Microhole coiled tubing drilling concept applied to mature Niobrara gas play in Kansas, Colorado

By Kent Perry, Gas Technology Institute

NATURAL GAS WAS first discovered in the Niobrara formation in 1912 when a strong flow of gas was encountered while drilling the Goodland No. 1 well near Goodland, Kan. The well was plugged and abandoned. Since that first well, the Niobrara gas play has undergone several episodes of activity driven by gas prices and improvements in technology. Recently, the development of coiled tubing drilling in combination with a microhole approach to borehole size has helped to re-energize activity in this mature gas play.

GEOLOGY, RESERVOIR

The Niobrara formation chalks were deposited during the last major transgression of the western interior Cretaceous sea, which extended from the Gulf of Mexico to the Arctic Ocean. The current play extends through Northwest Kansas and Eastern Colorado. Gas-bearing chalk of the upper Cretaceous Niobrara formation is encountered at depths from 1,000 to 3,000 ft. Gas accumulations in the Niobrara formation generally are related to low relief structural features found along the eastern margins of the Denver geologic basin.

Niobrara gas fields are characterized by high porosity, low permeability and low reservoir pressure. These features are typical of a chalk subjected to modest burial depths. At greater depth, porosity and permeability decrease, causing a reduced total pore volume and higher water saturation at a given structural position. Reported values for porosity in the Niobrara formation range from 30% to 50%. Despite the high porosity of the chalk, permeability is inherently low because of the fine grain size. Values for permeability range from 0.01 to 0.3 millidarcies in the fairway, with microdarcy permeability found on the fringes. The Niobrara is an underpressured gas reservoir with geostatic pressure gradient ranges from 0.06 to 0.24 psi/ft.

Thin pay zones, low reservoir pressures and low in-situ formation permeability combine to create a challenging environment for successful field development. Certainly, an efficient, low-cost approach to drilling and completion is needed.

A US Department of Energy research program is using a trailer-mounted coiled tubing drilling rig with a small footprint.

DOE PROGRAM

The Department of Energy's National Energy Technology Laboratory is implementing a research program to develop marginal oil and gas resources utilizing microhole wellbores. The approach is to develop a portfolio of tools and techniques that will allow the drilling of 3 5/8-in. holes and smaller to enable, through better economics, the development of marginal oil and gas resources. The field testing and demonstration of a fit-for-purpose coiled tubing drilling rig is a project within the program. The objective is to measure and document the rig performance under actual drilling conditions.

DESCRIPTION OF THE RIG

The coiled tubing drilling rig, designed and built by **Tom Gipson** with **Advanced Drilling Technologies Inc** (ADT), is a trailer-mounted rig with the coil and derrick combined to a single unit. The rig has been operating for about a year, drilling shallow gas wells operated by **Rosewood Resources Inc** in Western Kansas and Eastern Colorado. Rig operations have improved to the point where it drills 3,100-ft wells in a single day. Well cost savings of approximately 30% over conventional rotary well drilling have been documented. Improved well performance due to less formation damage as a result of minimizing formation exposure to drilling fluid through fast drilling and drilling operations is another important aspect.

EFFICIENT RIG MOBILIZATION

The rig moves with 4 trailer loads, mitigating mobilization and transportation cost while meeting US Department of Transportation limitations for highway transport. These features allow for smaller access roads and well locations. The rig contains all equipment needed for drilling operations, including a zero discharge mud system, has pipe-handling capacity for casing up to 7 5/8 in. and can support a rotary and top drive.

SMALL FOOTPRINT

The small size of the rig provides several environmental advantages over a conventional rig. As a result of its efficient design and size, the following environmental advantages are realized:

• A small drilling pad (1/10-acre), or no pad under some conditions, can be utilized. Smaller access roads are required.

