Drilling 101

Drilling of a Natural Gas Well and Natural Gas Production in the Piceance Basin

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Outline

- Geology of the Piceance Basin and Garfield County
- Natural gas in sandstone lenses
- Preparation for a natural gas well
  - Site Preparation
  - Drilling
  - Casing and Cementing
  - Fracing
  - Well completion
- A natural gas well in production
  - The well
  - The pipeline
- Transportation of the natural gas
- Time Table for a natural gas well

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Piceance Basin

- The Piceance Basin occupies approximately 6,000 square miles in northwestern Colorado
- The Piceance Basin covers most of Garfield County
- Due to advances in directional drilling of tight sand lenses, the Piceance Basin has become the new hotbed of natural gas plays

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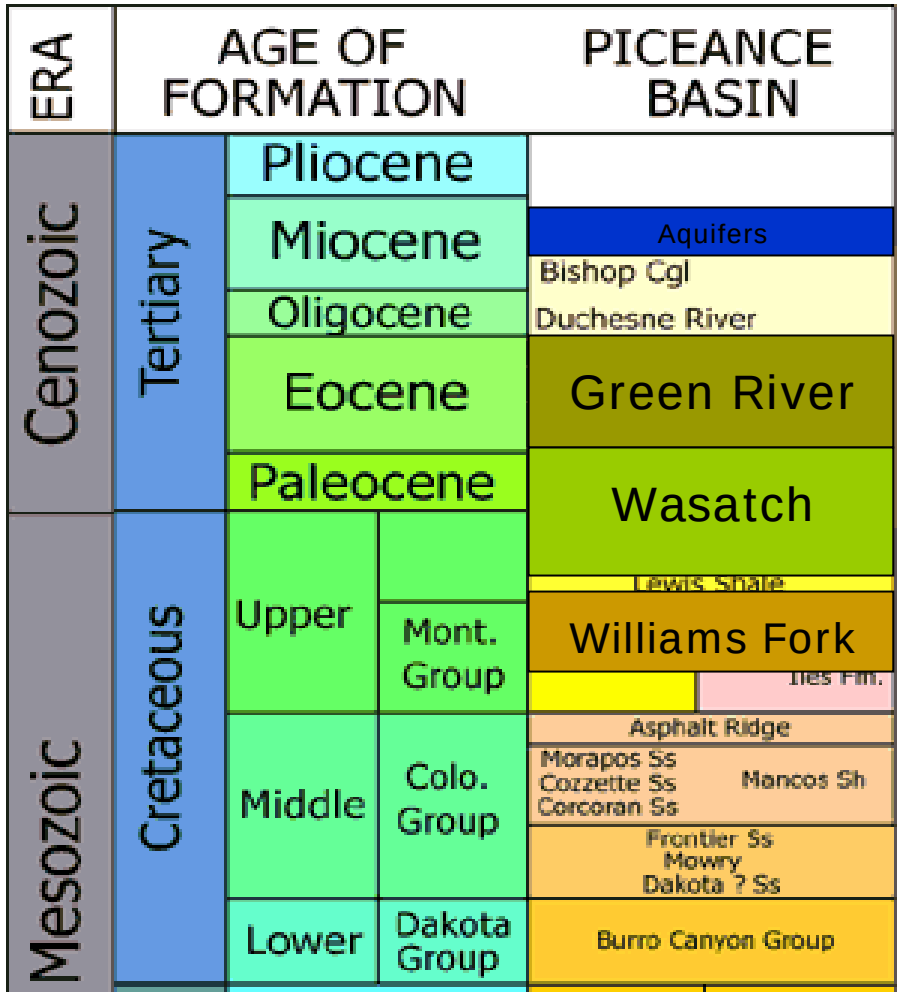
Geology of the Piceance Basin and Garfield County

- Exposed along the north side of I-70 is the Roan Plateau which is part of the Green River formation
- Below The Green River lies the Wasatch formation which occurs at or near the surface down to depths of about 3,500 feet
- Water from private wells is pumped out from alluvium and gravel deposits of the Wasatch located 20 to 250 ft below the surface



