COLORADO DEPARTMENT OF NATURAL RESOURCES

ROCK TALK

Colorado Geological Survey

Volume 13, Number 1
Spring 2011

Colorado's New Oil Boom—the Niobrara

Introduction

Niobrara shale oil is an exciting new hydrocarbon prospect for Colorado. Our resource-rich state, while having developed extensive natural gas reserves over the past couple of decades, is now in the process of 'rediscovering' its oil in organic-rich shale. The current economics of fossil fuels, combined with the development of new drilling and stimulation technologies, is driving this renaissance.

The Niobrara Formation, one such organic-rich shale, is a particularly hot target here in Colorado. While a large volume of natural gas (>700 billion cubic feet by one estimate) has already been produced, it is now Niobrara oil that is the focus of everyone's attention. Often mentioned for comparison purposes are the Bakken Formation of North Dakota or the Eagle Ford Shale of Texas. But, as producers are just beginning to ramp up drilling and production, the question of how much oil is really available for exploitation over the long term remains to be answered.

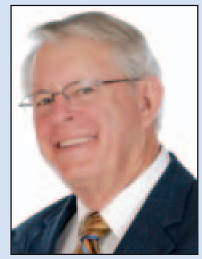
One of the first Niobrara horizontal wells, known as the Jake well, was drilled by EOG Resources in October 2009 and produced 50,000 barrels of oil in its first 90 days. After a year, it is still producing more than 2,500 barrels of oil per month. This is significant given that the average oil well in the U.S. generates just 300 barrels of oil per month. Another well, the Gemini well drilled by Noble Energy in early 2010, produced over 32,000 barrels of oil in 6 months. These early results are certainly promising, but for each of the more prolific wells, there are others that show little or no production. How quickly the flow of oil declines is very important for looking towards future potential of the resource as a whole.

So what is the Niobrara Formation? Where does it occur in Colorado? Why is there excitement about its development? How might this affect the economy and people of Colorado? This article will address some aspects of these important questions, providing a background on the geology, history of development, and current exploration activity in the Niobrara Formation.

Shale Oil (versus Oil Shale)

Shale oil should not be confused with the perhaps better known "oil shale" found in western Colorado. Shale oil and related shale gas occur in reservoirs where oil already exists as a liquid in very small openings between grains of rock. Oil shale, on the other hand, is an inorganic rock reservoir containing no liquid petroleum. It must be heated to high temperatures in order to convert solid organic material (kerogen) into a liquid or gas hydrocarbon. While oil shale in Colorado contains a potentially immense amount of hydrocarbon resources, producing the oil in economically, technologically, and environmentally feasible ways is still very challenging. Shale oil reservoirs, however, are today being successfully produced in a number of places including several Colorado basins. The Niobrara Formation is a great example.

Note from the Director:



"New oil boom." The words stir excitement in the hearts of landmen, landowners, geologists, engineers, regulators, environmentalists, tax collectors, the unemployed, and charlatans. Although oil production from the Niobrara strata began early in the 20th century; the new oil wells in Colorado are causing a land rush and drilling boom in many parts of the state.

The application of creative thinking and technology to these long-producing layers of rock named the Niobrara Formation, has raised the hopes of thousands of Coloradans. Many believe that the Niobrara, and associated formations, might provide a sustained drilling and production boom that is akin to the Bakken-shale, oil boom in North Dakota. Horizontal drilling and formation-stimulation technology are the keys to both plays.

Whereas some of the new horizontal wells have reported very high flows of oil, others have not been so productive. It is still early in the play. The potential is large, but widespread success remains to be proven. And, as in all oil or gas plays, it always gets back to the basic geology of the formations.

This *RockTalk* is an effort to help citizens, the media, and policy makers understand what all of the fuss is about.

Vince Matthews
State Geologist of Colorado

Figure 1. Paleogeographic reconstruction of an inland seaway during the late Cretaceous period (85 million years ago) in North America. Present-day Colorado was submerged under salty water. Deposition of limestone, silt, and sand were occurring across most of the state. Green line shows location of Figure 2 cross section below. (Map modified from Ron Blakey, Colorado Plateau Geosystems, Inc.)

Geology

Niobrara Distribution

The Niobrara Formation was deposited beginning nearly 90 million years ago. At that time, an inland seaway extended from the present-day Gulf of Mexico to the Arctic Ocean (Figure 1) submerging all of what is today Colorado in shallow (<100 feet), to moderately deep (>1500 feet), salt water. For the next six to seven million years, calcareous debris from algae and the remains of abundant marine life living in this seaway slowly accumulated. Additionally, sediment was shed from an ancient mountain range growing to the west in what today would be Utah.

When the sea finally withdrew, thick layers of clay, mixed clay and limestone, chalk, and smaller amounts of silt and sand were left behind to form some of the sedimentary rocks we observe today on, and beneath, the surface of Colorado. A geologic cross-section provides a useful tool for visualizing what the basin may have looked like at the end of the seaway's existence (Figure 2). In places, more than 10,000 vertical feet of sedimentary rock would have accumulated.

Studying the rock layers that make-up the Niobrara Formation helps geologists piece together the climate and environmental conditions at the time of the inland seaway. From analyses of the limestones, for example, it is thought that the seaway water was typically warm and the climate tropical. Further, models have suggested that common water circulation patterns involved cooler water flowing south along the western edges of the seaway, while warmer waters flowed

