PsNiobrara Core Poster Highlighting Bentonite Distribution and Their Impacts on Proppant Placement*

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Search and Discovery Article #41803 (2016)**
Posted May 16, 2016

*Adapted from poster presentation given at AAPG 2015 Annual Convention and Exhibition, Denver, Colorado, May 31 – June 3, 2015
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Abstract

We exhibit 160' of Niobrara core from the Whiting Razor 25–2514, Weld County, Colorado. The exhibited interval covers the productive Niobrara A chalk, the Niobrara A marl, the productive upper and lower Niobrara B chalk benches and most of the Niobrara B marl. Higher frequency cyclicity and lithologic variation is demonstrated within the chalks due to abundant, thin, black, marly interbeds up to 3” thick; conversely, the A and B marl intervals contain many, thinner, non-amalgamated chalk interbeds. The chalk interbeds within the marls have suppressed UV hydrocarbon fluorescence, probably due to UV quenching from associated elevated asphaltene content. All intervals, including the overlying Sharon Springs Member of the Pierre Shale have bentonites which range from 4” thick in the Sharon Springs to <1/8” thick within the Niobrara Marls. All the bentonites fall below wireline log resolution (with the exception of resistivity imaging), however, we emphasize their distribution with UV photos that highlight each and every bentonite based on bright UV fluorescence. Rock mechanical properties such as Poisson's Ratio and Young's Modulus calculated from dipole sonic logs are largely ignorant of the presence of these abundant, thin, yet very weak, ductile bentonites. Hydraulic Stimulation modeling based on wireline log properties therefore grossly underestimates the mechanical heterogeneity of the Niobrara. Furthermore, the bentonites are too thin and weak to be plugged for static rock mechanics evaluations. To address these limitations, we made extensive usage of the Equotip” “Bambino” micro-rebound hammer to measure closely spaced Unconfined Compressive Strength (UCS) at least every 6” while also covering each and every one of the hundreds of thin bentonites. The UCS from the micro-rebound hammer is compared not only with wireline dipole sonic based parameters, but also with UCS from TerraTek's “Scratch Test”. The Equotip-derived UCS curve, even when running-average-smoothed, demonstrates much greater UCS dynamic range, capturing the very weak bentonite interbeds. Not only do the bentonite (and marl) interbeds divide the chalks into multiple subtle mechanical stratigraphic intervals, but marly intervals with most abundant bentonites impact hydraulic fracture efficiency by limiting proppant placement to the main chalk benches. While fluid-filled fractures have rather extensive vertical propagation throughout the Niobrara A-B-C at peak pump rates, fracture offsets across bentonites and ensuing proppant embedment phenomena eventually render the main marl intervals as barriers to effective stimulation. The impact of bentonites on hydraulic stimulation efficiency was supported by proppant tracer studies in a vertical well stimulation scaled be proportionate to an individual horizontal frac stage. Bentonites changed from our “foes” to our “friends” because their impact on completions supports our multiwall development plans with separate A, B, and C horizontal well targeting.
Niobrara Core Poster Highlighting Bentonite Distribution and their Impacts on Proppant Placement

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¹Whiting Petroleum; ²Texas Bureau of Economic Geology

ABSTRACT: We exhibit 80' of Niobrara core from the Whiting Razor 25-2514, Weld County, Colorado. The exhibited interval covers the productive lower Niobrara B chalk bench and the upper portion of the Niobrara B marl. Higher frequency cyclicity and lithologic variation is demonstrated within the chalks due to abundant, thin, black, marly interbeds up to 3” thick; conversely, the A and B marl intervals contain many, thinner, non-amalgamated chalk interbeds. The chalk interbeds within the marls have suppressed UV hydrocarbon fluorescence, probably due to UV quenching from associated elevated asphaltene content.

All intervals, including the overlying Sharon Springs Member of the Pierre Shale have bentonites which range from 4” thick in the Sharon Springs to <1/8” thick within the Niobrara Marls. All the bentonites fall below wireline log resolution (with the exception of resistivity imaging), however, we emphasize their distribution with UV photos that highlight each and every bentonite based on bright UV fluorescence. Rock mechanical properties such as Poisson’s Ratio and Young’s Modulus calculated from dipole sonic logs are largely ignorant of the presence of these abundant, thin, yet very weak, ductile bentonites. Hydraulic Stimulation modeling based on wireline log properties therefore grossly underestimates the mechanical heterogeneity of the Niobrara. Furthermore, the bentonites are too thin and weak to be plugged for static rock mechanics evaluations. To address these limitations, we made extensive usage of the Equotip™ “Bambino” micro-rebound hammer to measure closely spaced Unconfined Compressive Strength (UCS) at least every 6” while also covering each and every one of the hundreds of thin bentonites. The UCS from the micro-rebound hammer is compared not only with wireline dipole sonic based parameters, but also with UCS from TerraTek’s “Scratch Test”. The Equotip-derived UCS curve, even when running-average-smoothed, demonstrates much greater UCS dynamic range, capturing the very weak bentonite interbeds.