• No mud pit is needed; mud tanks contain the required drilling fluids and are moved with the rig from one location to the next. Only a 3 ft-by-6 ft-by-6 ft pit is required for drill cuttings. If needed, cuttings are easily hauled off location, allowing no pit drilling as needed.

• Smaller equipment yields less air emissions, and low-noise engines minimize disturbances to the surrounding environment.

• The microhole approach (4 ¾-in. holes) requires less drilling mud and fluids to be treated and yields fewer drill cuttings.

• The utilization of coiled tubing mitigates the risk of spills due to no drill pipe connections.

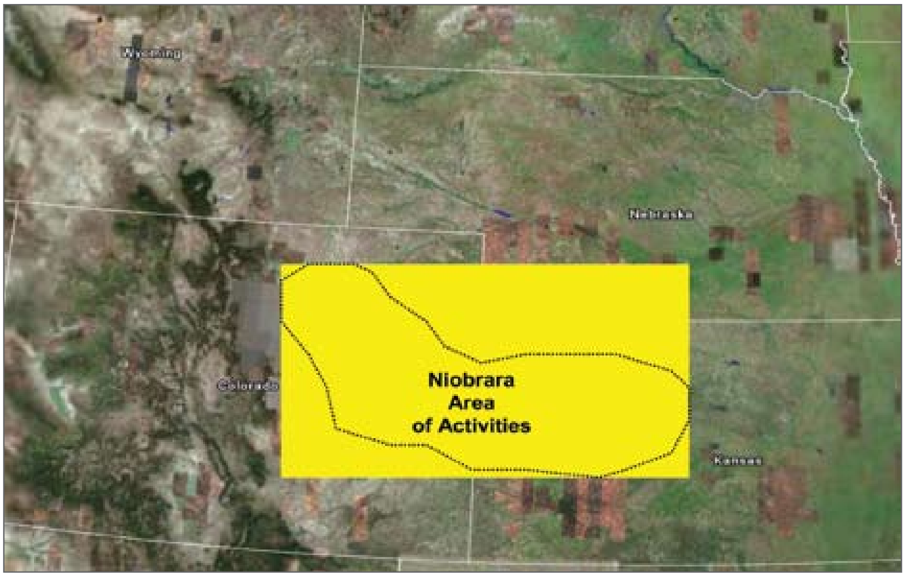
RAPID DRILLING

Very high rates of penetration have been achieved by experimenting with bit-downhole motor combinations and by fully utilizing the advantages of coiled tubing drilling. Drilling rates as high as 500 ft/hr have been realized, with the average rate of penetration per well in the 400 ft/hr range. This rate of drilling and other rig efficiencies allowed the drilling of a 2,850-ft well in 19 hours, including all rig-moving time, logging, casing setting and cementing, as illustrated in the figure on Page 90.

HOLE QUALITY, CEMENT

All wells drilled with the ADT rig have resulted in a gauge hole with very little hole deviation (1° to 2° — well within state requirements) despite the high penetration rates. Good cement job quality and well-bonded cement also derive from the gauge hole quality. As mentioned previously, the Niobrara is an underpressured reservoir and, as such, is susceptible to formation damage due to fluid loss from drilling operations. Both the rapid penetration rate through the pay zone and the lack of any pressure surges caused by conventional drilling pipe connections help to mitigate fluid loss and therefore formation damage. This is an important factor given the marginal nature of the resource.

No auxiliary equipment is required to run casing, log wells or for handling drill collars and bottomhole drilling assemblies. With its derrick, traveling block and rotary table components, all required drilling processes can be performed without additional equipment. While not currently equipped with a top drive, the rig can accommodate one if needed. Drilling with coiled tubing eliminates drill pipe connection time, and fewer crew members are required to operate the rig.



This map shows the Niobrara gas play area.

ZERO DISCHARGE

The rig has the capability to drill a well with zero discharge of any fluid or other materials if required. The procedure is as follows:

• Move the rig in and rig up on a sealed/booted tarp to contain any overflow or accidental spill.

