EXPLORATION AND EVALUATION OF FRACTURED RESERVOIRS WITH EMPHASIS ON FAULT-RELATED FRACTURE SYSTEMS

TECHNOLOGY | CONNECTIONS
PETROLEUM TECHNOLOGY TRANSFER COUNCIL

BOTTOM LINE

Understanding why and how fractures came about enables one to better predict and model their effect on fluid flow. Genetically, fractures can result from: (1) tectonic (fold- and fault-related), (2) regional (joint or cleat system), (3) contractional (chickenwire, diagenesis-related or columnar), and (4) surface-related or induced. Fractures can be open, deformed, mineral-filled or vuggy. Fractures can have both beneficial and detrimental effects. A reservoir typing system (Type I, II, III, or IV) is used to characterize flow characteristics of fractured reservoirs. Proper understanding of fractured reservoirs, as early in life as possible, can significantly reduce reservoir development costs.

PROBLEM ADDRESSED

Fractures are increasingly being recognized as contributing, even dominating, factors in reservoir flow capability. Dramatic advances have been made in defining fracture systems—the geology behind their evolution and semi-quantitative approaches for defining how they contribute to a reservoir's fluid flow capacity. Those exploring for and developing reservoirs must understand and apply these advances to better predict reservoir performance and reduce reservoir development costs.

KEY WORDS:
Causes of Fractures
Fault-Related Fractures
Fractured Reservoir Types
Modeling

TECHNOLOGY OVERVIEW

FRACTURED RESERVOIR SYSTEMS

Fractures can be open, deformed, mineral-filled or vuggy. Fractures can have both beneficial and detrimental effects. An experience-based workflow process has been developed to work with fractured reservoirs. Geoscientists work to create a static conceptual model while reservoir engineers work with flow and pressure data to develop a dynamic conceptual model. Their integrated efforts quantify fracture/matrix interactions and fluid flow. In recent years, industry has come to realize that fracture systems affect reservoir productivity much more, and in many more reservoirs, than previously thought.

Genetic Classification of Fracture Systems. Genetically, there are several mechanisms responsible for fracture formation. These include: (1) tectonic (faulat- and fold-related), (2) regional (joint or cleat system), (3) contractional (chickenwire, diagnesis-related or columnar), and (4) surface-related or induced.

With **fault-related fractures**, there is a narrow damage zone (a few feet) adjacent to the fault that usually has low permeability (i.e., don't drill a well too close to a fault). The fault itself may not necessarily be in the center of the damage zone. Beyond the damage zone, there is an effective process zone, which can be up to a few hundred feet, where fractures enhance productivity (the target area for wells). Fractures near faults can occur before faulting (pre-slip), during faulting (slip-related) and from stress field variations after faulting (post-slip). Storage volumes of intensely fractured reservoirs can be significant. Fracture swarms are more intense around faults. Drainage lengths along faults up to 6,000 feet have been observed. Fracture intensity should not be expected to be uniform along a fault, and it must be recognized that faults themselves are topographic surfaces, not uniform planar surfaces.

Other Fracture Systems. Fold-related fractures are those typically associated with anticlinal structures. There are compression and extension components. Regional fractures are those that are developed over large areas with relatively little change in orientation, show no evidence of offset along the plane, and are perpendicular to bedding. Contractional fractures are associated with a general bulk volume reduction throughout the rock. A chickenwire fracture (think drying mud on the surface) is a typical example. Other fractures can be induced by well operations.

Flow Classification. Industry has adopted a typing system for describing fractured reservoirs. In *Type I* reservoirs, fractures provide the essential storage capacity AND permeability. The matrix makes little porosity or permeability contribution. Examples would include fractured granite. In *Type II* reservoirs, the rock matrix provides the essential storage capacity WHILE the fractures provide the essential permeability. Permeability of the rock matrix is low, but matrix porosity can range from low to high. In *Type III* reservoirs, fractures provide a permeability assist. I.e., these reservoirs

Based on a workshop sponsored by PTTC's Appalachian Region on December 3, 2002 in Washington, Pennsylvania

SPEAKERS:

Ronald Nelson, Broken N Consulting, Inc.

are economically producible from the matrix alone. Fracture contributions are often not recognized until secondary or enhanced oil recovery operations. In *Type IV* reservoirs, fractures do not provide additional storage capacity or permeability in an already producible reservoir, but instead create unfavorable anisotropy. Simulation models should be matched to the reservoir type. Single porosity models are appropriate for Type I and IV reservoirs. Dual porosity models should be used for Type II reservoirs. Type III reservoirs are best modeled with dual porosity/dual permeability models.

Knowing how the fractures and matrix interact is critical. Fractured reservoirs are inherently a two-porosity system. Communication or crossflow between the fractures and matrix can be good, or it can be inhibited by mineralization within or deformation along the fracture planes. To estimate reserves, one must understand how fluids will flow between the matrix and fractures.

Screening For Fractured Reservoirs. There are screening tools that can be used to identify fractured reservoirs. Many of these tools are appropriate very early in a reservoir's life when few wells have been drilled. Why is that important? Where fractures exert a major influence, it is not uncommon that 50% of a reservoir's recovery results from only 10% of the wells. If fracture contributions can be defined before drilling, reservoirs can be developed with fewer, optimally-located and optimally-oriented wells. Savings in field development costs can be tremendous.

Were a significant number of fractures observed in cores or well-processed imaging logs? Do outcrops of the relevant formation contain abundant natural fractures? Are well test flow capacities (khs) a factor of two or more greater than those observed from core data? Does structural modeling predict significant brittle strain? Brittle rocks are naturally more susceptible to fracturing. Analogs to similar reservoirs provide valuable clues about the influence of fractures. Once a reservoir has been produced for a period of time with several wells, initial potential and cumulative production data are very indicative of the degree to which fracturing contributes/controls production. Classical indications are disparate initial potential and cumulative production.

Completions/Stimulation/Operations. Underbalanced drilling helps minimize fracture plugging by drilling mud. Open hole completions are preferred, since cased hole completion can isolate contributing fractures from the well (hard to know exactly which fractures are contributing). Slotted liners can be used in less stable wellbores. When producing, rate control may be necessary to minimize stress closure. Placing fracture proppant material into the natural fracture system can reduce fracture closure as pressures are drawn down.

ADDITIONAL RESOURCES

Nelson, R.A., 2001, Geological Analysis of Naturally Fractured Reservoirs: Gulf Publishing Co., 2nd Edition, Houston, TX. 332 p. Much information from the book can be downloaded at no cost from: www.bhusa.com/companions/0884153177/?mscssid=X3QM44FG5GCU8JVUGPBQ68S67PLE5TK2

The book itself may be ordered through Butterworth-Heinemann (http://www.bh.com).

CONNECTIONS:

Ronald Nelson
Broken N Consulting, Inc.
P.O. Box Q
445 Wrangler Road
Simonton, Texas 77476-1017
Phone & Fax: 281-346-2905
E-mail: nelson_consulting@hotmail.com