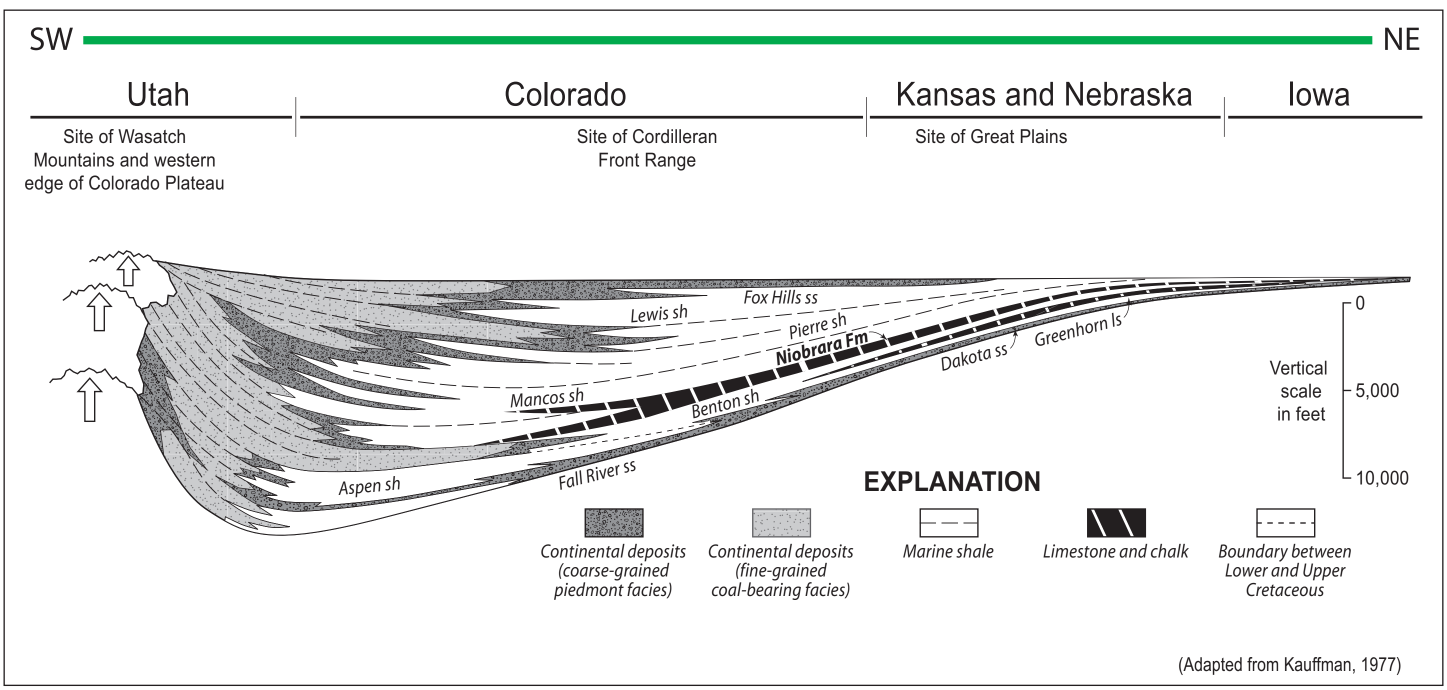


Figure 2. Regional cross section across area of the inland seaway of the late Cretaceous (see Figure 1 for location). A cross section is like taking a giant cake knife and cutting straight down into the earth. In removing a slice, we would expose what the rock strata beneath the surface look like in the third dimension. This cross section shows the accumulated sediments at about 60 million years ago. Toward the west, the Niobrara Formation is part of the Mancos Shale rocks; in the east it is usually identified as a distinct rock unit. Note that this cross section reconstructs areas that have been eroded by the present-day Rocky Mountains in Colorado.

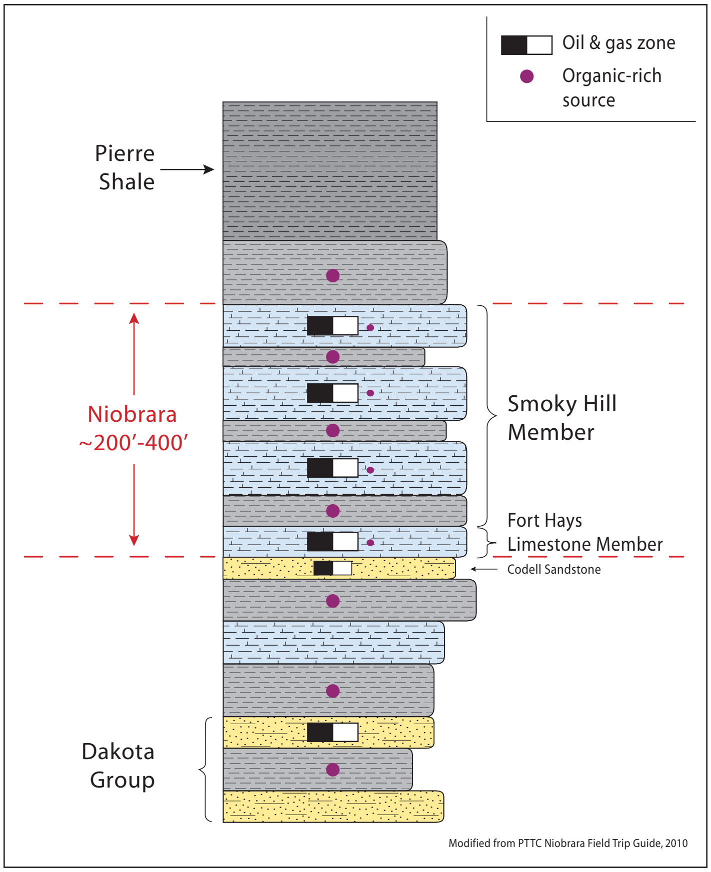


Figure 3. Generalized Niobrara Formation stratigraphy for northeastern Colorado. Shales (gray) usually act as source rock and fractured limestones (blue) act as reservoirs. In places, the limestones can also act as lesser source rocks. In rock units below the Niobrara interval, the sandstones (yellow) can be good hydrocarbon reservoirs as well.

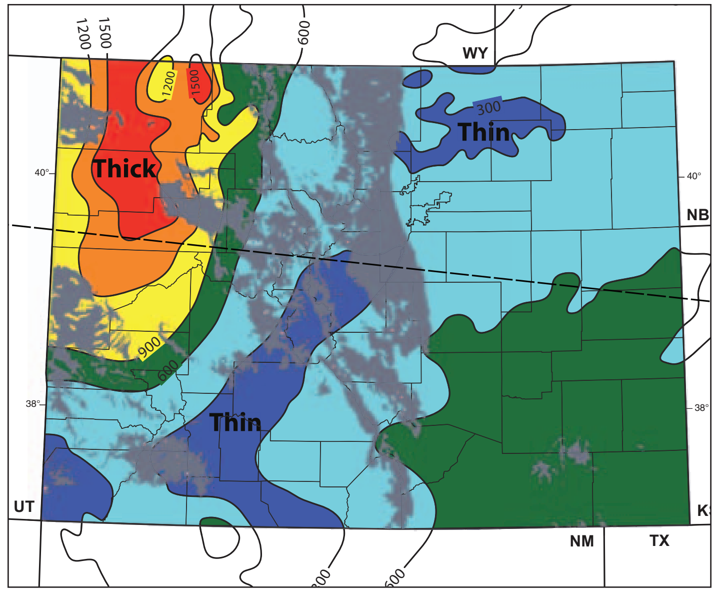


Figure 4. Total thickness of the Niobrara Formation and its equivalents in feet. Each contour represents 300 feet of thickness. Blue shows thinnest areas of Niobrara deposition. Note that throughout much of central Colorado the Niobrara has been eroded away during uplift of the present-day Rocky Mountains. This is shown as gray shaded areas on map. (Modified from Longman et al., 1998)

north into the central and eastern portions of the seaway. The interaction of these cooler and warmer waters occurred around the latitude of present day Colorado and Wyoming. When combined with overall fluctuations of sea level, this can explain much about the distribution of different rock types found in the Niobrara Formation today. In short, the alternating layers of shale and chalk generally coincide with the presence of cooler and warmer water respectively at the time of deposition.

The preserved rocks of the Niobrara Formation vary across the state, both laterally and vertically in the subsurface (Figure 3). Today, in the eastern basins of Colorado, deposits include chalk (made predominantly from algae-derived carbonate plates known as coccoliths), carbonate mud, shale, and silt. In the western basins, less chalk is present, with instead more shale, silt, and sand that was shed from the rising mountains to the west. Here the Niobrara is often grouped as part of the Mancos Shale Formation.

The overall thickness of the Niobrara Formation varies between 200 and 400 feet in northeastern Colorado (Figure 3 and 4). In northwestern Colorado, however, thicknesses can be much greater—in places more than 1500 feet (Figure 4).

The Niobrara Formation was originally deposited over the entire state and surrounding area (as shown in the Figure 4 thickness map). Where we find the Niobrara today, however, has been affected by erosion (Figures 4 and 5). The modern-day Front Range and associated mountain building events resulted in complete removal of sizeable portions of the Niobrara and all other Cretaceous sedimentary rocks. Gray shaded areas on Figure 4 show this erosion.