• No earthen pits are prepared; all cuttings and drilling fluid are confined to tanks, with which the rig is equipped.

• A hole is augured for conductor pipe, and a boot is placed around the conductor pipe.

Using this process, the ground is protected from any inadvertent spills, and all fluids and cuttings are removed from the location. While an added expense, this procedure may be required for drilling in sensitive environmental areas. The small rig size and efficiency of drilling coupled with the zero discharge capability enables drilling in sensitive areas.

IMPROVED SAFETY

Safety is always of utmost importance, and the conventional drilling rig environment is one where extra caution and safety training is necessary due to the handling of drill pipe and other equipment. The ADT coiled tubing rig significantly reduces drill pipe handling and has less equipment to mobilize from well to well. All of this creates a much safer operating environment, which is important during any time of drilling but especially so during today's high rig count when experienced roughnecks are difficult to find.

OPERATOR CONCERNS

Barriers exist to full utilization of this type of approach to the drilling and completion of marginal resources. Operators have identified the following as concerns that must be addressed for microhole to reach its full potential:

• Production engineers have long-term concerns about the ability to rework wells.

• Handling of significant fluids is an issue in small boreholes.

• There is limited space for downhole mechanical equipment.

• A general lack of experience and familiarity with microhole and coiled tubing drilling of this type was identified as a barrier to usage.

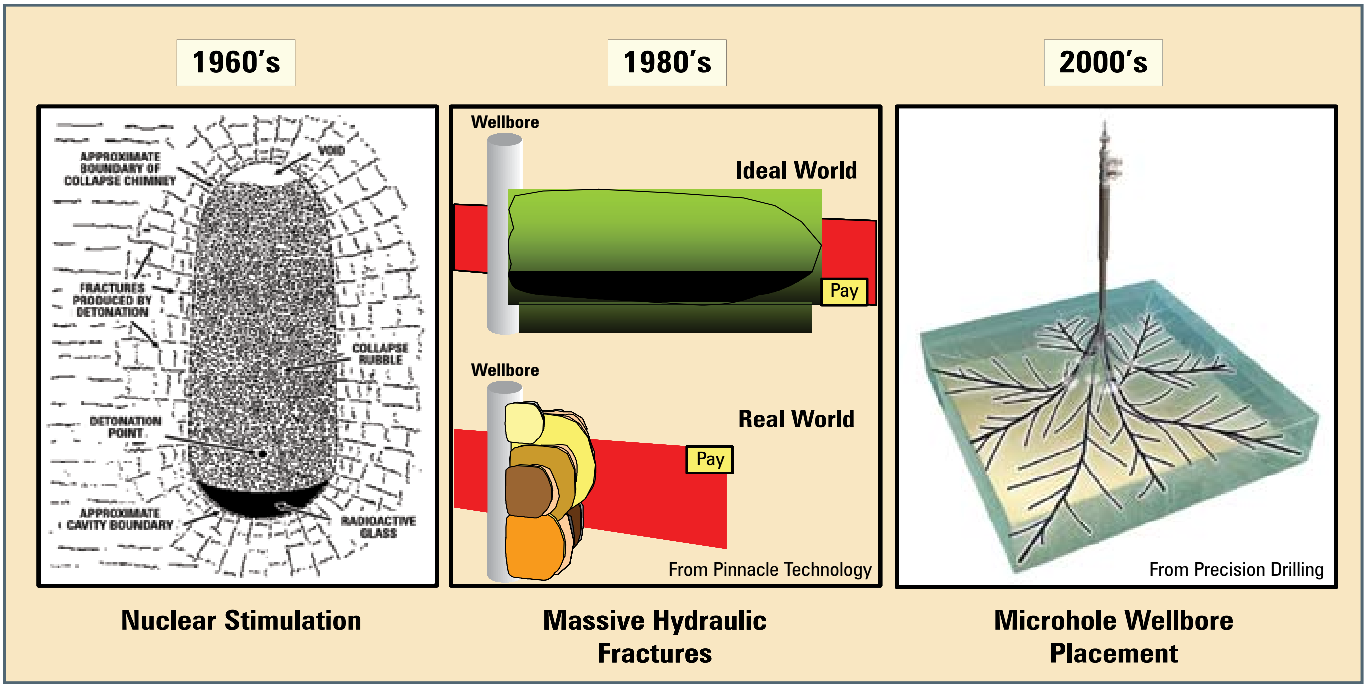
• There is a depth limitation given current coil metallurgy and coiled tubing procedures.

