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Niobrara Shale:
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An Anadarko wellhead in northeastern Colorado highlights cooperation between hydrocarbon production and agriculture in one of the nation's most prolific farming areas. *(Photo courtesy of Anadarko Petroleum Corp.)*

A Major Tight Resource Play in the Rockies

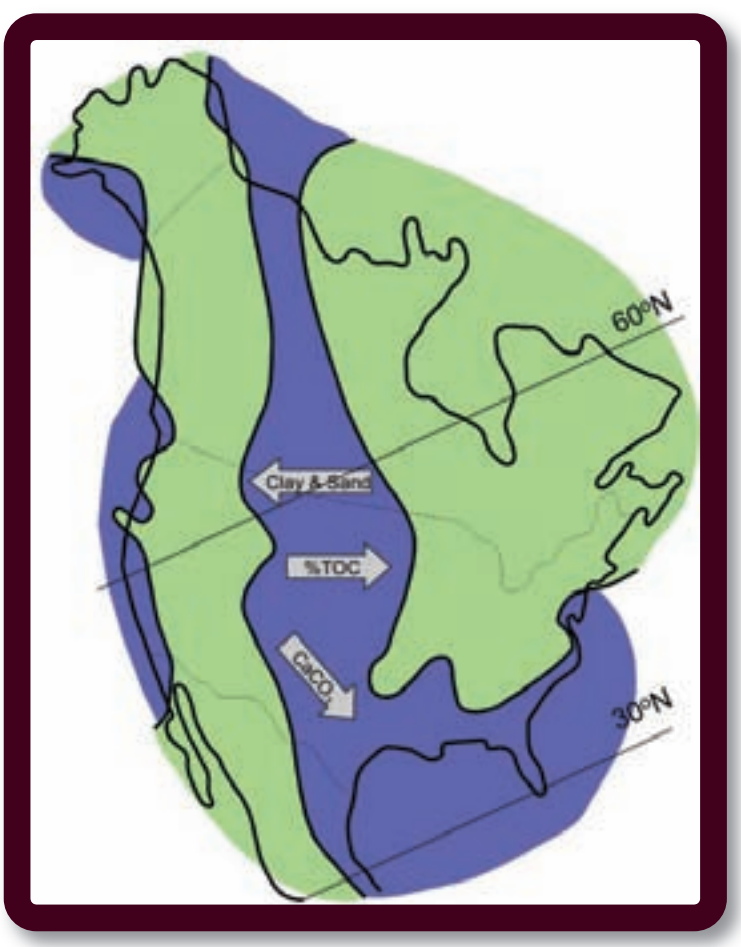
Understanding the distribution and occurrence of hydrocarbon source and reservoir rocks will aid future exploration.

By Stephen A. Sonnenberg
Dept. of Geology & Geological Engineering
Colorado School of Mines

The Niobrara is a significant, self-sourced resource play throughout the Rocky Mountain region. New technologies for horizontal drilling and multistage hydraulic fracture stimulation are unlocking reserves that previously were unobtainable.

Known production comes from both fracture and matrix porosity systems (dual porosity). High matrix porosity is present in the shallow biogenic gas accumulations of eastern Colorado and western Kansas, which is important for natural gas production at burial depths of less than 3,500 ft. The deeper Niobrara thermogenic accumulations generally occur at burial depths greater than 7,000 ft. Burial diagenesis (chemical and mechanical compaction and cementation) reduces porosities to values less than 10% in the deeper parts of the various basins where the Niobrara is prospective. Mature Niobrara source rocks are in these areas of low porosity. Natural fractures are important contributors to production in the deeper areas.

The Niobrara Petroleum System contains the aspects of a large resource play (e.g., widespread mature source and reservoir rocks, self-



The Niobrara was deposited in the WIC Basin and is a widespread unit in the Rocky Mountain region. The source area for clastics is dominantly to the west and TOC content increases to the east. Carbonate content generally increases on the eastern side of the WIC seaway and to the southeast. *(Image modified from Longman et al, 1990)*

sourced). The Niobrara was deposited in the Western Interior Cretaceous (WIC) Basin and is a widespread unit in the Rocky Mountain region. The WIC Basin was broken into numerous smaller basins during the Laramide orogeny.

The Niobrara contains reservoir rocks, rich source beds, and abundant seals. The various productive lithologies all have low porosity and permeability. Total organic carbon (TOC) values in shales locally range from 2% to 8% in the eastern WIC area and are reduced to 1% to 3% because of siliciclastic dilution in the western WIC area. Laramide structural events exert the primary control on fracturing within the Niobrara as well as thermal maturity. Neogene extension fracturing also is thought to be an important component for locating production "sweet spots." Understanding the thermal maturity of the source rocks will help to predict the distribution of hydrocarbon accumulations. Hydrocarbon generation could enhance the tectonic fractures and also could create new ones as a result of overpressuring associated with this process.

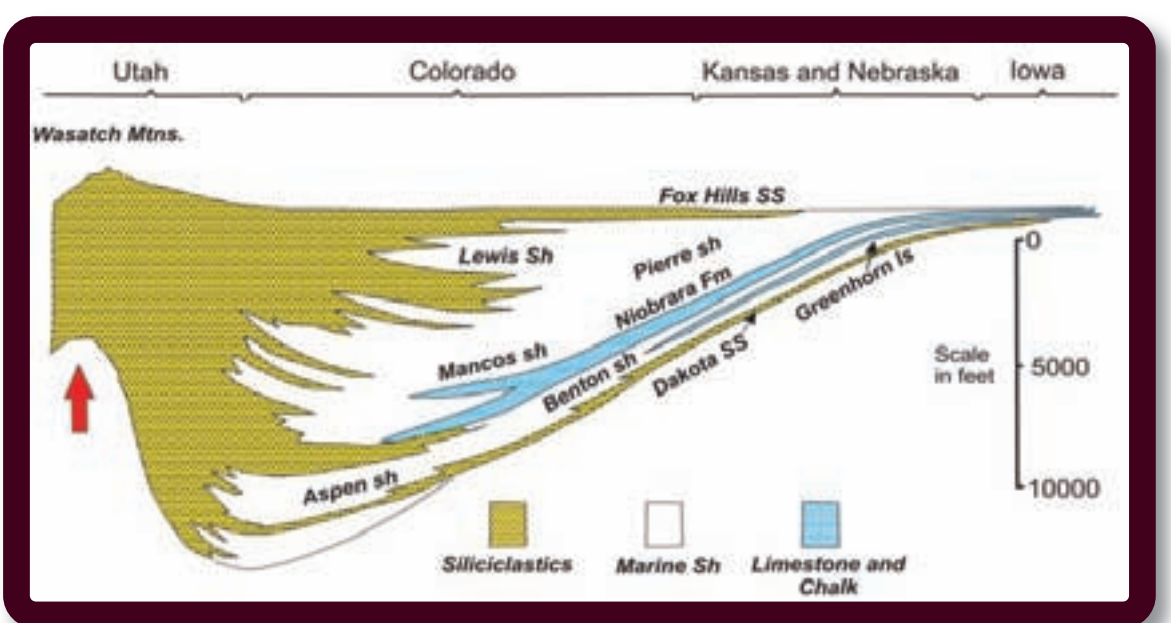
Factors thought to be important for Niobrara production in the Rocky Mountain region include presence of favorable reservoir facies (brittle chalk) and a diagenetic history that enables open fracture systems to exist; presence of mature source rocks to enable a continuous oil column to exist in the trap; source rocks interbedded with respect to the reservoir limestone (chalk); and a favorable tectonic history for fracture formation. Most fracture systems fall into two major categories: structure-related fractures and regional orthogonal fractures.

Resistivity mapping can be used to determine both the presence of a hydrocarbon accumulation and the maturity of source rocks for the Niobrara. The presence of oil in open fracture systems is thought to be the cause of the high resistivity anomalies in chalk beds. A relationship between increasing resistivity of source shales with increasing thermal maturity also has been demonstrated.

Knowledge of the distribution and occurrence of hydrocarbon source and reservoir rocks in the Niobrara interval will greatly aid future exploration.

Regional setting

The Upper Cretaceous Niobrara (Coniacian-Campanian: approximately 82 million to 89.5 million years ago) was deposited in a foreland basin setting in the WIC Seaway of North America during a time of a major marine transgression. This major transgression probably represents the maximum sea level high-



The WIC Basin was an asymmetric foreland basin with the thickest strata being deposited along the western margin of the basin. The cross section has been generalized across the WIC Basin. The Niobrara is Upper Cretaceous in age, and limestone and chalk beds are present over the eastern two-thirds of the basin. *(Image modified from Kauffman, 1977)*

stand during the Cretaceous and could contain the best source rocks in the Cretaceous. Present-day basins in the Rocky Mountain region formed during the Late Cretaceous to Early Tertiary Laramide orogeny.

The WIC Basin was an asymmetric foreland basin with the thickest strata being deposited along the western margin of the basin. It is a complex foreland basin that developed between mid to late Jurassic to Late Cretaceous time. The basin was bordered by mountainous areas to the west (zone of plutonism, volcanism, and thrusting that formed the Cordilleran thrust belt) and a broad stable cratonic zone to the east. The foreland basin subsided in response to thrust and synorogenic sediment loading and pulses of rapid subduction and shallow mantle flow.

During sea level highstands, coccolith-rich and planktonic foraminifera-rich carbonate sediments (chalks) accumulated on the eastern half of the seaway. Chalky beds extend into Montana and southern Canada (where they are called the White Spec zones) and into the Gulf Coast region (Austin Chalk). Chalk-rich carbonate facies change westward into siliciclastic-rich beds.

Stratigraphy, depositional setting

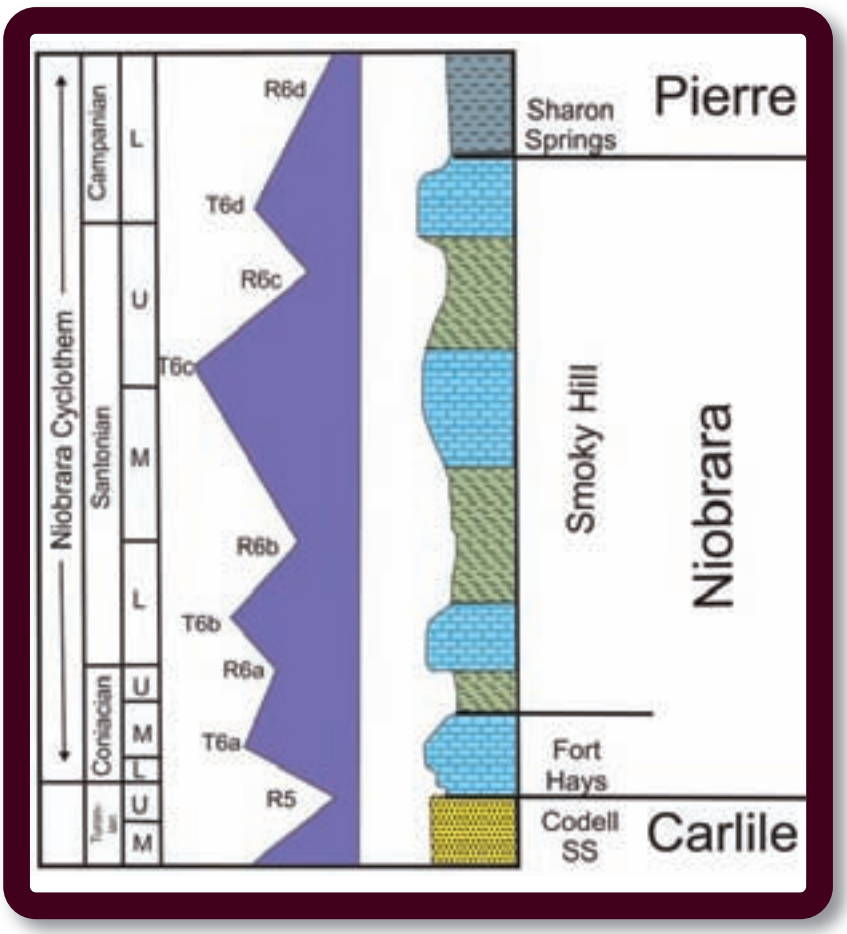
The Niobrara represents one of the two most widespread marine invasions and the last great carbonate-producing episode of the WIC Basin (the first widespread event is represented by the Greenhorn chalks). Dominant lithologies of the Niobrara Formation are limestones (chalks) and interbedded calcareous shales. The chalk-shale cycles are interpreted to represent changes from normal to brackish water salinities possibly related to regional paleoclimatic factors or sealevel fluctuations.

Chalk lithologies are thought to represent deposition in normal to near-normal marine salinities having a well-mixed water column and well-oxygenated bottom waters. The chalks reflect an influx of warm Gulfian currents into the WIC Seaway during relatively high sea levels. The interbedded shale cycles are interpreted to be caused by an increase in freshwater runoff caused by increased rainfall which could be related to climatic warming. The freshwater runoff creates a brackish water cap and salinity stratification. Vertical mixing of the water column is inhibited, causing anoxic conditions in the bottom waters which enhances preservation of organic material and results in organic-rich source rocks. Decrease in water salinities also is suggested by oxygen isotopic values. The shalier intervals could reflect lower sea levels and greater influx of clastic material from the west. The chalks previously have been interpreted to represent higher sea levels during Niobrara time.

Three major facies are present in the Niobrara and equivalents across the Rocky Mountain region. On the western side of the area, a sandstone facies is present that changes laterally to the east into a calcareous shale facies. This, in turn, changes eastward into a limestone and chalk facies. These various lithologies interfinger and facies changes are very gradational. The Niobrara name is used for chalk and shale units located on the eastern side of the WIC Seaway; whereas, the term Mancos generally is used for the equivalent shale and siltstone units in the western part of the area. The equivalent shoreline and non-marine sandstone units further to the west are known by a variety of names.

The limestone facies is composed of coccolith-rich fecal pellets probably derived from pelagic copepods, inoceramid and oyster shell fragments, planktonic foraminifer tests, micrite, clay, and quartz silt. The thick siltstone facies was derived from highlands to the west. The shales found in the Mancos/Niobrara are dark-gray to black and generally are organic rich (>1% TOC). The shales are fair to excellent source rocks and also provide seals for the chalky and sandy reservoir facies. TOC content in the interval increases to the east.

The chalks of the Niobrara are rich in organic matter and organic-related material (e.g., pyrite). On the east side of the WIC Basin, the Niobrara consists of four chalk beds and three shale intervals. The basal chalk bed is known as the Fort Hays limestone member, and the unit contains some of the purest chalk in the WIC Basin. The Fort Hays is regionally extensive and ranges in thickness from 50 ft in southeast Colorado to 120 ft in New Mexico, to less than 10 ft in southeast Wyoming. Carbonate content persists from the Denver Basin to southwest Colorado into the Laramie, North Park, South Park, and Sand Wash basins. The Fort Hays interval is difficult to distinguish from the remainder of the Niobrara north of the Laramie Basin.



Dominant lithologies of the Niobrara Formation are limestones (chalks) and interbedded calcareous shales. A generalized stratigraphic column is shown for the Niobrara from the Denver Basin setting. The Niobrara ranges in age from Coniacian to lower Campanian. Several transgressive and regressive cycles are noted for the Niobrara interval. Four chalk-rich intervals were deposited during transgressive events and three calcareous shales during regressive events. There is a six-member subdivision. *(Image modified from Longman et al, 1998; Barlow and Kauffman, 1985)*

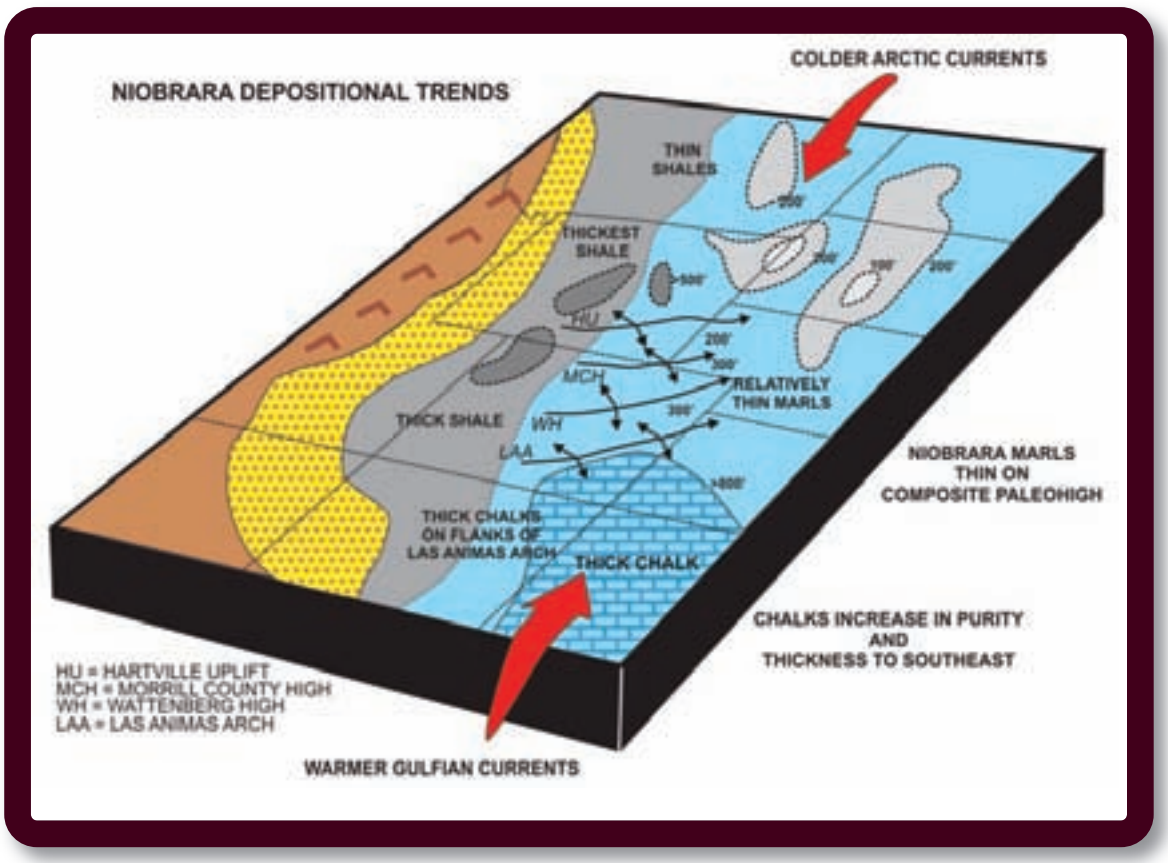
The Fort Hays is overlain by the Smoky Hill member, which consists of organic-rich shales to chalky shale (marls), to massive chalk beds. The interval has been subdivided by various authors into several units.

The Niobrara ranges in thickness from 100 to 300 ft along the eastern side of the WIC Basin to more than 1,500 ft on the west side of the basin. An isopach map illustrates the Niobrara across the northern Rockies region. Thinning occurs in a northeast trend across the map area. This thin trend was related to paleotectonic movement on the Transcontinental Arch. Superimposed on the Transcontinental Arch are northeast axes of thinning. Thinning in the Niobrara is believed to result from differing rates of sedimentation (i.e., convergence or divergence of section) and unconformities at the base, within, and at the top of the formation.

Niobrara deposition in the WIC Basin was influenced strongly by the interplay of warm north-flowing currents from the paleo-Gulf of Mexico and cooler southward-flowing currents from the Arctic region along with sea level fluctuations. Warm waters from the Gulf brought in rich carbonate flora of coccoliths and promoted carbonate production and deposition. Siliciclastic input from the west and cooler Arctic currents inhibited carbonate production and deposition.

Chalks and marls are abundant in the Denver Basin. The section changes to marl and is shalier west of the Front Range and north of the Hartville Uplift. Chalk intervals extend into the Laramie, Hanna, North Park, Sand Wash, and Piceance basins. The section in the Piceance consists of interbedded sandstone, siltstone, and shale. In the San Juan Basin, the Niobrara consists of a mixture of siliciclastic and marl lithologies.

The Niobrara is overlain by the Pierre Shale in the eastern part of the WIC Basin and its age-equivalent Mancos Shale in the western part. The Niobrara overlies the Carlile Formation across much of the WIC Basin and its members — the Codell sandstone, Sage Breaks Shale, etc. The Sharon Springs member of the Pierre Shale overlies the Niobrara in most of eastern Colorado and is an excellent source



Niobrara deposition in the WIC Basin was influenced strongly by the interplay of warm north-flowing currents from the paleo-Gulf of Mexico and cooler southward-flowing currents from the Arctic region along with sea level fluctuations. Chalk and limestone beds occur on the eastern side of the Cretaceous Basin whereas shales occur on the west side. Sandstone facies are further west in close proximity to the source area (Sevier orogenic belt). Variations in the amount of chalk could be a function of sea-level fluctuations and current flow from the northern and southern end of the seaway. *(Image modified from Longman et al, 1998)*

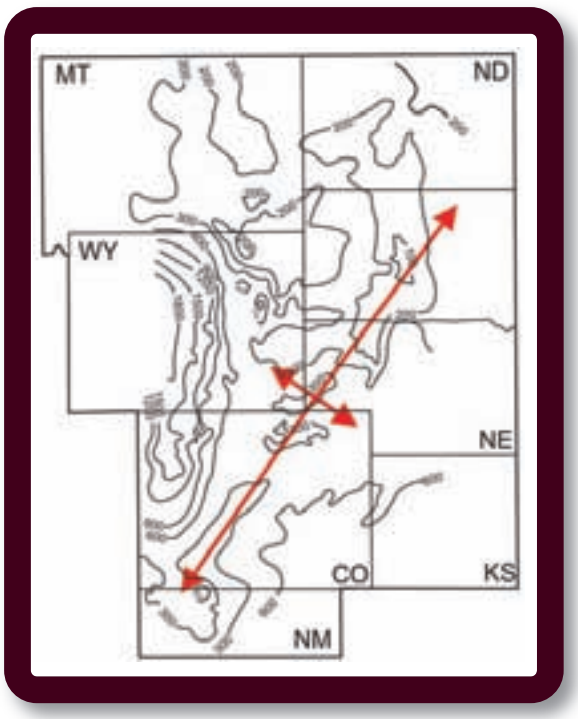
rock with TOCs ranging from 2% to 8%. The type locality for the Niobrara Chalk is Knox County in northeastern Nebraska.

Source rocks

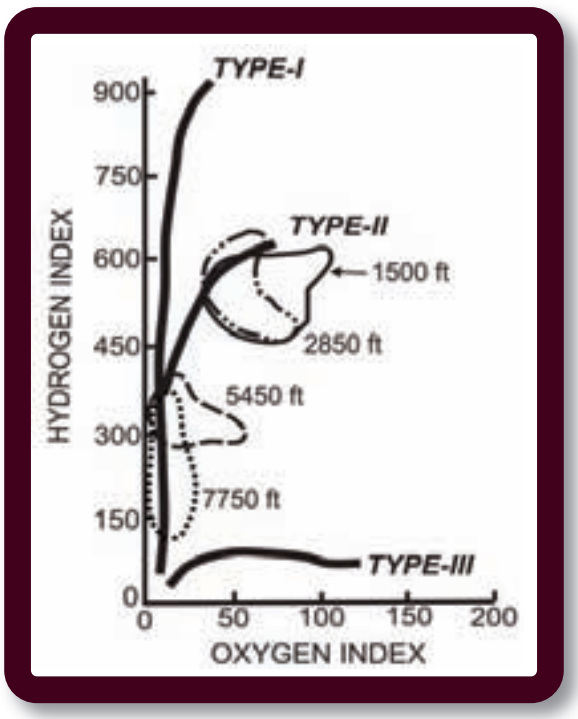
Several workers have discussed the organic-rich nature of the Niobrara Formation and the increased thermal maturity and resistivity with increased burial depth. Vitrinite reflectance and resistivity of the organic-rich shale increases with increasing thermal maturity. These values can be mapped to show areas of source rock maturity.

The Niobrara Formation has been analyzed using the Rock-Eval instrument by several workers. Organic-rich beds in the formation have an average 3.2% TOC value. A plot of hydrogen index versus oxygen index (modified van Krevelen diagram) illustrates the type and level of maturity of the source rocks for different depths across the Denver Basin. The plot also illustrates that the kerogen present in the Niobrara is Type II or oil prone (sapropelic).

The Niobrara section was analyzed in the Berthoud Field (Denver Basin) by scientists with the US Geological Survey (USGS). TOC content in the shales ranges from less than 1% to approximately 6%. The organic-rich shales generally are highly radioactive and thus are easy to recognize with gamma ray logs. Gamma ray values increase as a function of increasing TOC. The organic carbon tends to attract or be deposited with uranium which accounts for the high gamma radiation. TOC content in the Niobrara Forma-



An isopach map illustrates the Niobrara across the northern Rockies region. The Niobrara ranges in thickness from less than 100 ft to more than 1,000 ft. Thinning occurs in a northeast trend across the Transcontinental Arch area. *(Image modified from Longman et al, 1990; Weimer, 1978)*



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tion is proportional to the amount of acid-insoluble residue.