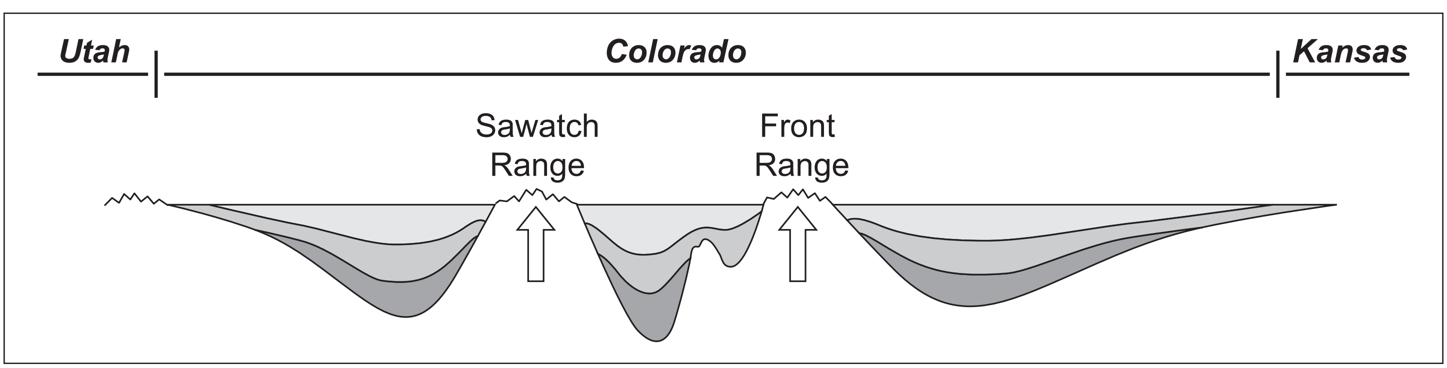


Figure 5. Generalized cross-section (see dashed line on Figure 4 above for approximate location) shows post-depositional uplift and deformation resulting in erosion of the Niobrara Formation over parts of Colorado, including the present day Front Range and Sawatch Range. (Modified from Kauffman, 1977)

Figure 6. Colorado sedimentary basins (dark blue) with known shale oil potential overlaid on paleogeographic map of late Cretaceous. The Denver Basin is the first basin to have significant shale oil production through horizontal drilling techniques. (Modified from Ron Blakey, Colorado Plateau Geosystems, Inc.)

All Colorado sedimentary basins include some Niobrara Formation rocks or equivalent. Oil and gas production from the Niobrara occurs in most of these basins (Figure 6). The Denver Basin has historically been the most significant producer, followed by the Sand Wash Basin, Piceance Basin, Douglas Creek Arch (not shown), and North Park Basin. There is also Niobrara production in the Raton and San Juan Basins (not shown). The depositional setting and subsequent geologic history determines whether a particular basin contains worthwhile exploration targets.

Surface outcrops that allow for visual inspection (Figure 7) of the Niobrara Formation are primarily limited to the southeastern portion of the state. Characterization of the Niobrara in the subsurface is typically done using rock cores and geophysical data collected from oil and gas wells.

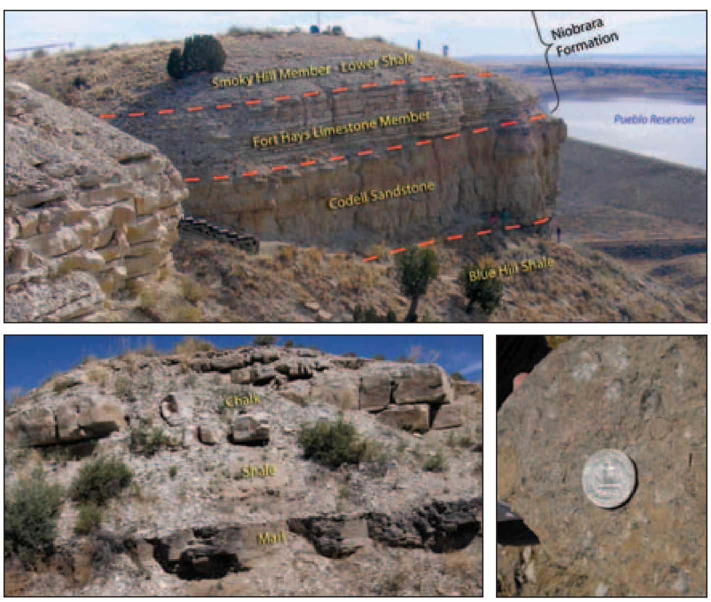
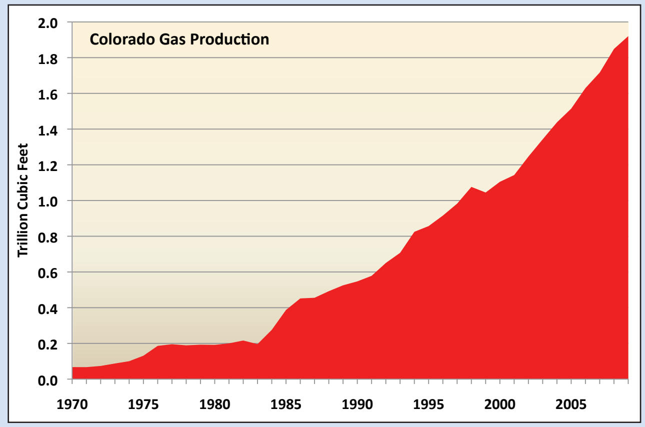
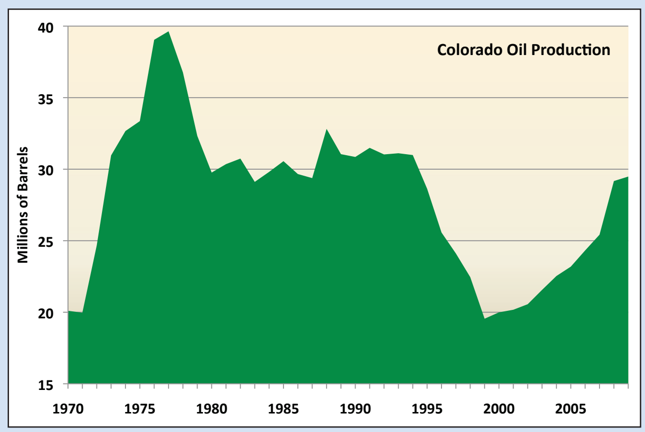


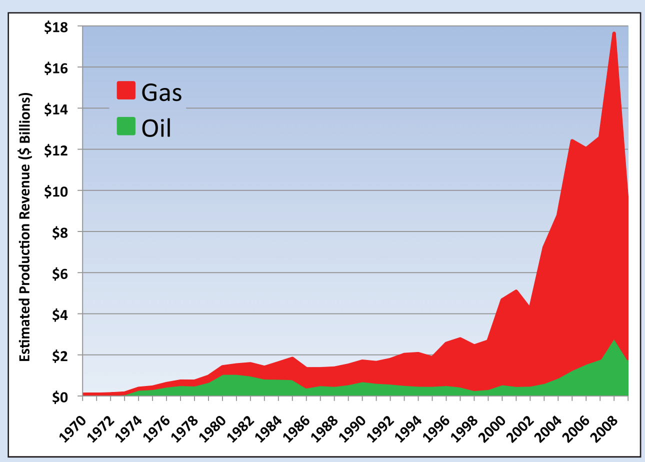
Figure 7. (Upper Photo) Surface outcrop of the Niobrara Formation west of Pueblo (upper photo) showing Lower portion of the Niobrara Formation, including the Fort Hays Limestone and Smoky Hill Member as well as underlying units. (Lower Photos) Exposure of Smoky Hill Member near Walsenburg—a mixture of chalks, clay-rich limestone, and shale. Close up of shell-rich limestone typically found within the Niobrara Formation. For much of Colorado the Niobrara is buried thousands of feet below the surface. (Photos by Dave Noe and Vince Matthews, CGS)

Did you know???

- As of 2009, Colorado has all, or part, of seven of the 30 largest gas fields in the nation by proven reserves. The San Juan Basin and the Wattenberg field are in the top 10.
- The Wattenberg field is also the 13th largest oil field in the US.
- Gas discoveries in the San Juan, Denver, and Piceance Basins have helped Colorado to reach 3rd in the nation for total gas reserves.
- For 2010, the total value of Colorado's oil and natural gas production is estimated to be $9.2 billion.







Members of the Niobrara Formation

In the eastern portion of the state, the Niobrara Formation can be subdivided into two units, the Fort Hays Limestone Member and the Smoky Hill Member. In the west, this distinction is more difficult to make.

The Fort Hays Limestone is characterized by a small, sandy section at the base with the majority being composed of carbonate sediments. Abundant chalk beds are separated by thin layers of limestone-rich shale, silt, and organic material. The Fort Hays is between 10 and 60 feet thick in eastern Colorado, and generally increases in thickness towards the south.

