Horizontal Drilling in Shallow, Geologically Complex Reservoirs

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Contract Number:
DE-AC21-91MC27260

Conference Title:
Natural Gas Research and Development Contractors Review Meeting

Conference Location:
Morgantown, West Virginia

Conference Dates:
May 5-6, 1992

Conference Sponsor:
U.S. Department of Energy Morgantown Energy Technology Center

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## CONTRACT INFORMATION

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| **Contractor**      | Hillin-Simon Oil Company  
P. O. Box 1552  
Midland, Texas 79702  
(915) 682-2202 |
| **Contract Project Manager** | Stanley D. Venable |
| **Principal Investigators** | Stanley D. Venable |
| **METC Project Manager** | Albert B. Yost, II |
| **Period of Performance** | September 30, 1991 to June 30, 1993 |
| **Schedule and Milestones** | FY92 Program Schedule |

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OBJECTIVES

Hillin-Simon Oil Company, in connection with the U. S. Department of Energy proposes to drill a horizontal well in the Niobrara formation, Yuma County, Colorado. The objective of this project is to test the concept that multiple hydraulic fracturing from a directionally-drilled horizontal well, using the medium radius build rate method, can increase gas production sufficiently to justify economic viability over conventional stimulated vertical wells. The test well is located in a favorable area of established production to avoid exploration risks.

The Niobrara is a low-permeability carbonate that must be fracture-stimulated to yield commercial quantities of gas. Reserve analysis indicates that due to this low permeability, a conventionally completed vertical well effectively drains approximately eighty acres. Because of the relatively small area drained by a vertical well, multiple or several staged fracture treatments in a horizontal section of significant length are expected to allow the drainage of a proportionately larger area. This, of course, would increase the recoverable reserves from a single wellbore (in comparison to a vertical well). Initial completions should experience substantially higher deliverabilities as more reservoir face is exposed to production. The resultant increase in $kh$ in the horizontal section of the proposed well is expected to significantly improve the performance profile (ie, producing rate) and enhance cash flow in this economically sensitive play.

BACKGROUND INFORMATION

Gas production from the Niobrara in eastern Colorado and northwestern Kansas began on a commercial scale in 1972. There are more than thirty-five fields located primarily in Yuma County, Colorado and Cheyenne County, Kansas. Biogenic gas is produced from the Smoky Hill Chalk, a high porosity (35-40%), low permeability member of the Cretaceous Niobrara Formation ranging in depth from 900 to 2800 feet. Producing areas are normally low-relief anticlinal closures, as the area is subject to extensive faulting.

The drilling and completion of Niobrara gas wells has basically become standardized since the late 1970’s. Surface hole is spudded and 8 5/8” (or more commonly 7”) casing is set according to Colorado Oil and Gas Conservation Commission rules and regulations as a minimum, but principally deep enough to protect fresh ground water supplies and shutoff shallow, unconsolidated formations. This depth averages 300 to 350 feet. Sufficient cement is pumped to circulate to surface.

After waiting on cement a minimum of 12 hours, a 6 1/4” hole is drilled out from under the surface casing to a total depth of approximately 150 feet below the encountered top of the Niobrara. The drilling mud program is fresh water with bentonite gel added to increase viscosity to effectively remove drilled cuttings. Important to drilling the productive interval within the Niobrara is to minimize fluid loss to the formation, ideally reducing this property to a value of 5 cm³/minute. The Niobrara is a low pressure reservoir, susceptible to permeability damage due to fluid invasion and associated fines deposition.

At total depth, the hole is circulated clean and openhole logs are run. The typical suite of logs includes a compensated neutron/formation density to determine porosity and a dual induction for resistivity measurement to determine water saturation. Porosity in the Niobrara is a function of depth (overburden pressure), and within a given area expected to be uniform from well to well. Development programs typically eliminate the porosity log and rely only on the resistivity log for evaluation and decisions. In the case of infill drilling or other field development wells, a resistivity "cutoff" is
established. As stated elsewhere, economically recoverable gas reserves are principally a function of water saturation and corresponding structure. Both can be determined from the dual induction log and then a decision to complete or plug and abandon made.

If the decision is made to complete the well, 4 1/2 inch casing is usually run. Cement design typically calls for conventional circulation through standard float equipment with the casing well centralized in the hole. Cement volume is normally 100-150 sacks of API Class "G" with additives, sufficient to isolate the Niobrara.

