PS Tight-Gas Produced Water Modeling of Mesaverde Group Sandstones in the Uinta Basin*

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Abstract

The Maastrichtian Upper Cretaceous Mesaverde Group has been and continues to be a major, tight-sand gas reservoir in Utah. It consists of over 9,000 feet of fluvial, coastal plain, braided stream, wave-dominated deltaic, and beach sandstone and siltstone with interbedded transgressive Mancos Shale tongues and marine sandstones. Gas production from Mesaverde fields increased from 80 BCFG in 2002 to 287 BCFG in 2012. Produced water increased from 2 million bbls in 2002 to 26 million bbls in 2012. The amount of produced water could increase by at least 1 million barrels per year. Handling produced water requires a significant investment in treatment and disposal. The cost for treatment and disposal will continue to climb as the water/gas ratio increases during prolonged production of the wells. Produced water has been historically evaporated or injected in disposal wells or could be reused in enhanced oil recovery, hydraulic fracturing, drilling mud preparation, and oil shale production. Our study focuses on detailed stratigraphic, petrophysical, and produced water production data from wells penetrating the Mesaverde Group. Results will include formation and unit tops, lithology, thickness, temperature, pressure, and other petrophysical data. Using these data, petrophysical modeling of type logs from the Mesaverde will be used to extrapolate potentially available produced water quantity and quality into geologically less well-known areas targeted by future exploration. Water quality and quantity associated with existing gas production will be evaluated and used to help understand produced water management and amounts.

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Summary

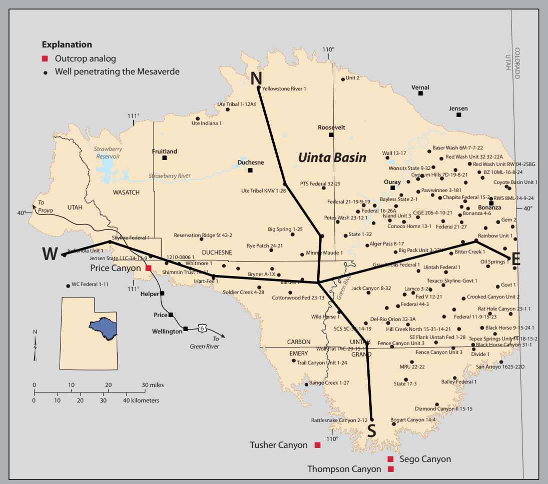
The Mesaverde Group has been and continues to be a heavily explored and produced tight–sand gas reservoir. The Mesaverde Group is comprised of the Price River Formation, Castlegate Sandstone, and Blackhawk Formation of the western and central part of the Uinta Basin. Similar units on the eastern side of the Uinta Basin are the Tuscher Formation, Farrer Formation, Neslen Formation, Sego Sandstone, and Castlegate Sandstone. The units consist of regressive fluvial sand and silt, coastal mud and sand, and beach sand deposits with interbedded transgressive Mancos Shale tongues and marine sandstones. The primary targets for gas production are the interbedded fluvial sandstone and siltstone, and shales. The Castlegate Sandstone is also a gas reservoir where it is capped by marine shale.

Well log and core analyses of the Mesaverde sandstones indicate which units are gas producers and which units produce only water and small amounts of gas. Companies spend considerable time and money determining which sandstones should be screened to allow gas entry into the well while not screening the sandstones with mostly water. Gas production, based on production records from the four primary counties in the Uinta Basin, has increased from 425 BCFG in 2009 to 471 BCFG in 2012. Produced water production increased from 94.1 million barrels in 2009 to 101.6 million barrels in 2012. The ratio of water/gas production dropped from 0.16 in 2009 to 0.14 in 2012. This drop in the production ratio suggests a large number of wells have been drilled and gone into gas production on the early part of the production decline curve. As production continues in these wells, more water and less gas will be produced in the next several years. The amount of produced water will steadily increase by at least 1 million barrels per year.