Not to Scale

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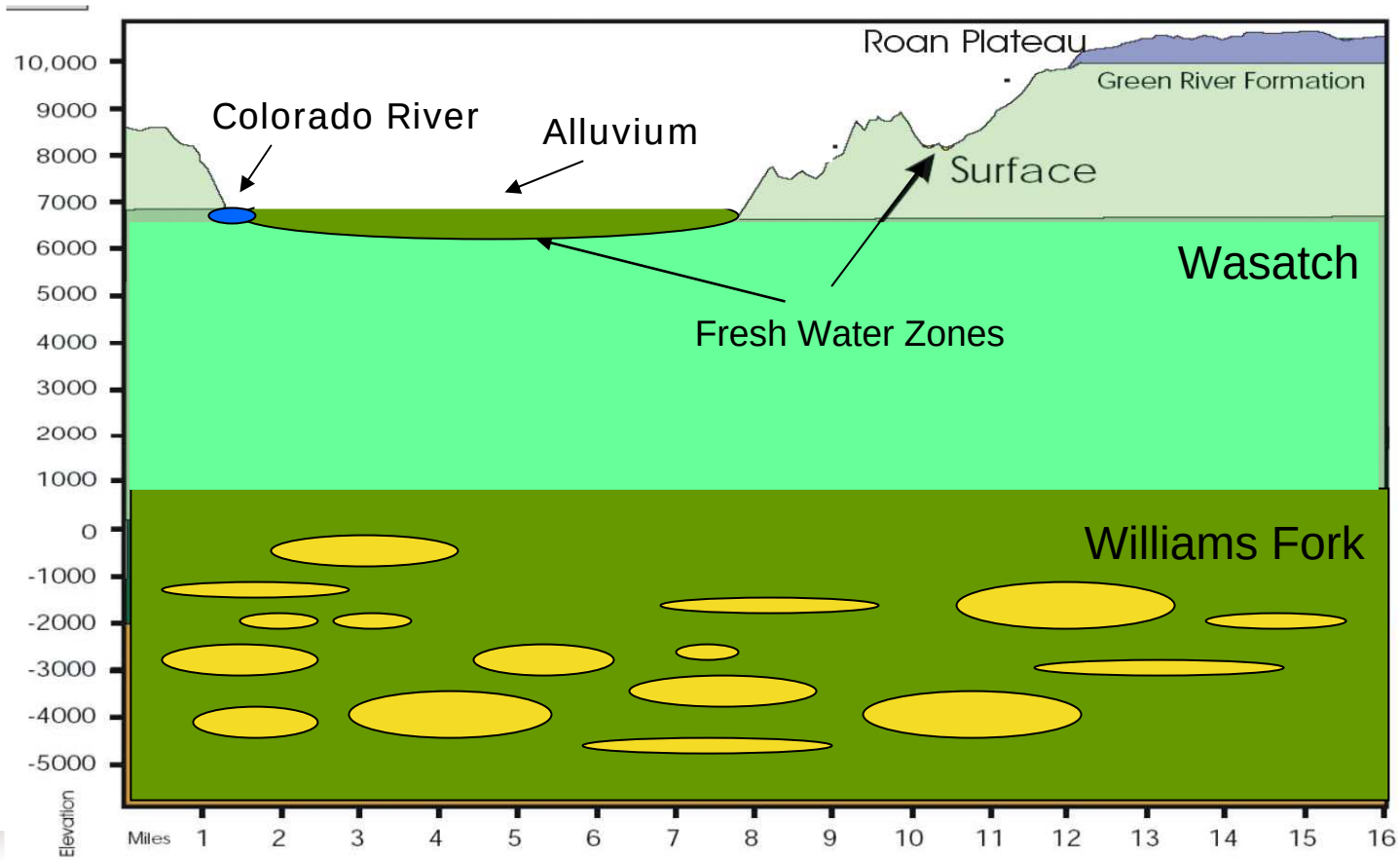
Geology (cont.)

- The Williams Fork Formation is the primary gas producer and occurs starting at about 4,000 ft in depth. The gas is trapped in “sandstone lenses” and sealed by impermeable shale layers.
- The natural gas wells in Garfield county are being drilled at depths of 4,000 to 9,000+ ft