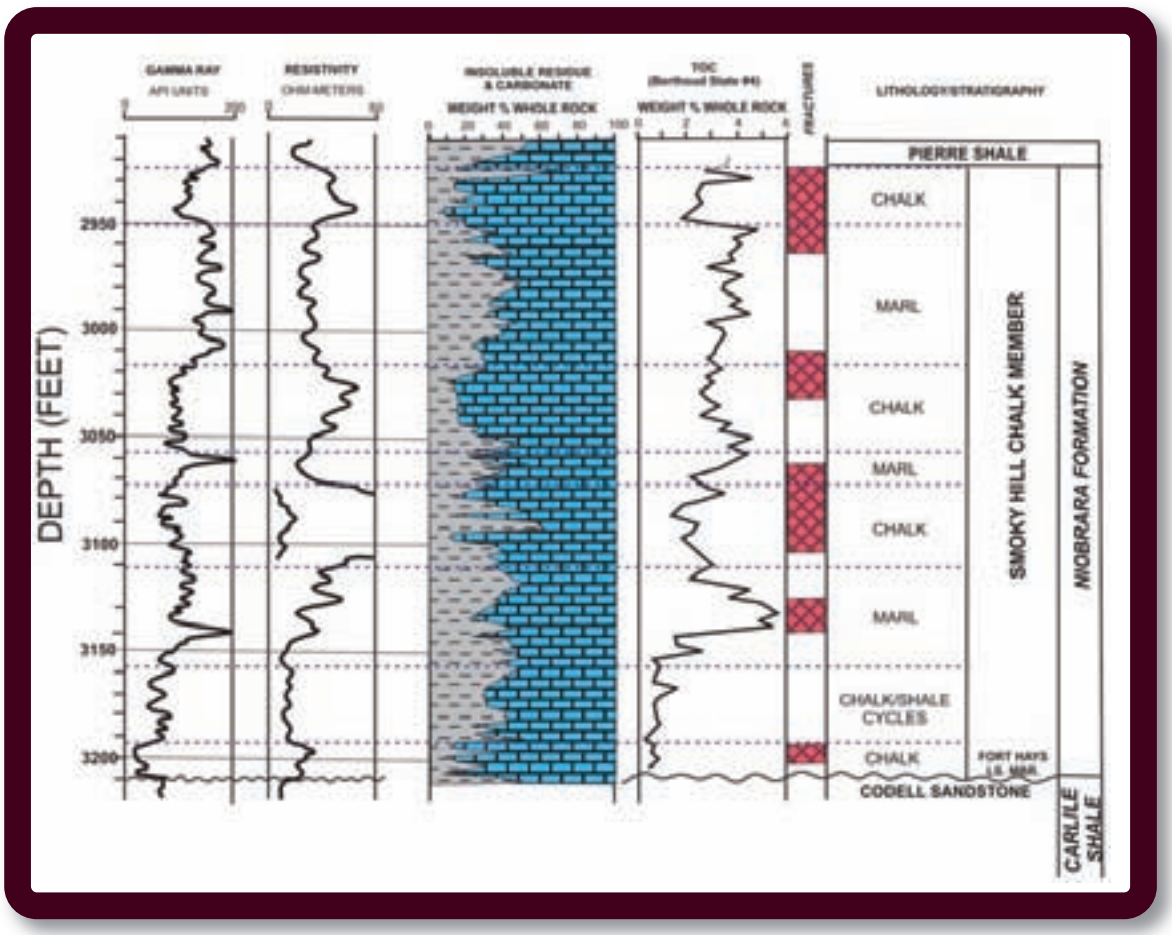
The Niobrara produces self-sourced oil and gas from tight (low porosity and permeability), fractured carbonate reservoirs. Niobrara source rocks are dominantly Type II, oil-prone kerogen. The richest source rocks are in the Denver Basin where the TOC content reaches 8%. In south-central Wyoming, the TOC content averages 2.1%. The 700-ft Niobrara section in northwest Colorado has good source rock potential. Source rocks in southwestern Wyoming are dominantly Type II with some mixing from Type III, gas-prone kerogen. The average TOC content from samples in southwest Wyoming is 1.85%.

Hydrocarbon generation starts at vitrinite reflectance values of 0.7% and began approximately 76 Ma in the Piceance/Uinta Basin areas. Hydrocarbon generation is estimated to have started approximately 72 Ma in southwest Wyoming. Hydrocarbon generation in the Denver Basin started in the Late Cretaceous.

Reservoir rocks

The lithology of the Niobrara changes from east to west across the WIC Basin. In the Denver Basin, the lithology consists of interbedded calcareous shale, shaley limestones, marls, and limestones. Westward, the lithology becomes shalier and sandier. The carbonates still are present in the western area, but clastics begin to dominate.

Most Niobrara reservoir rocks have undergone mechanical and chemical compaction and are low-porosity and low-permeability rocks. Burial depth is the single most important factor affecting porosity in the Niobrara. Chalks have high original porosities (50% or greater). Initial dewatering and mechanical compaction is the first diagenetic phase. Grain and fossil breakage and reorientation reduce porosity.



The Niobrara section was analyzed in the Berthoud Field (Denver Basin) by scientists with the US Geological Survey. Geophysical logs (gamma ray and resistivity), insoluble residue and carbonate content, and lithology and stratigraphy of the Niobrara from the Berthoud State #4 well (Denver Basin) are shown. Mechanical stratigraphy of the Niobrara is indicated by the presence of fractures in chalk intervals. Calcareous shales (marls) are ductile. *(Image modified from Pollastro, 1992)*

Initial coccolith grain sizes are 0.2 to 1 micron. Chemical compaction is characterized by calcite dissolution along wispy dissolution seams, microstylolites, and stylolites. Grain-to-grain dissolution along microstylolites is common and the dissolved calcite is reprecipitated locally.

A plot illustrates density log porosity versus depth for the chalks in the Denver Basin. The chalks have an average porosity of 6% at 7,000 ft. It appears that the porosity trend flattens with burial depth. Both shallow and deeply buried chalks have low permeabilities. Initial average pore throat sizes are a few tenths of a micron, which are further reduced with diagenesis. Fracturing is an important aspect for reservoir performance.

Mechanical stratigraphy, fractures

The generalized mechanical stratigraphy for the Niobrara shows chalk beds behave in a brittle fashion and are susceptible to fracturing; whereas, the marl or calcareous shales behave in a ductile manner and contain fewer fractures. Chalk beds are the target of horizontal drilling.

Fractures can be created in a number of ways, including folding related to basement or listric faulting or solution of evaporates, high fluid pressures associated with hydrocarbon generation, regional stress fields (regional fractures), regional uplift and stress relief, or a combination.

Major fracture zones in the Austin Chalk can be mapped into four major categories:

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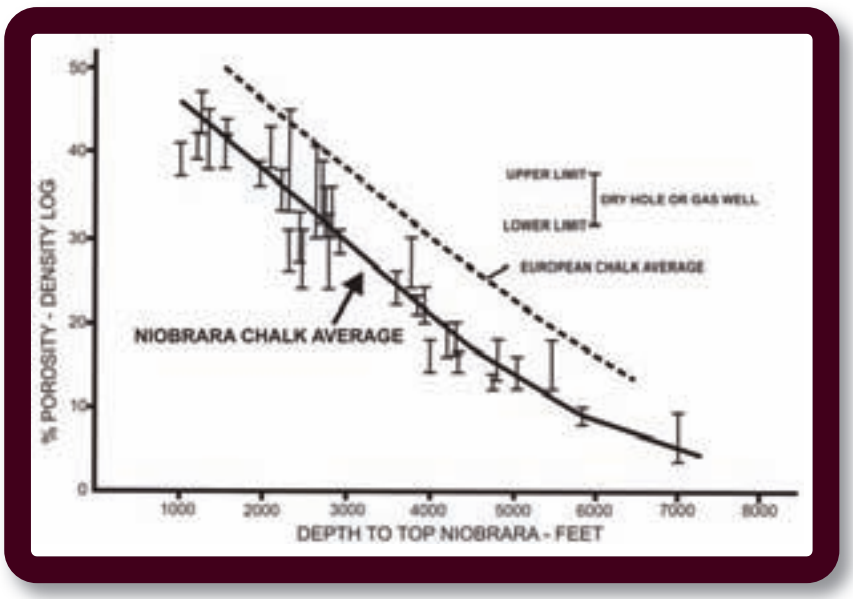

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1. Anticlinal folds.
2. Monoclinal flexures.
3. Listric normal faults.
4. Graben-in-graben normal faults.

A good understanding of orientation of fracture sets relative to local and regional structure has been developed. In addition, the size of the fracture halo (zone) adjacent to faults and folds is understood. These models could prove to be important for the Niobrara Formation in the Rocky Mountain region. The Silo Field fracture system, for example, fits into the monoclinal flexure model.

Fracturing often is associated with Laramide-age structures; however, they often are filled with calcite which results in poor production. Neogene-age extensional fracturing and/or microfracturing appear to enhance production. Fractures from productive fields generally are lined with calcite but are not cemented completely.

Resistivity anomalies have been observed in the fractured limestone reservoirs in the Silo Field and can be mapped by maximum resistivity (isoresistivity) and thickness of resistive bed. In the Silo Field area, both methods illustrate a northwest-trending anomaly that coincides with known production. Maximum resistivities for the productive chalk interval range from less than 20 ohm-m to greater than 100 ohm-m. Productive wells generally have maximum resistivities greater than 40 ohm-m. The thickness of resistivity (greater than 15 ohm-m) in the productive chalk zones is approximately 40 ft.

The high resistivity can best be explained by fractures filled with oil giving the anomaly; however, other factors could contribute, including calcite-filled fractures or increased local cementation related to faulting and fracturing. Resistivities diminish (using both methods) in all directions away from Silo Field, illustrating that the increase in resistivity is not simply a depth-related compaction-cementation phenomena. Regardless, there appears to be a mappable anomaly that coincides with production. Reservoir resistivity methods can be used to suggest where accumulations exist, but do not help predict the intensity of fracturing necessary for economic production. The resistivity anomaly might be caused by fractures filled with oil, but whether sufficient fractures are present to produce economic quantities of oil is another matter. This method should be used in conjunction with other information, such as structural mapping, to help predict where accumulations exist and also are sufficiently fractured to be productive.

Petroleum system events chart

A generalized petroleum system events chart for the Niobrara (page 13) shows the Niobrara is self-sourced and also has reservoir rock potential in the chalkier intervals. These intervals tend to be more brittle. This also is where fractures have been noted in cores.

Traps are formed during the Laramide orogeny and enhanced by later extension. Niobrara source rocks reached thermal maturity beginning in Late Cretaceous. Migration of oil from source rocks into reservoirs began in Late Cretaceous and continued into the Neogene. Burial history reconstructions are an important aspect for determining the type of hydrocarbons (oil or gas) expected at different depths in the Rockies basins.

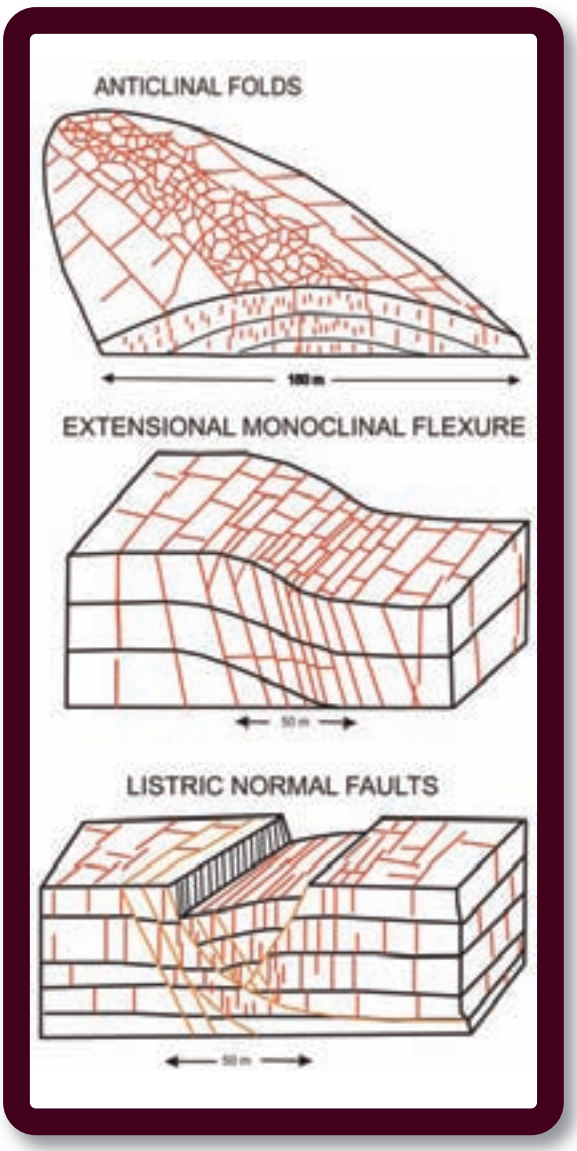
Hydrocarbon production

Niobrara production represents some of the oldest established production in the Rocky Mountain region. The oldest field in the region is the Florence-Cañon City Field which was discovered in 1881. The field produces from the Pierre Shale immediately above the Niobrara and is believed to be sourced from the Niobrara and Sharon Springs. The Boulder oil field (western Denver Basin) was discovered in 1901 and also is productive from the fractured Pierre Shale but also sourced from the Niobrara. Fractured Mancos Shale production was found in Rangely in northwest Colorado in 1902. Niobrara production was established in Tow Creek in the Sand Wash Basin in 1924. The Berthoud Field of the western Denver Basin was discovered in 1927 and is productive from several horizons including the Niobrara. Gas in the Niobrara was discovered in Beecher Island in eastern Colorado in 1919; however, commerciality was not established until 1972. The Niobrara interval is productive in the Bowdoin Field of Montana which was discovered in 1913. The reason for these early discoveries is that many of them are associated with surface structures which were the primary targets of early explorers.

Hydrocarbon production comes from all three major Niobrara lithofacies:

1. Microporous and fractured coccolith-rich and planktonic foraminifer-rich limestone (eastern part of the WIC Basin).
2. Fractured marls and shales (mainly in the central part of the seaway).
3. Fractured sandstone-rich and siltstone-rich facies, mainly in the western and southwestern parts of the seaway.

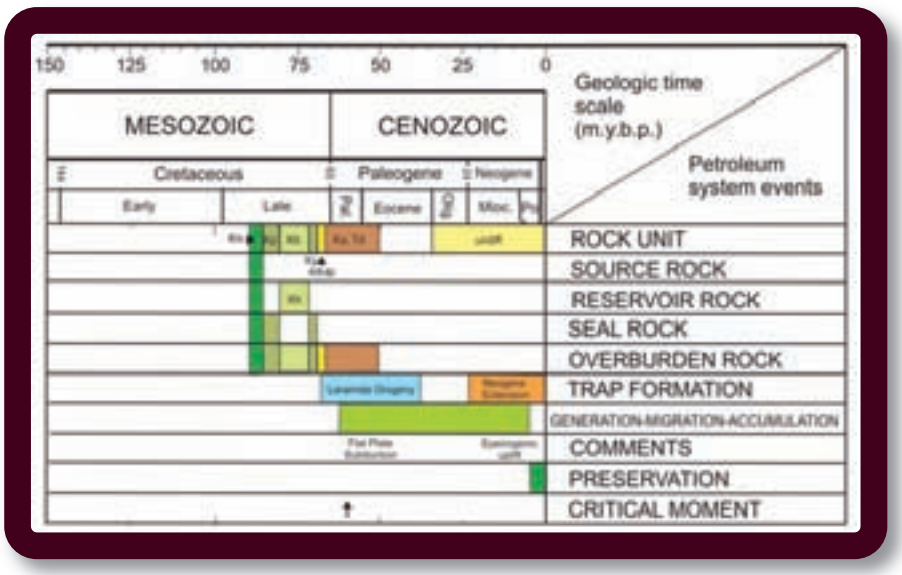
Production occurs in the Laramide-aged Powder River, Denver, North Park, Greater Green River (including Sand Wash), Raton, San Juan, and



Major fractures models in the Austin Chalk are mapped into three major categories: 1) anticlinal folds; 2) monoclinal flexure; and 3) listric normal faults. These models should apply to the Niobrara Formation. *(Image modified from Friedman et al., 1992)*

Piceance basins and in north-central Montana. The widespread distribution of production along with many wells with hydrocarbon shows across these basins suggests a large resource play might exist. The majority of recent drilling activity in the Niobrara has been in the Denver Basin, north of Wattenberg Field, and in southeast Wyoming near Silo Field.

Hydrocarbon production from chalk reservoirs occurs along the shallow eastern margin of the



A generalized petroleum system events chart for the Niobrara is shown. Trap formation and fracturing occurred during the Laramide. Late uplift (Neogene) results in extensional fractures or reopening of Laramide fractures. *(Image by Stephen A. Sonnenberg)*

Denver Basin. Many of the gas accumulations in this area occur in structural traps. Reservoirs require hydraulic fracture stimulation. The gas is biogenic or microbial in origin. Production in the shallow play comes from the upper chalk bench or Beecher Island member of the Niobrara and mainly is from microporosity within the chalks, but is enhanced by natural fracturing. Production from the shallow Niobrara from eastern Colorado is 600 Bcf of gas. Beecher Island Field is one of the first and largest fields discovered in the shallow Niobrara. Commercial production dates back to 1972 — the initial discovery was in 1919 — and the cumulative for the field is 100 Bcf of gas. Three-D seismic data have been used effectively to improve development and exploration success ratios in fields.

Shallow gas production from the Niobrara also occurs in north-central Montana. Bowdoin Dome has produced 62 Bcf of gas and 19,000 bbl of oil from the Niobrara. Additional Niobrara fields are to the west of the Alberta Basin which extends into Montana. The largest field to date is the St. Joe Road Field which was discovered in 2001 and has produced 18.2 Bcf of gas.

Deeper in the Denver Basin, the Niobrara is oil productive in a number of fields. The porosity of the chalks in the deeper part of the basin has been reduced dramatically by compaction and burial diagenesis. Production is attributed to the presence of fractures in the chalky intervals. Some attempts have been made to establish production from some of the rich, shaley intervals within the Niobrara. The shale gas and fractured chalk potential of the deep Denver Basin area is significant, as shown by fields like Wattenberg and Silo. Silo Field was discovered in 1981 and has produced approximately 10.4 MMbbl of oil and 8.9 Bcf of gas.

The Niobrara is productive on the Casper Arch of Wyoming at Salt Creek and Teapot fields. Total production has been 1.5 MMbbl of oil and 0.2 Bcf of gas. In the deeper Powder River Basin, production has been established in a number of accumulations including Fetter, Hilight, Brooks Draw, and Flat Top. Hilight has produced 411,000 bbl of oil and 0.8 Bcf of gas to date.

The western portion of the region is productive in a variety of traps and lithologies (mainly siliciclastic), and there is significant potential for hydrocarbon production in many of the western basins. The basal part of the Niobrara equivalent in the west yields oil and gas in the San Juan Basin from a sandstone and shale interval (Tocito and Gallup sandstones). Examples of producing fields from the Gallup are Bisti and Verde fields. Bisti Field has produced 41.8 MMbbl of oil and 79.2 Bcf of gas. Verde Field has produced 8.1 MMbbl of oil and 2.5 Bcf of gas. Examples of fields producing from the Tocito sandstone are the Blanco South and Chipeta fields. These fields have produced 4.2 MMbbl of oil and 18.8 Bcf of gas. Production is from interparticle porosity but is enhanced by fractures.

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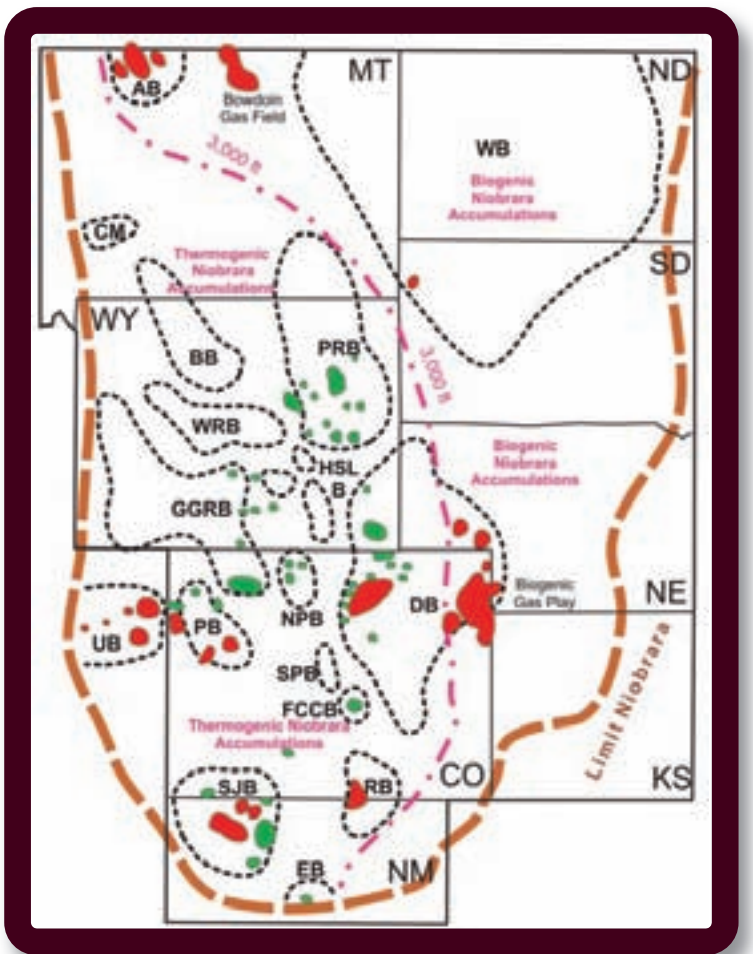


The Florence-Cañon City Field was discovered in 1881. The Niobrara has several producing areas across the northern Rockies. Oil fields are shown in green and gas fields are in red. Distribution of sapropelic oil generation-prone Niobrara source rocks are shown within the brown dashed lines. The dot-dashed line represents the 3,000-ft current burial depth. Biogenic accumulations are east of the line and thermogenic accumulations are west of the line. *(Image modified from Longman et al, 1998; Lockridge and Scholle, 1978)*

The upper Niobrara equivalent (Smoky Hill member) is productive in the Sand Wash Basin from fractured reservoirs, and perforated intervals are commonly long. Field examples are Buck Peak and Tow Creek. Buck Peak has produced 4.8 MMbbl of oil and 8.5 Bcf of gas. Tow Creek has produced 3 MMbbl of oil and 0.3 Bcf of gas. Farther to the west where the Niobrara equivalents are dominantly shale, production is found in the Rangely and Douglas Creek Arch fields. Production from the fractured Mancos Shale at Rangely represents some of the oldest production in Colorado (since 1902). The Mancos at Rangely has produced approximately 11.9 MMbbl of oil and 0.2 Bcf of gas. Neogene-age extensional faulting is key to production at Buck Peak and Rangely. Douglas Creek Arch production comes mainly from Cathedral Field. The field has produced 56.5 Bcf of gas and 40,600 bbl of oil from the Mancos (mainly the Mancos B zone).

Other production equivalent to the upper Niobrara zone comes from the Mancos interval in the San Juan Basin. Examples of Mancos producing fields include East Puerto Chiquito, West Puerto Chiquito, Rio Puerco, Gavilan, Basin, and Boulder. These fields are interpreted to be fractured reservoirs, and producing intervals are hundreds of feet thick. The Puerto Chiquito fields have produced 19.3 MMbbl of oil and 55.5 Bcf of gas. Gavilan Field has produced 7.8 MMbbl of oil and 111 Bcf of gas. Boulder Field has produced 1.8 MMbbl of oil and 1.6 Bcf of gas. Basin Field has produced 120,000 bbl of oil and 4.1 Bcf of gas. Rio Puerco Field has produced 1.3 MMbbl of oil and 1.4 Tcf of gas.

The Mancos is gas productive in the deeper parts of the Uinta Basin in several fields including Natural Buttes. Mancos also is productive in some silty and very fine-grained sandstone zones in the Cathedral Field of the Douglas Creek Arch. New Mancos/Niobrara production has been established in several areas of the deeper Piceance Basin (e.g., Mamm Creek Field).