The Smoky Hill Member of the Niobrara Formation is the much thicker portion of the Niobrara. Typical thickness across Colorado ranges from nearly 200 feet in the east, to more than 1400 feet in the northwest part of the state. This member has been divided into discrete intervals based on variability in the chalk and shale content. These intervals play an important role in hydrocarbon production—shales usually are the source rocks, while chalks and clay-rich limestones form the reservoirs. Indicators based on subsurface geophysical data as well as examination of well cores and outcrops have allowed identification of these various intervals.

Source Rock and Reservoir Rock

Source rock is composed of sedimentary layers (usually shale) rich in organic material that will convert into oil when buried deeply enough. Although the source rock generates the oil, the liquid must move into a reservoir rock to be producible. Reservoir rock has sufficient porosity (holes or pore space) to store the oil in a commercial accumulation. Moreover, a reservoir rock must also have sufficient permeability (interconnected pore spaces) for the stored oil to flow through the rock and out into the well.

Permeability can be enhanced by fracturing of the rock, either naturally or artificially. The Niobrara reservoirs may be naturally fractured at small or moderate scale. After drilling, artificial fracturing can increase oil and gas flow to make wells more economic.

Two factors—water depth and water circulation patterns within the Cretaceous inland seaway—played a primary role in controlling where we observe clay, shale, limestone, or sand in the subsurface Niobrara Formation today. After deposition was complete 80 million years ago, the Niobrara Formation rocks were buried and subjected to increasing temperature with depth. Indeed, burial of rock thousands of feet in the subsurface is a key factor in the generation of oil and gas. While Mother Nature never buried the oil shale of northwest Colorado deep enough to convert the organic material (kerogen) to oil, this process has occurred frequently for Niobrara shales. Elevated heat flow, in places such as the Raton Basin in south central Colorado and the Wattenberg Field northwest of Denver, has allowed for oil conversion at shallower depths than would normally be expected.

Figure 8. Geologist Susan Landon (white shirt) stands with hand on outcrop of fractured limestone. Fractures are critical for creating pathways that oil can flow through during production. Here, some layers of rock are intensely fractured (center of photo) while others (right side of photo) are not. (Photo by Vince Matthews, CGS)

Rock Properties: Organic Content, Porosity, Permeability, and Fractures

The total organic carbon (TOC) content is an important indicator of a rock's potential for generating oil and gas when heated. Normally, sedimentary rocks contain less than 1% organic carbon, while good 'source' rocks contain more than 5%. In places, the Niobrara clay-rich limestones and shales contain in excess of 8% TOC. This varies considerably, however, depending on geographic location in the state.

The northeastern portion of the Denver Basin has some of the highest TOCs in Colorado (>5%), whereas the Niobrara Formation found farther west usually has carbon contents that vary between 1 and 4%. The chalk layers, in some cases, may provide source rock potential as well, but organic content is generally limited to between 1 and 2%. For comparison, the Bakken shale play in North Dakota has TOCs that average more than 14%. The remains of marine organisms, algae, and some land-based plant material comprise the majority of organic material making up the Niobrara Formation source rocks in Colorado. As a consequence, these units will tend to generate gas and waxy oil.

Other critical rock properties for hydrocarbon reservoir development include porosity (the void spaces in the rock) and permeability (the connection between void spaces affecting the ability of fluid to flow). Porosity in the Niobrara is typically less than 10% and permeability is very low. While chalk can originally have porosity in excess of 50%, this type of limestone can become highly compacted when buried under thousands of feet of overlying sediment. Small grains can be very tightly packed, eliminating void spaces for trapping oil and gas. Further, chemical processes that involve dissolution and precipitation of calcite minerals can further weld the rock reducing the initial porosity and permeability.

The sedimentary basins of Colorado have evolved in unstable geologic terrain. Since the Niobrara Formation was deposited, the ground has been uplifted, depressed, uplifted again, and tilted. This movement at times has resulted in fractures, faults, and folding. With such low permeability, fractures in the Niobrara rocks (Figure 8) are of particular importance for oil and gas extraction. Permeability in the Niobrara chalks and clay-rich limestones is so low that for these rock types to make good oil reservoirs, fracture pathways must exist naturally, or be generated artificially as part of the drilling process.

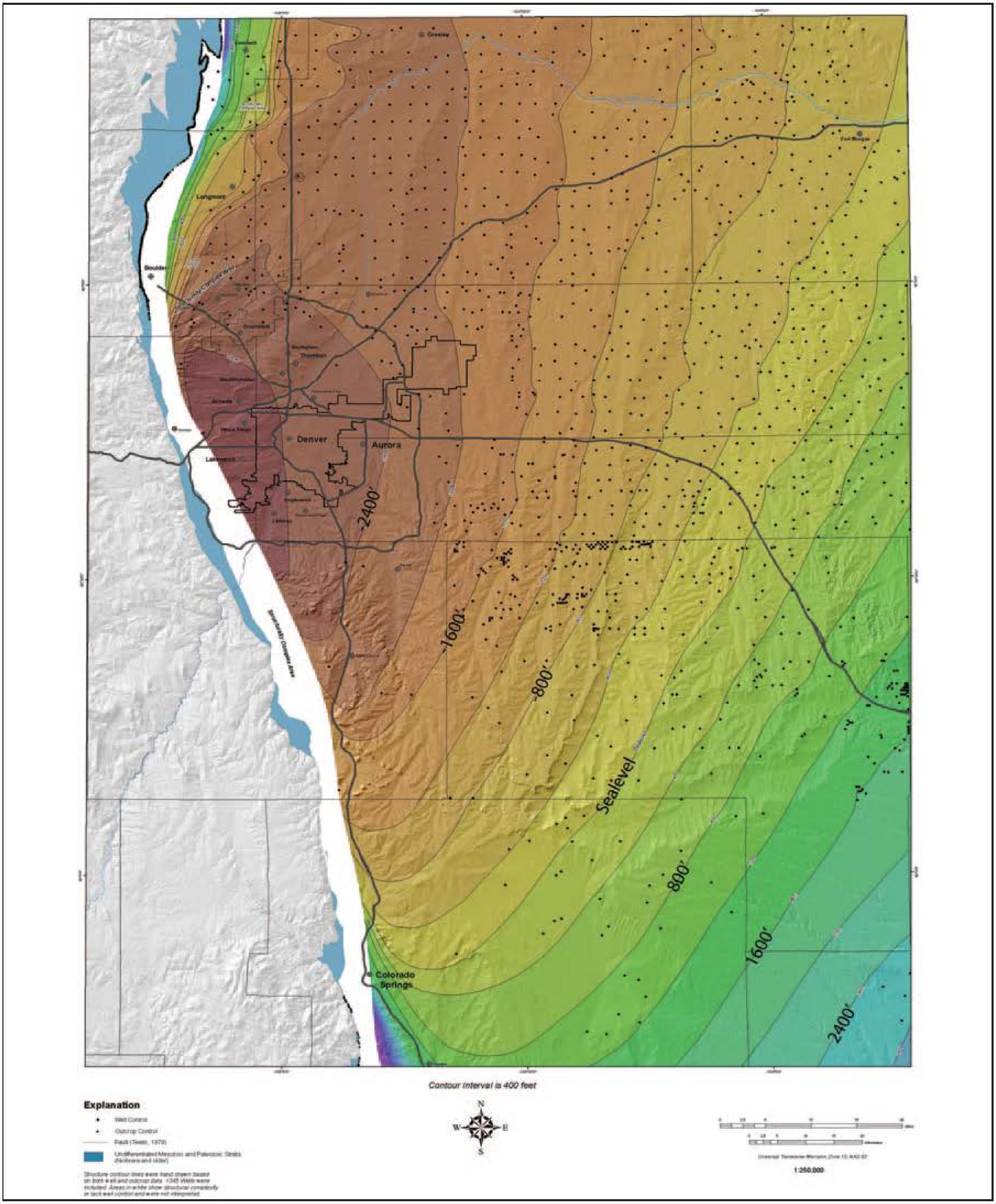


Figure 9. Top of the Niobrara Formation in the Denver Basin between Colorado Springs and Greeley. Black circles represent location of oil and gas wells used to determine elevation of surface. Red and orange colors show deepest parts of Niobrara. (Denver Basin Geologic Maps: Bedrock Geology, Structure, and Isopach Maps of the Upper Cretaceous to Paleogene Strata between Greeley and Colorado Springs, Colorado; Denver Museum of Nature and Science and CGS).