Geology of Garfield County



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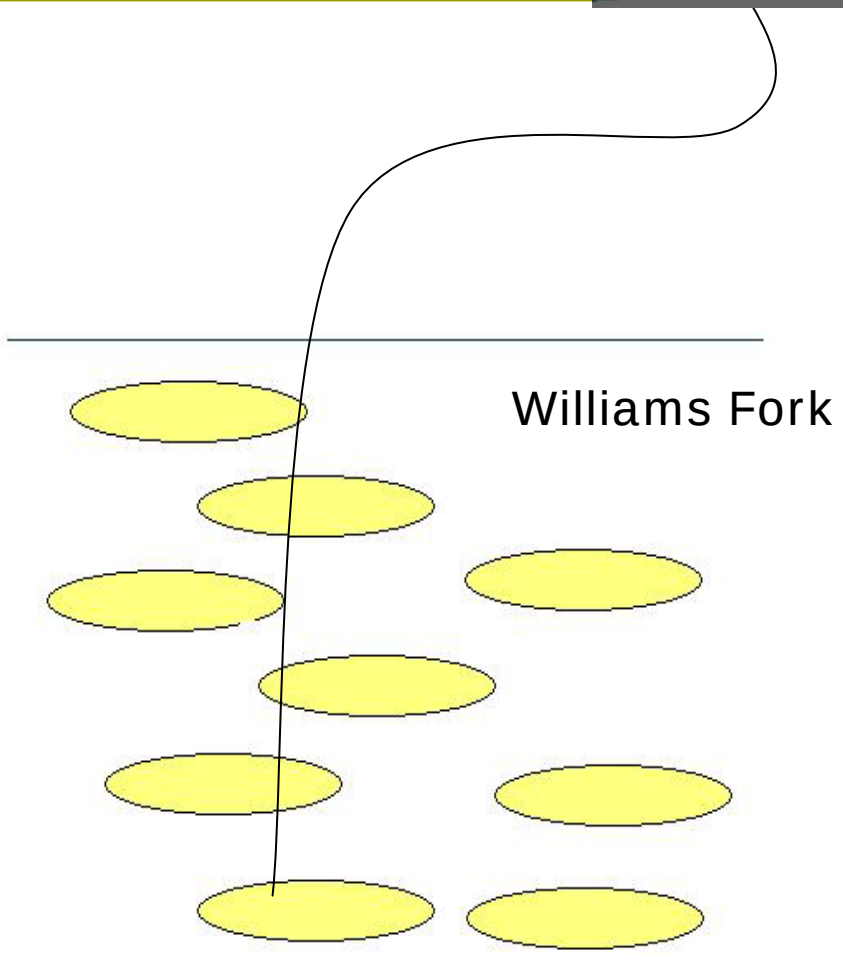
Sandstone Lenses

- In Garfield County, most production of natural gas is coming from sandstone lenses in the Williams Fork Formation of the Mesa Verde Group
- Williams Fork sandstones are referred to as “tight sands” due to their low permeability. Technological advances in drilling and stimulation techniques have increased the ability to produce this gas
- Williams Fork sandstone lenses range in thickness from 0.5 to 29.0 ft (average = 9.3 ft) and width from 40.1 to 2,791.1 feet (average = 528.4 feet) – Rex Cole, Mesa State College

Sandstone Lenses (cont.)

- Sandstone lenses are stacked vertically but are discontinuous horizontally and vertically with impermeable shale separating them
- Sandstone lenses must be penetrated vertically and most companies try to penetrate multiple lenses with each well
- The discontinuous nature and low permeability necessitates directional drilling on close spacing



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Drilling and Completion of a Natural Gas Well

- Site Preparation
- Drilling
- Casing and Cementing
- Fracing
- Well Completion

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Site Preparation

- Surveying and permitting
- Road and pad construction
- Reserve pit excavation

Surveying and Permitting (1 month)

- No heavy equipment work can be performed without a permit issued by the Colorado Oil and Gas Conservation Commission (COGCC).

Drilling Site

1.Reserve Pits 2.Pad 3. Drilling Rig

4.Rig Tower 5.Employee Trailers

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Road and Pad construction (1 week)

- Pad sizes are as large as they are to separate the wellhead from surrounding wildlife, crops or residences. In addition, the well pad must be large enough to accommodate emergency equipment, should it ever be necessary.
- Finally, a well pad must accommodate the various maintenance and construction equipment necessary for smooth operations and repairs during the life of the well.

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Reserve Pit Excavation

- Many companies are now starting to use “pit-less” closed-loop systems

- The reserve pit holds the fluid that comes out of the borehole during the drilling

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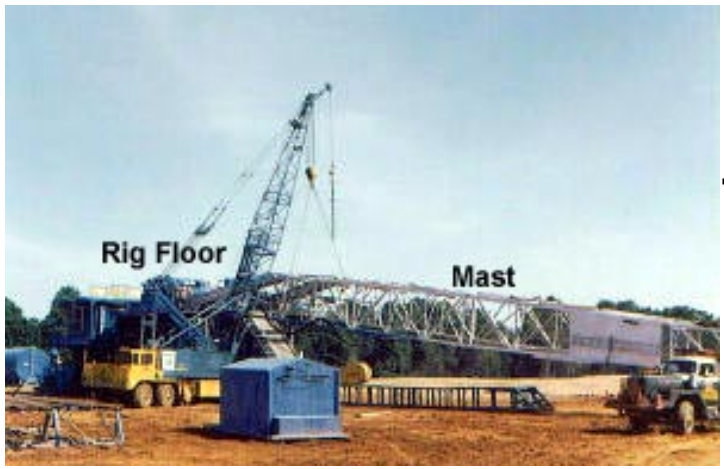
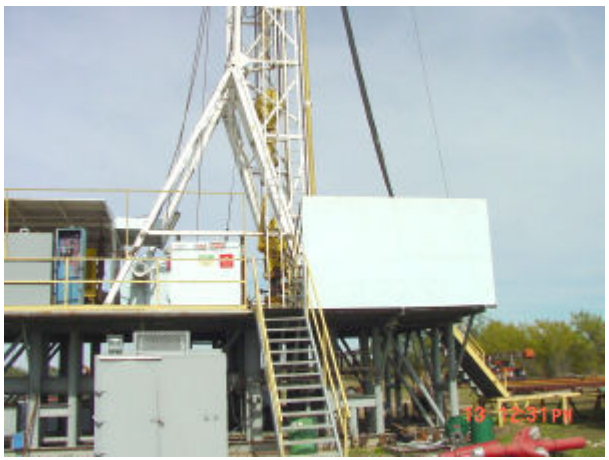
Installation of the Drilling rig





