An Outcrop Analog for the Williston Basin Bakken Hybrid Play, the Sappington Formation in Southwest Montana: Facies, Stratigraphic Architecture, and Controls on Porosity Distribution

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Abstract

The Devonian-Mississippian Bakken Formation in the Williston Basin is one of the most prolific petroleum systems in North America, but production results across the basin are highly variable, indicating that these rocks display considerable geological heterogeneity that can't be easily deciphered from subsurface data alone. In southwestern Montana, outcrops of the Bakken equivalent Sappington Formation preserve a wide variety of sedimentologic and stratigraphic characteristics, reflecting complicated and interrelated processes of sediment dispersal, stratigraphic architecture and diagenesis, that can be used as an outcrop analog for the Bakken in the Williston Basin.

The Sappington Formation contains facies ranging from organic-rich mudrocks (max. ~15% TOC), prominent in the Lower and Upper Sappington Shales, to dolomitic silty, very fine-grained sandstones, the dominant facies in the Middle Sappington. Facies distribution is strongly controlled by a series of basinward-dipping, low-angle clinoforms that can be mapped from outcrop. The best primary reservoir facies occurs near the upper foresets of individual clinoforms, while clay content in siltstones gradually increases down depositional dip of individual clinoform foresets.

Although not exclusively, as some structural lineaments also acted as fluid conduits and inhibit local control on cementation, this stratigraphic architecture strongly controls the distribution of diagenetic minerals. Dolomite and calcite cements are most abundant in the coarsest-grained depositional facies near the top of the clinoforms and occlude porosity. Conversely, well-developed illite linings are most abundant in the finer-grained facies and inhibit abundant dolomite cementation. Low permeability contacts between individual clinoforms compartmentalized diagenetic fluids resulting in vertically-stacked clinoforms with large variations in dolomite cementation.

This outcrop-based stratigraphic architecture, facies, and diagenesis study of the Sappington Formation provides insights into the scale of reservoir complexity that is likely to be present in the time-equivalent Bakken Formation over the length of a typical horizontal well. Integrating findings from this study to existing facies models and structural frameworks in the Bakken Formation will assist in predicting reservoir quality away from well control and enhance development strategies.

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