Use of Microseismic in Monitoring Hydraulic Fractures in the Bakken Formation, North Dakota, USA*

Gary Forrest¹, Tom Olsen¹, Aleksey Kazantsev¹, Ernest Gomez¹, Tim Dombrowski¹, and Wayne Rowe²

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¹Schlumberger Data and Consulting Services, Greenwood Village, CO (egomez@denver.oilfield.slb.com)
²Schlumberger Water Management Services, Denver, CO

Abstract

The Mississippian-Devonian Bakken Formation is a relatively tight mixed carbonate – clastics sequence in the Williston Basin of North Dakota. Although production can exceed 1000 BOPD, hydraulic fracturing is necessary to induce economic production. Until recently a great degree of uncertainty has existed regarding how the Bakken behaves during fracturing. In late 2007 seven (7) operators along with Schlumberger created a consortium that used the best available technologies to optimize understanding of certain geologic, drilling, and completion principles that affect production. As part of this, three (3) horizontal wells (each 4000 feet in length) were drilled in an east-west direction, 1500 feet apart into the Middle Bakken Member. An array of 15 triaxial geophones, with 100 feet between each sensor set, was placed into the middle lateral (Nesson State 42X-36) to monitor the microseismic activity during the hydraulic fracturing of the two (2) outside wells. Different hydraulic fracturing methods were tried in each of the wells, ranging from a single treatment in the northern lateral (Nesson State 41X-36) to a six (6) staged treatment with swell packers in the southern lateral (Nesson State 44X-36). The microseismic events were integrated with the geologic understanding of the area, radioactive and chemical tracers, and reservoir simulation to develop a robust interpretation of effectiveness of the hydraulic fracture treatments.

Reference

Microseismic Monitoring of Hydraulic Fractures: Bakken Formation, North Dakota

Gary Forrest, Tom Olsen, Aleksey Kazantsev, Ernest Gomez, Tim Dombrowski, Wayne Rowe, Alex Perakis
Schlumberger Data and Consulting Services, Denver

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Research Concept

- Drill three wells with single 4000 ft. laterals.
- Use the most advanced technology available.
- Design to support microseismic monitoring from the middle lateral.
Bakken Stratigraphy

Lodgepole

Upper Bakken

Middle Bakken

Lower Bakken

Bakken

Three Forks

Anoxic Marine

Marginal Marine Offshore Complex

Clastic

Carbonate

Clay

Pyrite

Laterals

(LeFever, 2005)
Three Additional Seismic Systems Installed and Monitored Separately

- Department of Energy (DOE) System: 3 bore holes, each with 3 sets of triaxial sensors grouted every 500 feet; maximum depth ~1500 feet
- Terrascience: 18 bore holes with triaxial sensors grouted at ~300 feet
- Microseismic, Inc: 24,000 single component geophones planted on the surface
Severe signal attenuation was a problem for the DOE and Terrascience.

They did not detect any seismic events, despite the quality and sensitivity of their instruments and deep installations.
Seismic Signal

From Geology Labs Online, University of California
• Each seismic signal is unique
• All have P and S wave arrivals
Recorded Seismic Event
NS 44X
All potential events before data editing

Y-axis 479600

NS 41X

NS 44X
Locations are based on P and S arrival times and measured P and S velocities ONLY.

There are no bulk shifts applied to these event locations.
NS 41X: Looking North
X-Linked Gel: Height Growth

NS 41X vertical growth at onset of X-Linked Gel

View to North

Slickwater Model

X-Linked Model
NS 44X: Map View
NS 44X: Looking North
NS 44X Comparison

Stage 3 Slickwater

Stage 3 X-Linked Gel
NS 44X, Stage 3: Radioactive Tag

Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6

Vol Carbonate
TXSP-Aniso
Fractures

Antimony
Scandium
Iridium

In Target
Perforations
Packers
Antimony Tracer

Map View
Production Correlates to the Number and Distribution of Events

Individual & Total Tracer Concentration, ppb

Cumulative Flowback Volume, bbl

NS 44X Chemical Tracer Flow Back

Stage 3

Other Stages
Production Model Fracture Fit
Model Validation: Well Oil Production Rate

NS 41X

NS 44X
Key Observations

- Seismic events show a strong correlation to the changes in frac fluid.
- Production history shows a strong correlation to the number and distribution of seismic events for each stage.
- History match from the seismic-based reservoir model was nearly perfect; requiring only a 10% adjustment to permeability for a fit.