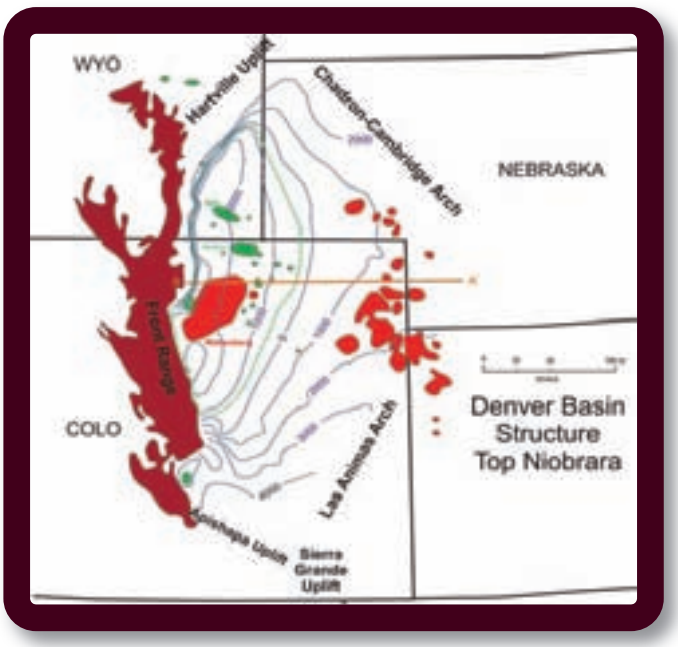
Resource estimates

The USGS has estimated recoverable resources from the Mancos/Niobrara for the following basins in the Rocky Mountain region:

- Greater Green River Basin: 103.6 MMbbl of oil, 62 Bcf of gas;
- Piceance Basin: Mancos/Mowry combined for 1.6 Tcf of gas;

- Uinta Basin: Mancos/Mowry combined for 3.1 Tcf of gas;
- Powder River Basin: Niobrara Formation for 520 MMbbl of oil, 0.95 Tcf of gas;
- Denver Basin: Niobrara/Codell for 39,800 bbl of oil, 328 Bcf of gas;
- Niobrara Biogenic Chalk: 984 Bcf of gas;
- San Juan Basin-Mancos Continuous: 5.1 Tcf of gas; and
- Hanna-Shirley-Laramie: 38 MMbbl of oil, 19 Bcf of gas.

The resource assessments illustrate the significant potential of the Niobrara across the Rockies, not only for thermogenic accumulations of oil and gas, but also biogenic accumulations.



The Denver Basin is asymmetric with a gentle east flank and a faulted to very steeply dipping west flank. The areas for thermogenic oil and gas accumulations within the Niobrara are within the green dashed line (assuming lateral migration is limited). *(Image by Stephen A. Sonnenberg)*

Niobrara Petroleum System in the Denver Basin

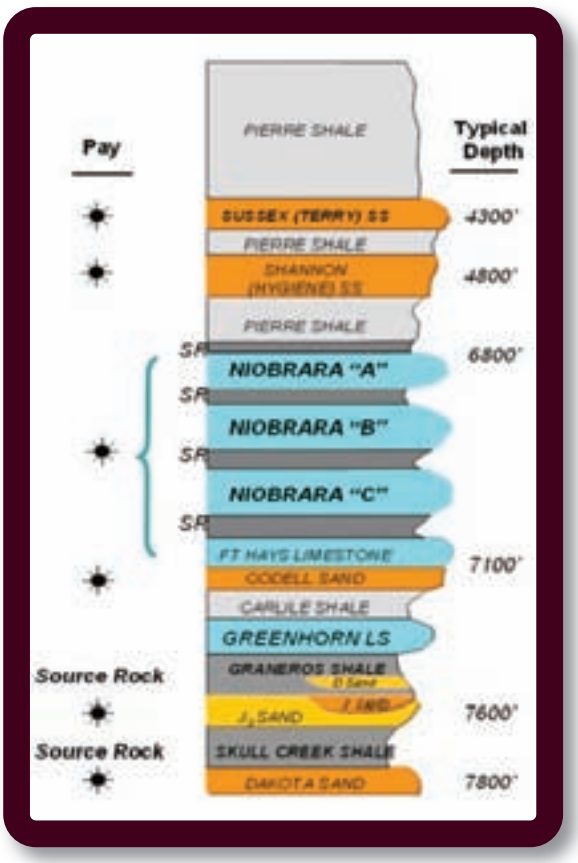
The Denver Basin is the current focus of most Niobrara drilling in the Rocky Mountain region. The Denver Basin was created by the Laramide orogeny and is one of the largest sedimentary basins in the region. The basin is asymmetric with a gentle east flank and a faulted to very steeply dipping west flank. Source rock intervals for the Cretaceous include the Skull Creek, Graneros, Carlile, Niobrara, and lower Pierre (Sharon Springs) shales. Most production in the basin comes from Cretaceous D and J sandstones. In the Wattenberg Field, production comes from the Dakota, J, D, Greenhorn, Codell, Niobrara, Hygiene, and Terry units. The Wattenberg area is a geothermal "hot spot." The principal reason for all the stacked pays in Wattenberg is the temperature anomaly.

The Niobrara Petroleum System consists of source beds and reservoir units in the Niobrara, but also the overlying Cretaceous Hygiene sandstones (Terry and Hygiene). Thermogenic oil and gas accumulations occur in the deeper part of the Denver Basin, while shallow biogenic accumulations of gas occur on the shallow east flank. Niobrara production turns to oil as the geothermal gradients decrease in all directions away from the Wattenberg area. An important aspect of the Niobrara Petroleum System is that it sources Upper Cretaceous reservoirs in the Denver (e.g., Terry and Hygiene) and Powder River (e.g., Parkman, Sussex, Shannon, and Teapot) basins.

New discoveries in the Niobrara in the Denver Basin include the Hereford Field area, northeast of Wattenberg. The field is being developed with horizontal drilling and multistage hydraulic fracture stimulations. The Hereford area is one of several areas that currently are being developed in the Denver Basin. The Silo Field area also is getting new horizontal wells.

Exploration methods

Exploration for fractured Niobrara reservoirs should incorporate many if not all of these methods: seismic acquisition, aeromagnetics study, surface lineament analysis, subsurface mapping, isoresistivity mapping, logging technology, and technology to produce the reservoir. Two-D and 3-D seismic are extremely important to map structural anomalies. Three-D, three-component (compressional and shear wave data) methods also have proved to be effective in analyzing the fractured reservoir.



In the Wattenberg Field, production comes from the Dakota, J, D, Greenhorn, Codell, Niobrara, Hygiene, and Terry units. The stratigraphic column illustrates producing horizons in the greater Wattenberg area. The Niobrara consists of four limestone (chalk) beds and three organic-rich calcareous shale intervals (marls). The basal Pierre Shale also has an excellent source bed (Sharon Springs). *(Image by Stephen A. Sonnenberg)*

Aeromagnetics is a tool that can identify basement shear zones' areas of potential fractures having gradient changes such as narrow zones of steep gradients. Aeromagnetic data examined in the Silo Field area illustrate possible northwest-trending shear zones. If basement fracture systems propagate all the way to the surface, then a surface lineament analysis also might be effective. Northwest-trending surface lineaments in the Silo area have been mapped by use of remote sensing techniques.

Resistivity mapping is important to show areas of oil accumulation. When resistivity mapping is combined with subsurface mapping, the most probable areas of fracturing can be predicted. Geophysical logs such as the FMS, FMI, and CAST logs are logging technologies that identify fractured reservoirs. Horizontal drilling and multistage hydraulic fracturing offer technologies to economically produce hydrocarbons from the reservoir.

An understanding of the regional stress field is important in most tight oil and gas plays. The direction of maximum horizontal stress (Shmax) generally is the direction of open fractures. Regional horizontal stress maps have been published for North America. Present-day stress fields reflect Neogene extensional tectonics and the epeirogenic uplift that has taken place in the Western US.

Regional epeirogenic uplift of western North America and subsequent erosion (denudation) might play a role in Niobrara microfractures. Overburden removal results in lowered effective stress in rocks that also might be overpressured. This mechanism could be important in all tight reservoir plays in the Rocky Mountain region.

Widespread source and reservoir rocks make the Niobrara Formation an attractive target for exploration across the Rocky Mountain region. The Niobrara contains mature source rocks interbedded with brittle limestones (chalks) in the deeper parts of many basins. Thermogenic production occurs from chalk intervals in the eastern part of the region and from siliciclastics and shales in the western and southwestern parts of the Uinta and San Juan basins. Biogenic gas production occurs at shallow depths along the eastern Rocky Mountain region in Colorado, Kansas, and Nebraska. Generally, production comes from depths less than 3,500 ft. Shallow gas production also occurs in several areas of north-central Montana and generally is structurally controlled.

Niobrara reservoirs generally have low permeabilities, so natural fracturing plays a role in economic production. Limestone (chalk) beds behave in a brittle manner; whereas, the adjacent calcareous shales often behave in a ductile manner. Fractures occur for a variety of reasons and several models can be used for exploration. Early created fractures are susceptible to extreme diagenesis and generally are cemented completely. Late-stage structural movement can help to reopen old fractures or create new ones in the Niobrara.

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Niobrara Spreads Through the Rockies

High-volume, liquids-rich wells goad operators into a Niobrara search in Colorado and Wyoming.

By Don Lyle
Contributing Editor

The Niobrara group occurs throughout the Rocky Mountains, with production from the nation's second-oldest oil field to some of the nation's newest fields, from Colorado, through Wyoming, and into Montana.

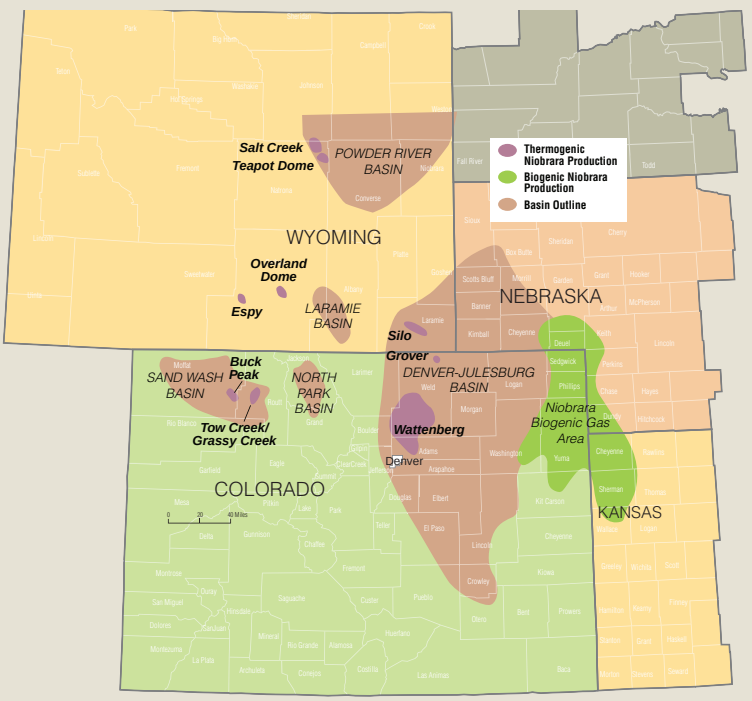
Operators are testing the Niobrara from the Bowdoin Dome near the Canadian border in north-central Montana, south through the Powder River Basin of Montana and northeastern Wyoming, into the Wind River Basin of central Wyoming, through the Greater Green River Basin in southwestern Wyoming and northwestern Colorado, into the North Park Basin of northern Colorado, and into the Raton Basin of southwestern Colorado.

The sweet spot to date has been the Denver Basin, also called the Denver-Julesburg Basin, or more commonly, the D-J Basin of southeastern Wyoming, southwestern Nebraska, northwestern Kansas, and northeastern Colorado.

EOG Resources Inc. sparked the play with the biggest well to date, the 2-01H Jake well in Hereford Field in Weld County, Colo. That well tested for 1,558 b/d of oil. In the same county, Noble Energy Inc. brought its Gemini well for 60,000 boe during 60 days and estimated an ultimate recovery of 500,000 boe. That was the biggest well to date in Wattenberg Field, and the seventh-largest oil and gas field in the Lower 48.

In Wyoming, SM Energy Inc. detailed a seven-day initial potential of 1,075 boe/d from a Laramie County, Wyo., well in Silo Field, the original horizontal Niobrara Field.

Horizontal Niobrara activity is red-hot in the Denver-Julesburg Basin, and explorers are evaluating the Cretaceous shale in other Rockies basins, particularly those with histories of vertical Niobrara production. *(Source: Hart Energy)*



Big wells generate big bids for land. A July 2010 land sale centered on Niobrara territory drew US $42 million in bids. In the November sale in the same area, one company paid $13.7 million for 21 parcels.

Bids on land with Niobrara potential in the D-J Basin in Colorado attracted bids as high as $2,200/acre.

A US Geological Survey study estimated mean undiscovered hydrocarbons from the Niobrara at 40 MMbbl of oil, 32 MMbbl of natural gas liquids (NGLs), and 330 Bcf of gas in the D-J Basin; 227,000 bbl of oil and 227 Bcf of gas from the Powder River Basin; and 104 MMbbl of oil, 3.7 MMbbl of NGLs, and 62 Bcf of gas in the Green River Basin.

Operating companies have located sweet spots in specific parts of Colorado and Wyoming. Now, they are trying to find similar high returns on other Niobrara areas.

Key Players

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Although Anadarko Petroleum Corp. has only just begun evaluating the horizontal Niobrara play in Colorado and Wyoming, it already holds a position as one of the biggest players in the emerging formation and has the potential to take a dominant position in the play.

The play currently might not boast the same status as the Marcellus and Eagle Ford shales, but it holds substantial promise and is an active and growing area.

In its 3Q 2010 operations report, Anadarko said it had drilled four vertical Niobrara test wells and started drilling its first operated horizontal Niobrara well. The company also had completed a 160-sq-mile 3-D seismic survey. It planned to remain active in the play throughout 2010 and increase its rig count in the Niobrara in 2011.

In an August 2010 presentation, Anadarko said it planned to complete six to 10 Niobrara wells that year.

The company acquired Union Pacific Resources Corp. in 2000. That company opened the Niobrara oil play in southeastern Wyoming when it drilled horizontally into a stress-fractured segment of the formation to discover Silo Field in Laramie County.

One well in that field, the No. 1 McGahan 21-5, tested 767 b/d of oil and 326 Mcf/d of gas from a 2,479-ft lateral. The field still is producing.

A flurry of activity followed the discovery, but the search for natural fractures in the Niobrara died out. Operators went looking for prospects with more potential.

Tools of the trade frame drilling operations on an Anadarko rig working Wattenberg Field in northeastern Colorado. *(Photo courtesy of Anadarko Petroleum Corp.)*

KERR-MCGEE ACQUISITION

In 2006, Anadarko acquired Kerr-McGee Corp., the largest operator in the Wattenberg Field in the Denver-Julesburg Basin northeast of Denver in Colorado. That field initially produced from the D and J sands, and as they peaked, operators started looking for additional opportunities. Early in the life of the Wattenberg Field, the Codell and Niobrara showed slim economics. However, through technical advances in fracture stimulation, the combination of the two formations produced growing profits as product prices ramped higher.

Operators, including Anadarko, gradually tightened spacing to a five-spot pattern on a quarter section and then filled in with wells at the center of section lines – up to 32 wells per section in the heart of Wattenberg Field – and still found virgin gas supplies with significant liquids yields.

Currently, Anadarko still is one of the most active Niobrara operators on the Kerr-McGee properties in Adams and Weld counties in Colorado. It also is acquiring more property in Weld County.

Niobrara potential for the company is huge. With the Union Pacific acquisition, it

picked up 100%-owned mineral interests on the 7.8-million-acre land grant, which include a checkerboard of sections on both sides of the Union Pacific Railroad track north through eastern Colorado and west through southern Wyoming into Utah. Much of that land in Colorado and Wyoming is prospective for Niobrara production.

ADDITIONAL PROPERTIES

Anadarko also holds coalbed methane (CBM) properties in the Powder River Basin, along with conventional properties and the only CO_2 import line into the basin, which it uses for enhanced oil recovery at Salt Creek Field near Casper, Wyo. Much of that acreage also holds Niobrara production potential. The company also holds CBM properties in the Atlantic Rim Field in the Washakie Basin of southern Wyoming, with additional Niobrara potential below the coal seams.

During 3Q 2010, Anadarko spent US $395 million on all of its Rocky Mountain properties, up from $312 million in 2Q 2010. The company produced 194 MMcf/d of gas, 8,000 b/d of natural gas liquids (NGLs), and 19,000 b/d of oil from its Wattenberg properties in 3Q 2010, up from 194 MMcf/d of gas, 8,000 b/d of NGLs, and 16,000 b/d of oil in the same quarter a year earlier.

Anadarko's 3Q 2010 operations report said it set a new weekly net production record in Wattenberg Field at 63,500 boe/d, along with a single-day oil gross delivery record of 29,000 bbl.

It drilled 96 wells in the field in 3Q 2010, finishing the quarter with six operated rigs.

New techniques have opened new opportunities for the company. It conducted 273 refracture and recompletion fracture treatments during the quarter, up from 102 in 3Q 2009. Through the first nine months of the year, the company performed 1,379 frac treatments on 854 well bores in Wattenberg, substantially eclipsing its record of 1,102 fracs in 2008.

It did not break down production or treatments by zone.

In spite of the heavy level of activity, Anadarko's Wattenberg operating team earned recognition from the Colorado Oil and Gas Conservation Commission with awards for operator excellence in operational efficiency and community involvement.

Apache Corp.

- *Net acres: 54,000*
- *Acquired through Mariner Energy Inc.*

Apache Corp. holds properties from offshore Australia to the deepwater Gulf of Mexico (GoM) and is working onshore properties in the Permian Basin. Now, the company might be making a move toward the Niobrara Formation in Colorado and Wyoming.

Apache picked up deepwater GoM properties when it acquired Mariner Energy Inc. in a deal that closed in November 2010.

That acquisition included 54,000 net acres of land prospective for the Niobrara Shale in Laramie County, Wyo.

When Mariner acquired the properties in April 2010, it said the land included fee, state, and federal leases in the county and "Mariner believes the acreage is on trend and contains shales with petrophysical properties similar to the commercial Niobrara Shale discoveries of the Jake 2-01H well and Silo Field."

EOG Resources Inc.'s Jake well in northern Weld County, Colo., tested for 1,558 b/d of oil and produced 14,156 bbl of oil and 2.94 MMcf of gas in eight days during October 2009.

Silo Field is a Niobrara field in Laramie County, Wyo. Union Pacific Resources Corp. initially discovered oil in the field and developed it with horizontal wells.

"This acquisition is consistent with our stated strategy of obtaining sizable low-entry-cost oily shale plays where we can operate," said Scott D. Josey, chairman, CEO, and president of Mariner at the time of the acquisition. "The acreage is close to existing infrastructure, facilitating development if our exploration efforts are successful."

Following the Mariner acquisition announcement, Apache participated in a US $48.8 million auction of Wyoming properties prospective for Niobrara Shale production.

Winning bids averaged $4,725/acre for all participants. Apache placed winning bids on 18 parcels with bids ranging from $9 to $850/acre.

Bill Barrett Corp.

- *Net acres: 111,265 in McRae Project*
- *Focus on Wind River Basin*

Bill Barrett Corp., a veteran Rocky Mountain oil and gas company with a strong reputation for finding oil

and gas through strong geology, has chosen a selective approach to Niobrara exploration.

The company took a more conventional approach to the unconventional shale and chalk formation as it acquired gas-prone Niobrara properties in the Denver-Julesburg (D-J) Basin.

By 2007, the company had signed a joint-venture (JV) agreement with Berry Petroleum Corp. to develop approximately 368,000 gross acres of Niobrara land in the northeast corner of the basin in Sherman County, Kan.; Nebraska; and Kiowa County, Colo.

Berry and Barrett shot 2-D and 3-D seismic over their Tri-State JV properties, and drilled both vertical and horizontal wells to prove up the properties.

By the end of 2007, however, Barrett announced the Tri-State project no longer fit its portfolio. Later, Berry sold its Niobrara properties in the D-J Basin.

That does not mean Barrett gave up on the Niobrara. According to IHS Energy, the company still has activity in Platte and Laramie counties in southeastern Wyoming and in Natrona County in the Wind River Basin in central Wyoming.

In a November 2010 presentation, the company said it spud a horizontal well to test the Niobrara at its McRae Gap prospect where it holds 130,000 gross, 111,265 net, acres in the Niobrara fairway.

That prospect has more than 300 ft of net pay in the Niobrara in some places. The formation lies between 4,000 and 14,000 ft deep, and the test well was scheduled to 8,200 ft.

According to Barrett, the prospect should yield oil similar to Niobrara production in the southern Powder River Basin. The McRae Gap area also has potential in the Meeteetse, Mowry, Frontier, and Muddy formations as secondary targets.

This is not new territory for Barrett. The area lies south of Barrett's Cave Gulch discovery, and the company already has some 18 MMcfge/d in production from Wind River Basin properties.

Barrett has pioneered in unconventional coalbed methane, tight gas, and shale plays throughout Colorado and Wyoming.

Black Raven Energy Inc.

- *Gross acres: 178,000*
- *Could get Chevron as a partner*

Black Raven Energy Inc., formerly PRB Energy Inc., holds properties with Niobrara potential in Sedgwick and Phillips counties in Colorado and in Chase, Dundy, and Perkins counties in Nebraska.

Those properties totaled 178,000 net acres at the end of 2009.

In 2010, Black Raven signed a farm-out agreement with Atlas Resources Inc., a subsidiary of Atlas Energy Inc., designating the properties in an area of mutual interest.

Under that agreement, Atlas paid Black Raven US $1 million and agreed to pay a $60,000 wellsite fee to help Black Raven recover sunk costs in the area. Atlas drilled the first six obligatory wells and paid those fees by the end of September 2010, according to Black Raven's 3Q 2010 report filed in November 2010.

Atlas also agreed to upgrade existing field facilities in the area of mutual interest and shoot 3-D seismic to choose drilling locations.

The agreement also allows Atlas to drill an additional 60 wells during the agreement period. The agreement can be extended in six-month increments after April 30, 2011. If Atlas chooses not to drill 60 wells in each period, Black Raven has the option of drilling for its own account the difference between the wells Atlas drills and the 60 contract wells.

Chevron Corp. acquired Atlas for $4.3 billion in February 2011. That deal could put Chevron into the Niobrara play, but Chevron probably is more interested in the extensive Atlas holding in property and infrastructure in the Marcellus play in the Appalachian Basin.

Bonanza Creek Energy Co.

- *Net acres: 69,463*
- *Works the North Park and D-J basins.*

Denver-based Bonanza Creek Energy Co. operates in Arkansas, California, and the Denver-Julesburg (D-J) and North Park basins of Colorado.

The company began its growth spurt in 2006 with a capital injection of US $120 million from D.E. Shaw & Co., and grew production from 200 boe/d to a current 3,160 boe/d from its three basins.

Those operations include a substantial position in the Niobrara Shale in McCallum Field in the North Park Basin and in the Rex and North Riverside areas of Wattenberg Field in the D-J Basin.

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CUDD ENERGY SERVICES

Currently, it holds 69,463 net acres with 338 net drilling locations and produces 1,240 boe/d from 5.9 MMboe in proved reserves.

Its operating subsidiary, Bonanza Creek Energy Operating Co., invests between $25 million and $75 million a year to drill 40 to 90 wells.

It invested $1 million on one vertical Niobrara well in the North Park Basin in 2010 and plans two vertical wells in 2011. It did not drill any horizontal wells, but plans to drill four of them in the D-J Basin in 2011 at a cost of $4 million.

The Niobrara is not the only potential target. Bonanza Creek also can look for production from the Codell and Dakota J Sand in eastern Colorado and from the Lakota/Dakota and Pierre B in northern Colorado.

According to a company presentation, some of its D-J Basin properties lie within a mile of properties that drew between $2,400 and $2,650/acre in recent bidding.

NIOBRARA DEVELOPMENT SCENARIO

	North Park Vertical	North Park & D-J Horizontal
Total Resource		
Gross EUR (Mboe)	48	263
% Oil	77%	88%
Locations	450	50
Type Curve Parameters		
30-day IP (boe/d)	61	302
First year decline	59%	77%
Terminal decline	13%	11%
Life (years)	16	33
Economics		
Capex ($M)	600	3,000
LOE ($/boe)	7.04	2.75
Realized oil price	83%	83%
Realized gas price	100%	100%
Royalty	15%	17%
Results		
PV10 ($M)	929	4,890
IRR	128%	81%
F&D ($/boe)	14.85	13.66

IRR based on flat $80/bbl of oil and $6.67/Mcf of gas. Assumes 12:1 oil-to-gas price ratio.

Bonanza set down parameters and economics for Niobrara vertical and horizontal wells in the Denver and North Park basins. *(Table courtesy of Bonanza Creek Energy Co.)*

Carrizo Oil and Gas Inc.

- *Net acres: 59,000*
- *Plans 5,000-ft laterals with 15 frac stages*

Carrizo Oil and Gas Inc. only recently added the Niobrara Shale to its portfolio of shale operations across the US.

According to a December 2010 presentation, net acreage positions include 47,000 in the Barnett in the Fort Worth Basin; 111,290 in the Marcellus Shale; 58,000 in the Marfa Basin of West Texas; 26,000 in the Fayetteville Shale; 20,000 in the Eagle Ford Shale; and 59,000 acres in the Niobrara Shale.

All Niobrara acreage lies in the heart of the play in Weld County in the Denver-Julesburg Basin of northeastern Colorado.

The company planned US $7 million in spending for drilling in the Niobrara in 2010 out of a total company drilling budget of $167 million. It planned to spend another $60 million in land and seismic acquisition divided between the Niobrara and Eagle Ford plays in 2010, a sharp increase from the $2 million it spent on both plays the previous year.

EXPECTATIONS

Carrizo has high expectations for the Niobrara. In its presentation, it quoted Noble Energy Inc. estimates of 500,000 boe in reserves for a horizontal well in Wattenberg Field.