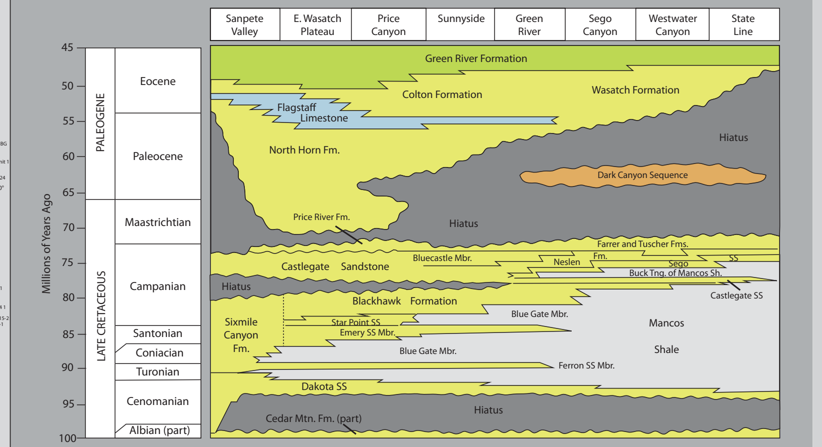
The production and disposal of water from tight-sand gas reservoirs in the Uinta Basin, Utah, affect the economics of gas resource development and have recently become a topic of much public debate because produced water is the largest-volume waste stream associated with these unconventional gas plays. Managing produced water can be a significant cost fraction of the value of the gas extracted, so there is an economic incentive to minimize this waste stream, and/or generate revenue from treating and reusing produced water in hydrocarbon production or other applications. Produced water could be reused in the following ways: enhanced oil recovery techniques, hydraulic fracturing, underground injection, drilling mud preparation, and oil shale production.

Our study focuses on collecting well and petrophysical data from the Cretaceous Mesaverde Group. This will include determining unit tops, lithology, thickness, temperature, and pressure. The study will compile and/or calculate permeability, porosity, and water saturations and other petrophysical properties as needed to understand the potential for water in the sandstones. Petrophysical modeling of type logs from the Mesaverde Group will be used to extrapolate potential water production into geologically, less well known areas for future exploration. Water quality, associated with gas production, will be evaluated and used to determine possible water quality and quantity in future exploration areas.

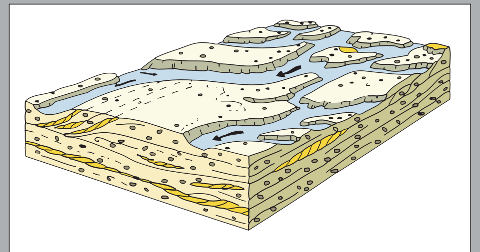
Regional Overview



Index map of the Uinta Basin with wells, cross section lines, and outcrop locations.



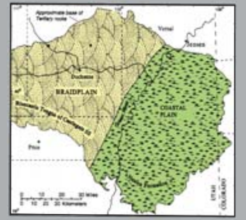
Stratigraphy of the Mesaverde Group in the Uinta Basin (modified from White and others, 2008).



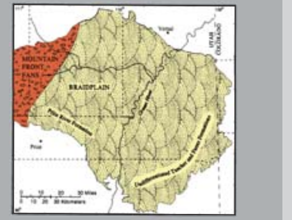
Braided Stream - Castlegate Sandstone analog (after Howell and Flint, 2005).

Paleogeography of the eastern Uinta Basin during the late Campanian - Late Cretaceous (modified from Fouch and others, 1992).

Deposition of the Castlegate Sandstone in a braided stream, lower coastal plain, and marginal marine environment.



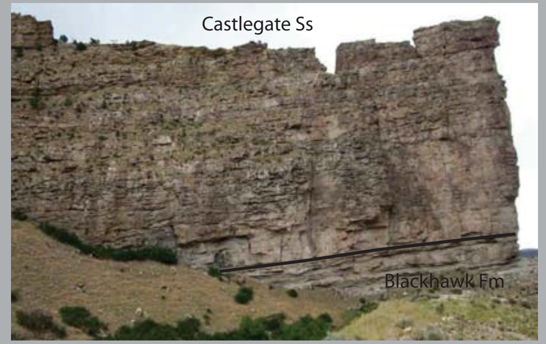
Deposition of the Neslen Formation in a coastal plain environment.



Deposition of the Farrer and Tuscher Formations in an alluvial plain environment.

