Completion and Stimulation
Transforming Shale Gas Reservoirs into Economically Successful Ventures
Applications

Completion Design:
- Lateral azimuth
- Fracture conductivity
- Fracture geometry
- Staging requirements

Features

- Determine the state of stress in the reservoir
- Design a perforation strategy to mitigate stress around wellbore
- Predict how the rock will respond when fractured
- Decide whether and where to fracture

Benefits

- Predict well success through knowledge of fractures
- Predict near-wellbore effects, fracture complexities, impact of cementing and perforation
- A variety of solutions tailored to the specific well:
  - Cementing
  - Perforation placement
  - Spacing clusters
- A completion process tailored to a well’s specific conditions

Completion and Stimulation Tools

- Stress anisotropy measurement via sonic logs
- Image logs to predict how the rock will respond when fractured
- Isolation and perforation methods to maximize the effectiveness of the stimulation while minimizing near-wellbore stimulation difficulties
- MiniFRAC to diagnose fracture complexity
- FiberFRAC* production comparison

AN EXCEPTIONAL OPPORTUNITY

Shale gas development is expanding at a rapid pace in the United States as rising energy prices and the drive to increase domestic energy production make this abundant resource an increasingly attractive play.

The successful and profitable completion of shale gas wells requires the collection and analysis of a large amount of data, an up-front investment that can make a very significant difference in the financial outcome of a project.

Gas shales are very complex resources, and Schlumberger offers an exceptional range of experience and unique tools and technologies to locate this gas and bring it to market.

The Schlumberger shale gas strategy is characterized by three key phases: Identifying the resource, evaluating its quantity and producibility, and optimizing the approach to recovering it efficiently and cost-effectively.
Gas shales are characterized by extremely low permeability, almost always requiring hydraulic fracture stimulation. Despite very low recovery rates, in the range of 8-12%, these wells contain an enormous amount of gas and have extremely long producing lives. The first shale wells, drilled in the 1820s, continued to produce for over a hundred years. Therefore, developing these unconventional resources efficiently requires an extensive program of technical evaluation.

We begin by identifying and quantifying the resource, determining the appropriate benchmarks for recovery factors. The next step is simulation, evaluating various stimulation strategies to optimize well performance (Figure 1). From individual well optimization we then move to optimization of well placement and resource development. This incorporates all available information: seismic, geochemistry, petrophysics and stimulation, into an Earth Model whereby we can determine the key producibility drivers (Figure 2).

**All Shales Are Not Created Equal**

The Barnett shale is the industry’s gold standard for shale gas production, but while all shales share certain basic characteristics, they vary widely in a number of factors that strongly affect the best approach to completion and stimulation.

Creating an optimal completion and stimulation strategy requires specific knowledge of the individual reservoir characteristics, including matrix permeability, formation pore pressure, relative degree of mechanical property and stress anisotropy, mineral content, fracture geometry, fracture conductivity and a host of other factors. Can we stimulate the shale? Can we keep the fracture in the zone? Do we have structural issues with implications on our fracture geometries and pressures? Are we normally faulted? What works in the Barnett may or may not be appropriate in other locations, and determining what will work requires extensive data gathering and analysis.

**Effective Fracturing Strategy**

Developing an effective fracturing strategy requires careful consideration of a number of key elements, including:

- Fracture geometry/lateral azimuth
- Hydraulic fracture spacing, staging and complexity
- Effective fracture conductivity

**Fracture Geometry/Lateral Azimuth**

The great majority of these projects are developed using horizontal wells. When planning these wells one must know the azimuth of the hydraulic fractures. Is it best to drill in the direction of maximum stress so that a fracture co-linear with the wellbore is created? Or is it better to drill in the direction of minimum stress, with perpendicular fractures spaced as closely together as possible? Ideally, in these low permeability rocks, the more fractures the better.

We utilize the ShaleGAS Simulator to model various “what if” scenarios, taking into account the role of desorption in long-term recovery. We can put in an extremely complex fracture network and see how the reservoir is going to respond, and we can try different schemes for well placement. Such evaluation allows us to accelerate the successful development of these plays and quickly develop optimum completions.

The mineralogy of the shale has a big impact on its mechanical properties, which in turn drive fracture geometry. For example, where
clay volumes are higher and quartz volumes lower, the rock is going to be much more difficult to frac. We use the innovative ECS* geochemical log tool to achieve a detailed and accurate analysis of composition of the shale’s mineralogy.