• Coiled tubing is limited in its ability to overcome problems in difficult drilling environments. One example is where fluid loss and severe pipe sticking is encountered. Coiled tubing has limited tensile strength for freeing stuck pipe.

TECHNOLOGY TRENDS

Operators pursuing marginal resources are doing so in a new era. Driven by a growing economy, US energy demand is expected to reach record levels in the near future. The higher-quality resources have been exploited, increasing the challenge for future developments.

The rate of new technology improvement is beginning to be offset by the increas-



Above: Over the past 4 decades, marginal oil and gas technology development has evolved significantly. Above is an illustration of the evolution of these technologies since the 1960s. Below: By experimenting with bit-downhole motor combinations and fully utilizing coiled tubing drilling, an average rate of penetration of 400 ft/hr was realized, allowing a 2,850-ft well to be drilled in 19 hours. This graph shows the allocation of drilling time.

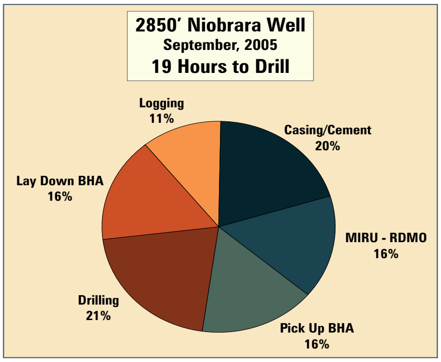
ing challenges created by lower-quality reservoir rock and increasing costs from environmental issues.

A concerted technology effort to both better understand marginal oil and gas resources and develop solid engineering approaches is necessary for significant production increases from these widely dispersed resources.

HISTORICAL DEVELOPMENT

Marginal oil and gas technology development has evolved significantly over the last 40 years. The trend has moved from one of high horsepower approaches to one of precision in all aspects of development. During the 1960s, nuclear detonations were being tested with the goal of fracturing or stimulating a large volume of low permeability rock, allowing for the recovery of a significant volume of gas from a single wellbore. This technical approach failed for many reasons, including the fusing of rock as opposed to fracturing of rock.

During the 1970s and '80s, the approach to marginal oil and gas formations evolved to massive hydraulic fracture treatments. Here the goal was to create very long hydraulic fractures reaching hundreds of feet into the pay zone, allowing for the production of large volumes. As research on the topic of hydraulic



fracturing progressed, it was determined that extended-length fractures were difficult, if not impossible, to create. The lack of formations to serve as fracture barriers to contain the upward growth and the complexity of multiple fractures limited the desired fracture length.

Today the evolution of lateral and horizontal drilling technology is beginning to allow the development of unconventional resources through the placement of smaller wellbores into exactly the area and location required for optimum production. Hydraulic fracturing remains an important and necessary well stimulation procedure but is being done in a highly optimized manner, integrated with unique well completion procedures.

The trend overall has been from large to small. Hydraulic fracture jobs pumped today are significantly smaller in size but more effective than those in the 1970s. Microhole technology is being developed by the Department of Energy that will enable efficient placement of wellbores while minimizing the surface and other environmental impact. The evolution of "fishbone" well drilling patterns and the ability to identify, drill and produce very thin pay zones all add to the "lighter and smaller" and more efficient approach.

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