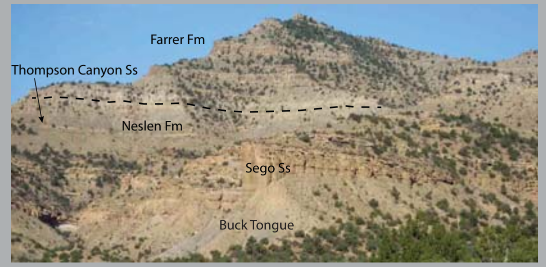
Mesaverde Group Outcrop Overview

Price River Formation in Price Canyon. The formation consists of poorly sorted siltstone and sandstone deposited within a meandering fluvial system (Hettinger and Kirschbaum, 2002).

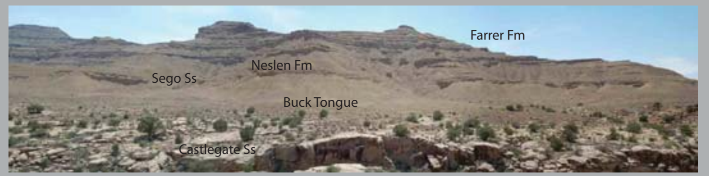


Type section of the Castlegate Sandstone overlying the Blackhawk Formation in Price Canyon. The lower Castlegate is composed of massive sandstones deposited in a braided, sand-rich stream environment while the upper Castlegate contains interbedded mudstone and sandstone from a meandering stream (Hettinger and Kirschbaum, 2002). The unit is thickest in the west and thins to the east.

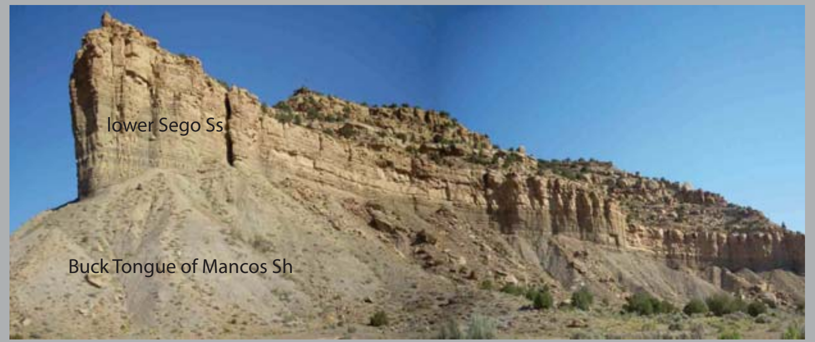
Mancos Shale, Desert Member of the Blackhawk Formation, and lower Castlegate Sandstone at the mouth of Thompson Canyon. The Desert Member comprises sandstone, mudstone, carbonaceous shale, and some coal.



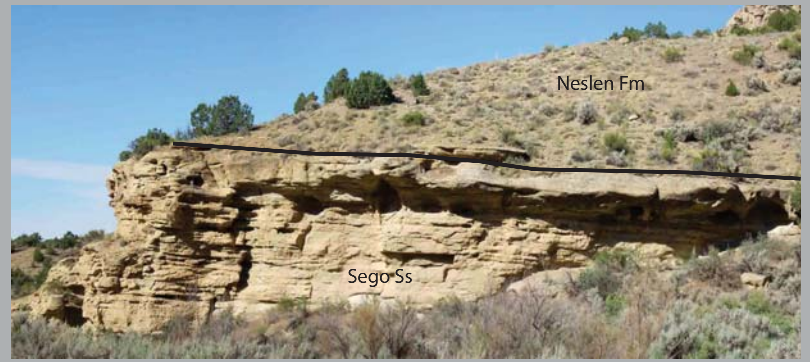
Buck Tongue of the Mancos Shale, Sego Sandstone, Neslen Formation with Thompson Canyon Sandstone, and Farrer Formation in Sego Canyon.



Lower Castlegate Sandstone, Buck Tongue of the Mancos Shale, Sego Sandstone, Neslen Formation, and Farrer Formation in Tusher Canyon.



Buck Tongue of the Mancos Shale - lower Sego Sandstone contact in Sego Canyon. The Buck Tongue consists of interbedded, gray sandstone, siltstone, and mudstone (Franczyk and others, 1990).