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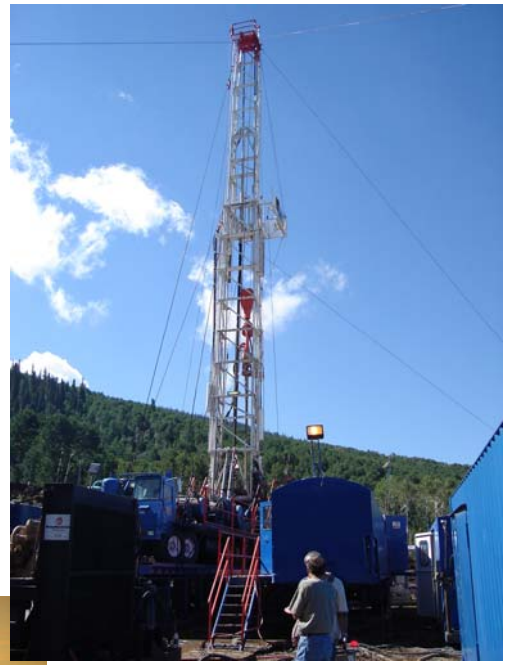
Drilling rigs



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Drill Rig Ancillary Equipment

Rig Power-Generating Equipment

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Drill Rig Ancillary Equipment

Tubular (Pipe) Handling Components

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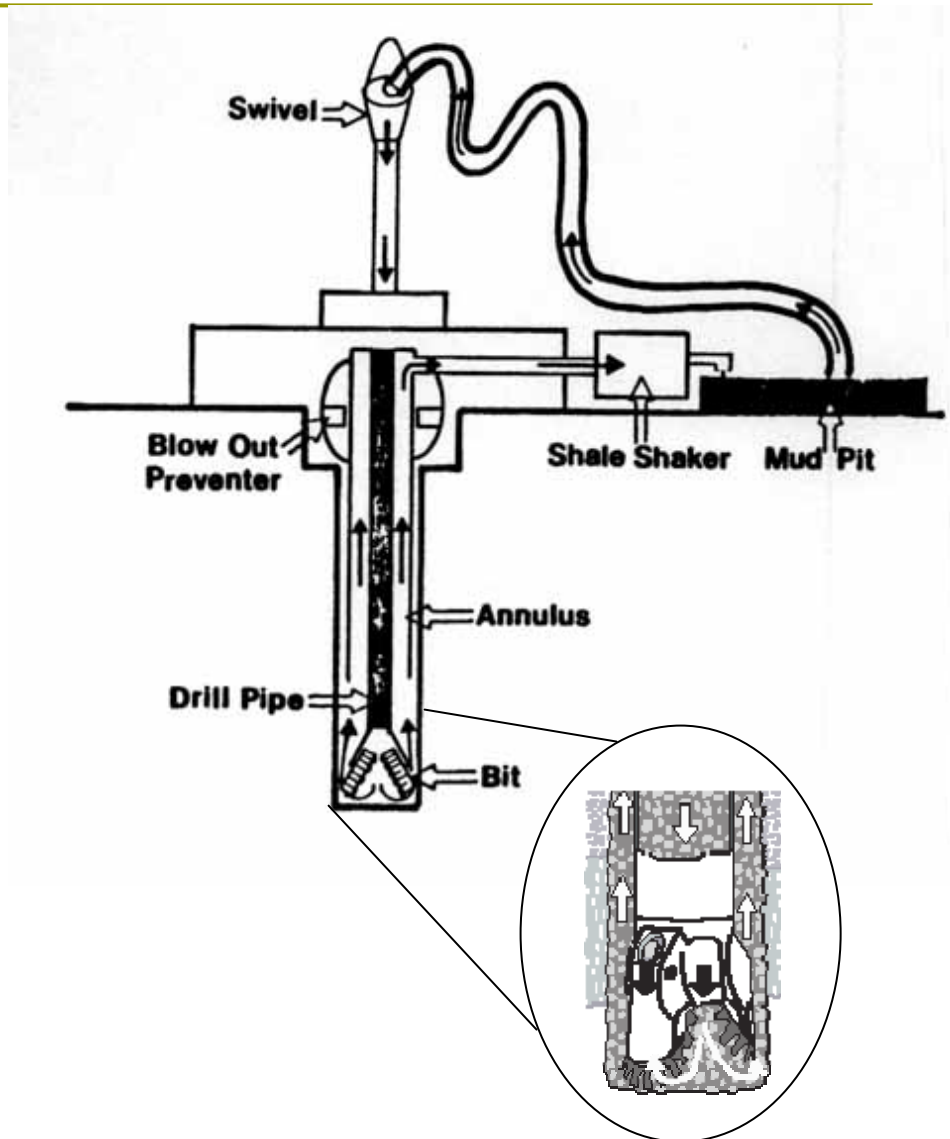
Drilling the Well