The company also did its homework on financial expectations. Assuming a $3.5 million horizontal well with 240,000 boe in net reserves, it planned on finding and development costs of $14.58/boe. With an $80/bbl oil price on the New York Mercantile Exchange, it anticipated a 139% internal rate of return. That return dropped to 88% with $70 oil and 58% with $60 oil. The undiscounted payout period with $70 oil was 1.3 years.

On the operational side, the company planned wells with 5,000-ft laterals and approximately 15 frac stages. A well that showed an

initial production rate of 800 boe/d should drop to 250 boe/d after six months, 150 boe/d after a year, 100 boe/d after 18 months, and continue a shallow decline thereafter, according to Carrizo's calculations.

It dropped its first bit into the ground on the State 16-11-9-60H well in 3Q 2010. In its 3Q 2010 report, released in December, it said it expected flowback that month. By that time, Carrizo had completed the horizontal leg and set production casing on its second well, the Bob White 36-44-8-62H, and planned stimulation in January 2011. The company also was moving the drilling rig on location for its third 2010 well.

Chesapeake Energy Corp.

- *Net acres: 800,000*
- *Signed up CNOOC for a one-third interest*

Chesapeake Energy Corp. reinforced its dominant position in US shale plays as it entered the Niobrara liquids-rich play in 4Q 2008.

Since that time, the company has grown into the biggest land holder in the play, with approximately 800,000 acres split almost equally between the Powder River Basin in northeastern Wyoming and the Denver-Julesburg (D-J) Basin in northeastern Colorado and southeastern Wyoming.

That acreage includes the Frontier Formation, which underlies the Niobrara in the Powder River Basin, and the Codell Formation, which underlies the Niobrara in the D-J Basin.

The position lines up with Chesapeake's standing in the oil and gas industry.

The company is the top driller in the US with 150 operated and 113 non-operated rigs working, and has drilled nearly 11,000 wells in the past 20 years, according to its January 2011 presentation.

The 4,000 horizontal wells drilled in the past 20 years make Chesapeake the top horizontal driller in the world. It also is the world's top horizontal shale drilling company, with approximately 3,100 wells drilled in the past decade.

A rig drills to the Niobrara in the Converse County section of the Powder River Basin in northeastern Wyoming. *(Photo courtesy of Chesapeake Energy Corp.)*

It is the top-ranked owner of shale gas, with approximately 142 Tcfge of unrisked net unproved resources.

SHALE LEADER

In the 18 months leading to December 2010, Chesapeake captured leading positions in five of the six best unconventional oil plays in the nation:

- Number two in the Eagle Ford with 425,000 net acres and 2.4 Bboe in unrisked, unproved resources;
- Number one in the Anadarko Basin with one million net acres and 3.8 Bboe of unrisked, unproved resources; and
- Number one in Permian Basin unconventional oil with 675,000 net acres and 1.9 Bboe of unrisked, unproved resources.

The company also is number one in an as-yet unnamed liquids-rich play with 1.2 million acres. It plans to announce details on that play in 2011.

The fifth liquids play is the Niobrara, where its 800,000 acres hold an estimated 4.5 Bboe in unrisked, unproved resources.

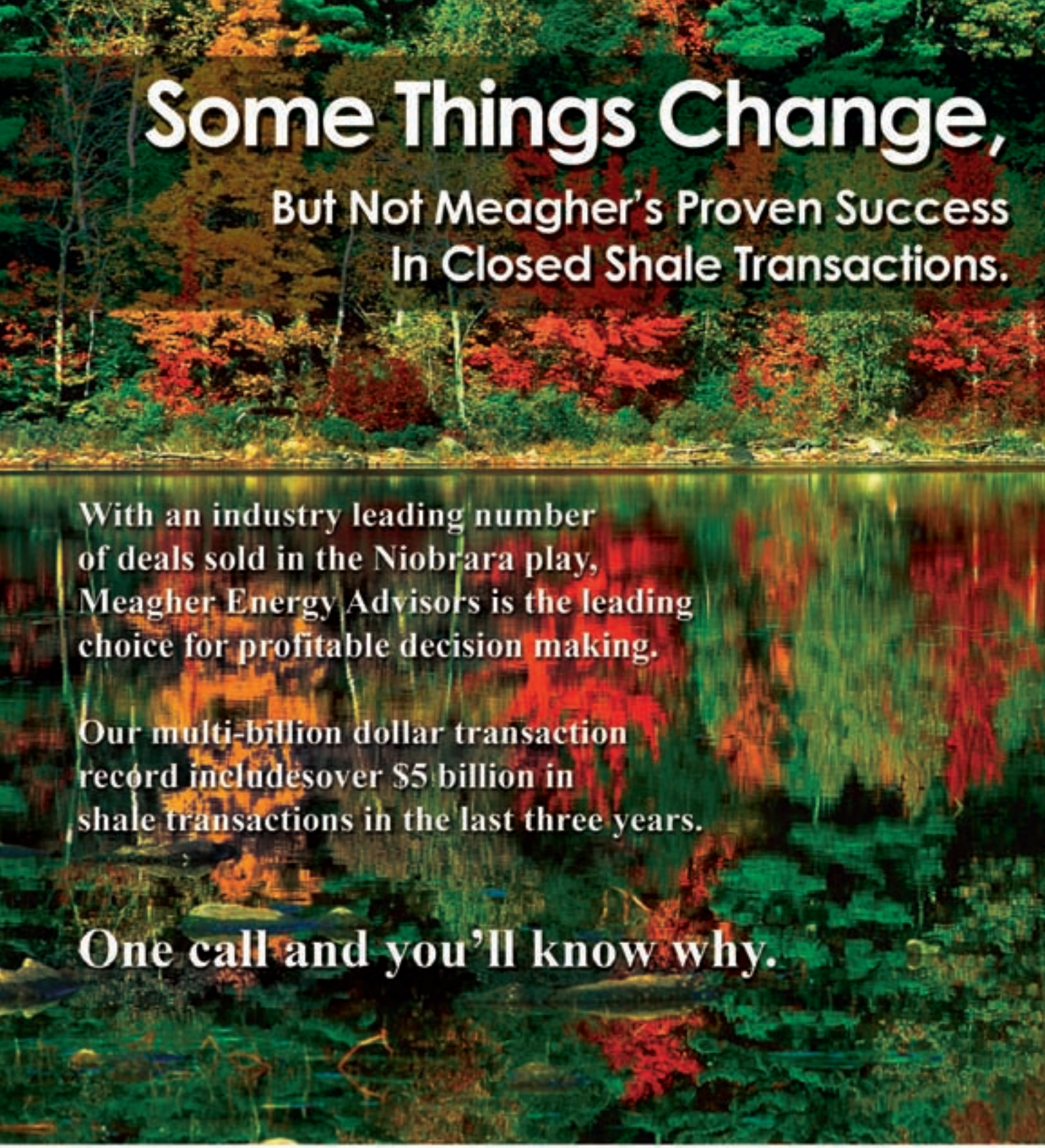
At the end of January 2011, Chesapeake said it signed an agreement in which China's CNOOC Ltd. would take a 33.3% interest in Chesapeake's properties with Niobrara potential in the D-J Basin in Colorado and Wyoming and the Powder River Basin in Wyoming for US $570 million at closing. Although Chesapeake will remain the operator, CNOOC also will carry two-thirds of the drilling expenses for the partners until payments reach $697 million, probably by the end of 2014.

The Chinese company also got an option to pick up a one-third share of any additional acreage resulting from production from the properties.

That is the same system Chesapeake has used on other major unconventional plays as it brought in Total in the Barnett, BP in the Fayetteville, Plains Exploration in the Haynesville and Bossier, Statoil in the Marcellus, and CNOOC in the Eagle Ford plays.

Regarding the Niobrara agreement, Fu Chengyu, chairman of CNOOC, said, "It is a great pleasure to establish further cooperation with Chesapeake in shale oil and gas development. The project highlights the joint interests of energy companies in both US and China to accelerate the development of shale oil and gas, increase energy supply, and reduce greenhouse gas emissions. We believe this project is meant to be mutually beneficial to both parties as well as for both Sino-US energy industries."

Chesapeake CEO Aubrey K. McClendon added, "We are very pleased to announce our sixth industry development agreement and our second transaction with CNOOC Ltd., China's largest producer of offshore oil and natural gas and one of the largest independent oil and gas companies in the world. This transaction will provide the capital necessary to accelerate drilling of this large domestic oil and natural gas resource, resulting in a reduction of our country's oil



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NIOBRARA STANDING

In the Niobrara play, Chesapeake has an average 20% royalty with room for an unrisked net 11,100 undrilled wells with unrisked, unproved resources of up to 5 Bboe, after deducting the 20% royalty, according to the company.

By the end of January 2011, Chesapeake had operated 16 producing wells in the D-J and Powder River basins, with initial production rates up to 1,000 b/d of oil and 3 MMcf/d of gas. In the Powder River Basin, its State 16-1H in the Spillman Draw Unit tested for 300 Mcf/d of gas and 655 b/d of oil, or 705 boe/d, from a horizontal Niobrara section in Converse County, Wyo.

Also in Converse County, its Wagonhound 23-1H horizontal Frontier well tested for 1 MMcf/d of gas and 1,064 b/d of oil, or 1,230 boe/d.

It also staked a remote horizontal wildcat to Niobrara about eight miles east-southeast of Chugwater in Platte County, Wyo., with plans to drill the State 20-65-16-1H with a lateral to the south. The well is approximately 24 miles west of Niobrara production in Silo Field, according to IHS Inc. Chesapeake expected to find the Niobrara at a true vertical depth of 8,408 ft.

At the end of January 2011, the company was running five drilling rigs in the Niobrara play and planned to raise that number to approximately 10 by the end of 2011 and as many as 20 rigs by the end of 2012 with the help of the CNOOC cash infusion.

Cirque Resources LP

- *Gross acres: 1.22 million, 481,000 in the Niobrara*
- *Will participate in 10 to 12 Niobrara wells in 2011*

Privately held Cirque Resources LP focused its E&P activity on company-building oil resource plays in the Rocky Mountains immediately after its formation in mid-2007, with evaluation of prospects in the Bakken, Heath, and Mowry formations, in addition to the Niobrara, according to an August 2010 article in *Oil and Gas Investor* magazine.

Since mid-2007, the company leased approximately 1.22 million net acres of land, largely in oil resources projects, and currently retains 500,000 net acres after bringing in partners.

The Bakken and Niobrara plays were obvious winners in the evaluation contest. "The Niobrara was an easy sell for me because I had worked it in the late 1980s and early 1990s at Exxon," said Cirque president and CEO Peter Dea. In those days, Union Pacific Resources Corp. found Niobrara oil in Silo Field in a naturally fractured area of southeastern Wyoming, but the natural fractures were not widespread.

Multistage frac jobs in horizontal laterals made a difference in the economics, and Cirque looked for Niobrara potential to leverage evolving technology that worked in the Bakken and other shale gas plays. Cirque enjoyed first-mover advantage as it assembled 481,000 net acres in two areas with Niobrara potential, including 306,000 acres in the northern Denver-Julesburg (D-J) Basin. The company assembled much of that land early in the play before prices soared above US $3,000/acre.

With 231,000 retained net acres, Cirque remains one of the top Niobrara leaseholders after bringing in Noble Energy Inc. as a 55% partner in the D-J Basin properties. Noble Energy already was the biggest producer in the basin.

Cirque has not disclosed the location of the remaining 175,000 acres. Overall, in 2011, the company plans to drill 10 to 12 exploratory tests in seven oil resource projects in addition to participating in 10 to 12 Niobrara wells in the D-J Basin.

That activity meshes with Cirque's strategy, which is to identify company-building oil resource plays based on geology and engineering, assemble large positions of contiguous long-term leases, manage the company's risk exposure by attracting industry partners, participate in exploration and early development, and monetize its position before major capital investments are required to substantially develop successful projects.

Comet Ridge Resources LLC

- *Net acres: 11,670*
- *Working the second oldest oil field in the US*

Comet Ridge Resources LLC plans to use modern E&P techniques to tap the Pierre Shale segment of the Niobrara Formation in Florence Field, the second oldest oil field in the US.

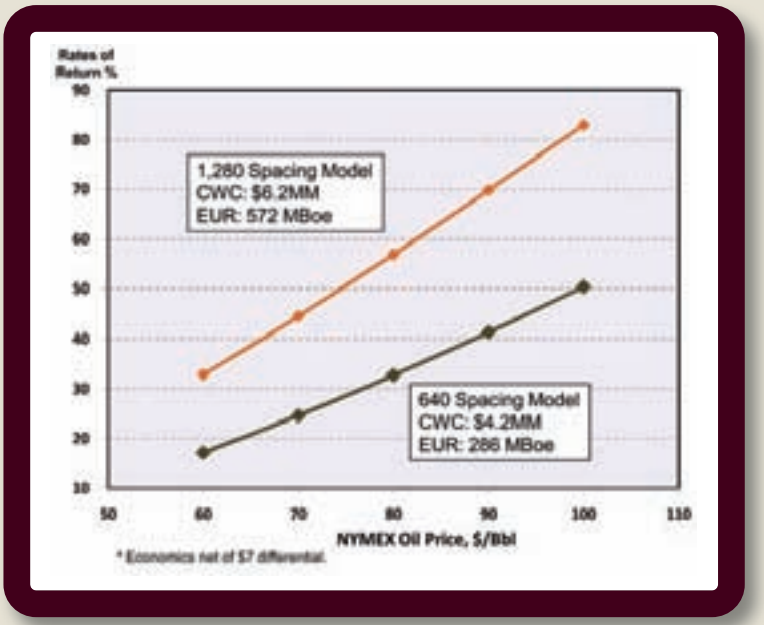
Comet Ridge is a joint venture (JV) with Denver-based Pine Brook Road Partners LLC and Brisbane, Australia-based Comet Ridge Ltd.

Comet Ridge Resources subsidiary Pine Ridge Oil & Gas LLC is the operator of the JV's Florence project near the city of Florence in southeastern Colorado. That was the second oil field in the US.

Pine Ridge holds a 97.25% interest in more than 12,000 acres in the field that has produced more than 15 MMbbl of oil in the past 126 years. The field historically has produced from depths between 1,800 and 3,500 ft.

Comet Ridge Ltd. acquired eight sq miles of 3-D seismic in 2007 and generated drillable prospects from that information. Pine Ridge then drilled three vertical wells and produced oil. The company is evaluating that production.

It planned to drill vertical wells in the field, but it could drill horizontal wells at sites where vertical wells are not acceptable.



Horizontal Niobrara wells in Weld County, Colo., offer positive gains at current oil and gas prices. *(Graphic courtesy of Continental Resources Inc.)*

Continental Resources Inc.

- *Net acres: 73,009*
- *Started first 1,280-acre horizontal drilling unit*

Continental Resources Inc., one of the stronger players in the Bakken oil shale play in Montana and North Dakota, is starting operations in the Niobrara play using similar techniques to those that made it a success in the Bakken.

The company's 3Q 2010 update, released in early December, said it holds 73,009 net acres in the Niobrara play, with 28% in Colorado and the remaining 72% in Wyoming. Those leases give the company 228 net potential drilling locations on 320-acre spacing and an unrisked 53 MMboe in potential net resources.

The Wyoming properties are in Goshen, Platte, and Laramie counties, while the Colorado properties are in Weld County, northeast of Wattenberg Field, not far from the Wyoming border.

PUMP HOUSE PROJECT

The key prospect in Continental's portfolio is its Pump House project in Weld County where it holds 14,400 net acres.

The company planned to acquire approximately 80 sq miles of 3-D seismic in the area, and it planned to drill the first horizontal well in the basin on 1,280-acre spacing in January 2011, a technique that should yield higher returns.

Continental estimated a cost of US $4.2 million to drill and complete horizontal wells on 640-acre spacing and $6.2 million to drill and complete horizontal wells on 1,280-acre spacing. The 640-acre wells would offer an ultimate recovery of 286,000 boe, while the 1,280-acre wells would yield 572,000 boe.

At $80 oil, the more tightly spaced wells would return about 32%, while the longer-lateral wells would offer about 58%.

An IHS Inc. report said the 1-9H Newton well in Keota Field is about 16 miles southeast of EOG Resources Inc.'s landmark Hereford Field Jake well. It was proposed as a 15,232-ft horizontal well, including the 9,200-ft lateral.

"If the results of the 1-9H Newton go as planned, we expect to spud additional Niobrara wells early in

the second quarter next year," said Harold Hamm, Continental chairman and CEO.

Double Eagle Petroleum Co.

- *Net acres: 70,000*
- *Holds non-operated acreage in Atlantic Rim Field*

Double Eagle Petroleum Co. had no Niobrara production early in 2011, but it held land with Niobrara potential and revealed plans to drill between one and six wells in the formation during 2011.

The Niobrara potential lies in the company's non-operated acreage in the massive Atlantic Rim Field in the Carbon County section of the Washakie Basin in southern Wyoming.

Most of the company's 2% oil and gas production increase — to 2.3 Bcfge in 3Q 2010 — came from that field.

The company also purchased additional working interests to raise its share of the Sun Dog Unit in the field from 8.89% to 21.54%.

Double Eagle could participate in up to 75 development wells and six exploratory wells during 2011, and one to six of those wells could aim at the Niobrara, the company said in its 2011 drilling plan. It holds approximately 94,000 gross, 70,000 net, acres with Niobrara potential, including 60,000 gross, 37,000 net, acres within Atlantic Rim.

Encana Corp.

- *Net acres in Piceance Basin: 610,000*
- *Determined 80 Niobrara drilling locations*

Encana Corp. prides itself on its scientific approach to technical innovation and operational efficiencies to make the company a high-volume, low-cost producer of natural gas with operations throughout North America.

According to the Calgary, Alberta, Canada, company's website, "Our strategic focus... is sharpened on what we do best: the successful exploration and development of unconventional natural gas – an abundant, affordable, and clean source of energy for generations to come."

In 2010, the company set a goal to double production on a per-share basis in the next five years, and its Niobrara holdings in the Piceance Basin of western Colorado are a part of that plan.

Overall, the company holds approximately 12.7 million acres of land containing 12.8 Tcfge of proved reserves that produced approximately 3.3 Bcfge/d during 2010.

In a 2010 investor presentation, Encana described its Piceance operations, which currently produce primarily from the Williams Fork tight sand.

The company entered the basin in 2001 when it acquired Mamm Creek Field and added to the position with the acquisition of Tom Brown Inc. in 2004.

Between 2005 and 2010, production grew from 325 to 440 MMcfge/d.

NIOBRARA POTENTIAL

The Tom Brown acquisition also put the company into the Niobrara play in the basin. It now holds approximately 800,000 net acres in the basin with approximately 480,000 acres prospective in the Niobrara.

According to Encana, throughout the basin, the Niobrara holds between 125 and 175 Bcf of gas per section. Wells come in at 9,000 ft vertical depth. The basin holds an estimated 100 Tcfge in place.

Encana currently holds 80 net Niobrara drilling locations in its inventory, and it anticipated initial potential production of 6 MMcfge/d from those wells.

According to IHS Energy, the company staked the 1-10H Kyne Federal horizontal well to the Niobrara in Plateau Field in Mesa County in western Colorado in 2008, but later abandoned the location.

GAS FACTORY

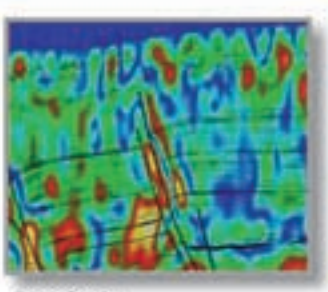
Darrin Henke, vice president of the South Rockies Business Unit, described the company's path to efficient production in the Piceance Basin with its North Parachute Ranch gas factory approach.

It uses up to 52-well pads with horizontal drilling. The pads take up only 4.2 acres and host fit-for-purpose rigs with self-skidding systems, top drives, and closed-loop mud systems. They contain nine production meter houses and three gas-lift meter houses. There are no tanks, separators, trucks, or vapors.

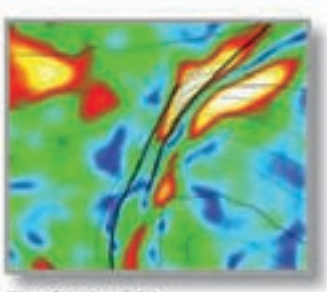
Encana pipes production to the Middle Fork Central Facility, which takes care of gas dehydration and compression, condensate treatment and stor-

Real World Collaboration

Real World Results



Cross Section



Time (Horizon) Slice

Seismic attribute analysis enabled the interpreter to better understand the interplay of local structure, fracturing and stresses.

ION optimizes productivity in the Niobrara shale

The Niobrara play with its rugged terrain, environmental sensitivities, structurally complex geology and fractured shale reservoir exemplifies the unique operational and imaging challenges often found in unconventional reservoirs. For one E&P operator looking to optimize the location of horizontal wells and their associated hydraulic fracturing designs, ION conducted a new wide-azimuth seismic survey that combined ION's expert survey design and planning, data acquisition using the FireFly® cableless system and VectorSeis® sensors, and data processing using GX Technology's AZIM/OVT PreSTM technology. As a result, the client was able to quickly and efficiently locate and complete three new horizontal wells that resulted in a 5-10x increase in productivity relative to previous wells in the area. Stories like these abound at ION. Find out what real collaboration feels like. iongeo.com/collaboration

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age, vapor recovery, production management and sales, and water treatment and storage.

Dry gas moves by pipeline 15 miles to a sales line; condensate leaves by truck. Water comes in from other operations as well as the Colorado River, and water that is not recycled moves 20 miles by pipeline to injection facilities.

From an environmental point of view, that operation has reduced truck trips by more than 50,000 per year, and Encana recycles 90% of its produced water.

At the same time, the company's well costs, through tie-in to the gathering system, dropped from US $2.53 million in 2005 to $1.9 million in 2010. Drilling cycle time fell from 26 days to eight days, and 30-day initial production rose from 1.25 to 1.85 MMcf/d of gas. Its 2009 finding and development cost was $0.58/Mcfge.

Encana has spent $750 million on its Piceance Basin developments since 2006, and has committed another $370 million from third-party farm-outs and joint ventures.

Entek Energy Ltd.

- *Holds Sand Wash Basin properties*
- *Started active drilling campaign*

Entek Energy Ltd. of Perth, Australia, is working the Niobrara play through its Entek GRB (Green River Basin) LLC affiliate. In a press release, the company said it acidized and perforated the Butter Lake 32-10 well for an early flow of 25 b/d of oil and 30 Mcf/d of gas, with an anticipation that rates will increase as the well cleans up. The company was working on the solution of technical issues that inhibited hydrocarbon flow from the well.

Entek had perforated only 70 ft of the 370-ft potentially productive zone of the Niobrara.

At its Battle Mountain 14-15A well, the company found an early flow of 12 b/d of oil and had not yet measured gas flow from the apparently damaged well bore. The well showed strong oil and gas indications while drilling. The Robidoux 13-15T well also showed poor hole conditions.

Entek's Focus Ranch 12-1 well flow tested 240 b/d of oil and 2.75 MMcf/d of gas from the Niobrara. That well offered proved reserves of 233,699 bbl of oil and condensate and 2.1 Bcf of gas with probable reserves of 14,439 bbl of oil and condensate and 25 Mcf of gas.

Total proved reserves for that well and eight direct offsets are 2.1 MMbbl of oil and 19 Bcf of gas.

The company also noted the Niobrara in the Sand Wash Basin (at more than 1,000 ft including the Carlile) is three times thicker than the formation in the Denver-Julesburg Basin. Geology in the Sand Wash Basin shows 68 MMbbl of oil in place per section, or 2.7 to 5.8 MMbbl of recoverable oil where igneous sill reservoirs are present.

EOG Resources Inc.

- *Net acres: 340,000*
- *Started Niobrara development rush with Jake well*

EOG Resources Inc. lights up liquids-rich hydrocarbon plays in the US. It flipped the switch to turn on the Barnett Combo play northwest of the Barnett Shale gas play in the Fort Worth Basin of Texas, and it lit off a land and drilling rush in the Niobrara play in the Rocky Mountains.

It also has major positions in the Eagle Ford, Bakken, and Leonard (Avalon) liquids shale plays.

The company's spotlight well in the Rockies was the Jake 2-01H horizontal well in Weld County in the Denver-Julesburg Basin in northeastern Colorado. That well came in at 1,558 b/d of oil from the Niobrara.

EOG also recorded 730 b/d of oil from the Elmer 8-31H and 1,100 b/d of initial oil potential from the Red Poll 10-16H, according to a December 2010 presentation.

East of the Jake landmark well, EOG recently tested two Critter Creek wells on managed restricted rates of 690 b/d of oil from the 5-10H and 748 b/d of oil from the 9-15H.

NIOBRARA ACTIVITY

EOG holds 340,000 net acres of land with Niobrara potential. Early in 2010, it had permitted, completed, or was drilling wells in Weld County in northeastern Colorado; Jackson County in western Colorado; and Campbell, Converse, Goshen, Laramie, and Platte counties in southeastern Wyoming. The company was only concentrating on 100,000 acres of those properties.