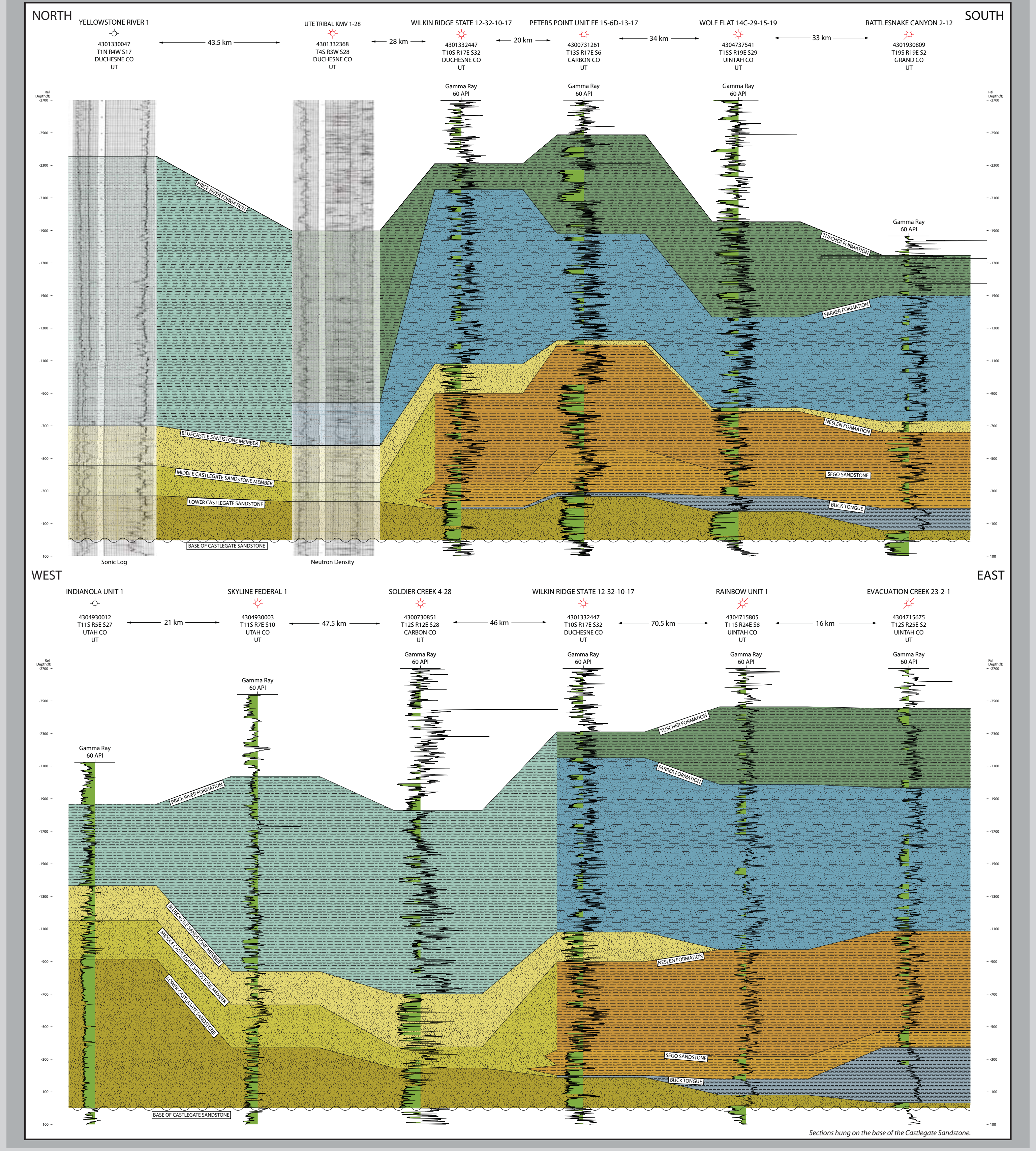


Sego Sandstone - Neslen Formation contact in Sego Canyon. The Sego Sandstone thickens to the east and then thins in western Colorado; it contains stacked cross-bedded sandstone packages with parallel laminations in the uppermost package. The contact with the Neslen Formation is conformable and sharp (Franczyk and others, 1990). The Neslen Formation includes carbonaceous mudstone, sandstone, coal, and channelized sandstone beds which increase toward the top (Cole and others, 2008).

