Diagenetic Variability in the Upper Shale Member of the Upper Devonian-Lower Mississippian Bakken Formation of North Dakota—Implications for Source Rock Quality and Rock "Fracability"

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The Upper Devonian-Lower Mississippian Bakken Formation of the Williston Basin, North Dakota, is a major source rock and "unconventional" petroleum reservoir. A relatively porous unit, the informal middle sandstone member of the Bakken, from which much of the production occurs, is enveloped between two organic-rich shales (source rocks), the informal lower and upper shale members. An investigation of the diagenesis of the upper shale member was undertaken on cores, with sampling constrained through detailed sedimentology analysis, to evaluate any depositionally-controlled diagenesis.

Distinct facies belts identified in the upper shale member, from proximal to distal environments, include 1) extensively bioturbated mudstone (EBM) with total organic carbon (TOC) of 8.25-9.83%, 2) minimally bioturbated mudstone (MBM) with TOC of 7.85-8.52%, 3) non-bioturbated radiolarian-bearing mudstone (RBM) with TOC of 6.54-7.8%, and 4) non-bioturbated radiolarite (chert) with TOC of 3.41-5.87%. Organic material in all facies belts is dominantly amorphous in nature. Petrographic and X-ray diffraction analyses reveal that detrital and authigenic illite and(or) chlorite, as well as early authigenic pyrite (as disseminated framboids, localized microconcretions, and as a massive cement), are abundant in the MBM and RBM facies belts, and decrease markedly in abundance in the most distal radiolarite facies belt. Conversely, authigenic quartz, as early-formed chert, is minimal in the proximal EBM facies belt and increases distally such that quartz now comprises much of the radiolarite facies belt. Importantly, detrital grains (e.g. quartz and clays) are rare in the most distal radiolarites.

The relatively low abundance of early authigenic pyrite in radiolarites probably reflects the limited availability of soluble iron in the seawater and sediment pore fluids due to the lack of an iron source (iron-bearing detritus, e.g. clays) in the most distal reaches of the sea during deposition of the upper shale member. Limited iron availability might also have resulted in lower rates of organic productivity (iron is a necessary nutrient), which may explain why radiolarites have the lowest TOC contents of any lithology in the upper shale member. Nevertheless, the high quartz content of radiolarites make them attractive where "fracing" the upper shale member is desired for enhanced production or as another potential interval for exploration in the Bakken.