Not only do the bentonite (and marl) interbeds divide the chalks into multiple subtle mechanical stratigraphic intervals, but marly intervals with most abundant bentonites impact hydraulic fracture efficiency by limiting proppant placement to the main chalk benches. While fluid-filled fractures have rather extensive vertical propagation throughout the Niobrara A-B-C at peak pump rates, fracture offsets across bentonites and ensuing proppant embedment phenomena eventually render the main marl intervals as barriers to effective stimulation. The impact of bentonites on hydraulic stimulation efficiency was supported by proppant tracer studies in a vertical well stimulation scaled (fluid, proppant, & net stress) to be proportionate to an individual horizontal frac stage. Bentonites changed from our “foes” to our “friends” because their impact on completions supports multiwall development plans with separate A, B, and C horizontal well targeting.
### 5 GENERALIZED FACIES

**CHALK**

- Borrowed Chalk
- Laminated Chalk
- Laminated Chalk with foraminifera and/or hardgrounds
- Laminated Chalk with foraminifera and/or hardgrounds, skeletal-rich
- Laminated Chalk with foraminifera and/or hardgrounds, coarse-grained, skeletal-rich

**MARLY CHALK**

- Laminated Marly Chalk
- Laminated Marly Chalk with foraminifera
- Laminated Marly Chalk with foraminifera and hardgrounds
- Laminated Marly Chalk with foraminifera and hardgrounds, skeletal-rich

**MARL**

- Laminated Marly Chalk with foraminifera and/or hardgrounds
- Laminated Marly Chalk with foraminifera and/or hardgrounds, skeletal-rich
- Laminated Marly Chalk with foraminifera and/or hardgrounds, coarse-grained, skeletal-rich
- Laminated Marly Chalk with foraminifera and/or hardgrounds, coarse-grained, skeletal-rich, coarse-grained

**ORGANIC RICH MUDSTONE**

- Laminated Organic-rich Mudstone
- Laminated Organic-rich Mudstone, high resistivity
- Laminated Organic-rich Mudstone, intermediate resistivity
- Laminated Organic-rich Mudstone, low resistivity

**BENTONITE**

- Organic-rich bentonite
- Organic-rich bentonite, partially bioturbated and/or organic-rich bentonite
- Organic-rich bentonite, partially bioturbated and/or organic-rich bentonite, low resistivity
- Organic-rich bentonite, partially bioturbated and/or organic-rich bentonite, moderate resistivity
- Organic-rich bentonite, partially bioturbated and/or organic-rich bentonite, high resistivity
- Organic-rich bentonite, partially bioturbated and/or organic-rich bentonite, very high resistivity

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### FACIES #

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<th>Facies</th>
<th>DETAILED FACIES</th>
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<td>Borrowed Chalk</td>
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<tr>
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<td>Laminated Chalk</td>
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</tbody>
</table>

### Well: Razor 25-2514H

- A Marl
- B Chalk
- B Marl

**interval on display**

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**ECGR**

- 0
- 0.3

**HNPO**

- 0
- 0.3
- 0.6
- 0.9

**Facies**

- 0
- 0.3
- 0.6
- 0.9

**Bentonite**

- 0
- 0.3
- 0.6
- 0.9
Conclusions: The Niobrara Formation has abundant very thin bentonites. All individual bentonites fall below dipole sonic and gamma ray wireline log resolution; consequently, we captured their distribution from core observation. Rock mechanical properties such as Poisson’s Ratio and Young’s Modulus calculated from dipole sonic logs are largely ignorant of the presence of these abundant, thin, yet very weak, ductile bentonites. Hydraulic stimulation modeling based on wireline log properties, therefore, grossly underestimates the mechanical heterogeneity of the Niobrara. To address these limitations, we made extensive usage of the Equotip™ micro-rebound hammer to measure Unconfined Compressive Strength (UCS) of each and every one of the hundreds of thin bentonites.

A scaled and radioactive proppant traced fracture stimulation within a vertical well demonstrated that the A and B marly intervals with most abundant bentonites impact hydraulic fracture efficiency by limiting proppant placement to the intervening B chalk bench. While fluid-filled fractures have rather extensive vertical propagation throughout the Niobrara A-B-C at peak pump rates, fracture offsets across bentonites and ensuing proppant embedment phenomena eventually render the main marl intervals as barriers to effective stimulation.