- The well is drilled by the rig rotating pipe (drillpipe) with a bit attached to the end – drillpipe is added in 30' lengths
- Weight is applied to the bit through the use of drill collars - thick-walled tubular pieces machined from solid bars of steel
- Mud is circulated in the hole during drilling to remove cuttings and maintain hydrostatic pressure
- Mud is circulated through the drillpipe, out through the bit, and back to the surface on the outside of the drillpipe



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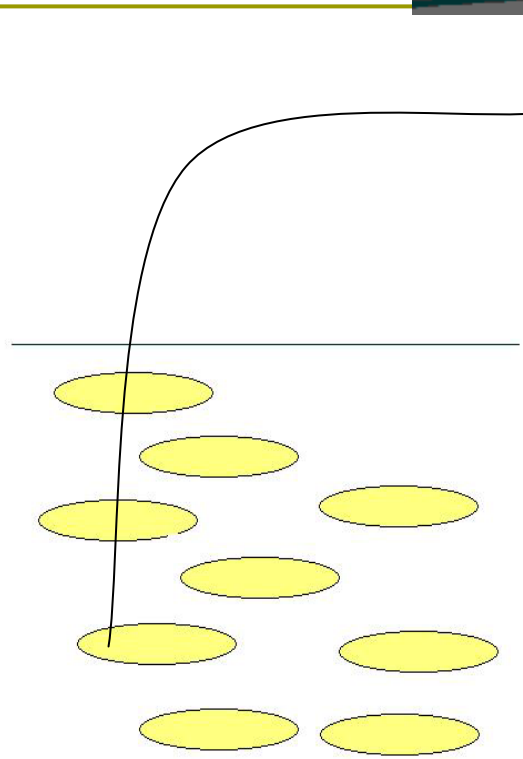
Drilling the Well (continued)

- Blow-out preventers (BOPs) are installed at the surface to control any unexpected "kicks" in pressure – the BOPs have automatic and redundant systems to shut-in wells
- Most operators in this area are also using equipment to separate gas from the mud stream in order to minimize flaring
- In order to change bits, the drillpipe is periodically "tripped" out of the hole and stacked adjacent to the rig derrick

Directional Drilling

- The advancement of directional drilling techniques has been key to tapping the resources of the Piceance Basin
- Directional drilling from widely spaced well pads will minimize costs and environmental impact.
- Directional drilling allows a well to be drilled that deviates from the vertical



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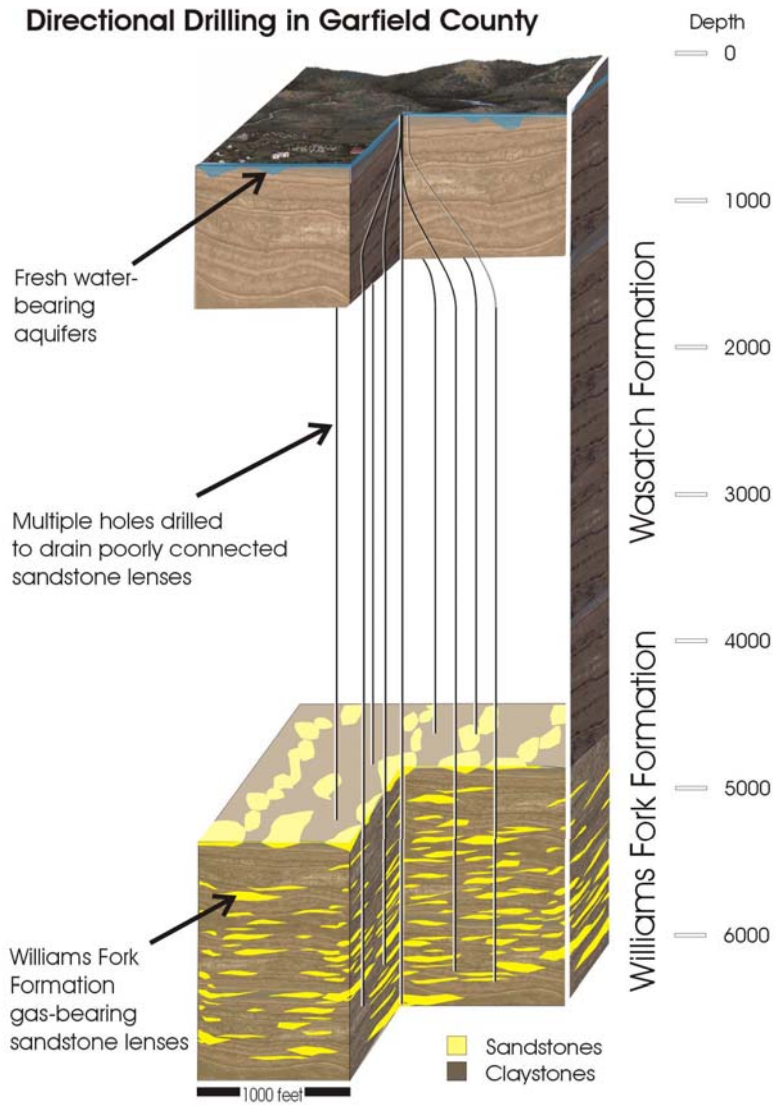
Directional Drilling