Staking our ground in Colorado's Niobrara

With ~30,000 net acres of high potential leasehold

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Privately owned, established 1927
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EOG said it has not yet determined the ultimate recovery expected from the Niobrara properties, but it is concentrating on monitoring production history with three rigs operating in the play.

A typical EOG well in Weld County offers 82% oil, 12% natural gas liquids, and 6% gas.

An October-November activity report by IHS Inc. said EOG had completed five additional horizontal wells in its Hereford Field area, which it opened with the Jake discovery about nine miles northwest of Grover, Colo. Those new wells produced at initial rates up to 299 b/d of oil from fractured laterals on single-section spacing.

Those wells lie west, southwest, and south of the Jake well, also in Hereford Field, which produced 14,156 bbl of oil and 2.94 MMcf of gas in eight days in October 2009 before the company choked it back to 247 b/d of oil, 174 Mcf/d of gas, and 175 b/d of water from fractures between 7,591 and 11,185 ft. The field produced 50,000 bbl of oil in the first 90 days online.

The choked-back Jake discovery produced 78,599 bbl of oil, 47.3 MMcf of gas, and 21,201 bbl of water from the time it went online in October 2009 through August 2010. August production was 108 b/d of oil, 87 Mcf/d of gas, and 20 b/d of water.

TWO-SECTION LATERALS

EOG planned a new twist in the Hereford Field where it has drilled on 640-acre spacing. The company asked the Colorado Oil and Gas Conservation Commission for permission to drill horizontal wells on 1,280-acre spacing on three proposed units.

According to IHS Inc., the company said, based on geological studies and previously drilled wells, the longer laterals of the two-section wells might produce economic volumes of oil.

Those wells raised Hereford Field activity to 10 horizontal wells, but the Colorado Oil and Gas Conservation Commission approved 58 approximate 640-acre spacing units for the Niobrara in the area.

In Platte County, Wyo., EOG scheduled five horizontal Niobrara wildcats on its Black Bear, Klondike, and Bruin leases, according to IHS Inc., but no activity had been reported on the leases. Those leases are generally west and southwest of Chesapeake Energy Corp. activity in southwestern Goshen County, Wyo.

Earlier in 2010, EOG drilled three exploratory wells in Goshen County – the 05-34H Silvertip, 06-34M Silvertip, and 16-35H Panda – but it did not release details on the wells.

The company had proposed a southeast lateral on the 05-34H Silvertip to a measured depth of 13,656 ft and a true vertical depth of 8,410 ft. That well was mapped to pass by the 06-34M Silvertip vertical well drilled as a fracturing monitor well. It planned the Panda well to 13,734 ft measured depth and a true vertical depth of 8,214 ft.

NORTH PARK BASIN

EOG also opened the Eclipse Field in the North Park Basin in late 2007 when it completed the 1-32H Buffalo Ditch well for 550 b/d of oil, 402 Mcf/d of gas, and 552 b/d of load water. According to IHS Inc., that well was completed with a multistage frac job in a horizontal interval between 8,550 and 11,543 ft. True vertical depth was 7,415 ft.

Through August 2010, Eclipse Field produced 105,863 bbl of oil, 137.8 MMcf of gas, and 88,265 bbl of water from the Niobrara. The two active wells in the field produced 770 bbl of oil, 2 MMcf of gas, and 412 bbl of water in August.

EOG staked 12 more horizontal Niobrara locations in the field.

Gulfport Energy Corp.

- *Net acres: 24,468*
- *Active 3-D seismic program in progress*

Gulfport Energy Corp. holds proven reserves in the Niobrara and put together a comprehensive plan for development of its most promising prospect in western Colorado.

In a January 2011 presentation, the company said it had 24,468 net acres of Niobrara properties and 900,000 boe in proven reserves from a recent acquisition. Company-wide proved reserves amount to 20.8 MMboe.

Properties in the Niobrara include 23 gross proved undeveloped locations and three producing wells and existing well control. Gulfport-operated Niobrara land contains between 75 and 150 MMboe of original oil in place per section.

The company's properties lie in the Piceance and Sand Wash basins of western Colorado, generally

near the uplift that separates the basins, according to the presentation.

Gulfport plans to complete a 60-sq-mile 3-D seismic acquisition program in the area of its Craig Dome Field in the first half of 2011, interpret the seismic and identify locations in 3Q 2011, and drill three to five vertical wells in 4Q 2011.

In all, the company allotted between US $1 million and $2 million in capital expenditures to its Niobrara program for 2011.

The company estimates a cost of $1.4 million per vertical well to get an average ultimate recovery of 120,000 boe per well.

Initially, it will focus on Craig Dome Field in the Sand Wash Basin where one vertical well drilled and completed with a slotted liner produced a cumulative 262,000 bbl of oil and 208 MMcf of gas. A 2007 well, completed open hole and unstimulated, has an estimated ultimate recovery (EUR) of 103,000 bbl of oil, and a 2009 well completed the same way has an EUR of 143,000 bbl of oil.

Gulfport holds 8,630 gross, 4,315 net, acres in the field with 11 Niobrara penetrations for well control. At the beginning of 2011, the company had two drilling permits in hand and 23 proved undeveloped drilling locations.

Historic recoveries in the area range from 0.01% to 1.1% of original oil in place with an average recovery of 0.12%. Gulfport figures it can improve those recoveries with horizontal drilling and modern fracture treatments. A one percentage point increase in recoveries would increase recoverable resources to 750,000 boe to 1.5 MMboe per section, the company added.

Lario Oil & Gas Co.

- *Net acres: 30,000*
- *Ramping toward Niobrara development*

Lario Oil & Gas Co. – privately held Wichita, Kan., and Denver, Colo., independent – moved the Niobrara into the high-priority section of the company portfolio as it assembled 30,000 acres of leases in the

Denver-Julesburg Basin east of Denver and south of Denver International Airport.

The company's holdings include properties in South Texas, the Permian Basin in West Texas and New Mexico, the Greater Green River Basin in Colorado and Wyoming, the Arkoma Basin of Oklahoma, the Sacramento Basin in California, and Alberta and Saskatchewan in Canada. It lists its high-priority areas as vertical drilling in western Kansas and horizontal drilling in both the Williston Basin in Montana and North Dakota and the Niobrara play in Colorado.

Lario chooses projects with opportunity for organic growth, low risk, and low finding and development costs, particularly those projects that lend themselves to development with 3-D seismic analysis and horizontal drilling and advanced fracturing techniques. That combination means a large part of the company's inventory lies in unconventional resources, according to its website.

Lario's top liquid play is the Bakken/Three Forks in Montana and North Dakota, where it holds approximately 194,500 net acres and interests in 375 horizontal Bakken wells drilled since 2007. Those wells currently produce a net 3,200 b/d of oil.

Lario plans to bring that Bakken/Three Forks experience to its second top liquids play, the Niobrara in Arapahoe County, Colo.

The company is working off the Bakken model and an updip thermal maturity trap like the Parshall Field, the most prolific field in the Bakken play.

It has mapped wells near its properties, including a vertical Niobrara producer, and collected resistivity anomalies and other data to find its prospective core area. The company was able to assemble a concentrated block of acreage before competition forced land prices higher than US $3,000/acre.

Lario also contracted geochemical and petrophysical workups for the area to support its expectations and planned a proprietary aeromagnetic survey in 1Q 2011.

The company has conducted groundwater studies and started survey operations for a 3-D seismic acquisition program in 2Q 2011.

If the area continues to look promising, Lario said it plans to drill its first vertical "science" well, including continuous cores and advanced openhole logs in 3Q 2011. The company will use that well for pump-in testing and microseismic monitoring on nearby horizontal wells. It plans to spud that vertical well in 3Q 2011 and move to a full development plan with the start of a development program in 2Q 2012.

Lario also was one of the first companies to join a Niobrara consortium formed at the Colorado School of Mines. That effort will support operations of producers working the Niobrara and serve as an instruction tool for the school's engineering and geology students in both the Niobrara play and in liquids-rich shales in general.

Marathon Oil Co.

- *Net acres: 175,000*
- *Will drill first wells in 2011*

Marathon Oil Co. entered the Niobrara Shale play in a big way as it acquired 120,000 net acres of leases in the potentially new unconventional oil play in the Denver-Julesburg (D-J) Basin in 2010.

In a 3Q 2010 report, the company said it acquired properties in the D-J Basin in northeastern Colorado and southeastern Wyoming and expected to begin drilling in 2011.

The company projected that those 120,000 acres hold estimated net resource of approximately 125 to 175 MMboe which should support 600 net wells with an estimated ultimate recovery of up to 250,000 boe per well, Marathon said in a 3Q presentation.

By January 2011, Marathon had increased its leases to 175,000 net acres. The company also said it is continuing to acquire acreage in the play and plans to leverage its experience from the Bakken play in North Dakota.

ECONOMICS

In a November presentation, a review of industry reports on activity in the D-J Basin shows Niobrara horizontal wells typically cost approximately US $4 million with 30-day initial rates of approximately 260 boe/d.

During a 3Q 2010 conference call, Dave Roberts, executive vice president, upstream, discussed the company's unconventional opportunities in the Niobrara, North Dakota Bakken, and Oklahoma Woodford shales. "As we have said before, one of the

attractions of these unconventional plays is the ability to dial up or dial down activity as needed," he said. "The large and growing number of future locations we list on this map is a great well stock – one that today we are using eight rigs to prosecute (across the three unconventional oil plays), but could expect that number to potentially double in the next two years. And as opportunities remain, our acreage acquisitions continue in all these plays as well as others in North American unconventional liquids.

"We are in many ways transitioning the portfolio – balancing the large projects we have in our international business and those we expect to deliver from impact exploration with repeatable and sustainable unconventional businesses, largely in North America."

MDU Resources Group Inc.

- *Net acres: 66,000*
- *Sold part of its holding to Itochu Corp.*

MDU Resources Group Inc., through its Fidelity Exploration & Production Co. subsidiary, conducted a research and evaluation program on its Niobrara properties in 2010 and planned to drill its first well to the formation in early 2011.

The company acquired 88,000 net acres of land with Niobrara potential in Laramie and Goshen counties in Wyoming. The properties are in three blocks. One block in Laramie County lies southeast of Silo Field, which produces from the Niobrara. Another block is north of the field on the Laramie-Goshen county border. The third property is east of Chesapeake Energy Corp. and Samson Oil & Gas Ltd. properties in Goshen County.

In October 2010, MDU reached an agreement to sell a 25% interest in its Niobrara acreage to JD Rockies Resources Ltd., a subsidiary of Japan's Itochu Corp. That reduced MDU's net position to 66,000 acres. The company did not disclose the sale price.

Fidelity planned to operate the properties using horizontal drilling and staged fracture treatments

similar to those that worked for the company in the Bakken play in the Williston Basin in eastern Montana and western North Dakota and South Dakota.

MDU said the company got into the play with low-cost five-year leases with options for another five-year extension, and its subsidiary will drill its first test wells in 2011.

The company also said it had more than 120 drilling locations on its properties.

Based in Bismarck, N.D., MDU has operations in regulated utilities, energy production, and construction materials and contracting.

Noble Energy Inc.

- *Net acres: 830,000 in the D-J Basin*
- *The Gemini well produced more than 100,000 boe in four months*

Noble Energy Inc. is one of the most active companies in the Denver-Julesburg (D-J) Basin of northeastern Colorado, with a focus on the Niobrara.

According to IHS Inc., the company has permitted, is drilling, or has completed wells in Sherman County, Kan.; Chase, Dundy, and Perkins counties in Nebraska; Adams, Broomfield, Weld, and Yuma counties in Colorado; and Laramie County, Wyo.

The company acquired at least some of the Wyoming properties in a joint-venture agreement with Cirque Resources LP.

Noble Energy picked up much of its central D-J Basin property with the acquisition of Patina Oil & Gas Inc. in 2005 for US $4.9 billion. It acquired another large batch of D-J Basin assets early in 2010 in a $494 million deal with Suncor Energy Inc. subsidiary Petro-Canada Resources (USA) Inc. Noble Energy estimated proved reserves of 53 MMboe (45% liquids) from the Petro-Canada properties. Of the 53 MMboe, 80% was in Wattenberg Field. Those leases added 340,000 net acres to the company's inventory, with more than 1,000 Codell-Niobrara drilling locations in Wattenberg alone. The acquisition brought the company's D-J Basin holdings to 830,000 net acres.

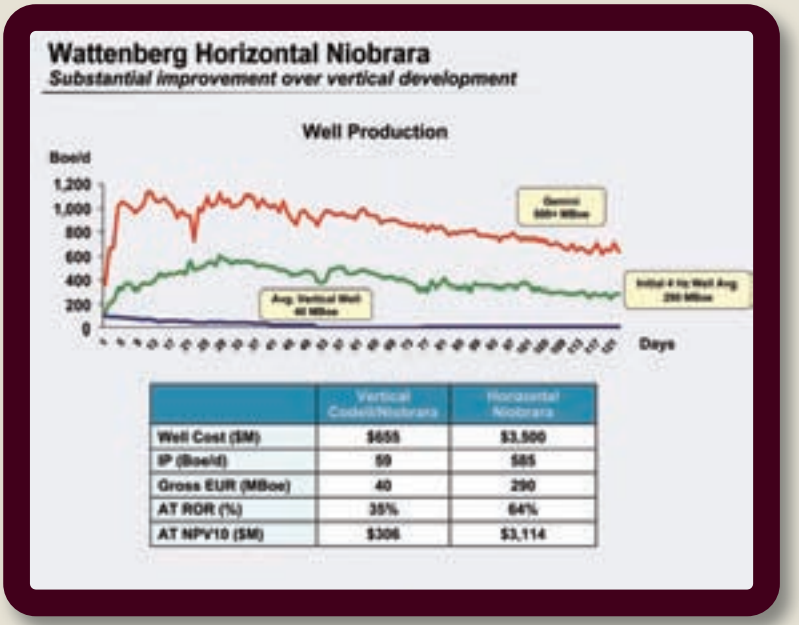
NIOBRARA PLANS

In a September 2010 presentation, Noble Energy said it had plans for the Niobrara Formation in the central D-J Basin at least through 2015, primarily in Wattenberg Field. That field is Noble Energy's largest onshore field and the seventh largest oil and gas field in the US.

The company planned to complete 21 wells on its Wattenberg properties, six more wells in northern Colorado, and three wells in southeast Wyoming during 2010 and drill 60 wells the following year, said Dave Stover, president and COO, in a 3Q 2010 conference call.

Most of the company's production comes from the Codell-Niobrara combination. It produced 53,000 boe/d from all zones in September and raised that number to 55,000 boe/d in December.

Noble Energy had six vertical rigs and two horizontal rigs working in September. It added another horizontal rig by December and planned to add a fourth horizontal rig in 2Q 2011 and a fifth in 3Q 2011.



Even average horizontal wells drilled to the Niobrara in the Denver-Julesburg Basin beat results from traditional vertical wells. Figures assume $80 oil and $5 gas in 2010. *(Graph and table courtesy of Noble Energy Inc.)*

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The company's land position in the central D-J Basin climbed from 750,000 acres in September to 830,000 acres by December. Its net unrisked potential climbed from 1.1 to 1.7 Bboe between September and December.

According to Stover, Noble Energy planned to complete 3-D acquisition of 300 sq miles in the Niobrara play in 2010 and add another 1,000 sq miles in 2011.

GEMINI WELL

By August 2010, Noble Energy had drilled 10 horizontal Niobrara wells. The company's best well, the 01-99HZ Gemini-K well in southwestern Weld County, Colo., produced as much as 1,110 boe/d and more than 100,000 boe in four months. The well continued to produce 600 boe/d at the end of that period.

Noble Energy completed the Gemini well with a 4,000-ft lateral and a 16-stage frac treatment, according to IHS Inc. It drilled the horizontal leg westward to a measured depth of 11,370 ft.

The company said two late-2010 wells produced at initial rates of 580 and 845 boe/d, and 70% to 90% of that production was liquids.

Early results from four horizontal Niobrara wells indicated returns and ultimate recoveries seven times as high as typical vertical Wattenberg wells.

At mid-year 2010, a typical horizontal Niobrara well in Wattenberg could be drilled and completed for $3.5 million, compared with $655,000 for a vertical well. However, a horizontal well had the potential to produce 585 boe/d with an ultimate recovery of 290,000 boe, compared to a vertical well with a potential production rate of 59 boe/d and an ultimate recovery of 40,000 boe.

RESERVOIR CHARACTERISTICS

Reservoir characteristics for the Niobrara show a good matrix contribution from chalks, according to Noble Energy, but production is not limited to natural fractures. The brittle chalk responds well to fracture treatments.

While the Niobrara is the current hot play in the central D-J Basin, Noble Energy has not neglected other opportunities. In November 2010, IHS Inc. said the company completed a Permian Lyons discovery, flowing 68 b/d of oil and 108 b/d of water. The 10-01 Ab Dillard produced from an unstimulated zone between 8,788 and 8,795 ft. The company unsuccessfully tested the deeper Pennsylvanian Virgil in the same well. The Niobrara Formation top lies at 6,715 ft in the same area.

None of the more than 22,000 wells and workovers completed in Wattenberg produces from the Lyons. That formation has produced from only 75 wells in the entire basin.

Petroleum Development Corp.

- *Net acres: 70,000*
- *Beginning horizontal drilling campaign*

Petroleum Development Corp., doing business as PDC Energy, traditionally a gas developer and producer, is swinging toward liquids production with a focus on its Niobrara properties in the Denver-Julesburg (D-J) Basin of northeastern Colorado.

Moving into 2011, the company had 70,000 net acres in the play, and 88% of its total production came from the Rocky Mountain area. During the year, it purchased properties in the Wolfberry play in the Permian Basin and held properties in the Marcellus play in Appalachia.

Approximately 92% of its Wattenberg Field properties in the D-J Basin are held by existing production. By June 2010, PDC had identified prospective horizontal drilling locations offset from wells recently completed by other operators.

ADDING LEASES

PDC added 5,500 acres to its Wattenberg properties with its Krieger acquisition during 2010. That Weld County property is about 10 miles northeast of the company's core area in the field.

The company produced 33 Bcfge from the Rockies during 2010 and had up to four rigs running in the Niobrara play in Wattenberg Field in Colorado.

PDC called 2010 a base year as the company anticipated a new phase of growth.

It started the horizontal Niobrara program in 2010. The company drilled and fractured its first horizontal well on the Krieger acreage during the year, and the well had started flowing back to the well bore. Plans called for additional horizontal wells on the properties in 2011 and 2012.

In November 2010, PDC offered its capital spending and production guidance for 2011. The preliminary spending plan called for an investment of US $260 million to $300 million with $205 million to $240 million of that figure directed toward development drilling, including horizontal Niobrara wells.

"We are encouraged by recently released horizontal Niobrara results in the Wattenberg Field, as well as the results northeast of the field," said Richard W. McCullough, chairman and CEO. "These early results also indicate horizontal potential for sections previously drilled vertically."

Rex Energy Corp.

- *Net acres: 40,000*
- *Horizontal wells permitted and drilled*

State College, Pa.-based Rex Energy Corp. moved into the Niobrara Shale play in the second half of 2010 with the acquisition of 26,900 gross, 18,700 net, acres of prospective land in the Denver-Julesburg (D-J) Basin for US $18.7 million and continued to build on that position.

The company began a drilling campaign near Silo Field in Wyoming shortly after the acquisition.

"I am extremely pleased to be acquiring this acreage in the Niobrara oil fairway in the D-J Basin," said Benjamin W. Hulburt, president and CEO. After this acquisition is closed, Rex Energy will control approximately 11,800 gross, 6,700 net, prospective Niobrara Shale acres in Weld County, Colo., and 48,500 gross, 32,400 net, acres in Laramie County, Wyo.

"Our average acreage cost in the D-J Basin is still relatively low at $600/acre," Hurlburt said at the end of June 2010. "We plan to begin our horizontal Niobrara Shale well drilling program during July 2010.

"Although this play is not yet at the stage where we can update our production guidance through the end of this year and into 2011 to account for the significant new oil asset, we believe our Niobrara position has the potential to be a very significant growth driver for the company."

By the time the company put together a December presentation, it had assembled approximately 56,000 gross, 40,000 net, acres in the play and had one rig running.

By December, Wyoming drilling progress included:

- Silo State 41-22H: recovering load water;
- BJB #1 H: spud planned by year-end 2010; and
- Herrington Farms 1H: drilled, awaiting completion.

Rex Energy completed the Silo State well in southern Silo Field with a 13-stage slickwater frac in late September. The tubing string parted on the well during flowback and had to be repaired. The company expected to put the well on artificial lift, according to its 3Q 2010 report.

The Herrington well, with a 4,300-ft lateral, was the second in the program. That well was 12 miles east of the Silo State well and outside previous Niobrara production. It started oil sales during drilling operations.

Rex Energy has permitted four additional wells in Laramie County.

In describing the play, Rex Energy said the Niobrara in the D-J Basin was a 300-ft-plus source rock with a total organic content of 2% to 10%. It has a strong matrix contribution from high-porosity chalk, and production was influenced by faults and fractures.

The company anticipated well costs between $3.5 million and $4.2 million.

Rosewood Resources Inc.

- *Operating in Niobrara from 2006 through 2010*
- *Active in Kansas and Colorado*

Rosewood Resources Inc. is a longtime player in the Niobrara with discoveries and production from 2006 through 2010 in shallow zones in western Kansas and eastern Colorado.

Rosewood is a privately held subsidiary of The Rosewood Corp., started by Caroline Rose Hunt, daughter of H.L. Hunt.

The company has Niobrara operations in Cheyenne and Sherman counties in Kansas and Kit Carson and Yuma counties in Colorado.

In early 2011, IHS Inc. listed 143 permits, reissues, drilling operations, and completions in the Niobrara for the company.

Wells were completed at depths shallower than 3,000 ft. Kansas wells, mostly in the Goodland Niobrara gas field at approximately 1,500 ft, produced small amounts of gas. Colorado wells were deeper, and some produced both gas and condensate.

The company brought in a new field wildcat in the Niobrara in Kit Carson County with its 33-32 Brenner in 2007. It did not report initial potential figures on a well about 2.5 miles southeast of Bonny Field. The 14-32 S Brenner in Bonny Field, a development well drilled by the company, tested for 267 Mcf/d of gas and 12 b/d of water from perforations at 1,388 to 1,418 ft after a fracture treatment in 2008.

Rosewood also operated Niobrara wells in Whisper, Waverly, Eckland, Armel, Tierra Plano, and Ballyneal fields in Yuma County, Colo.

Royal Dutch Shell plc

- *Net acres: 100,000*
- *Entered with East Resources acquisition*

Royal Dutch Shell plc bought into the Niobrara Shale play in mid-2010 with its US $4.7 billion acquisition of East Resources Inc.

The main target of that acquisition was East Resources' large acreage position in the Marcellus Shale play, focused on Tioga County, Pa. Following the July 2010 acquisition, Shell controlled 700,000 gross acres of Marcellus rights, according to the company's website.

Also, according to the website, "In 2011, Shell will continue to focus Marcellus Shale development in Tioga County, Pa., while exploring other parts of the leased acreage."

East Resources produced 10,000 boe/d from more than 2,500 wells in New York, Pennsylvania, West Virginia, and Colorado at the time of the acquisition. Those wells concentrated on tight hydrocarbon plays.

Overall, the company controlled 1.05 million net acres of land, including 650,000 net acres in the Marcellus play. According to Hart Energy's *Pipeline and Gas Technology* magazine, East Resources also controlled 100,000 net acres in the Niobrara play in Moffat and Routt counties in the Sand Wash Basin of northern Colorado. That basin lies between Shell's Pinedale Anticline properties in southwestern Wyoming and its shale oil play in western Colorado's Piceance Basin.





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INTEGRATED PRODUCTION SERVICES

SAND WASH BASIN

Shell has contacted landowners in the Sand Wash Basin in Moffat County about property acquisitions since the purchase, according to posts on Mineralrightsforum.com.

In December 2009, East Resources staked two horizontal Niobrara wildcats in the Sand Wash Basin, south of Craig, Colo.

The 1-Spring Gulch Unit was proposed for southeastern Moffat County, a half-mile northeast of the abandoned Peck Ditch Field discovery, which logged the top of the Niobrara at 3,700 ft, according to IHS Inc.

The Spring Gulch well also was 3.5 miles northeast of Waddle Creek Field where East Resources planned a development program in the Niobrara with locations staked for several wells.

More than six miles west of that field, East Resources staked a 5,062-ft horizontal Niobrara wildcat at its 2-Castor Gulch Unit. The company also staked a location for the 1-Castor Gulch Unit less than one mile southwest of the 2-Castor Gulch Unit well. The 1-Castor Gulch was proposed as a 5,700-ft wildcat.

Samson Oil & Gas Ltd.

- *Net acres: 16,300*
- *Completed seismic acquisition in Wyoming*

Samson Oil & Gas Ltd., with headquarters in Perth, Australia, saw potential in the Niobrara in 2006; picked up a half interest in 100,000 acres of leases in Goshen County, Wyo.; and now is homing in on acreage with the highest potential.

The company's property is north of Silo Field in Laramie County, Wyo., which produces from horizontal Niobrara wells, according to an article in the August 2010 issue of *Oil and Gas Investor*.