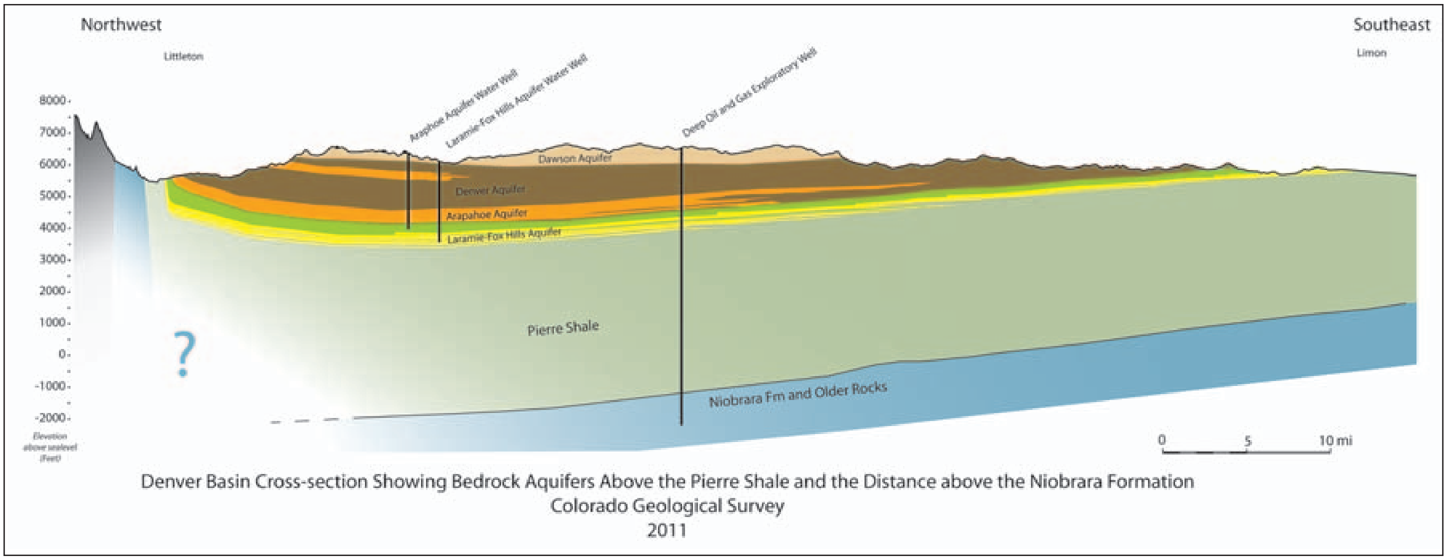


Figure 10. Cross-section through the Denver Basin from northwest to southeast showing Cretaceous rock layers including Niobrara Formation in blue. For much of the Denver Basin, the Niobrara rocks are typically greater than 5,000 feet beneath the surface. (Denver Basin Geologic Maps: Bedrock Geology, Structure, and Isopach Maps of the Upper Cretaceous to Paleogene Strata between Greeley and Colorado Springs, Colorado; Denver Museum of Nature and Science and CGS).

Niobrara Formation Depth and Temperature in the Denver Basin

The Denver Basin has been a prolific oil and gas producing region since the discovery of oil in the Pierre Shale near Boulder back in 1901. The northern Colorado portion of this basin, where much of the current Niobrara drilling activity is taking place, has been buried at a sufficient depth for sufficient time to generate oil and gas.

The elevation of the top of the Niobrara Formation is shown in Figure 9. The deepest portion lies approximately 8000 ft beneath the surface in Denver and Lakewood. The western boundary of the deepest part of the basin is interpreted to lie just east of the Front Range, although this is not well constrained. The eastern boundary of the basin, located near the Colorado–Kansas border has layers of rock dipping very gently towards the west. Today's Denver Basin in cross section (Figure 10) has a shape not dissimilar to the larger sedimentary basin that existed during the late Cretaceous time period 60+ million years ago (Figure 2).

Depth and temperature of rock formations play a critical role in the generation and subsequent accumulation of oil and gas. The geothermal gradient describes how temperature increases with depth in the subsurface. In Colorado, the gradient is variable depending on location. Factors such as the rock type and thickness are important, as are variations in the heat produced by the crust and mantle. In sedimentary basins, the presence of shale, a rock type with low thermal conductivity, has a notable influence. For the Denver Basin, the geothermal gradient can be calculated based upon the measured temperature in oil and gas wells drilled to the Niobrara Formation. Values between 25 and 45 degrees Celsius per kilometer (°C/km) of depth are common. The highest values are around 70 °C/km observed more often along the edges of the Denver Basin. Here the sedimentary rock layers are thinner allowing for potentially higher heat flow.

Oil and Gas Production

Oil

The Niobrara Formation has long been recognized as a hydrocarbon producer in Colorado. The earliest oil production from the Niobrara was in the 1920s in the northwestern part of the state in Rio Blanco, Moffat, and Routt counties. Starting in the mid 1950s through the 1960s, the occasional Niobrara producing wells were drilled in the Denver Basin. It wasn't until 1975, however, that the pace of development increased substantially. As of November 2010 more than 900 wells have at one time produced oil from the Niobrara Formation in the Denver Basin, the overwhelming majority in Weld County (Figure 11).

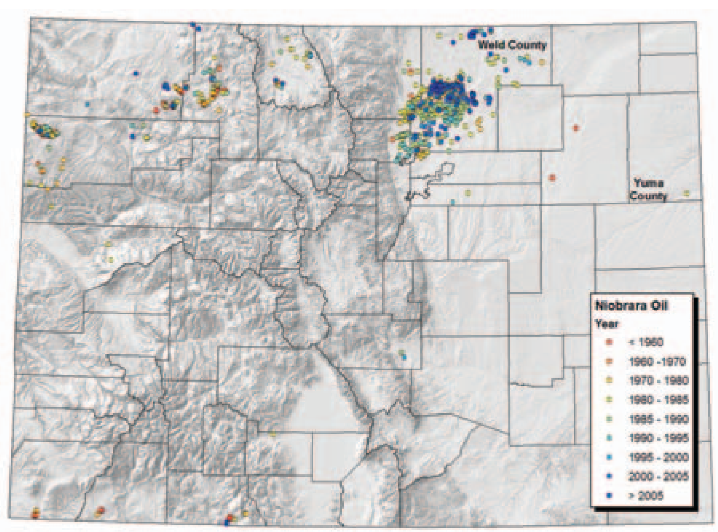


Figure 11. Oil wells in the Niobrara Formation. Date of completion by color with blue most recent. (IHS Energy Well Database, 2011)

Natural Gas

More than 4,000 Colorado wells have produced natural gas from the Niobrara (Figure 12). This is a minimum number, however, as it does not include Niobrara comingled wells (i.e. wells that produce from multiple rock formations). With these wells included, the total Niobrara gas well count jumps to more than 15,000 (Figure 13). In either case, the vast majority of Niobrara gas wells are found in Yuma and Weld Counties, with less than 3% having been drilled outside the Denver Basin.

Drilling for natural gas in the Colorado Niobrara accelerated in the 1980s, and then picked up even more rapidly in the late 1990s. In the last decade, 2,738 Niobrara-exclusive gas wells have been completed in Colorado. Horizontal drilling and artificially fracturing the rock have encouraged Niobrara drilling activity in recent years.

