A Completions Guide Book to Shale-Play Development: A Review of Successful Approaches toward Shale-Play Stimulation in the Last Two Decades

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Abstract
Almost three decades have passed since the early exploration of the north Texas, Barnett shale. The Barnett serves as an example study for the shale life cycle. Operators in North America have used the Barnett-shale development as a roadmap for the exploration of new shale plays like the Marcellus, Haynesville, and Eagle Ford, as well as others. Each new shale play is unique in nature with respect to geologic setting, lithology, and production mechanism. It is useful to have a defined strategy for the discovery, development, and decline phases of each individual shale play. The roadmap to shale well-completion designs should include the following key factors:

- Fracability: capability of the reservoir to be fracture stimulated effectively
- Producibility: capability of the completion plan to sustain commercial production
- Sustainability: capability of the field development to meet both economic and environmental constraints

This paper reviews the evolution and development of completion practices of the major US shale reservoirs in the last two decades and presents a roadmap for effective completion practices for shale stimulation. The completion roadmap uses the history of 16,000 shale frac stages in the Barnett, Woodford, Haynesville, Antrim, and Marcellus shales. Following the map through specific decision points will alter the path for individual shales. These decision points will be influenced by geologic, geochemical, and geomechanical information gathered along the way. The path toward a commercially viable shale play from the early asset-evaluation phase to the late asset maintenance-and-remediation phase evolves from a series of decision trees throughout the process.

Information presented in this paper provides a completion engineer with better understanding of the factors involved in shale-play stimulation and provides a methodical approach to select appropriate and optimum solutions that have evolved during the last two decades.

Introduction
In the mid 1800s, expanding uses for oil extracted from coal and shale began. Gas production from the Devonian shale in the US can be traced back to 1821. A review of more recent shale exploration and development can be found in SPE reprint series No. 45, "Production from Fractured Shales?? (Lancaster et al. 1996). As the title infers, commercial production from nanodarcy shale was most likely from the existing natural fractures providing "transmissibility and economic permeability.?? Later, when more cores became available, the natural fractures that existed in most gas-shale plays like the north Texas Barnett were found to be filled with calcite or quartz, not oil or gas (Lancaster et al. 1996).

However, filled natural fractures are thought to have dilated during the massive hydraulic fractures used to stimulate the Barnett from 1985 to 1991. This dilation of filled fractures created the large fracture networks, exposing large surface areas and sustainable production.

The north Texas Barnett serves as a study in shale-completion evolution. Table 1 illustrates the Barnett development history.

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Momentous developments in the global economy over the last two decades have dramatically increased the availability of industrial investment sites and lowered the cost of relocating core activities to new countries. But how should these developments be exploited for competitive advantage? This book examines how location decisions have contributed to the global dominance of U.S. firms in the hard disk drive industry. In analyzing the industry since its beginnings some forty years ago, the book explains how American leadership in disk drives has rested on the formation of two complementary industrial clusters. This duality has proven key to the successful competitive position of the U.S. disk drive industry.