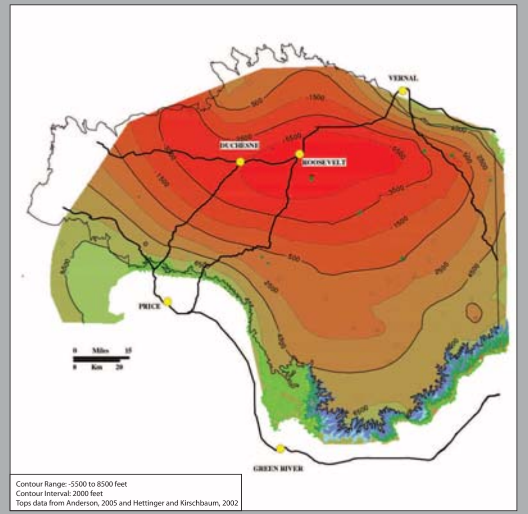
Lower Farrer Formation in Sego Canyon. The Farrer Formation contains significantly more sandstone than the underlying Neslen Formation. Both formations were deposited in eastward-flowing straight and sinuous river systems across a coastal plain (Cole and others, 2008).

The Tuscher Formation is recognizable by multi-story sand bodies overlying the Farrer Formation. The Tuscher Formation was deposited within a fluvial environment (Cole and others, 2008).

Regional Correlation of the Mesaverde Group

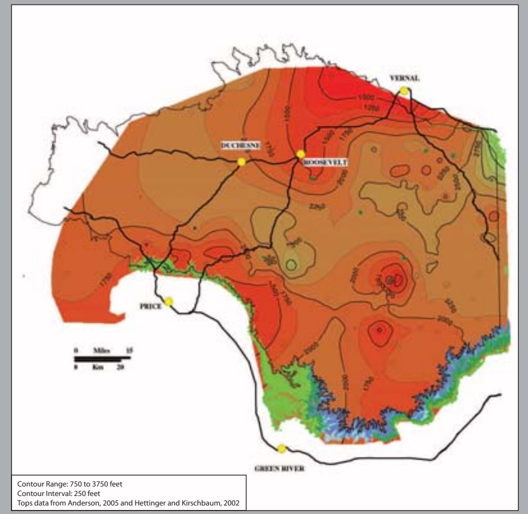


Structure & Reservoir Thickness



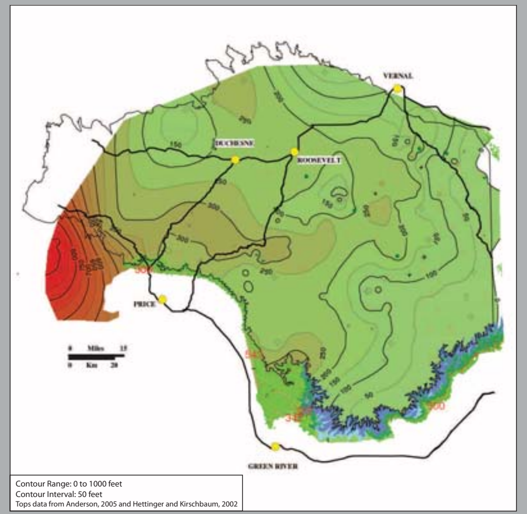
Mesaverde Group Structural Top

The southern outcrops plunge north, northwest at approximately 3 degrees. The contours show the synclinal structure along the northern part of the basin. The deepest portion is approximately -7500 feet msl.



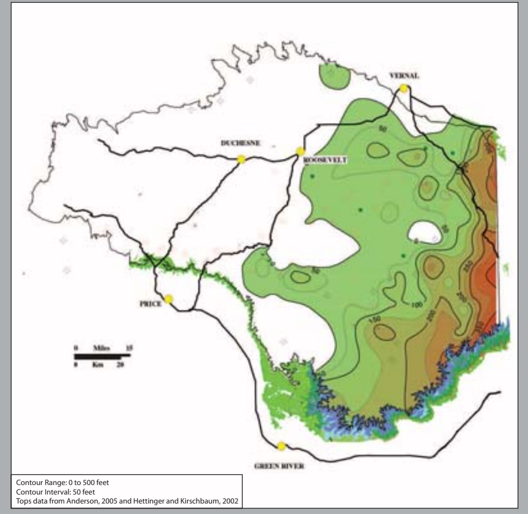
Mesaverde Group Isopach

The group thickness varies from 1000 feet in the north and south and thickens to 3000 feet in the depositional center in the middle of the basin. The center of the basin trends west to east.