- Typical horizontal deviation of wells in this area is a maximum of about 2,500 feet
- The nature of the Williams Fork formation being developed in this area requires that the formation be penetrated vertically – the “S” curve
- Although directional drilling increases the cost of a well, much of this cost is recouped through reduced pad construction and co-locating facilities on one pad
- As many as 12 wells have been drilled from one pad in this area



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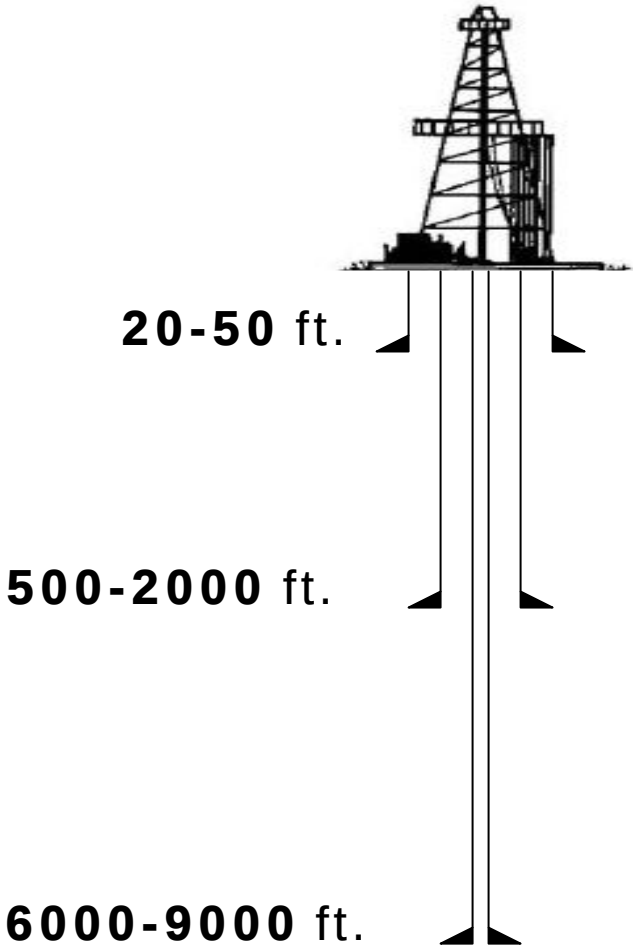
Casing and Cementing

- Conductor
- Surface
- Production



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Conductor Casing

- Conductor casing is installed first, usually prior to the arrival of the big drilling rig. The hole for conductor casing is often drilled with a small auger drill, mounted on the back of a truck.
- Conductor casing, which is usually no more than 20 to 50 feet long, is installed to prevent the top of the well from caving in and to help in the process of circulating the drilling fluid up from the bottom of the well.
- This casing is usually 16 to 20 inches in diameter.
- The conductor casing is cemented in place with normal cement and often is removed after the well is completed.

Surface Casing

- Surface casing, placed in a 12 ¼ inch borehole is a smaller diameter casing (9 5/8 inches) installed inside of the conductor casing.
- The primary purpose of surface casing is to protect shallow groundwater from drilling, completion and production operations.
- Surface casing in this area is set at a minimum of 10% of the total depth of a well - generally 600 to 1000 feet.
- Surface casing is cemented in place and is permanent.

