How Anoxic Are Black Shale Settings? Views from the Upper Bakken Shale as a Possible Answer

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Abstract

Black shales are excellent source rocks for hydrocarbons but remain a mystery in terms of the exact environment in which they were deposited. Some geochemical studies argue for an anoxic or even euxinic setting for black shale deposition and envision sedimentation in a tranquil environment by suspension settling. In contrast, the sedimentological community is becoming increasingly convinced that at least dysoxic conditions prevailed during deposition of black shales, and sedimentation was partly through bed load transport with suspension settling playing a minor role. That dysoxic conditions existed during deposition of black shales is supported by an abundance of bioturbation in these rocks. Trace fossil occurrence in black shales is considered crucial as an indicator for some oxygenation of bottom waters. This study focuses on recognizing the stratigraphic and spatial distribution of bioturbation within the upper shale member of the Devonian-Mississippian Bakken Formation, an important source rock and potential unconventional petroleum reservoir in the Williston Basin, US and Canada. This depositional system was characterized by three distinct facies belts with amorphous organic material occurring in all of them. On a transect from proximal to distal, these facies belts are: (1) a heavily bioturbated mudstone, with scours and local fossil lag deposits, (2) a laminated silt-rich mudstone with horizontal burrows and fecal strings, and (3) a radiolarian-rich mudstone with varying content of silt and clay. Burrows and fecal strings decrease in diversity with increasing paleo-basin depth.

The presence of bedding-parallel burrows as well as multidirectional fecal strings in most of the upper Bakken member rocks clearly points to the presence of burrowing organisms present during and after deposition, which argues against persistently anoxic conditions even some millimeters below the sediment-water interface. Only some of the most distal radiolarian-rich facies, which contain very limited bioturbation and are largely devoid of tempestite-formed structures, may have been deposited under temporarily anoxic conditions.

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Sven O. Egenhoff was born in Germany, and raised in Germany, Iran, and Argentina. He studied at the Universities of Clausthal and Heidelberg, Germany, and received his PhD from Technische Universität Berlin, Germany, in 2000 for a basin analytical study of the Ordovician succession in southern Bolivia. After a five year lecturer position at Technische Universität Bergakademie Freiberg in south-eastern Germany he was appointed Assistant Professor at Colorado State University in 2006 and promoted to Associate Professor in 2010. Sven's areas of expertise are understanding sedimentary processes in carbonates and shales, and using them to reconstruct fossil depositional environments. His projects apply these models to characterize oil and gas reservoirs and to reconstruct fossil habitats of long extinct animal groups such as graptolites.