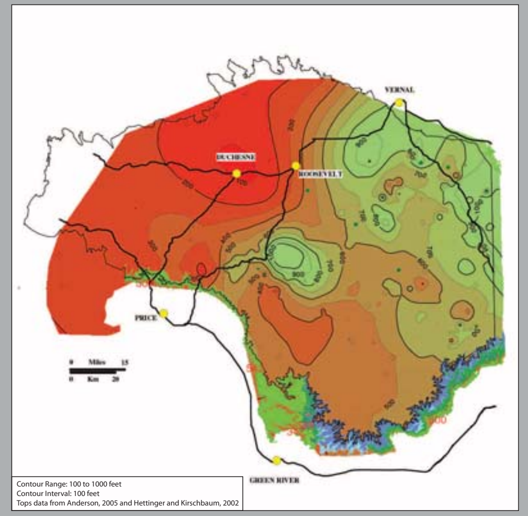
Lower Castlegate Sandstone Isopach

The lower Castlegate Sandstone thickness shows a thinning trend from over 800 feet in the southwest to pinching out on the eastern side of the basin near the Utah/ Colorado border.



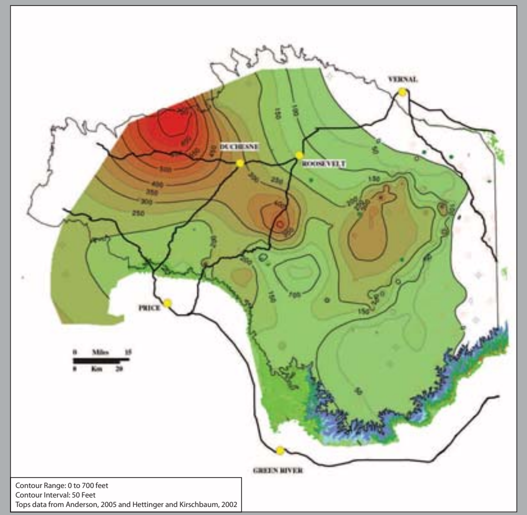
Buck Tongue Isopach

The transgressive shale thins from over 400 feet on the east to nothing near the middle of the basin. The thickness trends show the paleotopography at the time of the marine incursion.



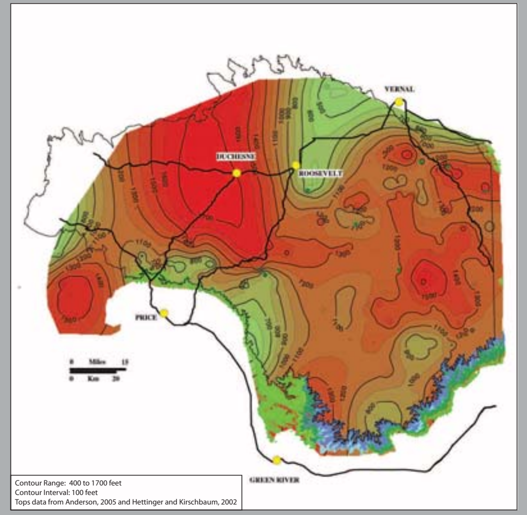
Middle Castlegate and Neslen/Sego Isopach

The combined group thickness from 200 feet thick in the west as the middle Castlegate or mudstone member to over 800 feet thick as combined Neslen Formation and Sego Sandstone.



Bluecastle Member of the Castlegate Sandstone Isopach

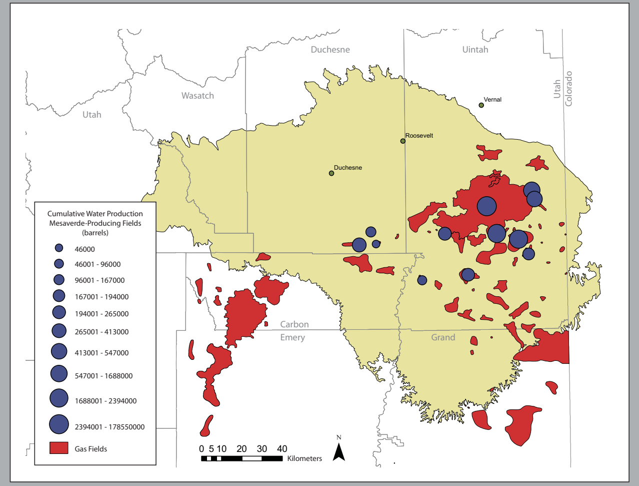
The upper sandstone member is thickest in the northwest and pinches out in the east. The depositional trend changes from the southeast and east to northeast.