The presence of natural and drilling-induced fractures can also have a major impact on fracture geometry and well productivity. Schlumberger imaging tools, the wireline-conveyed FMI tool and the LWD-conveyed GVR* resistivity sub, provide a clear picture of near-wellbore fractures and aid in designing strategies (Figures 4 and 5).

Hydraulic Fracture Staging, Spacing and Complexity

The number and placement of perforations is another key variable. Ideally, the more fractures the better, because it takes so long to lower the reservoir pressure in these nanodarcy-permeability rocks. But in many situations, fractures placed too close together can interfere with each other and drive up pressures. The industry term for this interference is the “stress shadow effect” (Figure 6), and predicting and mitigating such problems can make a major difference in the success of stimulation.

Orientation matters, as well. Shooting the well with 60° phasing, forcing perforations to be active on the sides of the wellbore where compressive stress is normally greatest, can create near-wellbore problems. In such cases, orienting the perforations at 0° and 180° can dramatically improve the ability to place proppant. Another alternative is to employ acid soluble cement that can be dissolved early in the treatment to improve the perforation-to-fracture communication.

The stress picture is also critical. Fractures form and propagate differently depending on the relative degree of stress isotropy/anisotropy, another key factor in designing an effective stimulation program. In an area with low stress anisotropy, maximum and minimum stress are very close together; so when a fracture propagates and encounters a natural fracture, it has a tendency to open those up, creating a broad “fracture fairway.” Conversely, where you have high stress anisotropy, there is a definite, preferred fracture plane that may or may not see the natural fracture. A game-changing new technology from Schlumberger, the Sonic Scanner* platform, allows us to determine the state of stress in three dimensions around the well bore. This then allows us to optimize perforation and fracture staging requirement to achieve ideal fracture geometry and minimize potential near-wellbore fracturing issues.

Figure 5: Fracture geometry information attained from drilling-induced fractures identified with GVR image logs in a horizontal Barnett shale

Figure 6: Schlumberger StimMAP* fracture diagnostics figures depicting perf clusters in lateral and corresponding microseismic events demonstrating “stress shadow effect”
Most shale gas reservoirs are developed with horizontal wells that require multiple stimulation treatments along the lateral to maximize well performance. Because of the very low permeability of these reservoirs the reservoir pressure does not drop far into the reservoir for a very long time (Figure 7).

By creating closely spaced fractures we will be able to increase the recovery factor close to the borehole. We may also be able to accelerate the desorption of gas from the organics in the shale.

**EFFECTIVE FRAC CONDUCTIVITY**

Waterfrac treatments are popular, and frequently successful, in shale gas reservoirs. But the key to success is creating a large, effective fracture area. This requires enough conductivity to allow the created fracture area to be productive. Conductivity is especially vital in transverse fracs, where the pathways to the wellbore can become quite complex and large pressure drops can lead to a restriction near the wellbore.

Formation mineralogy drives the selection of fracturing fluid that is utilized. Fluid incompatibility can result in unproductive fractures due to a lack of fracture conductivity. The capillary suction-time test procedure gives us information on formation sensitivities to salinity, pH and other factors that can impact fluid selection. The use of the PressureXpress* service to provide an accurate determination of pore pressure is also important since this can drive the fracture fluid selection. Slick water has been used successfully in the majority of Barnett shale stimulations. Nitorgen foam fracs have been successful in the underpressured shales in the Appalachian Basin. Crosslinked gels have been used successfully in other basins.

Schlumberger FiberFRAC technology, utilizing mechanical transport, has achieved superior results in the Barnett, outperforming slick-water offsets with a 10-20% increase in recovery performance (Figure 8).

FiberFRAC technology does an excellent job of keeping proppant suspended until pressure can be reduced, with a positive impact on long-term conductivity.

Unconventional Reservoirs require Unconventional Solutions

Combining all of these variable to achieve an optimal stimulation program may result in some very complex strategies, and Schlumberger is uniquely qualified to gather and analyze the data required to provide the client with the information they need to make sound economic decisions.

With unsurpassed experience and a record of success in shale gas recovery, Schlumberger can bring together the full spectrum of capabilities – petrophysics, geophysics, completion and well testing tools and technologies – to design an optimal completion and stimulation approach suited precisely to each specific reservoir.
Integrated Model Approach achieves unparalleled results in shale gas recovery.