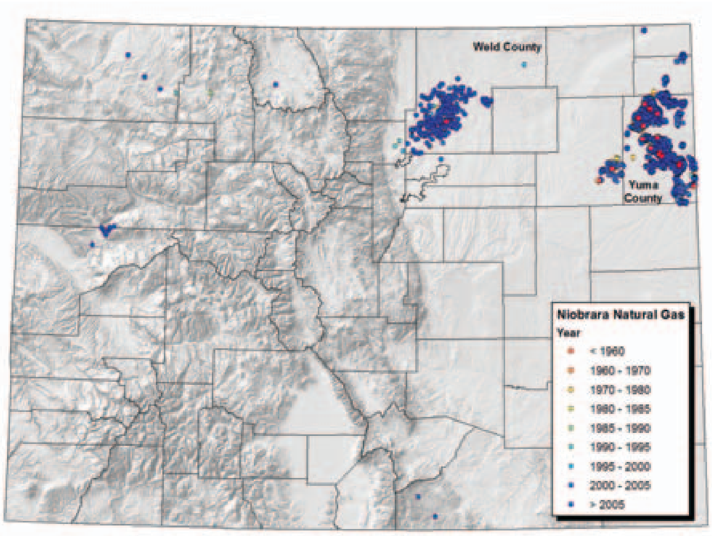


Figure 12. Gas wells in the Niobrara. Date of completion by color with blue most recent. (IHS Energy Well Database, 2011)

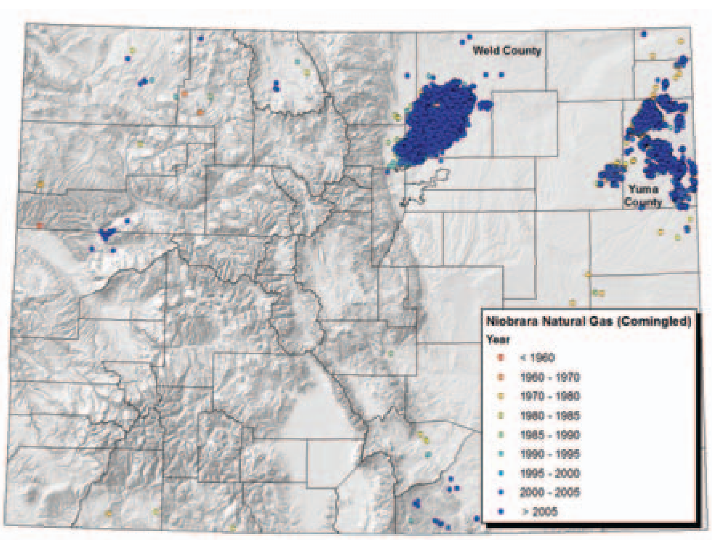


Figure 13. Gas wells in the Niobrara including comingled production. Date of completion by color with blue most recent. (IHS Energy Well Database, 2011)

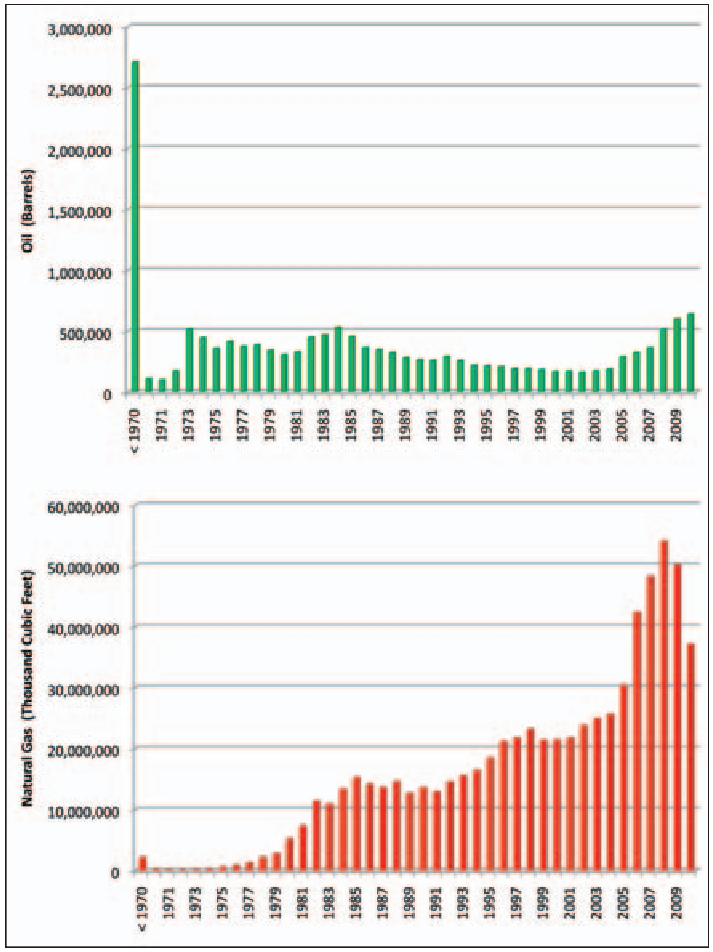


Figure 14. Historical oil (top) and natural gas (bottom) production from the Niobrara Formation in Colorado not including comingled production. Data for 2010 is incomplete due to lag in reporting to COGCC. (IHS Energy Production Database, 2011)

In shallower portions of the Denver Basin (primarily in Yuma County near the Kansas border), the Niobrara produces gas that was generated through microbial activity instead of by heat associated with increasing depth. In the mid 1970s, artificial fracturing of the limestone chalk allowed commercial production. Individual wells have produced between 10 and 20 million cubic feet of gas. Porosity can be substantially higher (between 30 and 40%) in these rocks versus Niobrara plays located deeper in the basin to the west.

More than 700 billion cubic feet of gas and 15 million barrels of oil have been produced from the Niobrara Formation in Colorado (not including comingled Niobrara production). In Figure 14, Niobrara historical production for oil and gas is shown by year. Cumulative production for the Niobrara is shown by county in Figure 15. Again, these are minimum volumes without comingled Niobrara production being taken into account.

Increased Niobrara oil production related to new horizontal drilling technologies is just beginning for the northern Denver Basin. Interestingly, even for the most promising new wells in this area, there is a long way to go before reaching

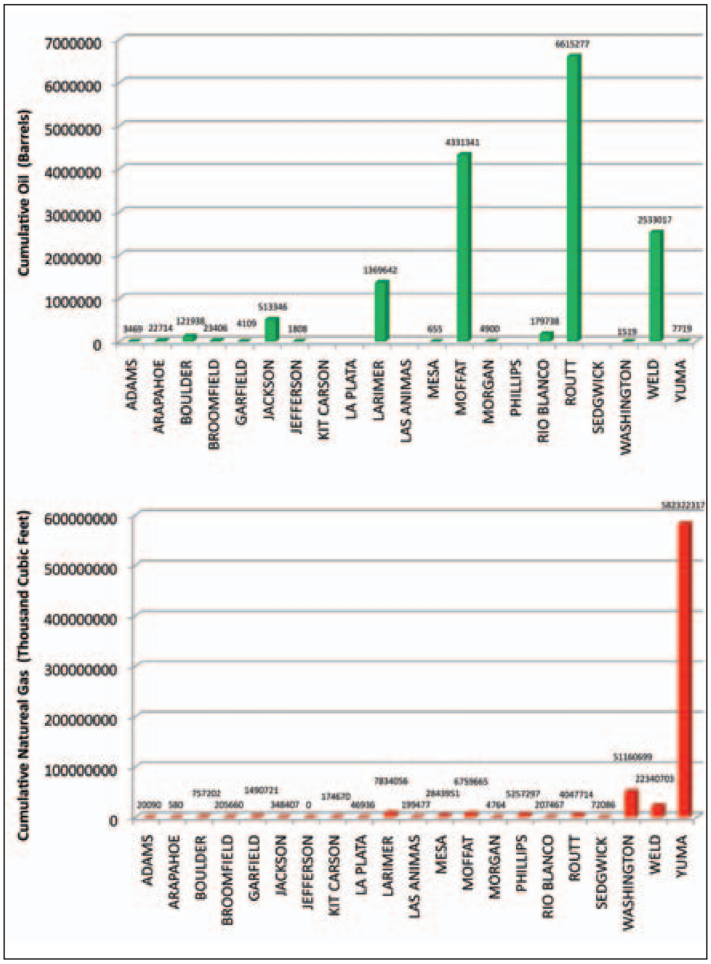


Figure 15. Cumulative oil (top) and natural gas (bottom) production from the Niobrara Formation in Colorado by county not including comingled production. Data for 2010 is incomplete due to lag in reporting to COGCC. (Source: IHS Energy Production Database, 2011)

the oil production levels achieved by several ’60s and ’70s Niobrara wells drilled in the northwest part of the state—wells that have produced more than 500,000 barrels each! Still this recent activity seems to be putting us on the right track.

