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Facies and Mechanical Stratigraphy of the Middle Bakken, Mountrail County, North Dakota

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We recognize five facies within Middle Bakken cores from Sanish and Parshall fields of Mountrail County, North Dakota. Facies E is a basal unit abruptly overlying the Lower Bakken shale. This thin, one to four feet thick facies is characterized by muddy, intraclastic-skeletal lime wackestone. It exhibits distinctively cleaner Gamma Ray log signature than the overlying Facies D and is commonly oil-stained with yellow UV fluorescence.

Facies D is a bioturbated, argillaceous, calcareous, poorly sorted, very fine grained sandstone/siltstone with common *Helminthopsis/Sclarituba* burrow traces. This thickest Middle Bakken unit is interpreted as offshore deposition below storm wavebase. Both intergranular pores and open horizontal discontinuous microfractures are rare in this poor to fair reservoir quality facies which is subject to progressively increasing bedded to nodular calcite cementation to the south and dolomitization to the east.

Facies C is composed of rhythmic, varve-like, mm- to cm-laminated, well-sorted, very fine grained sandstone and siltstone with considerable calcite cement. Dominantly parallel laminae and subordinate very low angle, hummocky cross-stratification grade upward to increased wave-ripple lamination. This facies is interpreted as a combination of distal storm deposits and distal prodelta hyperpycnal gravity flows. Visible porosity is limited to rare intergranular, clay intercrystalline, and minor open discontinuous horizontal microfractures. Facies C is confined to middle Bakken paleolows.

When present, Facies B forms the Middle Bakken “clean bench” characterized by the cleanest Gamma Ray log signature in the middle Bakken. Facies B varies from 0 to >20’ with two sub-facies. Basal Facies B2, a muddy calcareous sandy/silty “disturbed” facies, has common syn-sedimentary micro-faults, microfractures, and slumps representing soft-sediment deformation concurrent with inferred structural movement on Nesson Anticline. Facies B1 is the highest energy, coarsest grained unit in the Middle Bakken, represented by alternating units of cross-bedded bioclast-rich, very fine to fine-grained sandstone and sandy skeletal lime grainstone deposited subtidally in shoals and/or channels above storm wave-base. True trough or planar tabular cross-stratification is rare; most inclined bedding is either swaley or disturbed. Pore types include rare to common intergranular and minor clay intercrystalline. Syntaxial calcite cement in crinoidal lime grainstone B1 occludes all primary pores. Primary porosity retention in Facies B1 improves with greater allochem diversity and/or quartz abundance. To an even greater extent than Facies C, Facies B1 and especially B2 are largely confined to and sandier in paleolow areas. This facies is not present at Parshall Field – instead the “clean bench” at Parshall consists of tight crinoidal lime pack/grainstones deposited as local carbonate shoal complexes.

Facies A contains four sub-facies (from bottom to top): 1) A-GR marker is a thin organic-rich mudstone forming a widespread Gamma Ray log marker at base of A; 2) A2 is a laminated dolomite packstone and algal boundstone that is significantly more dolomitic than any other middle Bakken facies; 3)

A1 is a calcitic, whole fossil, dolo-to lime-wackestone with fossil-rich storm beds that constitute "guide beds" while drilling; and 4) A0 is a "patterned" pyritic dolomudstone immediately below the contact with the Upper Bakken Shale. Rare visible porosity in thin sections is limited to secondary pores and rare open discontinuous microfractures. Despite the paucity of visible porosity in core and thin sections, Facies A has weak yellow UV fluorescence emanating from micropores in grainy beds.

Facies successions and event stratification also yield a mechanical stratigraphy thought to impact fracture height and spacing. Facies D is a single, massive mechanical unit; as such it has the greatest fracture spacing. By contrast, Facies A, B, and C are composed of thin mechanical beds. Dolomitic, centimeter- to decimeter-bedded Facies A is the thinnest bedded and most fracture-prone. Linking core facies to MWD GR, drilling time and mud gas enhances real-time tracking of horizontal wellbore trajectories. Facies A, B, and C remain the principal horizontal target due to greater porosity, fracture susceptibility and therefore permeability.