Samson drilled a couple of wells on its Hawk Springs project. The #1 London Flats was a vertical pilot hole and the 1-29H London Flats was the first horizontal well.

The horizontal well, completed at 9,173 ft in 2006, found good shows in the Niobrara in the 2,400-ft lateral, but the well did not meet economic expectations.

The company reached an agreement in June 2010 to sell 24,166 acres of its 40,800 net acres in the play to a large independent. Samson retained 16,300 net acres.

In early 2011, the company completed acquisition of its North Platte 3-D seismic project covering 60.4 sq miles. Samson will identify natural fracture systems in the Niobrara and prospective locations in the Codell, Muddy, Dakota, and Pennsylvanian Des Moines sands. That survey started in November near Lingle in Goshen County.

Slawson Exploration Co. Inc.

- *Net acres: 24,000*
- *A 50-50 JV with Voyager Oil & Gas*

Slawson Exploration Co. Inc. opened operations in the Niobrara play in the Denver-Julesburg Basin of northeastern Colorado after forming a joint venture (JV) with Voyager Oil & Gas Inc.

Since Slawson is privately held, it does not report results, but Voyager is a public company and released its own results from the partnership.

Voyager entered the JV on June 28, 2010, on a heads-up basis for a 50% working interest in Slawson's 48,000-net-acre position in the basin.

In an October update, Voyager said it participated with Slawson in three gross Niobrara wells.

The initial three Weld County wells in the series included:

- Bushwacker 24-11-67: 19-stage frac, US $3 million, low from Niobrara B target;
- Moonshine #1-36H: 19-stage frac, $3.29 million, 20 b/d of oil; and
- Outlaw 1-16H: awaiting completion.

"We are encouraged by what we are seeing as we move east in the lease block with the Moonshine and the Outlaw wells," said J.R. Reger, Voyager CEO. "We are especially encouraged by the drilling and completion costs of approximately $3 million per well. We expect the Niobrara play to continue to evolve and improve. Recent results by other operators in the area are beginning to come in, and the operators are beginning to share data regarding target zone, azimuth (horizontal direction), and completion techniques. The horizontal Niobrara play is in its infancy and we expect the learning curve to be steep."

Subsequent information from Voyager in November said the Moonshine well flowed at a peak rate of 650 b/d of oil and, at that time, was flowing at a rate of 480 b/d of oil without artificial lift.

It still planned to fracture the Outlaw well.

Meanwhile, Slawson set surface casing on 22 additional wells the companies had high-graded from nearby well reports and from its own wells. By setting surface casing, the company extended the leases by a year. It planned to drill those wells during 2011.

SM Energy Inc.

- *Net acres: 25,000*
- *Completed high-volume Wyoming well*

At the end of 2010, SM Energy Inc. completed its first well in the Niobrara Formation, awaited results on the second well, and planned more drilling during 2011.

The company held 25,000 net acres in the play south of Silo Field, a field that has produced for years from horizontal Niobrara wells on a naturally fractured structure in Laramie County, Wyo.

The company's Atlas 1-19H, also in a naturally fractured area, produced 13,000 bbl of oil while drilling. By the end of November, the Atlas well was producing approximately 350 b/d of oil. SM held a 94% interest in that well. Production came online after correcting a treater failure that created an oil spill on the property.

According to an IHS Inc. report, the Atlas well flowed at a seven-day initial rate of 1,075 boe/d and still produced 500 b/d of oil after six months online.

SM drilled the well to about 12,000 ft, including a horizontal lateral of about 4,000 ft. It completed the well with a multistage frac treatment.

SM's prime exploration areas are in the Bakken Shale in North Dakota and the Eagle Ford Shale in South Texas, but it does not plan to neglect the Niobrara. It has set aside US $25 million, or 3% of its $830 million drilling budget for 2011, for the Niobrara and other oil plays. Its Niobrara activity will focus on the area around Silo Field.

Sundance Energy Inc.

- *Net acres: 18,467*
- *Drills and sells portions of properties with potential*

The US-based Sundance Energy Inc. arm of Sundance Energy Australia Ltd. might be a small player in the Niobrara Formation in the Denver-Julesburg (D-J) Basin, but its operating plan generates substantial profits.

The company acquires land in resource plays. It then either operates on its own behalf, or sells portions of its position for high returns.

Sundance purchased its D-J Basin properties for less than US $40/acre, the company said.

Through October 2010, it had drilled the Mary-Jon 13-5D#2 and set production casing to 8,159 ft to test the Codell, Niobrara, and J-Sand zones. It also drilled the Mary-Jon 24-5D#4 and was awaiting fracturing equipment, according to a November 2010 report.

In all, the company planned nine gross, 2.8 net, wells in 2010 at a cost of $2.47 million from its 160 net acres at Mary-Jon, 50 acres at Boomerang, 22 acres at North Washington, 4,965 net acres at Cutthroat, and 13,372 net acres at McElvain. Sundance controlled a total of 18,467 net acres, the company said in an August presentation.

In Wattenberg Field, it planned vertical drilling at a cost of approximately $600,000 per well, with refracs or tri-fracs at a cost of approximately $75,000 per zone. Its plan called for low-risk, low-cost recompletions in behind-pipe zones, primarily the Niobrara.

In mid-2010, Sundance sold a 75% interest in its Twister prospect to Noble Energy Inc. Under the agreement, Noble Energy must drill one commitment well within one year. After that, Sundance can propose wells on the property. The sale to Noble Energy gave Sundance an internal rate of return of more than 350%.

Synergy Resources Corp.

- *Net acres: 13,124*
- *Growing by drilling and acquisition*

Synergy Resources Corp. chose the Denver-Julesburg Basin as its core area, and is actively engaged in drilling wells to the Codell, Niobrara, and J-Sand zones in Wattenberg Field.

According to a company fact sheet, the reasons are simple. The basin offers:

- Low drilling and completion costs;
- Rapid return on investment;
- A high level of predictability;
- A high drilling success rate; and
- Rich drilling opportunities.

In its latest move in December 2010, the company bought four producing wells in Wattenberg

Field from Noble Energy Inc. The property contained an additional 20 potential drilling sites. Those wells were adjacent to the company's Pratt lease in southern Weld County, Colo. In return, Synergy turned over lease rights on 340 net acres in northern Weld County to Noble Energy, but retained an overriding royalty interest.

"We are pleased to have consummated this acquisition with Noble Energy, and by acquiring these wells, it will allow Synergy to commence drilling the first of six wells on the Pratt lease by the end of the year," said Ed Holloway, Synergy CEO.

The transaction left Synergy with 20,767 gross, 13,124 net, acres of properties in the basin.

The company previously bought six producing oil and gas wells; two shut-in wells; and 15 gross, 6.25 net, well sites for US $1 million.

Synergy reported record results in fiscal 2010 – which ended Aug. 31 – as revenue more than doubled to $2.16 million from the previous fiscal year. During the fiscal year, the company drilled 36 new oil and gas wells, all commercially productive. By Nov. 15, 2010, 36 of the company's 38 wells were producing and two were being completed.

Synergy produced 21,080 bbl of oil and 141.2 MMcf of gas during the year.

Texas American Resources Co.

- *Net acres: 27,300*
- *Strong production with many undrilled locations*

Texas American Resources Co. built a substantial position in the Wyoming and Colorado portions of the Denver-Julesburg Basin and followed up with economic production, high reserves, and an abundance of drilling locations.

In early 2011, the Austin, Texas, company produced 800 boe/d from 162 operating wells on its Adams and Weld county properties in Colorado and its Laramie County, Wyo., leases. Texas American had 27,300 net acres of leases with another 226 drilling locations still undrilled. Approximately 200 of those 226 wells are low-risk proved, undeveloped locations. Reserves total 13.01 MMboe, according to the company's website.

Late in 2010, Texas American staked two more horizontal wildcats aimed at the Niobrara, about five miles southwest of Burns in Laramie County.

The 44-33H Mordoch was projected to 7,501 ft true vertical depth. That well was more than one mile south and slightly east of the company's proposed 11-10H Waldon, projected to 7,548 ft, according to IHS Inc.

The nearest production was approximately two miles away at an abandoned Codell Formation producer in Arcola Field. That well produced 5,975 bbl of oil between 1982 and 1986.

The Texas American wells are approximately 12 miles southwest of the Simray Production Co. 1H State, a horizontal Niobrara discovery with an initial potential of 831 b/d of oil and 205 Mcf/d of gas from a 5,298-ft horizontal lateral with 20 frac stages. About three miles east of the Mordoch well, Simray drilled a horizontal Niobrara well that was not a commercial success.

The Texas American wells also are about 12 miles north of the EOG Resources Inc. horizontal Jake discovery in Hereford Field in Weld County. That well tested for an initial 1,558 b/d from Niobrara and kicked off the current Niobrara land rush. The well produced 50,000 bbl of oil in its first 90 days online.

Warren Resources Inc.

- *Net acres: 80,000*
- *Niobrara potential lies under CBM production*

Warren Resources Inc. holds an acreage position with Niobrara potential beneath its existing coalbed methane (CBM) operations in the Atlantic Rim area of southern Wyoming.

The CBM acreage alone has proved reserves of 72 Bcf of gas and a potential 623 Bcf of gas. The area has the potential for approximately 1,800 CBM wells. In that area, it has a joint-venture agreement with Anadarko Petroleum Corp., in which Warren holds an average 42% working interest.

So far, 214 CBM wells are producing, with 13.6 MMcf/d of production net to Warren.

The company's property also contains 80,000 net acres of deep rights with Niobrara potential, and 200 deep wells already are approved under the existing environmental impact statement. That acreage is in the eastern Washakie Basin in southern Wyoming.

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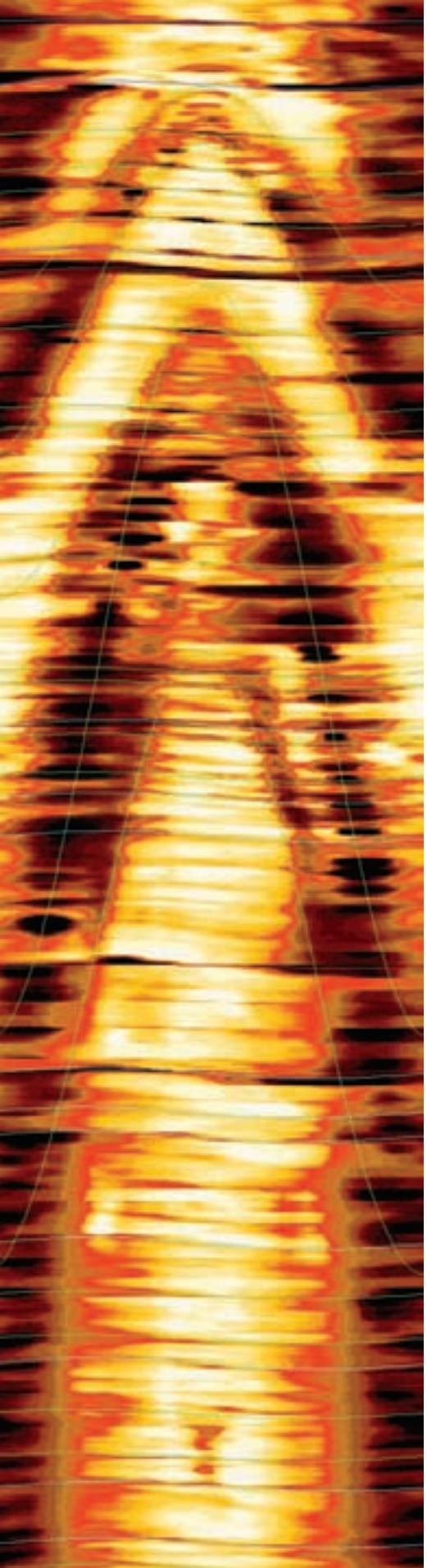


What's Old Is New Again

Drilling and completing Niobrara horizontal wells require latest technologies.

By Jerry Greenberg
Contributing Editor

The Niobrara Formation has been drilled and produced for nearly 100 years, primarily with vertical wells that sought gas rather than oil. Operators continue to drill new vertical wells and refracture and restimulate older wells to increase production. Drilling to deeper zones also has occurred. During the past couple of years, horizontal drilling and large multistage fracture and stimulation jobs prevalent in other shale plays have been applied to the oil-rich Niobrara Formation.

Operators and service companies still are experimenting to develop the optimal Niobrara completion system, including fracture fluids and the most efficient fracturing and stimulation methods, whether it is plug-and-perf or sliding sleeve or, in the future, coiled tubing (CT).

Some of the completion methods in the Bakken play to the north of Niobrara have been applied to the Niobrara Formation. That is not necessarily the case for the exploration side of the equation due to significant faulting of the Niobrara Formation not experienced in the Bakken.

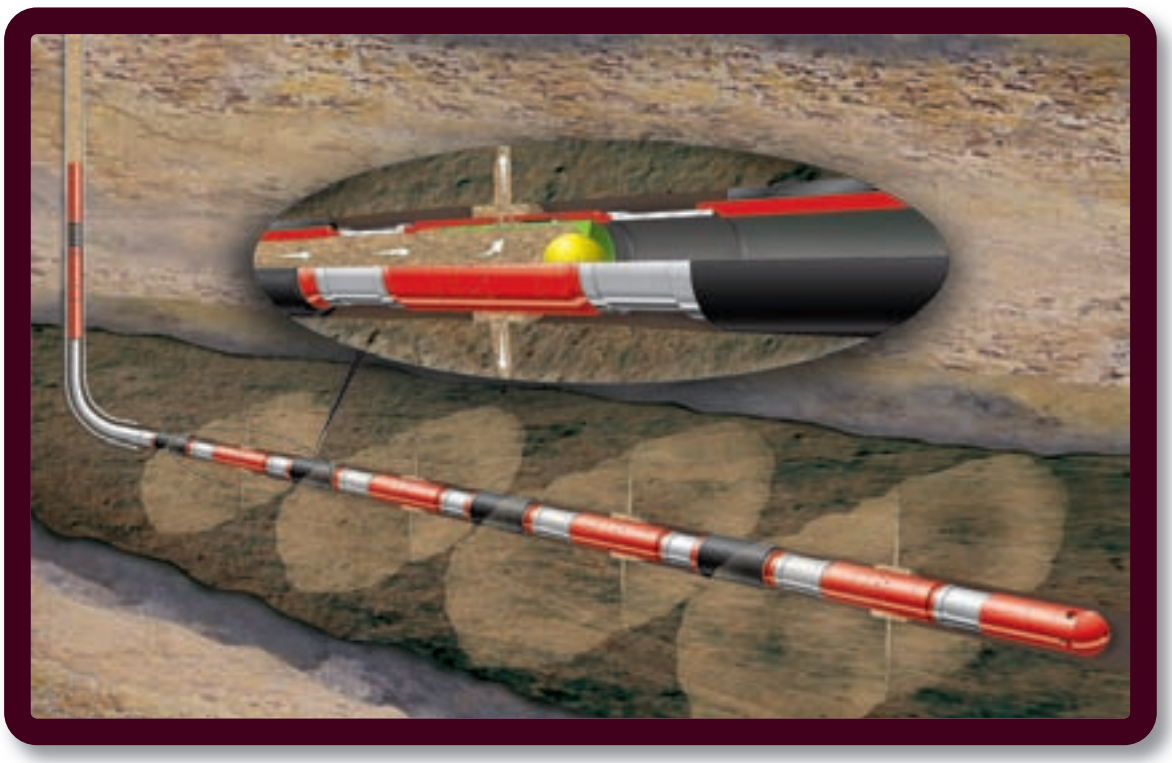
"We have seen perforating to complete multistaged fracing in the Bakken that is a transition to sliding sleeve technology," said Darren Schmidt, senior research advisor and professional mechanical engineer at the University of North Dakota's Energy & Environmental Research Center (EERC). "We have gone to so many stages on some of these wells that it has been a combination of sliding sleeve and plug-and-perf.

"With shorter laterals in the Niobrara, service companies are going to push sliding sleeve technology because they have been able to maximize the number of stages they can accomplish on a sliding sleeve string."

However, that depends on what formation is being completed, Schmidt noted. If it is a limestone interval, sliding sleeve would be the technology of choice, he believes, but if an operator is going to try to complete a shale interval, there is some merit to plug-and-perf.

While sliding sleeve technology might be the most efficient, it is not without issues. "There is some inefficiency to swell packers and sliding sleeves," Schmidt said.

GeoVision Resistivity illustrates an 80-ft section of the Niobrara Formation, showing bedding planes and cross-cutting fractures. *(Image courtesy of Schlumberger)*



Halliburton's Delta Stim Plus 20 completion service enables accurate fracture placement with minimal or no intervention. *(Image courtesy of Halliburton)*

"For example, they may find they are fracing around the packers and not getting new initiating points as they would expect.

"With a highly fractured formation like Niobrara, that might be a bigger issue than in the Bakken, and I can tell you it is an issue in Bakken."

One way to mitigate that problem is using additional technologies to more carefully choose fracture initiation points and to customize the location of those initiation points. "Instead of a manufactured approach, where every stage is equal distance from each other, perhaps go in with a formation imager or look at the structure and divide the stages where they are more likely to initiate a fracture," Schmidt said.

One similarity to Bakken concerns fracture fluids and deciding on the most optimal formulation. "There was a lot of experimentation of Bakken completions early on," said John Harju, associate director of research at the EERC. "They are using gel fracs almost exclusively now (in Bakken), although there were some slickwater fracs being done earlier."

Several operators and service companies have had success with gel fractures in the Niobrara Formation following experimentation with several fluid formulations, including slickwater, low and high pH fluids, and crosslinked fluids.

CT completion is another technology that is being used in the Bakken (at least the Canadian portion) and could be applied to the Niobrara. "There is a lot of flexibility with that approach," Schmidt said. "There is flexibility in where you locate your perforations, and you can be more aggressive on pumping your jobs because if you screen out, you are already set up to clean it."

Drilling technology for quality Niobrara wells

Niobrara has been garnering significant attention from operators and observers primarily due to a "boom" in the horizontal play in the formation, much of which began in late 2008 and 2009. But the Niobrara actually is a fairly old play that is being rediscovered as operators move to horizontal drilling and massive hydraulic fractures.

Wells in the Silo Field in Laramie County, Wyo., just the other side of the border with Colorado, have been producing from horizontal laterals since the 1990s. Several of those wells were using the same technologies developed in the Austin

The OnTrak LWD system offers a better understanding of the actual well position by taking measurements close to the bit. *(Image courtesy of Baker Hughes Inc.)*

Chalk trend, according to Dr. Peter Kaufman, principal geologist for Data and Consulting Services, a Schlumberger division. There also has been some horizontal drilling in the Sand Wash Basin, although not as extensively as in the Silo Field.

What really kicked off the recent horizontal play were operators that took their technologies from other shales, such as the Barnett and Bakken, and applied them to the Niobrara, which actually is not a shale, but rather an alternating series of chalks and marls, very fine-grained limestone deposits. After drilling horizontal wells, operators would apply large multistage hydraulic fracturing methods to stimulate large volumes of the low-permeability rock. That method worked well in the Bakken Field to the north and also appears to be working in the Niobrara Formation.

A key drilling process is pay identification. Depending on the location in the basin, there are three or four chalk benches from which to choose the optimal formation. "The zone that has the best quality reservoir rock changes as you move from place to place within the basin," Kaufman said. "Operators need to spend time before drilling any laterals to identify which one of the multiple targets has the best quality pay, and which are potential targets for later development."

When drilling the lateral horizontal section in the Niobrara, staying in the zone sometimes is difficult without some sort of bit-steering method. Steering the well into the best quality rock zone can become a problem in the Denver-Julesburg Basin due to hidden subtle structures that cannot be resolved on 3-D seismic.

"We have a number of cases where operators were trying to land a horizontal well, logged the well afterward with image logs, and we can clearly see where they were offset by 20-, 30-, or 40-ft faults," Kaufman said.

"The operator can be steering along and suddenly find himself popping out of the zone and ending up in marginal rock," he added. "Knowing whether to steer up or down to get back into the best quality rock can be challenging."

Once the operator has effectively steered into the best quality rock zone, it is important to take account of what actually was drilled, not what the operator thought it was going to drill, to optimize the completion design. Much of the Niobrara is naturally fractured. Operators want to take advantage of that fact and try to avoid putting in hydraulic fractures that would be ineffective.

"Logging and quantifying the rock properties along the horizontal lateral is critical to the overall completion design," Kaufman said.

Operators drill the Niobrara Formation with motors and bent subs with some success, but rotary

steerable systems (RSS) are beginning to be used more often to drill horizontal laterals.

"Rotary steering has been most effective because it is the most responsive," said Mike Brunstein, vice president, sales and marketing for Rocky Mountain Basin, Schlumberger. "The quality of the well bore from rotary steering provides a much smoother facies for the completion. Packers also are much more effective with a smooth well bore."

"Well placement using real-time borehole resistivity images will work better in the Niobrara than in some other plays," Kaufman said. "The structural complexity of the Niobrara Formation creates a need for well placement, while the reservoir's high degree of depositional lateral continuity is more favorable for following thin zones using resistivity images."

One of the complexities of the Niobrara is staying in the zone as the operator drills across the natural faults and through poorer quality reservoir zones. Schlumberger's GeoVision 475 slimhole imaging service provides real-time resistivity measurements and reveals formation structure and geologic features, allowing the operator to steer the bit into the optimal part of the formation. The high-resolution images provide the necessary data to identify natural fractures and induced fractures to understand the orientation of the formation stresses, resulting in the operator being able to design the most effective fracture and stimulation.

"The ability to steer and stay within zone and characterize fractures and fault patterns as you are drilling will be a benefit," Kaufman said.

In one case in the Niobrara Formation, an operator wanted to place a well inside a 10-ft zone of a 40-ft chalk zone. Using GeoVision 475, the company was able to maintain the bit's trajectory within the 10-ft target for more than 3,000 ft. Schlumberger used the images to identify the reservoir facies as well as the natural fractures to design the hydraulic fracture and stimulation of the reservoir.

"This capability allowed us to shift packers away from zones of intense natural fractures and move frac ports left or right to better stimulate rock that already had cracked naturally," Kaufman said.

Despite good results from RSS, high-resolution image logs to steer the bit, and real-time data for designing effective completions, the jury is still out on whether most of the Niobrara laterals and builds will be drilled with RSS. Most of the wells still are conventionally drilled with varied success. However, unlike some drilling plays, an operator cannot go into the Niobrara with one template and reconstruct the well each time.

"Operators can be much more proactive about staying in the sweet spot rather than having to work with a well that's already drilled," Kaufman said. "We are a strong advocate of formation evaluation in these horizontals, but conducting a wireline measurement after the well means the operator doesn't have options to change what he was doing during the drilling operations."

Kaufman noted that Schlumberger has a number of examples where an operator logged the well with their imaging tool after drilling and discovered that they had crossed numerous faults, moving in and out of the better zones and not optimizing the path of the horizontal well bore.

RSS with wellbore imaging tools have additional benefits. One aspect is wellbore stability. The zones immediately above the Niobrara Formation tend to be weaker. As operators try to build a curve through those zones, they often encounter technical problems and issues such as stuck pipe and breakouts. Image logs can provide the resistivity of the formation in addition to gamma ray that can be indicative of shale and hydrocarbon content.

Another tool that can aid the operator is Schlumberger's CMR tool. "We believe a key to characterizing the Niobrara is to gain an understanding of the pore size distribution continuously through the vertical pilot well. Data (from the CMR) help the operator identify which zones are going to be the most productive and which zones have very low permeability that an operator should not be drilling," Kaufman said.

Some operators in the Niobrara will log with a triple combo, he noted, which will provide a basic understanding of the formation. "What we are seeing in Niobrara is a porosity system that is somewhat different from a lot of other plays, with extremely small pores, very low permeability, and high capillary pressure.

"It's a much more unforgiving system in the Niobrara than what you would see in a dolomitized formation such as the Bakken," he said.