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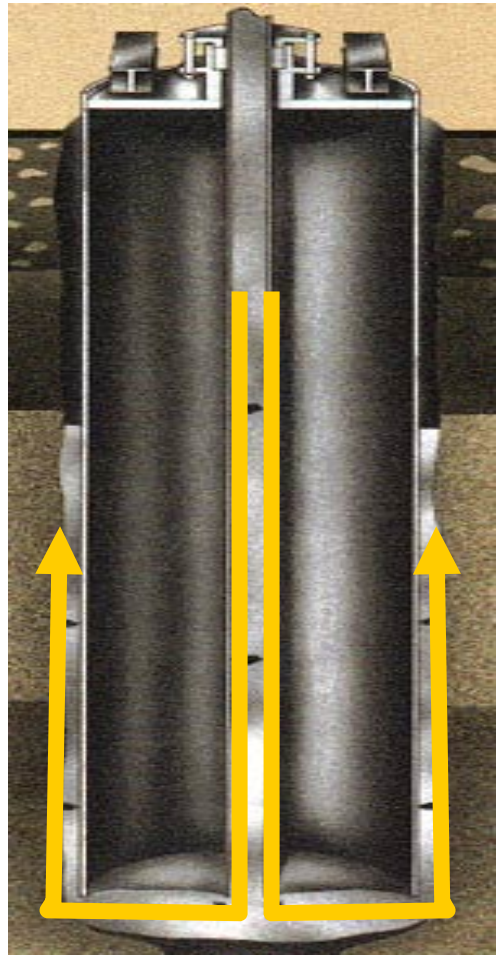
Cementing the Casing

- Each layer of casing is cemented in place by a highly viscous cement
- Once the casing is set in place cement is pumped through the casing and back up into the space between the earth and the casing



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Production Casing

- Production casing provides a conduit from the surface of the well to the petroleum producing formation
- Provides a conduit to allow hydrocarbons to be extracted without intermingling with other fluids and formations found underground
- Used to prevent blowouts, allowing the formation to be 'sealed' from the top should dangerous pressure levels be reached
- Is cemented in place and is permanent

Production Casing

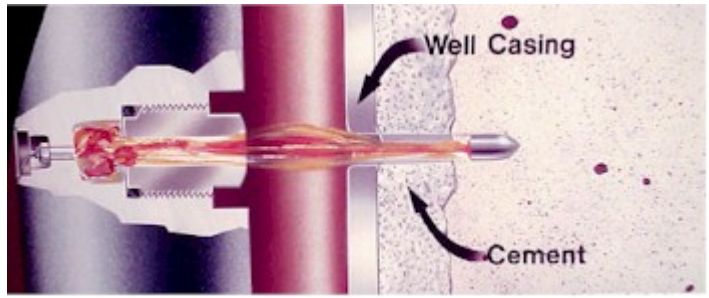
- Setting production casing is the final step before well stimulation or fracing can begin
- The production casing is set all the way to the bottom of a 7-inch diameter borehole
- The casing is 4.5 or 5 inches in diameter
- When cementing in the production casing, the same technique is used as in the other two layers of casing but the cement to hold this casing stops at least 500 ft above the “Top of Gas” layer to prevent natural gas leaks

Well Stimulation

- Well stimulation consists of various techniques used to increase the efficiency of the flow of gas into the production tubing
- Hydraulic fracturing (fracing) is the most commonly used method of well stimulation in this area

Fracing

- The first part of stimulation is to penetrate the lenses
- Once there is a hole, water is pumped into the fractures at more than 10,000 psi from about ten pressure trucks. This is known as fracing



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Fracing (continued)

- Fracing consists of pumping a water-based solution into the formation via perforations in the production casing under high pressure inducing fractures in the rock
- The fracing fluid contains a proppant (usually clean sand) to hold the fractures open after the fluid is removed
- Length of fractures can be controlled but generally has a maximum length of approximately 1,500 ft

Well Completion

- Well completion commonly refers to the process of finishing a well so that it is ready to produce natural gas
- Completion consists of inserting production tubing into the well, installing the final well head assembly, plumbing the well head to the production equipment, and flowing back the well
- Completion operations commonly require a short period of flaring to drill out plugs installed during the fracing operations
- Initial flow back of well is monitored very closely until impurities (sand, mud, etc.) have been completely removed from the gas stream

Well Completion (continued)

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Well Completion (continued)

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Production

- Once the well has been completed, it moves into the production stage
- Gas stream is separated from liquids on site with gas being transported from the site via pipeline – liquids are generally stored in tanks and moved via truck
- Maintenance operations with a work-over rig may be required throughout the life of the well
- Interim reclamation of site consists of reclaiming pits and shrinking site to area required for production

The Wellhead

- This four foot tall wellhead will remain on site in production for about 30 years until the well is plugged and restored.

