Quantitative Mineralogy and Microfractures in the Middle Bakken Formation, Williston Basin, North Dakota*

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Search and Discovery Article #40628 (2010)
Posted December 14, 2010

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-15, 2010. Please refer to companion articles, “Abnormal Pressure Analysis in the Bakken Formation, a Key to Future Discoveries,” Search and Discovery Article #40629 (2010), and “Petroleum Geology of the Giant Elm Coulee Field, Williston Basin,” Search and Discovery Article #20096 (2010), both by the first author of this article.

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Abstract

Fractures are considered to play a key role in controlling Bakken petroleum production in the North Dakota part of the Williston Basin. Generally, wells are oriented to intersect the maximum number of fracture swarms, and fracture stimulation is employed resulting in initial producing rates of several hundred to over one thousand barrels per day in some fields.

This study utilizes a new approach to assess the impact of microfractures on fluid flow by integrating mineralogy and fracture analysis using SEM-based quantitative mineralogy on several drill core samples from North Dakota. Due to the high spatial resolution of the analysis (~2 μm) even very small fractures can be detected using this technique. In addition to fracture abundance quantification, fracture size, orientation and mineral associations can also be investigated.

Quantitative mineralogy shows that samples of the Middle Bakken Formation consist of silt-to sand-sized grains of quartz, feldspar (plagioclase and K-feldspar), dolomite and limestone with minor amounts of clays indicative of a marine depositional environment with water depths ranging from shallow (within wave base and tidal influence) to deep neritic. Texturally the samples may be massive, display cross stratified or subparallel bedding and laminated zones.

Preliminary results of quantitative mineralogy microfracture analysis show that microfractures generally are oriented parallel to bedding (i.e., horizontal microfractures), hence along natural planes of weakness. Fracture widths range from 2 μm to 25 μm, and fracture lengths from 6 μm to several 10s of microns. In the studied samples the vast majority (~95%) of horizontal fractures appear to occur within clay-rich horizons. Some areas in the Williston Basin, such as the Parshall Field, are known to contain additional fracture swarms that are
oriented in a northeastern direction perpendicular to bedding resulting in a well fractured petroleum system. However, at least on a microfracture-scale, similar vertical fractures were not identified in the samples presented here.

This study demonstrates that the analysis of microfractures by quantitative mineralogy, in particular in conjunction with other macro- and mesofracture analyses, has the potential to be a powerful tool in well design and may provide new insights into fracturing behavior and fluid flow in petroleum reservoirs.

References


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Fractures are considered to play a key role in controlling Bakken petroleum production in the North Dakota part of the Williston Basin. Generally, wells are oriented to intersect the maximum number of fracture swarms, and fracture stimulation is employed resulting in initial producing rates of a few thousand barrels per day. However, the initial high production rates decrease over time, and secondary recovery methods such as water flooding, steam injection, and carbon dioxide injection are required to increase cumulative production. This study demonstrates that the analysis of microfractures by quantitative mineralogy, in particular in conjunction with other macro- and mesofracture analyses, has the potential to be a powerful tool in well design and may provide insights into fracturing behavior and fluid flow in petroleum reservoirs.

Quantitative mineralogy shows that samples of the Middle Bakken Formation consist of silt-to sand-sized grains of quartz, feldspar (plagioclase and K-feldspar), dolomite and limestone with minor amounts of clays indicative of a marine depositional environment with water depths ranging from shallow (within wave base and tidal influence) to deep neritic. Texturally the samples may be massive, display cross stratified or subparallel bedding and laminated zones.

Preliminary results of quantitative mineralogy microfracture analysis show that microfractures generally are oriented parallel to bedding (i.e., horizontal microfractures), hence along natural planes of weakness. Fracture widths range from 2 μm to 25 μm, and fracture lengths from 6 μm to several 10s of microns. In the studied samples the vast majority (~95%) of horizontal fractures appear to occur within clay-rich horizons. Some areas in the Williston Basin, such as the Parshall Field, are known to contain additional fracture swarms that are oriented in a northeastern direction perpendicular to bedding resulting in a well fractured petroleum system. However, at least on a microfracture-scale, similar vertical fractures were not identified in the samples presented here.
Bakken Fractures

Working Hypothesis

Vertical fractures, bedding plane partings, and reticulated fractures all play a role.

Azimuth of fractures in oriented cores from Mission Canyon Formation in Little Knife Field area (from Narr and Burruss, 1984).

Orientation of petal, induced fractures illustrating Sh maximum direction is northeast.

Stages of migration of kerogen-rich black shales and respective changes in their composition, porosity structure and fluid situation (Zimm, 1984).

Map showing major tectonic left-lateral shear sets (late Proterozoic) that formed the Central Rocky Mountain province and Williston Basin Block (Gerhard et al., 1990).

Parshall Field, located in Mountrail County, ND. Most horizontal wells drilled in a northwest to west-northwest direction.

Facies found in Bakken and Three Forks formations (facies modified from LeFever, 1991; Canter and Sonnenfeld, 2009).

Heterogeneous lithologies in shales and Middle Bakken, horizontal bedding and laminations: planes of weakness.

Bakken Fractures

- Tectonic/structural
- Regional Fractures (NE)
- Local structures
- Hydrocarbon generation
- Prairie salt dissolution

Permeability (fracture or matrix or both) indicated on resistivity logs (drilled with salt mud) because of separation of shallow and depth investigation curves.
Summary

- Fractures and partings are common in Bakken
- Vertical and reticulated fractures and bedding-plane partings enhance low reservoir quality
- Bedding-plane partings are inherent weaknesses in rock arising from thin bedding (laminations), fissility and/or lithologic contacts
- Partings may be a consequence of oil generation and overpressuring in the Bakken