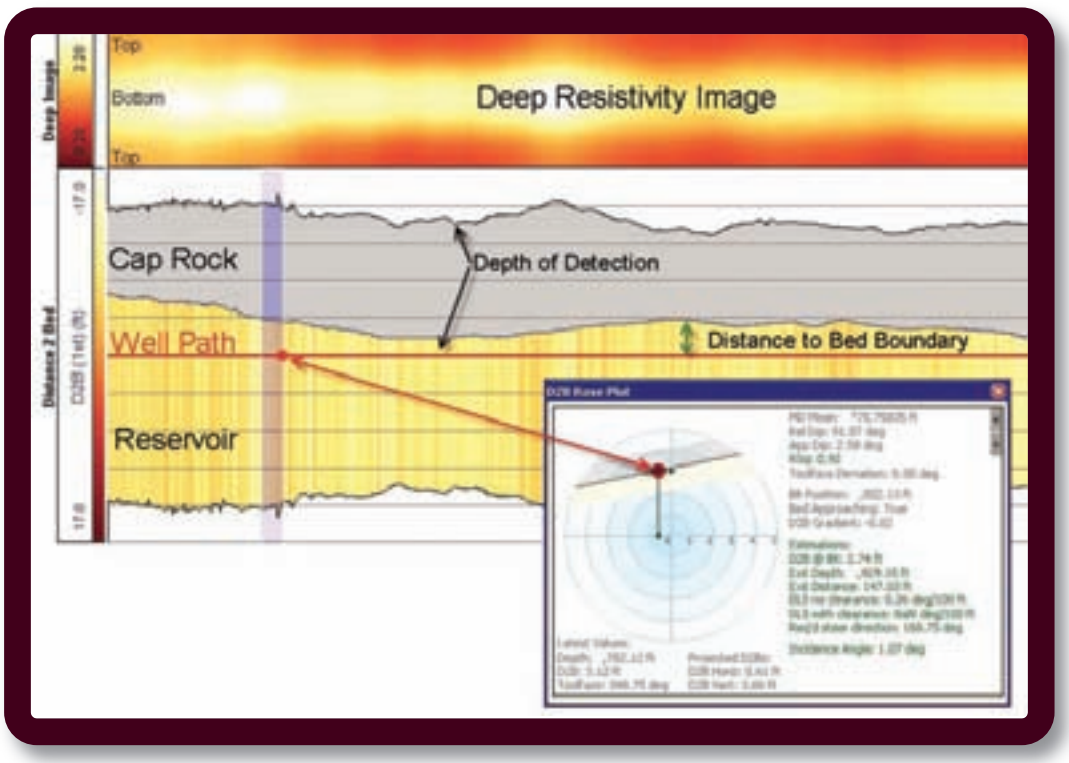
Optimal drilling, completion techniques

It is very early in the horizontal exploratory phase of the Niobrara play, and most companies are restricting the release of their drilling and completion results for competitive purposes. As more wells are drilled and more public data become available, key reservoir elements and drivers of the resource will become apparent. Consequently, service companies are not always sure whether a particular fracture fluid formula is better than another, or if a stimulation job was optimal or even completely successful in terms of production and optimal reserves.

Drilling the lateral section of Niobrara wells can be difficult due to the anisotropy and complex heterogeneity of the formation. While drilling with a motor and bent housing still is used in a majority of the wells, RSS with sophisticated geosteering tools and software are being used more often. Data gleaned from formation evaluation or reservoir characterization tools while drilling aid the operator when planning the completion and stimulation design.

"People are going to see more reservoir characterization (in the Niobrara) than they have in almost any of the US shale plays due to the complexity," said Gary Malasky, principal reservoir advisor and professional engineer for Baker Hughes Inc. in Denver. "People will realize that they can try different drilling techniques and completion and stimulation designs, but without proper integrated reservoir characterization and diagnostics, I believe they will experience limited success.

"Reservoir characterization is a critical element that should be gathered before and during drilling operations and updated after stimulation, production, and diagnostic results," Malasky said.



AziTrak deep azimuthal resistivity measurement service data and other while-drilling downhole images can be shared between field- and office-based experts to streamline real-time collaboration on critical issues including dip-picking and distance-to-bed-boundary analysis for optimized wellbore placement. *(Image courtesy of Baker Hughes Inc.)*

Service companies use RSS for better steering control and a smoother well bore, and an extremely high build motor to get the turn put in as quickly as possible to maximize time in the pay zone. It depends upon operator preference and requirements.

"There is a lot of variation due to faulting within the formation," said Derek Allan, formation evaluation business development manager for Baker Hughes in the western US. "Many operators are turning to rotary steering for better directional control through geosteering because of changing formation structure during drilling.

"The faulting is considerable," he said. "You can be drilling ahead and suddenly there is a 30- to 40-ft fault that didn't show up on seismic. Depending on formation thicknesses, the pay zone can move by that amount, seriously impacting the net/gross percent that a well is accessing."

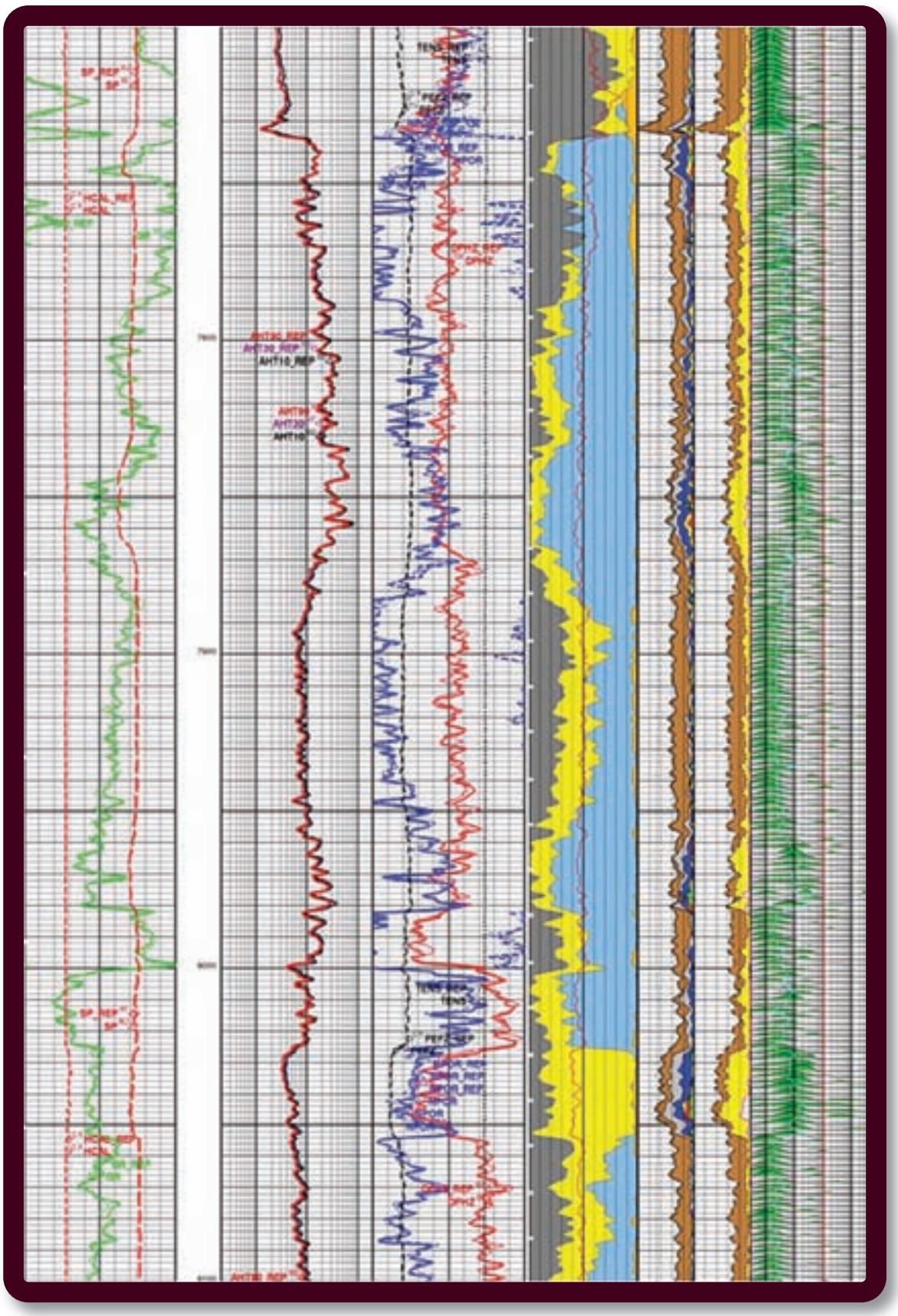
"Tectonic activity – the dip, angle, and complexity – are critical driving factors (for rotary steering) as much as the thickness of the formation," Malasky said.

This is one major difference between the Niobrara Formation and the Bakken Shale to the north. There was speculation that the two formations would be similar during drilling and completion operations. This idea resulted from similar vertical exploration wells drilled in both plays, but when it came to drilling horizontals in the Niobrara, it was learned that any hope for similarities was misguided optimism. The Niobrara has a great deal more variation along the horizontal due to faulting and thicknesses of the formation.

"The issue with horizontal wells (in the Niobrara) is that some operators made the assumption that they could do the same as they did elsewhere," Allan said. "Operators that have moved on from that assumption are the more successful now."

The main point about the drilling operation, Allan noted, is that operators do not have the luxury that they do in the Bakken of drilling to the correct depth and then turning 90 degrees. "We are having to geosteer the wells using formation evaluation sensors to detect changes and variations in the behavior of the Niobrara formations – how it moves due to faulting and thinning," he said.

"There is no point in drilling the well and then evaluating it to find whether it's in the right or wrong place."



Taken from a section of the Niobrara Formation, Schlumberger's combinable magnetic resonance (CMR) tool illustrates Track 1, which shows gamma resonance; Track 2 is resistivity; and Track 3 shows neutron/density. ECS mineralogy in Track 4 helps illustrate chalk benches and marly zones. Track 5 shows the porosity bin size distribution from the CMR, highlighting the larger pores in the chalk zones. A field default for porosity distribution between clay bound porosity (brown) is shown in Track 6. The T2 distribution from the CMR, highlighting the larger pores in the chalk benches, is shown in Track 7. *(Image courtesy of Schlumberger)*

There is no individual service type that addresses the Niobrara's challenging formations. Due to the significantly varying geology within the Niobrara, almost every area has its own challenges. Formation evaluation perhaps is the primary improvement that service companies are using in the Niobrara. It is not only the use of RSS, but the MWD/LWD that helps reservoir navigation. This includes azimuthal gamma, azimuthal resistivity, nuclear measurements, etc., with real-time data accessibility to help predict the Niobrara's variances and react to those variations when drilling. Formation evaluation also aids the completion engineer to maximize production.

"The basic suite that we would use for prediction would be azimuthal gamma and azimuthal resistivity in real time with the rotary steerable system," Allan said. "With the resistivity tool, we can identify fractures as we are drilling through them and have a much better understanding of where they are, how many there are, and the spacing. We can also give an indication of how ductile or brittle a particular zone is likely to be, which also enhances the stimulation strategy and planning.

"It's critical that the well is evaluated continually while we're drilling," he added. "The changing structure and geology of the Niobrara needs more than just reactive mud logging or wellsite geology applications. It needs full-time predictive analysis to keep the well in the optimum zones. We can provide that information to the operator and the completions team so they can optimize that part of the well."

During the completion phase, operators are using either the plug-and-perf method or sliding sleeves for fracturing and stimulating the well. However, more operators presently are using hydraulic packers rather than swell packers.

"I would say that a vast majority of the operators are using sleeves," said Renee Supplee, Baker Hughes sales engineer, Completion Systems, Western Hemisphere, "but a lot of operators are recommending plug-and-perf for better placement."

There are benefits to both methods. Both fracture and stimulation methods allow the operator to re-evaluate and redesign their fracture and stimulation jobs. "One benefit of plug-and-perf over sleeves is the time element," said Kristian Cozyris, region engineer, Rocky Mountains for Baker Hughes Pumping Services. "While plug-and-perf may be more expensive than sleeves, the method provides the operator with the opportunity to re-evaluate and redesign the frac job."

With plug-and-perf, operators can be more selective. If real-time microseismic monitoring is being performed during fracturing, the operator can alter and change spacing of the fractures and densities, for example, providing more flexibility to the operation.

One of the main benefits of using sleeves, however, is economics. A multistage completion could be done in one or two days, compared to a week or more with the plug-and-perf method. The increasing use of sleeves is being driven by a scarcity of fracture crews due to increasing demand across the US. "It's easier to hire a frac crew when you have 20 stages of sleeves rather than a 35-stage plug-and-perf program," Supplee said.

One fracture method currently used in Canada with significant success, and which could migrate to the US, is CT fracturing that involves sand plugs and sand jetting to perforate the casing. In Canada, Baker Hughes is using the OptiPort CT system which uses a ported collar that allows the operator to pump fracture fluid and proppant into the formation.

"OptiPort is a ported collar coiled-tubing system with a bottomhole assembly that seals and allows the sleeve to shift open, fracing down the annulus between the casing and the coiled tubing," said Anthony Hooper, director of marketing, Pumping Services for Baker Hughes. "The method assures that the operator is isolated from the previous zone, which is a priority when completing a horizontal well."

"Because the OptiPort system pumps on the outside of the annulus between the coiled tubing and casing, the operator can utilize lower pumping horsepower," said Jose Iguaz, marketing director for US Land for Baker Hughes.

The smaller the zone being fractured the more emphasis can be focused toward optimal performance. With a 250-ft zone, for example, fractures will begin diffusing and the entire 250-ft zone likely will not receive optimal treatment. Instead of doing one 250-ft fracture, three 80-ft fractures and stimulations can be directed more efficiently with OptiPort.

"With a smaller fracture, but with more stages, the result is better exposure to the rock," Iguaz said.

There also has been a great deal of experimentation with different fracture fluids. "We've looked at low-pH fluids, slickwater systems, high-pH crosslinked fluids, acid systems, and linear gel systems," Cozyris said.

He added that there have been successes with each fluid formulation, but an optimum fluid has not been decided as yet. "Operators continue to experiment with all treatment types," Cozyris said, "including high and low treatment rates, large volumes of fluid, and proppant. They have all been successful to a degree, but not necessarily optimal."

One fluid with which the company has seen successes is the QuadraFrac low-pH fracturing system. It is compatible with most formations and has been particularly useful in underpressured formations. The adjustable crosslink delay also makes the fluid useful for CT applications. The fluid can be energized or foamed with nitrogen or CO_2.

Rotary steerables, hybrid fracture fluid system are among Niobrara solutions

There are different opinions on whether the Niobrara is similar to the Bakken play to the north, and whether some of the technologies used in the Bakken can be applied in the Niobrara. Most people agree that some of the technologies and methods used to explore and develop the Bakken at least helped to open up the Niobrara play.

"Horizontal drilling activity in the Niobrara is continuing to increase," said Mike Eberhard, Halliburton's technical manager for the Rockies. "Operators are taking a hard look at where they can apply that technology.

"The success of operators in the Bakken, where the horizontal wells and the completion techniques used are different than in the more traditional shale gas plays, has opened up other oil plays for more horizontal completions."

Drilling fluids used in the Niobrara are not complex and are fairly generic water-based systems, according to Eberhard. He noted, however, that closed-loop mud systems are used for wells targeting the Niobrara and other formations in Wyoming and Colorado as part of the overall surface solids control systems. "It's becoming a pitless world," Eberhard said.

Bit designs continually are evolving to reduce drilling time and for optimal drilling of the vertical and the lateral sections as well as the build. "We are seeing long gauge, stabilized PDC bits providing good well bores," said Jeff Sack, sales manager, Well Construction for Halliburton.

Regarding actual drilling technologies, more operators are running RSS, although using motors with bent housings for directional drilling still is prevalent in the Niobrara. Due to the play's faults and variances, more operators are using resistivity LWD tools.

"Niobrara is perhaps the first onshore play that is adopting rotary steerables as a solution due to the issues involving faulting and getting these wells down in a timely fashion as well as keeping costs in line," Sack said.

RSS help reduce drilling time and increase the ease of drilling horizontal laterals due to the drillstring rotation, eliminating sliding required with a positive displacement motor. Rotary steering also enables the driller to keep the bit on the bottom and continuously clean the hole.

"Borehole quality is another advantage to rotary steering," Sack said. "You get a gun-barrel type hole, which assists in the completion."

Halliburton's Sperry Drilling Services provides the Geo-Pilot RSS. The point-the-bit system provides real-time continuous at-bit steering and formation evaluation data for accurate wellbore positioning. The system can warn the operator of trajectory changes in real time by the at-bit inclination.

Azimuthal directional resistivity data allow the driller to see the well bore in a 360-degree view. To use this tool, the drillstring needs to be rotating. Without rotary steering, the operator will need to spend additional time to take measurements after a slide. Resistivity information can be obtained when drilling with a motor, but the process is more efficient with RSS.

Halliburton can monitor data from the azimuthal resistivity tool in real time from remote locations with the Insite Anywhere service. The service provides instant and real-time access to wells from any location and across all aspects of well construction, from drilling to the completion process. Data can be hosted on a secure website at Halliburton's facilities or at the operator's location, and can be accessed via computer or smart phone device.

The service allows the transfer of real-time data from multiple data providers into a single source of information, allowing the operator to control multiple operations from a single well site, or operations at multiple well sites.

Most operators currently are completing wells with uncemented liners and compartmentalized, multistage completions. Eberhard noted that due to the faulting that is prevalent in the Niobrara, some operators are using microseismic technology to aid in their understanding of how the formation fractures to better improve design treatments.

When fracturing the well, Halliburton has been successful with a hybrid fluid system consisting of a slickwater pad and crosslink gel proppant stages. "The reason for this hybrid fluid design is that Niobrara is primarily an oily reservoir," Eberhard said. "Fracture conductivity is needed to produce these wells, which are different than shale gas formations where you don't need as much conductivity to move the gas through the fractures.

"Most operators are using some kind of external packer system for their completions," he added. "We use the swell packer system while other companies use mechanical set packers. Operators switch between sliding sleeve technology and plug-and-perf systems.

"That decision usually is based on what they have seen used in the Bakken play," Eberhard said.

Halliburton combines the swell packer system with the Delta Stim completion service in the Niobrara, allowing operators to compartmentalize and complete the entire lateral in one pumping event. Opening the sleeve permits compartment stimulation through the selected sleeve. After stimulation, cleanup is assisted by flowing all compartments simultaneously.

Use of swell packers and sliding sleeve methods saves time and costs compared with a plug-and-perf fracture and stimulation. "It's a matter of getting pumping equipment on location and the cost of the equipment and crew for one or two days, compared with five or six days or longer for plug-and-perf operations," Eberhard said.

Niobrara Midstream

The Niobrara Shale play is home to several large pipeline systems and more capacity is likely to be built next year as the land rush continues.

By Skip Simmons
Contributing Editor

During the past decade, crude oil in the Denver-Julesburg (D-J) Basin's Niobrara play area was routed mostly within and from the region by truck and rail. Much of the oil produced from the area was trucked or pipelined to local refineries in the Rocky Mountain area.

In fact, because regional demand for refined products essentially was flat, and Bakken-play resources competed for Rockies' regional crude oil markets, developing Niobrara crude supply outpaced regional demand. As a result, light crude oil production from the Niobrara drove area producers to seek markets elsewhere.

In response to that trend, the first regional crude oil pipeline to exit Colorado in many years was completed in 2009 by SemCrude, a subsidiary of Tulsa, Okla.-based SemGroup Corp. SemCrude gathers, transports, stores, markets, and distributes crude oil through the White Cliffs Pipeline, the Cushing, Okla., storage facility, and a system of smaller gathering pipelines in Kansas and Oklahoma.

Today, the 526-mile, 12-in. diameter White Cliff is the only pipeline that moves crude oil out of the D-J Basin directly to Cushing, the largest crude oil market in the world. The company has more than 4 MMbbl of crude oil storage in Cushing, and plans to build additional tank capacity. The 30,000 b/d pipeline is co-owned by SemCrude (51%), Plains All-American Pipeline (34%), Western Gas Partners LP (10%), and Noble Energy Inc. (5%).

To further enhance White Cliffs' capability and near-term use, Plains All-American is connecting portions of its Colorado and Kansas crude oil gathering pipelines to White Cliffs as well as providing downstream connections to other crude supply gathering assets in Kansas and Oklahoma. This extended reach for White Cliffs adds additional gathering capabilities in portions of the extended Niobrara development area. Also, it provides White Cliffs with ongoing revenue and expansion potential as Niobrara production increases.

Operators still are somewhat reliant on trucks to provide transportation. For those activities, SemCrude operates a truck offloading and storage facility that can accommodate 150 trucks per day (equal to 30,000 b/d with 20,000 bbl of local storage) while, separately, SemCrude can store up to 100,000 bbl at the White Cliffs pipeline origin. The pipeline has a single pump station at Platteville, Colo., that could be expanded with additional pump station locations to 50,000 bbl.

In its first partial year of operations in 2009, SemCrude reported crude oil deliveries of approximately 4.5 MMbbl.

Niobrara gas infrastructure

Regional gas infrastructure generally is west and north of the current Niobrara play areas in the D-J Basin near Wattenberg and in Powder River. Much of the infrastructure moves legacy gas, but gas received from the Niobrara has been and should continue to be accessed.

Key to the region is ongoing development centered near the Wattenberg Field where existing major gas-gathering systems integrate with numerous gas-processing plants. The processed natural gas liquids (NGLs) are either exported via the D-J Basin Lateral Pipeline into the Overland Pass pipeline system or trucked to local markets.

Operators of the Niobrara's midstream facilities include Anadarko Petroleum Corp., Western Gas

Partners, BP plc, and DCP Midstream Partners LP. Western Gas Partners recently acquired Encana Corp.'s Wattenberg gathering assets and Encana's Ft. Lupton gas plant to integrate with its current operations in the area.

The D-J Basin Lateral Pipeline began operation in March 2009 and is a 125-mile NGL line connecting the D-J Basin with the Overland Pass Pipeline. The 760-mile Overland line can transport 110,000 b/d of NGLs. It runs from Opal, Wyo., to Conway, Kan. The pipeline's capacity is 55,000 b/d from existing gas-processing facilities in the D-J Basin. Such gas-processing facilities include DCP's Lucerne and Mewborne plants. Additionally, DCP's Platteville and Greeley facilities are connected to Mewborne.

With a primary focus on oil, operators still must accommodate gas produced, although gas essentially is a byproduct, and its netback price often is a lesser concern. Therefore, connections to nearby or existing gas-gathering or pipeline infrastructure is sought aggressively, even though companies seek to minimize long-term commitments to gas infrastructure.

Continuing onward in these initial development stages of the Niobrara oil play, and with the primary emphasis being to capture crude oil and liquids value rather than focus on gas price, near-term commitments to new midstream gas-gathering and infrastructure by Niobrara operators are projected to be modest until overall regional scale alters that path.

With many of the regional gas pipelines at the Cheyenne Hub (the gas-marketing hub in Cheyenne, Wyo.) fully contracted for firm service and operating at high usage levels, gas associated with Niobrara oil generally will be attached to existing nearby pipelines owned by the Front Range gas utilities or to some nearby exit pipelines to be backhauled to the Cheyenne Hub for marketing. Colorado Interstate Pipeline and Public Service of Colorado also are positioned there and often are a connection choice.

Elsewhere, Trailblazer Pipeline Co. LLC owns and operates a 436-mile gas takeaway pipeline system that runs from Colorado through southeastern Wyoming to Beatrice, Neb. Kinder Morgan Energy Partners owns 100% of Trailblazer.

The pipeline is operated by Natural Gas Pipeline Co. of America, which is operated and partially owned by Kinder Morgan. Trailblazer provides an outlet for Rocky Mountain gas seeking Midwest and East Coast markets. The pipeline receives gas from various interconnections and receipt points in Colorado, including Wyoming Interstate's Dull Knife point and Colorado Interstate's Tomahawk point.

Some of the largest delivery points for Trailblazer include NGPL-Gage Co. and NNG-Beatrice in Nebraska. The top gas-transportation customers for Trailblazer are Colorado Interstate Gas Co. and Marathon Oil Co. Although the pipeline provides firm transportation and interruptible transportation services, it does not offer storage services.

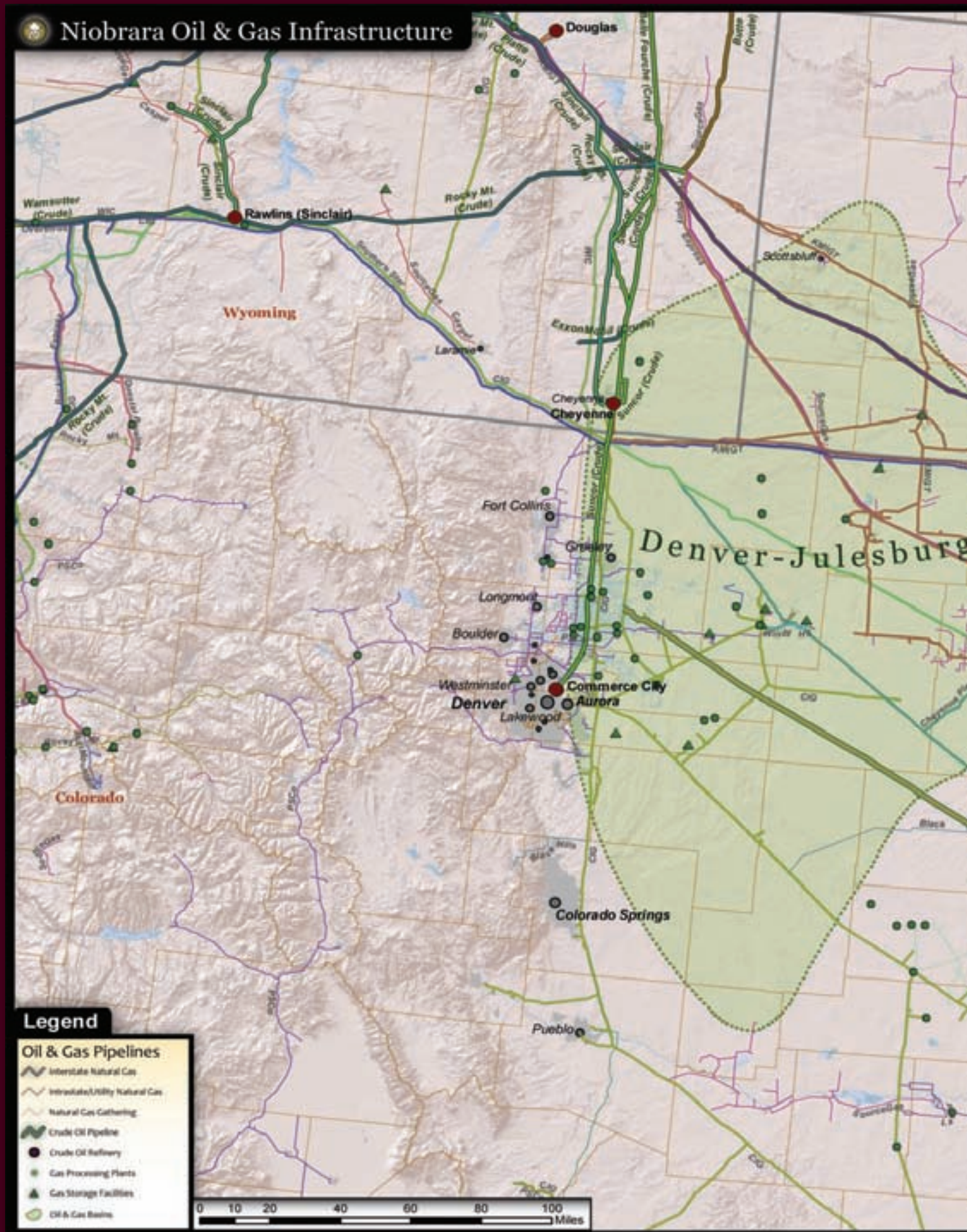
Colorado Interstate Gas (CIG) pipeline is a 4,200-mile pipeline with a design capacity of approximately 3.7 Bcf/d. El Paso Pipeline Partners owns the controlling interest (58%) in CIG. The pipeline delivers gas from production areas in the Rocky Mountains and the Anadarko Basin directly to customers in Colorado and Wyoming and indirectly to the Midwest, Southwest, California, and Pacific Northwest. CIG also owns interests in five storage facilities in Colorado and Kansas, which collectively have approximately 35 Bcf of underground working natural gas storage capacity and one natural gas processing plant in Wyoming.