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Natural gas well in Production

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Site Cleanup

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Interim Well-Site Reclamation

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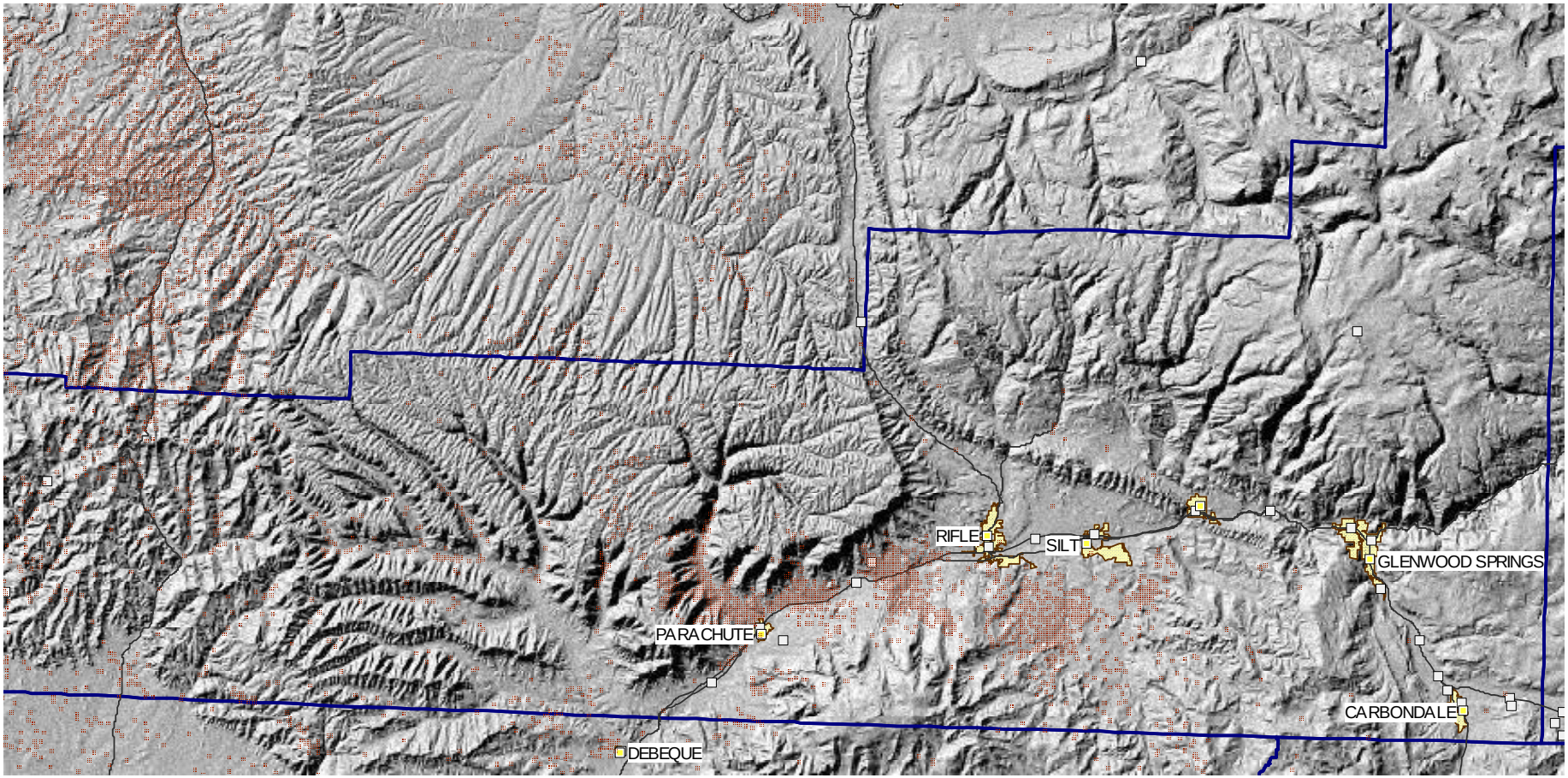
Garfield County Wells in Production



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The Transportation Process

- Once the gas is removed from the well it is purchased as it is transferred to the pipeline.
- Meters are installed from the wellhead to measure the amount of gas that is being purchased.

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The pipeline and transportation

Laying Of Canyon Gas 8 Inch Pipeline

The pipeline runs from the production site to larger pipelines that carry the gas to processing plants and then onto the consumer

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Estimated Time Table

Action	Time
Surveying and Permitting	1 month
Pad and Location Construction	1 week
Drilling	3 weeks
Completion of drilling, “fracing,” and installation of production equipment	3 weeks
Typical “life” of a Williams Fork well	30 years

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For More Information

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