erosion of already deposited mud and interpreted as reflecting sediment starvation. Clay clasts are lacking in western and southern portions of the basin.

The study of the upper Bakken shale therefore suggests that fracks originating in the middle Bakken member will likely not cut through the entire upper Bakken shale member but mostly through interval 1, the stratigraphic portion that contains abundant brittle material. Fracks will likely leave interval 2 largely untouched because of a lack of brittle components, and its high clay content. The TOC values of upper Bakken shale samples will likely be higher in the western and southern parts of the basin as organic-poor clay clasts are absent in that area, and lower in the eastern portion of the basin. This study therefore allows a prediction of shale source rock characteristics that are highly superior to just classifying the upper Bakken member as one simple monotonous shale unit as has been previously suggested.

Speaker Biography:

Sven was born in Germany, and raised in Germany, Iran, and Argentina which helped shape his career path as a geologist. After finishing high school in Buenos Aires, Argentina, Sven studied at the University of Clausthal for his undergraduate degree, and obtained his Diploma (equivalent to a Masters' degree) from Heidelberg University, Germany, on a field study in the breathtaking Italian Dolomites. Moving to Technische Universität Berlin, Germany, Sven received his PhD in 2000 for a study on basin analysis in southern Bolivia. After a five year lecturer position at Technische Universität Bergakademie Freiberg in south-eastern Germany, he accepted the position as Assistant Professor at Colorado State University in 2006, was promoted to Associate Professor in 2010, and to Full Professor in 2016. Sven's areas of expertise are understanding sedimentary processes in carbonates and shales, and applying resulting depositional models to better characterize oil and gas reservoirs.

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