Horizontal Drilling and Artificial Fracturing

Horizontal drilling for oil and gas wells has become a critically important technology for developing unconventional resources. The Niobrara Formation, like most sedimentary rock layers, is vastly larger in the horizontal dimensions than vertical. Consequently, a wellbore that parallels the layers (and the oil zone in the case of the Niobrara) will allow for a single well to be exposed to far greater area of the reservoir than a vertical well (Figure 16). In the Denver Basin, the typical Niobrara Formation is approximately 400 feet thick and consequently the potential production zone exposure for a single well will be limited to 400 feet. A horizontal well, however, can increase this reservoir exposure by 10 to 12 times. Wells are often drilled for 4000 feet or more, parallel to the producing layer after the targeted vertical depth is reached.

Several newer technologies are used in horizontal drilling. A hydraulic motor just above the drill bit allows the bit to be rotated without rotating the drill pipe. The most recent generation of equipment can allow for a 90 degree turn in just a few feet. A suite of sensors provides the compass direction, the inclination of the drilling assembly, and can even provide the three dimensional position (x, y, and z location) of the drill bit. Other sensors let drillers know what the conditions are deep in the subsurface including the temperature and some important physical properties of the rocks. While variable for different reservoir targets, production ratios for a horizontal will typically be 2 to 7 times the rate and volume of an equivalent vertical well.

A horizontal well also increases the possibility that the wellbore will intersect naturally occurring fractures and positions it for better generation of artificial fractures. Additionally, horizontal wells reduce the surface footprint of wellhead operations as several wells can originate from the same point on the surface. The downside to this technology, however, is the price—usually two to three times greater for drilling and completing a horizontal well versus a vertical well.

Hydraulic fracturing is a critical technology for the generation of fractures in the Niobrara. Pumping water and other fluids into the formation to raise pressure and force localized cracks to penetrate farther into the reservoir formation is the first stage. Once the fractures are opened, a proppant such as sand is typically used to keep these fluid pathways open. The Colorado Oil and Gas Conservation Commission (COGCC) is responsible for reviewing the design and operation of artificially fractured wells to ensure their safety.

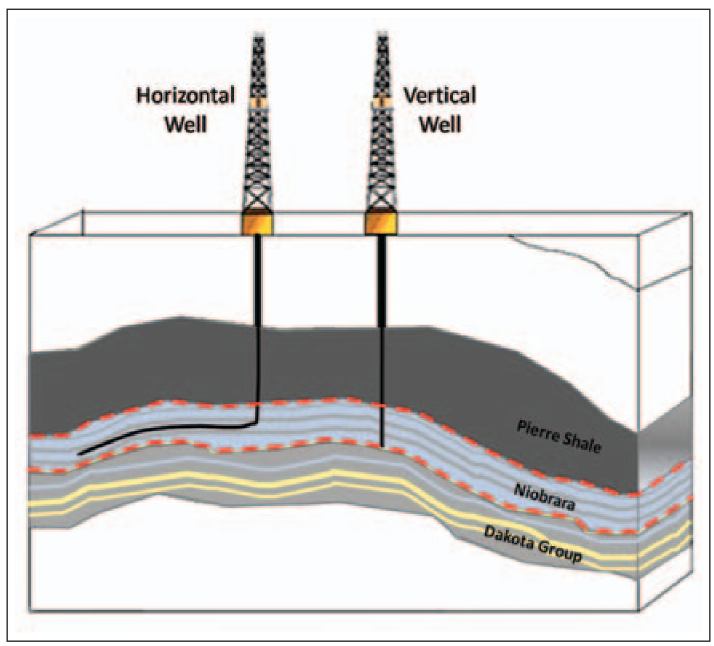


Figure 16. Drilling horizontal versus traditional vertical wells. Horizontal drilling allows for more area of reservoir interval to be exposed to wellbore and more natural and artificial fractures to be contacted. Horizontal drilling often increases production significantly. (Modified from EIA, Office of Oil and Gas, 1993)

Current Permitting Activity

The Colorado Oil and Gas Conservation Commission (COGCC) permits all oil and gas wells in the state. A review of horizontal wells for 2010 highlights the fervor regarding the Niobrara (Figure 17). Last year more than 190 horizontal wells were permitted in this formation—nearly 70% of all horizontal wells in Colorado. Weld County saw the vast majority of these new horizontal well permits, a significant change from previous years when most horizontal wells were permitted in western slope counties. Interestingly, the traces of horizontal wells shown on a map provide insight as to the orientation of the regional rock stress directions (Figure 18) in Weld County. Because producers want to intersect as many natural micro-fractures as possible, horizontal wells have been oriented perpendicular to the most common direction for existing cracks. In this case the well design suggests that these fractures run northeast–southwest.

Expectations are that horizontal well activity will remain high in 2011, and for the next several years as new parts of the Niobrara (and other similar formations) are explored.

Summary & Future Developments

Like other shale oil resources in the US, the Niobrara play takes advantage of horizontal-drilling technologies combined with artificial-fracturing methods to achieve economic production. The Denver Basin, especially in northern Weld County, is the target of most current drilling activity. As the Niobrara Formation is further explored and understood, other parts of Colorado including the greater Denver Basin, North and South Park Basins, and basins along the western slope will likely see increased Niobrara activity.

