Greater Green River Basin

Oil and Gas Geology, Production, and Future Development

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Basin geology

The Greater Green River Basin is an amalgamation of several sub-basins, including the Green River Basin, Great Divide Basin, Washakie Basin, and Sand Wash Basin. These sub-basins were formed during the Late Cretaceous to Early Eocene Laramide orogeny, with the uplift of the Moxa arch, Rock Springs uplift, Cherokee Ridge arch, and Wamsutter arch. An intermittent record of sedimentation from the Cambrian through present is preserved in the basin, with total compacted sediment fill that can be greater than 9,144 m (30,000 feet) thick.

Many oil and gas fields in the Greater Green River Basin occur in anticlinal traps (Law, 1988). These anticlinal traps are secondary folds on the larger-scale Laramide uplifts. Stratigraphic traps are rare in the basin, with the exception of the Cretaceous formations, such as Patrick Draw field, where an up-dip pinch-out of the Almond Formation traps a significant accumulation of oil (Weimer, 1965, 1966). Structural traps occur in fields such as the giant Jonah gas field, where natural gas is trapped in the Lance Formation sandstones within a fault-bounded wedge (Cluff and Cluff, 2004).

Primary oil production is from the Upper Cretaceous Frontier Formation and Mesaverde Group, followed by the Lower Cretaceous Dakota Sandstone ("Dakota Sandstone" is a formation name borrowed from neighboring states and frequently used in the hydrocarbon industry, but is unofficially recognized in Wyoming). Carbon dioxide and helium production on the LaBarge platform is from the Mississippian Madison Limestone. Hydrocarbons are also commonly produced from the Pennsylvanian and Permian Tensleep/Weber Sandstone. