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Contacting More of the Barnett Shale Through an Integration of Real-Time Microseismic Monitoring, Petrophysics and Hydraulic Fracture Design

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Abstract
Horizontal wells represent a growing percentage of the rig count in unconventional gas wells in the United States. With effective stimulation techniques they have been shown to have favorable economics compared to vertical wells in the same reservoir. This is because of the large hydraulic fracture surface area that can be created from horizontal wells if effective stimulation techniques are employed. The Barnett Shale formation is the reservoir that has seen the largest growth using this technique in recent years.

Estimated to extend over 54,000 square miles, the Barnett Shale formation displays different reservoir characteristics and properties in its different regions. The heterogeneous nature of this unconventional play makes standardization of the completion process problematic. One technology that has been used with increasing regularity to understand complex fracture geometry is microseismic (MS) fracture mapping[1]. Recent technology advances have made it possible for an onsite computer to process the thousands of seismic traces and deliver MS events hypocentral locations in a matter of seconds to a viewer in the fracturing treatment vehicle. Microseismic mapping used in conjunction with wellbore images and sonic logs has shed considerable light on the challenges faced in this reservoir.

Massive water fracs are currently used to create complex hydraulic fracture networks. This stimulation technique, while successful, often leaves behind unstimulated sections of the reservoir. In order to achieve optimum horizontal well stimulation the lateral section must be characterized so that geologically different intervals can be identified and the proper stimulation technique employed. Technology has progressed to the point that microseismic monitoring of hydraulic fracture stimulation can efficiently provide extensive diagnostic information on fracture development and geometry in real-time.

The case studies in this paper show how the use of real-time fracture mapping allows for on-the-fly changes in fracture design. Mapping also impacts the perforation strategy and re-stimulation designs to maximize the Effective Stimulation Volume (ESV). ESV is defined as the reservoir volume that has been effectively contacted by the stimulation treatment as determined by microseismic event locations and density. This paper further correlates MS activity to log data and illustrates how logs can be used to estimate fracture geometry. This data is then used to design a fit-for-purpose stimulation that has the greatest chance of maximizing the ESV and production.

Introduction
The Barnett Shale is a Mississippian-age marine shelf deposit that unconformably lies on the Ordovician-age Viola Limestone/Ellenberger group and is conformably overlain by the Pennsylvanian-age Marble Falls Limestone[2]. The Barnett Shale, located within the Forth Worth basin, is the focus of this study. We concentrate on wells within Denton, Wise, and Tarrant counties: the “core area.” The Barnett in the core area ranges from 300 to 500-ft thick. Matrix permeabilities range from 0.00007 to 0.0005 md with porosities ranging from 3 to 5%. The Barnett is its own source rock and is abnormally pressured in this area, with a pore pressure gradient of approximately 0.5 psi/ft. Commercial production is only achieved through hydraulic fracture stimulation.

Before 1997, Barnett wells were completed with massive hydraulic fracture treatments consisting of crosslinked gelled fluids and large amounts of proppant. Difficulties in effectively cleaning up fracture damage from the crosslinked gel and the high cost of these massive stimulation treatments led to marginally economical wells. In 1997 large volume, high-rate slick water fracture stimulation treatments were tested as a less expensive alternative. While well performance was not drastically increased by using slick water, completion costs were reduced by approximately 65%. In 2002, experimentation with horizontal wells began in an effort to increase the wellbore’s exposure to the reservoir. The result was that the first horizontal wells increased the estimate