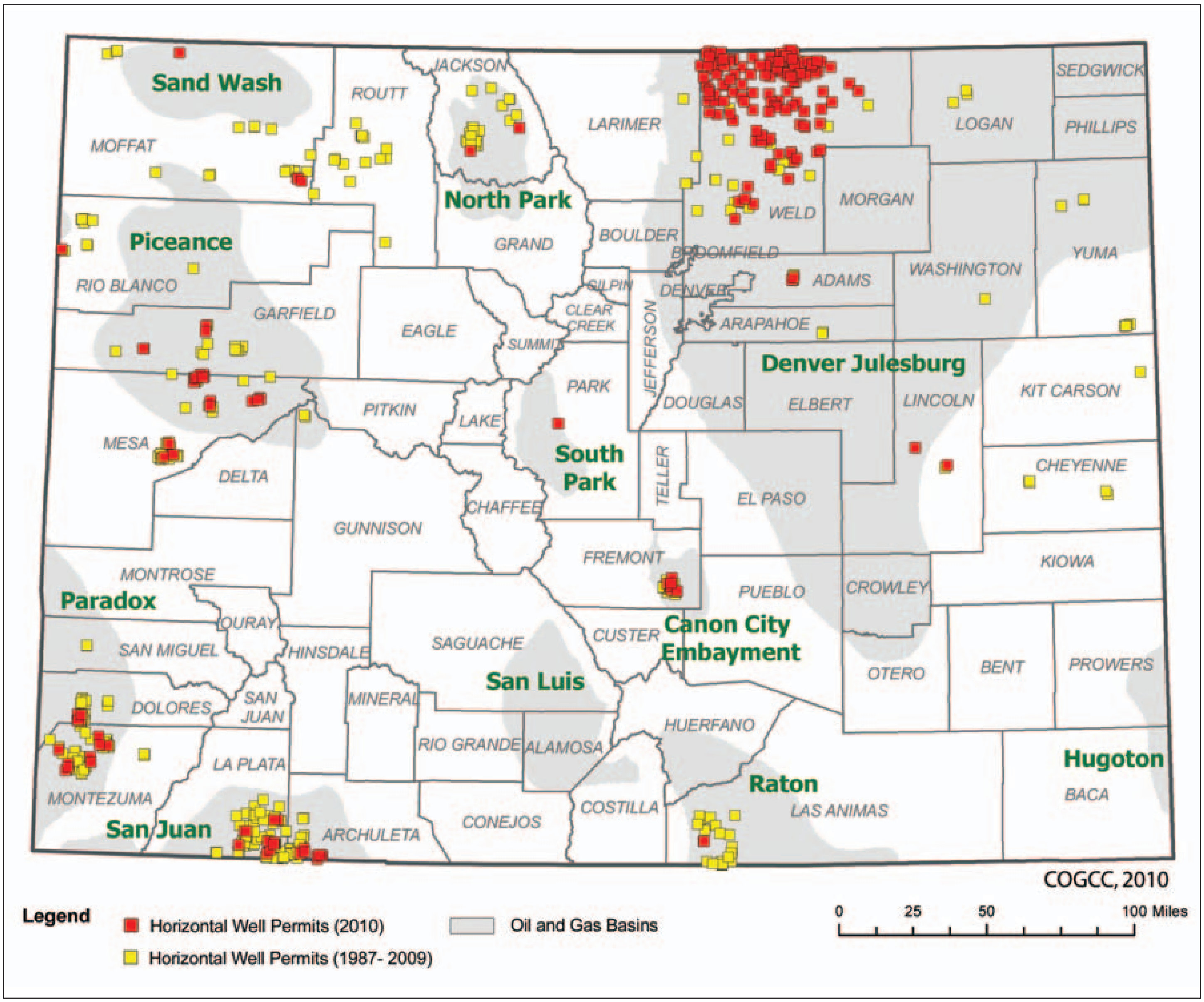


Figure 17. Horizontal well permits in Colorado. Red squares for 2010; yellow squares for 2009 and prior. (COGCC, 2010)

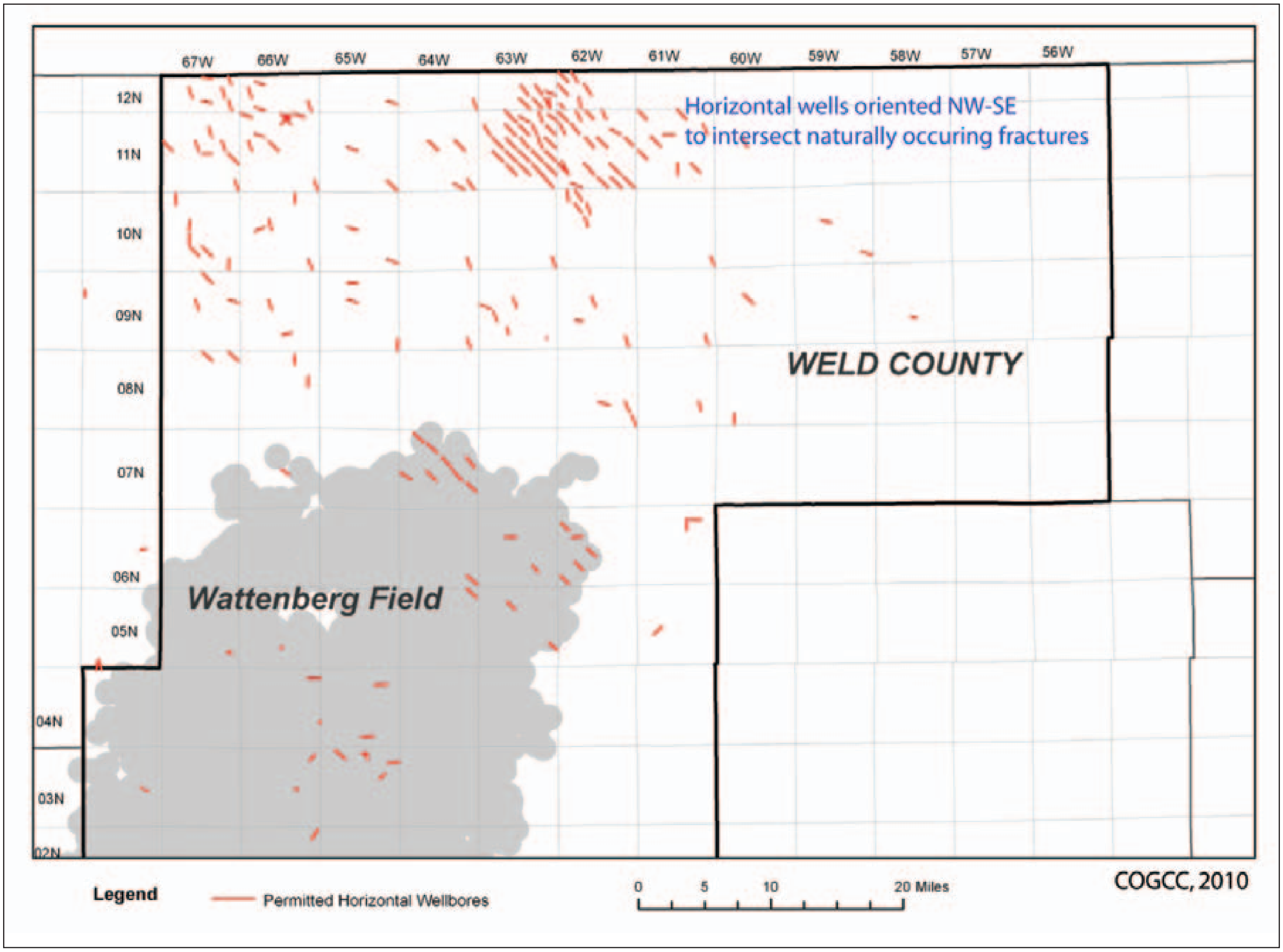


Figure 18. Orientation of permitted horizontal wells (red lines) in Weld County. Much of the recent activity has been concentrated on Niobrara production in the northern part of the county. The northwest/southeast orientation of the wells indicates that the operators believe the fractures run at right angles to their well bores, or northeast to southwest. (COGCC, 2010)

Whereas the Niobrara Shale play's potential is quite large, it is important that the resource be developed with some key aspects in mind: (1) Geology—the character of the Niobrara is not uniform across the state. Only select locations will have conditions appropriate for economic development of hydrocarbon resources. (2) Environment—considerations of the impact of horizontal drilling and associated hydraulic fracturing should be taken into account. While these technologies have proven to be safe, effective, and economic for hydrocarbon production at sufficient depth, Colorado's other surface and subsurface resources should be respected. (3) Economy—the Niobrara Formation has the potential to bring billions of dollars to the state of Colorado. The direct monetary benefits, as well as the creation of jobs and infrastructure, can have a substantially positive impact for our state, when well managed. All this depends, however, on the Niobrara being as lucrative a play as many are hoping for.

ROCKTALK

is published by the
Colorado Geological Survey
1313 Sherman Street, Room 715,
Denver, CO 80203

State of Colorado
John W. Hickenlooper, Governor

Department of Natural Resources
Mike King, Executive Director

Colorado Geological Survey
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THIS ISSUE
Editor: Chris Eisinger
Production: Rick Ciminelli/IDS

ROCKTALK

Colorado Geological Survey
1313 Sherman Street, Room 715
Denver, CO 80203

M#341100043

DOI: https://doi.org/10.58783/cgs.rt1301.zjzb5290

Further Technical Resources

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