Completion is normally in the porosity of the Smoky Hills Chalk member, a 30-40 feet thick section in the top of the Niobrara. The section is perforated, then fracture stimulated immediately. (The Niobrara is approximately 80 percent soluble in acid and there is very little matrix cementation, therefore pre-frac acidizing on initial completion is not required or recommended.) Fracture stimulation treatments were initially gelled, crosslinked water fracs. As the technology became available, fracturing techniques utilizing carbon dioxide or nitrogen gas were used. In the Bonny Field, a typical "frac job" is 30,000 gals of 30 lb/gal CO2-laden crosslinked freshwater gelled, fluid and 90,000 pounds of 10/20 and 20/48 mesh sand as fracture proppant. This was ideally suited to the low pressure Niobrara, minimizing fluid leak-off and facilitate rapid load recovery. Well testing should consist of a qualified flow period to establish deliverability, and a subsequent shut-in bottomhole pressure buildup survey of sufficient duration to accurately determine the static pressure and pertinent reservoir properties. Comparable tests should be conducted on a semi-annual basis to enhance material balance reserve calculations.

PROJECT DESCRIPTION

Location Selection/Geologic Considerations

The proposal is to drill a horizontal borehole, with a surface location described as 2310 feet from the north line and 2310 feet from the west line of Section 17, Township 5 South, Range 43 West, Yuma County, Colorado. The proposed well is to be drilled using the medium-radius build rate method to a true vertical depth of approximately 1400 feet to encounter the Smoky Hills Chalk member of the Niobrara formation, a low-permeability carbonate designated as a tight reservoir by the Federal Energy Regulatory Commission and the State of Colorado. A lateral extension of not less than 1,000 feet within the productive interval of the Niobrara is planned.

The proposed well is immediately offset to the north by two gas wells of significant production and reserves in of the Niobrara formation, Bonny Field, Yuma County, Colorado. These wells and leases are presently owned and operated by Hillin-Simon. The Bonny Field has over one hundred producing wells completed in the Niobrara. The wells in Section 17 identified on Figure 1 as the Weyerman 6-17 and the Weyerman 7-17 are two of the best wells in the field, with estimated ultimate recoveries (EUR) of 604,000 MCF and 490,000 MCF, respectively. An average recovery for a Niobrara well in the Bonny Field is just under 400,000 MCF. Recoverable gas reserves in the Niobrara, and particularly the Bonny Field, are a function of water saturation which in turn is a direct function of structural position. Gas accumulations occur in the Niobrara on low-relief anticlinal structures and/or closures.

Geologically this acreage looks prospective for excellent production and recoverable reserves, but has not yet been developed. The south half of Section 17 is within a large Federal Lease, which in part protects the surface in and around the Bonny Reservoir. Stipulations contained in this lease prohibits the drilling of a well with a surface location within the boundaries of the lease itself. Lease boundaries within section 17 can be seen on Figure 1, represented there by the fence line. Considering these limitations, it is readily apparent that production of gas reserves in the south half of section 17
Figure 1

EXISTING LEASE ROAD(s)

HILLIN-SIMON OIL COMPANY
WEYERMAN 10-17
BONNY FIELD
YUMA COUNTY, COLORADO
SECTION 17, T-5S, R-43W
must be through directional drilling. To minimize the number of directional or deviated holes necessary to effectively drain this acreage, horizontal completions are recommended.

The proposed development well site was selected after considering several factors. Detailed geology indicates that drilling the south half of section 17 will be updip to the existing production, and approach an east-west fault along the south line of the section (Figure 2). This location will provide, not just one but both of the consideration necessary for a successful Niobrara completion—structure and closure. Having both structure and closure offsetting excellent Niobrara production will minimize the associated risk of a successful completion. Additionally, approaching the fault in a perpendicular orientation would enable the well bore to encounter fracture systems, considered to run parallel to and in the vicinity of existing faults planes. Exploration of these possible fracture systems is a secondary objective, as production from and reserves in the Niobrara are primarily from the matrix porosity.

Preliminary Work Plan

Drilling Prognosis. The project well is to be drilled using the medium-radius build rate method to achieve a true vertical depth of approximately 1400' in the Smoky Hills Chalk member of the Niobrara formation. Conventional rotary tools will drill an 11 inch hole to 350 feet, and 8 5/8 inch casing will be set and cemented for the surface string. Conventional rotary tools will then drill a 7 7/8" vertical hole to approximately 1400 feet true vertical depth (TVD).

