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Induced Seismology and Hydrocarbon Production

M.W. Puckett, SPE, and J.H. Le Calvez, SPE, Schlumberger Oilfield Services

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Abstract

Microseismicity generated during hydraulic fracturing operations provides information to (i) optimize stimulation design, (ii) direct treatment operations, and (iii) more effectively manage the stimulated reservoir by understanding the dimensions of the treatment footprint. Microseismic monitoring technique is applicable to all reservoirs requiring hydraulic stimulation to assure commercial productivity. Geophysics moves beyond mere reflection seismic to applying the principles of earthquake seismology to address issues related to hydraulic fracture stimulation and reservoir management.

Introduction

Microseimic techniques have been used to map hydraulic fracturing operations since the mid-1980s. The method received curious stares until the seminal works in the mid- to late-1990s at the M-Site near Rulison, Colorado (1) and the Cotton Valley Field in Texas (2) began appearing in industry publications. Commercial interest in the technology heightened, and is now offered by several service companies, typically using systems originally built for recording vertical seismic profiles. Entire sections are now devoted to microseismic monitoring of hydraulic fracture operations at the international conferences for both engineering and geophysics.

As a business in the United States, it is estimated that microseismic monitoring of hydraulic fracturing operations has grown from a few dozen wells in 2002 to over 600 wells monitored in 2006 (Figure 1). Moreover, the number of stages being monitored has grown from just over one stage per well to more than three stages being monitored per well. The staggering growth of this technology highlights both its broad acceptance in industry, as well as the great need for the information it provides, especially in horizontal wells.

Applications

Microseismic hydraulic fracture monitoring (MHFM) demonstrates value to the operator in three distinct applications: fracture treatment diagnostics, fracture treatment control, and reservoir management. The locations of the microseismic events are displayed in 3D volumes, minimally with sketches of the treatment well and observation well to provide geometrical context (Figure 2).

Fracture Treatment Diagnostics

The use of MHFM for fracture treatment diagnostics seeks to answer two main questions:

1) How did the treatment perform versus design?
2) What parameters or assumptions need to be changed to achieve a higher performing treatment design?

Weak assumptions of symmetry, rock properties, and treatment pressure interpretation often lead to an improper analysis of treatment performance. The MHFM data provides measured context for understanding the treatment behavior and performance. The MHFM results constrain the possible interpretation of the treatment data, and can lead to more productive treatment designs (3) (Figure 3).

Fracture Treatment Control

MHFM operations can provide valuable real-time control information for the treatment operations. The questions MHFM can answer are:

1) How well is the treatment being contained?
2) When should pumping stop due to terminating mechanical growth or geological concerns?

The answers to these questions require real-time (within a few seconds or minutes) mapping of the microseismic event locations and real-time interpretation of the event map and fracture treatment data (Figure 4).

Reservoir Management

The most foundational challenge of reservoir management is to maximize both the reservoir recovery factor and profitability at the same time. To accomplish this task, the operator must drill the right number of wells in the right places. In what was called tight gas sands ten to twenty years ago, in which permeability was measured in millidarcies, radial flow would be achieved within a few early years of reservoir life, and well placement was a matter of pattern drilling. Now, with micro-darcy reservoirs dominating as