Also, CIG has a 50% ownership interest in WYCO Development LLC, a joint venture with an affiliate of Public Service Company of Colorado, and operates WYCO's High Plains pipeline and Totem Gas Storage facility.

El Paso also owns Wyoming Interstate Co. (WIC), an 800-mile pipeline with a design capacity of approximately 3.3 Bcf/d. WIC is unique in the region in that it can provide gas-transportation capability eastward and westward within its footprint. WIC is a mainline system that extends from western Wyoming to northeast Colorado (and the Cheyenne Hub) and has several lateral pipeline systems that extend from various interconnections along the WIC mainline into eastern Utah, western Colorado, and northeast Wyoming.

WIC is one of the primary interstate natural gas transportation systems providing takeaway capacity from the Overthrust, Piceance, Uinta, Powder River, and Green River basins. CIG is the operator of the WIC system via a service agreement with WIC.

Also, El Paso owns 48% of Young Gas Storage Co., a facility with 6 Bcf of capacity in Colorado.


Niobrara Oil & Gas Infrastructure
Douglas
Rawlins (Sinclair)
Wyoming
Cheyenne
Fort Collins
Greeley
Longmont
Boulder
Westminster
Denver
Commerce City
Aurora
Lakewood
Colorado
Colorado Springs
Pueblo
Scottsbluff
Denver-Julesburg
Legend
Oil & Gas Pipelines
Interstate Natural Gas
Intrastate/Utility Natural Gas
Natural Gas Gathering
Crude Oil Pipeline
Crude Oil Refinery
Gas Processing Plants
Gas Storage Facilities
Oil & Gas Basins
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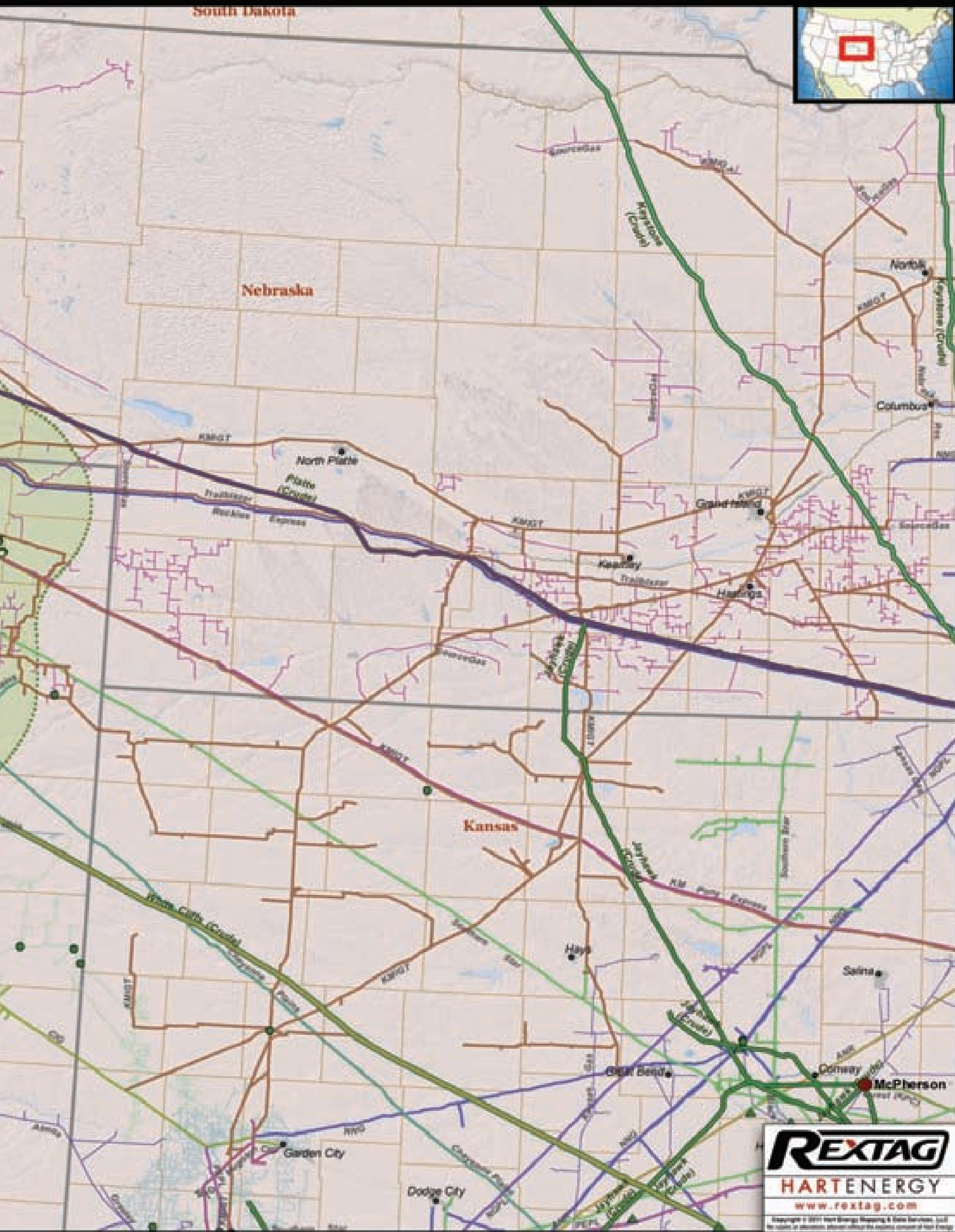
South Dakota
Nebraska
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North Platte
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Columbus
Grand Island
Kearney
Hastings
Hays
Salina
Great Bend
Conway
McPherson
Garden City
Dodge City
KMGT
Keystone (Crude)
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The New Economics of the Niobrara

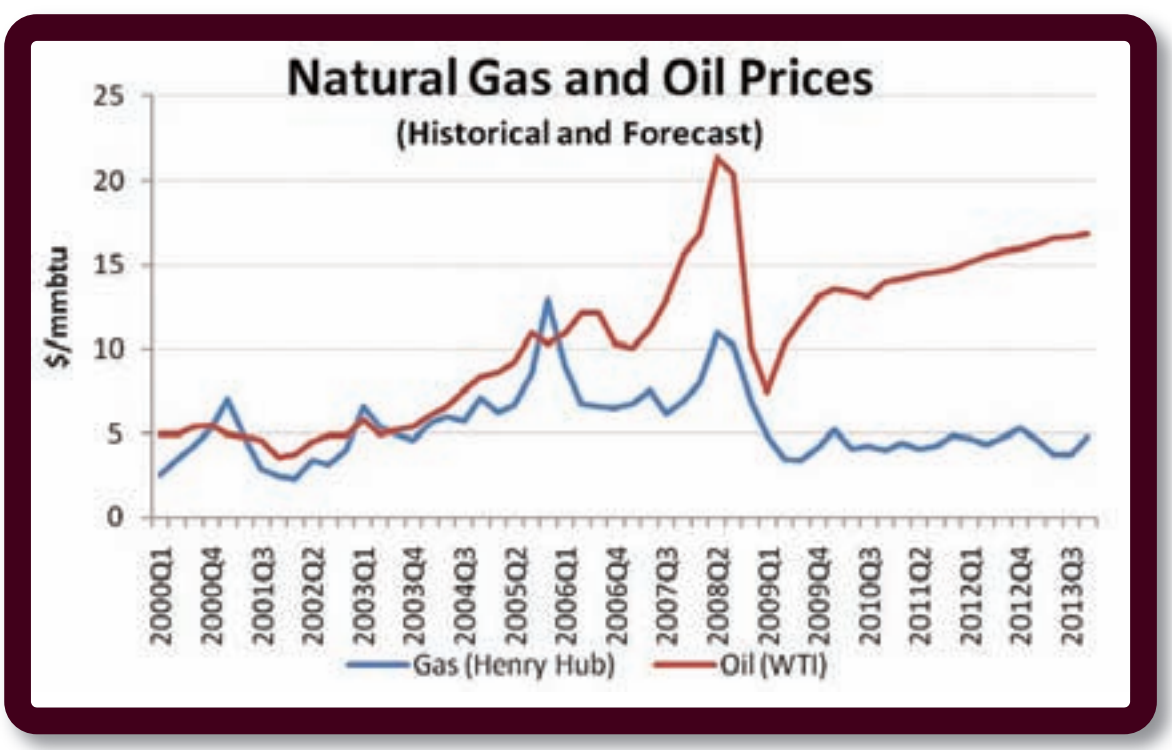
Developments in technology and economics have combined to renew interest in the Niobrara Shale play.

By Opoku Danquah
Director of Upstream Research, Hart Energy

The Niobrara is no stranger to petroleum E&P. Shale rock with specific qualities related to this play can be found sporadically through several basins in the Rocky Mountain region, especially in northeastern Colorado, southeastern Wyoming, northwestern Kansas, and southwestern Nebraska.

In the Piceance Basin, natural gas is the dominant resource exploited, whereas E&P activities are focused more on liquids and oil in the Greater Green River Basin and even more so in the Denver-Julesburg (D-J) Basin.

During the past three decades, hundreds of vertical wells have been drilled in these old basins and through the Niobrara Formation, which spans a depth of 4,000 ft to a little more than 10,000 ft. So why all of the buzz over this shale play? Because there are two key factors that have helped to make Niobrara a household name: technology and economics.



Historically, there was an observable correlation between natural gas and oil prices. However, since early 2009, a delinkage has occurred, and these prices have moved independently and on divergent paths since then. *(Source: Hart Energy)*

EST. DRILLING COSTS (millions US)	
Carrizo	3.5
Continental	4.2
EOG	3.4
Mariner Energy	3.3
Noble	3.5
PDC	3.5
Recovery	3.5
Rex	3.9
Sundance	4.6

*Drilling costs include stimulation and IP rates may vary according to completion stages and flow restriction techniques.

IP RATES FOR HORIZONTAL WELLS

	WELL DESCRIPTION	IP Rate b/d
Atlas	Atlas 1-19H	1075
Chesapeake	Spillman Draw Unit State 16-1H	705
EOG	Jake 2-01H	1558
EOG	Elmer 8-31H	730
EOG	Red Poll 10-16H	1100
EOG	Critter Creek 5-10H	690
EOG	Critter Creek 9-15H	748
Noble	Gemini K1	900
Noble	11 Hz	450
Petroquest	Nevis #2	831
Rex	Silo State 41-22H	201
Rex	Herrington Farms 1H	450
Voyager	Moonshine 1-36H	650

Drilling costs vary throughout the play according to the depth drilled and the number of frac stages required for an optimal IP rate. *(Source: Hart Energy; company reports)*

The old process of drilling has become new again, thanks to a combination of horizontal drilling and enhanced stimulation techniques (multistage fracing) at affordable costs. Also, the solidity and gradual elevation of oil prices relative to natural gas prices have created an inadvertent shift and a renewed focus on shale-oil development by companies. Consequently, among geological laymen, the Niobrara Shale play is no longer associated with natural gas, but rather it is perceived as an oil play.

Shifting to oil

Corporate strategic shifts to focus on oil in the Niobrara by companies that historically have exploited natural gas are due to the disappointing outlook of natural gas prices and confidence that oil prices will stay above minimum levels for individual project finance viability and will provide an overwhelmingly better return than natural gas.

Natural gas commodity prices in North America principally are regional with little influence by outside factors, while oil price fundamentals are influenced heavily by the global supply and demand of the commodity. Historically, there was an observable correlation between natural gas and oil prices. However, since early 2009, a delinkage has occurred, and these prices have moved independently and on divergent paths since then. A return to US $30/bbl of oil, as seen in the early 2000s, is almost impossible without major derailing developments on the economic and technological front. However, industry experts do not question the recurrence of the $3 to $4/MMBtu for natural gas from the early 2000s, and even go a step further by predicting similar price levels in the near to medium term.

Hart Energy is confident that the price of oil, benchmarked to West Texas Intermediate (WTI), will remain high by historical standards in the medium term and should continue to trend higher, testing the $100 marker occasionally. Natural gas prices are forecast to be capped around $5 through 2013, averaging a little more than $4.50 during this time frame. On an MMBtu basis, the oil-gas differential of more than $10 that was seen only when WTI prices hit $124/bbl should have no hesitation occurring again. This time, the wide differential would not be mainly due to a spike in oil prices, but the sustained depression in natural gas prices – a phenomenon that makes economic sense for producers to

acquire acreage and invest heavily in the oily portion of the Niobrara.

Operations

Even though acreage acquisition could be considered a sunk cost in oil and gas project finance, there is a first-mover advantage when owning land in a hot new shale play before the rush drastically reduces a company's overall investment, thereby freeing up money for other E&P activities. Most companies with expansive land positions have an acreage cost of approximately $300 to $400. An acre in the Niobrara region could go for approximately $50 long before the play's potential was made public in early 2010. Now, deals have been reported with land going for almost $5,000/acre — a huge upfront investment for any late-comer looking to get into the play.

Drilling costs also vary throughout the play according to the depth drilled and the number of frac stages required for an optimal IP rate. For example, Niobrara's formation depth within the Wattenberg Field of the D-J Basin is approximately 7,000 ft, whereas it can measure as deep as 12,000 ft in the Silo Field. In addition, this nonuniformity affects the well economics due to varying liquids-gas production mix. For example, the play gets oilier and less gassy as one transitions from the Wattenberg Field to the Silo Field.

Although most wells are in the experimental period, companies have been averaging 16 frac stages with horizontal laterals between 4,000 and 5,000 ft. However, this might not be the norm over time as the geological intricacies of the play are better understood.

Compared to other shale plays such as the Haynesville and Eagle Ford, where overall well costs can be $7 million and $5.5 million, respectively, horizontal well expenditure in the Niobrara is much more economical at roughly $3.5 million, depending on the extent of completion services contracted. Vertical wells in the area cost approximately 75% less. Even though pressure pumping equipment supply is expected to be tight in the region through 2011, well costs are not expected to inflate to a level that will affect scheduled project finances.

Reported IP rates for horizontal wells have been impressive, despite significant variations. The highest rate reported was from EOG Resources Inc.'s famed Jake 2-01H well, which flowed a maximum unrestricted rate of 1,558 b/d of oil. Wells are expected to average around 800 b/d of oil in the D-J Basin. Estimated ultimate recoveries for horizontal wells are anticipated to be in the 300,000 to 400,000 boe range, depending on field characteristics, with less gas than traditional vertical wells.

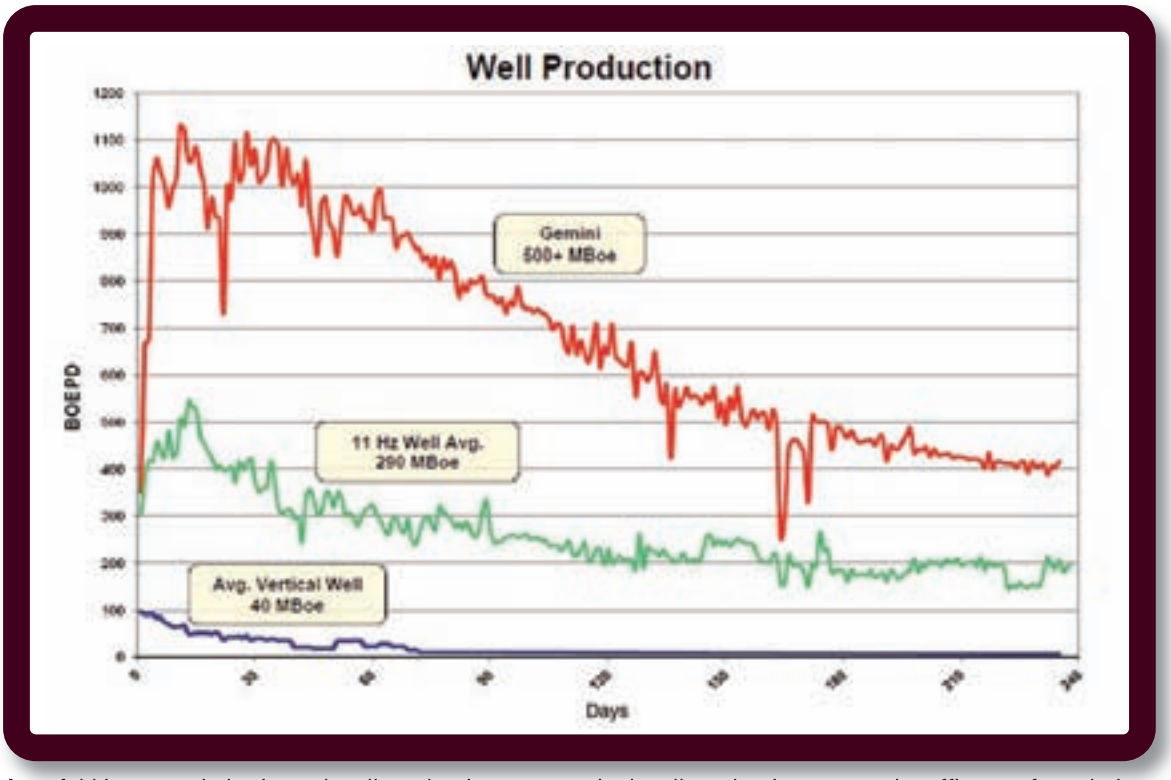
For example, Wattenberg Field vertical wells typically have a 40,000 bbl ultimate recovery with about 60% natural gas. Despite steeper horizontal well declines, a tenfold increase in production proves the efficacy of revolutionary stimulation techniques associated with horizontal drilling and more than justifies the extra capital outlay. Recovery results are based on 320-acre spacing. Existing vertical wells within the play will affect future downspacing and could further influence horizontal decline rates.

Because only a few horizontal wells have been drilled recently, and most producers in the play are in the exploratory phase – not to mention the geological convolutedness of the formation – it is impractical to establish a standard type curve. Although the horizontal well IP rates are far higher than those of vertical wells, it is not yet fully understood how fast they will decline. While most predict a gentle slope, others are a little less optimistic.

For example, Carrizo Oil and Gas Inc. anticipates an IP rate of 600 b/d of oil with a gradual decline to about 80 b/d in 24 months. Whereas, Rex Energy Corp.'s Silo Field type curve has a 400 b/d IP rate with a 24-month decline also to around 80 b/d. Rex Energy's assumptions include a 13% severance and ad valorem tax and 18% royalties, as well as operating and gathering transportation costs of $13/bbl.

Infrastructure

Gathering infrastructure and transportation to take petroleum products to market is critical in any developing play. The Niobrara, an old play that has been renewed by technological advancements and favorable economics, will not see many major greenfield infrastructure projects due to its existing facilities, but some overall regional infrastructure will be needed.



A tenfold increase in horizontal well production over vertical well production proves the efficacy of revolutionary stimulation techniques associated with horizontal drilling and more than justifies the extra capital outlay. *(Source: Noble Energy Inc.)*

Several pipelines traverse the Niobrara play, but only one is a major oil system. In the D-J Basin, SemGroup Inc.'s 526-mile, 12-in.-diameter White Cliffs pipeline provides approximately 30,000 b/d of oil takeaway from the area into the oil hub at Cushing, Okla. The pipeline is expandable to 50,000 b/d.

Producer price realizations with this pipeline were estimated to save approximately $4 to $6/bbl across the field (Anadarko Petroleum Corp. and Noble Energy Inc. are major shippers on White Cliffs). Operators also are anticipating significant increased takeaway capacity for condensates and natural gas liquids. Despite recent additional capacity, robust development in the play will require at least 20,000 b/d of additional takeaway capability to prevent bottlenecks in the next three years.

The future

The Niobrara is not a typical shale play and hence the dissection of its economic specifications cannot be standardized and is yet to be fully understood. Nevertheless, the initial diagnosis of any horizontal well within the tested acreage predicts a healthy financial upside.

Long-term performance is essential to understanding and predicting the evolution of this complex naturally fractured play. The regional learning curve to unlock shale oil will only get better since most operators in the Niobrara have simultaneous operations in the nearby Bakken – another shale play with strikingly similar geological characteristics.

Improvements in Niobrara operational efficiencies cannot get worse, but economies of scale will be indispensable in operational optimization. Associated natural gas monetization will be the icing on the cake for major producers in the play whose main focus is the higher margin liquids. Currently, the main barrier to entry for new producers is acreage acquisition, which, to some extent, can be surmounted by acquisitions and joint ventures. Once entry barriers are overcome, the outlook on economic feasibility should be positive. ■

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A rig hand climbs the mast during drilling operations in Anadarko's Wattenberg Field in Colorado. *(Photo courtesy of Anadarko Petroleum Corp.)*

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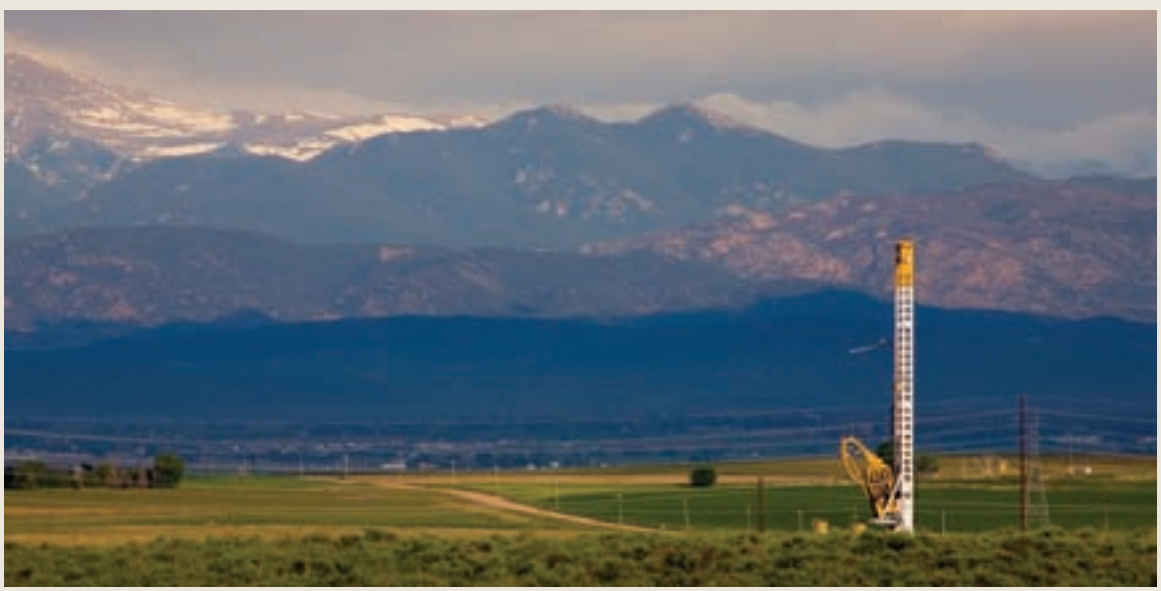

A drilling rig handles completion operations for Anadarko's active drilling operations in Wattenberg Field in Weld and Adams counties in Colorado. *(Photo courtesy of Anadarko Petroleum Corp.)*

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A cyclist cruises past a Niobrara outcrop along Colorado Highway 7, north of Boulder. *(Photo by Lowell Georgia)*

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