Price River Formation (West) - Tuscher & Farrer Formations (East) Combined Isopach

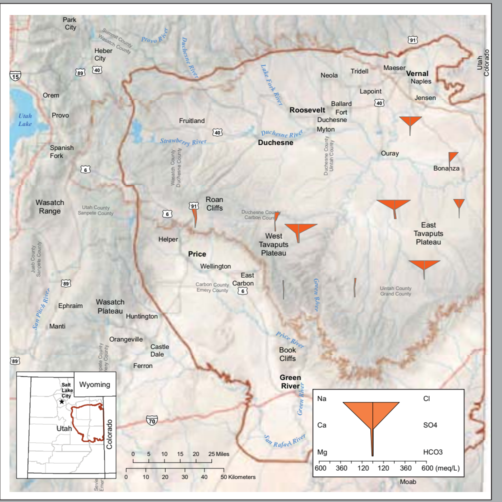
The combined group has several thick depositional centers in the southwest, northwest, and east central portions of the basin.

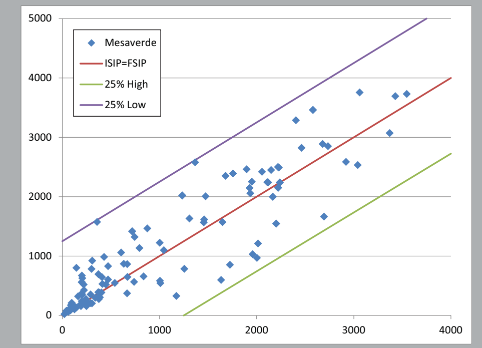
Water Production



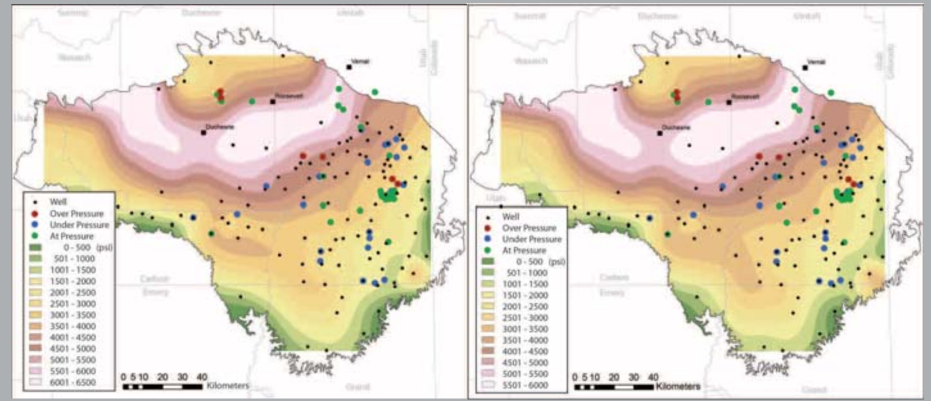
LEFT - Cumulative water production in fields producing from the Mesaverde Group. Note: the fields may also produce from additional formations, and produced water values are not divided by lithologic unit.

RIGHT - Stiff diagrams of produced water in the Mesaverde Group. The formation waters near the southern outcrops of the Uinta Basin are relatively fresh, while deeper waters are NaCl type brines. (Generated by Stefan Kirby; data from the Utah Division of Oil, Gas, & Mining database)





Final shut-in pressure (FSIP) values within a 25% envelope as reported in drill-stem tests.



Over-, under-, and normal-pressure observations from drill-stem tests within the Mesaverde Group. **LEFT** - Contours show the predicted saline hydrostatic pressure in the middle Mesaverde. **RIGHT** - Contours show predicted fresh water hydrostatic pressure in the middle Mesaverde.