An attempt to drill a conventional whole core in the Niobrara will occur in the vertical hole. The subsequent whole core analysis is expected to yield porosity and permeability data, however the principal objective of the coring operation is to identify the direction of any existing, naturally-occurring fractures. Results of this determination could verify or possibly re-orient the direction of the horizontal borehole to be drilled. A drillpipe conveyed mini-frac will be performed on the Niobrara to attempt to determine the orientation of hydraulic fractures. The results will assist in the stimulation design in the completion phase of this project.

Upon completion of these operations, the vertical wellbore will be plugged back to approximately 900'. Drilling would kickoff at this point, building angle at 14°/100' to 83°. A 134' tangent section is planned at 45° to allow for an adjustment, should build rates be different than planned and/or to adjust for any change in target depth. A steerable motor assembly designed to build angle at 3°/100' would be used to build to 90° prior to drilling the horizontal section. No problems associated with drilling the build, tangent, or horizontal sections are expected. It is estimated that it will take five (5) days to drill from kickoff point to total depth. Principal consideration will be given to wellbore hydraulics with respect to effective hole-cleaning. This will be the determining factor in the rate of penetration in the horizontal section. Considering the shallow depth of the well, the relatively short anticipated time to drill the horizontal section, and geological control available, the formation analysis will be provided by the continuous surveying of the MWD system.

At total depth, the hole will be circulated clean and 4-1/2" casing set. The casing will be well-centralized throughout the horizontal section and approximately 500' up into the build section. A standard cement slurry of sufficient calculated volume to properly isolate the horizontal section will be conventionally circulated. Essential to the success of the cementing design is the calculation of the critical pumping rate at which the slurry entered the turbulent flow regime. Turbulent flow is essential to the effort to minimize the problems associated with conventional cementing of a horizontal well, principally channeling and inconsistent quality.

Completion Prognosis. Stimulation in the form of hydraulic fracturing will be completed in several stages within the horizontal section. Although a cross-linked polymer, water-based fluid is anticipated, Hillin-Simon is presently conducting reservoir modeling studies and field operations to
Project Well Surface Location

1" = 2000'
CI = 25'

HILLIN-SIMON OIL COMPANY
Midland, Texas

STRUCTURE: T/NIODRARA
"BEECHER ISLAND"
BONNY FIELD, YUMA CO., CO
determine if a more effective design is possible. Results from these and the findings of the research done in the vertical wellbore as discussed above will have an impact on completion design.

The completion prognosis includes a four-stage frac job. Each stage is planned to consist of 10,000 gallons of a 30-lb/gal crosslinked 2% potassium chloride water-based gel system and 32,000 pounds of 20/40 mesh Ottawa sand. An average of 2,200 scf of CO₂ per barrel will be pumped, resulting in a total fluid volume of 14,000 gallons per stage. Maximum sand concentration will be 5.0 ppg. Additives to minimize clay swelling, eliminate bacterial degradation of the gelled system, and reduce friction while pumping the slurries will be included. The total volume would be 56,000 gallons of CO₂-laden fluid and 125,000 lbs of sand.

The proposed frac job is a water-based system, and although the CO₂ content is high, this is not a foamed treatment. Several hundred Niobrara wells have been completed in this trend, and fracture stimulations have included nitrogen, carbon dioxide, and methanol foam, foamed acids, and straight water-based gel systems. Extensive study has shown the CO₂-water systems to be optimum. The gas is necessary to effect flowback of the frac fluid from and assist in the cleanup of the low-pressured Niobrara. Total CO₂ to be used in the stimulation is approximately 150 tons.

Storage treatments will allow conventional pumping rates to be utilized, since each fracture will be treated independently. It will allow a relatively inexpensive step-test and minifrac to be performed. The results may be used to redesign the frac treatment to reflect actual downhole conditions. The results of the first stage frac treatment combined with the step test and minifrac will allow further refinement of the next subsequent frac treatment to maximize the frac results.

**Production Testing.** Production and associated testing of the well will begin upon completion. Hillin-Simon has constructed and operates a low-pressure gathering system in the immediate area. The completed well’s producing characteristics will be monitored and recorded daily. Each of the 4 proposed stages of completion will be production tested individually, prior to completion of the next. Bottomhole pressure surveys are anticipated upon completion of the four stages to obtain data to correlate to earlier information obtained by core analysis, minifrac data, etc.

**FUTURE WORK**

Planning for the project is ongoing, with an anticipated spud date of the well in September or October of 1992. Presently, the spud date is primarily a function of the time required for an environmental clearance under the NEPA.

The project completion time is anticipated to be less than 90 days, including completion and production testing.