General Mesaverde Group Characteristics & Production

Thickness – 1000 to 3000 ft
Drill Depths to Base – 0 to 12,000 ft
Depositional Environments – marginal marine to fluvial, sand-rich braided stream, upper coastal plain, and alluvial-plain deposits at top
Lithology – sandstone, siltstone/mudstone, shale, coal
Reservoir Geometry – stacked, lenticular channels with limited lateral extent
Trapping Mechanisms – stratigraphic conventional (lateral change in porosity and/or permeability due to local change in depositional environment) and basin centered; anticlinal
Source Rocks – Cretaceous coal and shale
Outcrop Analog – Book Cliffs, Utah

Production from the Mesaverde Group

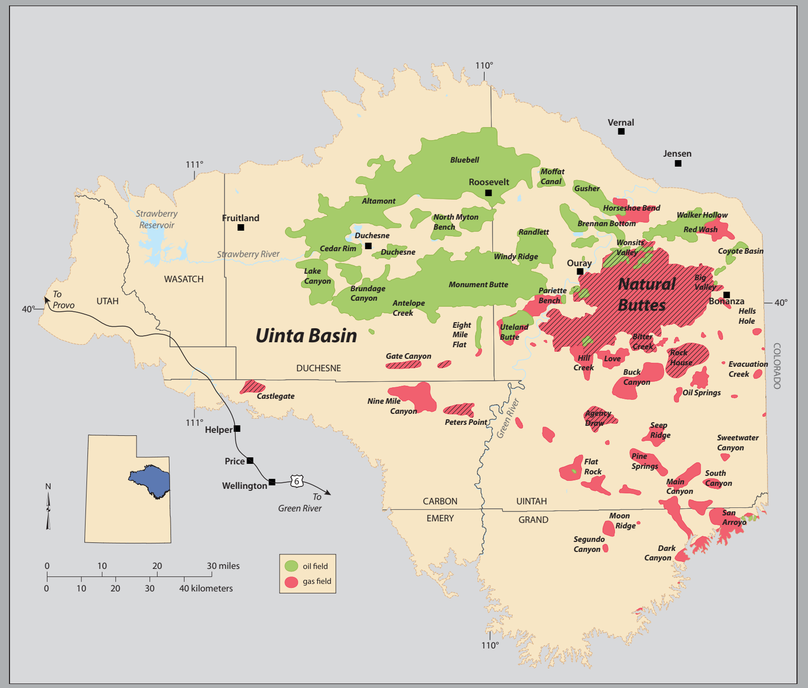
Current Major Operators – Anadarko Petroleum Corp., QEP Resources, EOG Resources, XTO Energy Inc., Rosewood Resources Inc., Enduring Resources LLC, Gasco Production Co., Enervest Operating LLC, Koch Exploration Co.
Number of Active Fields/Wells – 24 fields/5747 wells
Recent Monthly Production (March 1, 2014) – 23.4 BCFG, 2,473,912 BW
Cumulative Production (as of March 1, 2014) – 3.59 TCFG, 197,022,041 BW
Production often co-mingled with the Tertiary Wasatch Formation

Greater Natural Buttes field (largest field)

13 individual units
Wells – 5020
Recent monthly production (March 1, 2014) – 20.9 BCFG, 2,360,882 BW
Cumulative production (March 1, 2014) – 3.1 TCFG, 177,065,821 BW
Estimated ultimate recovery per well for co-mingled Wasatch-Mesaverde – 1.4 to 6 BCFG

Reservoir Data (Natural Buttes)

Spacing – 10 to 40 acres
Net Pay – individual sand bodies up to 30 ft
Porosity – 2 to 18%
Permeability (from core) – generally less than 0.1 mD; some zones 4 to 30 mD
Water Saturation – 15 to 35%
Water Resistivity – 0.160 ohm-m @ 68°F, 25,000 TDS
BHT – 140 to 210°F
Type of Drive – gas pressure depletion
Completion Technique – multi-stage hydraulic fracturing



Oil and gas fields in the Uinta Basin. Greater Natural Buttes field is the largest field that produces from the Mesaverde Group. Fields with diagonal lines produce in part from the Mesaverde Group.

Gas Characteristics (Natural Buttes)

Methane – 94 to 94.9%
Ethane – 3.4 to 3.8%
Propane – 0.8 to 1.0%
CO_2 – 0.18%
Heating Value – 1066 to 1179 Btu

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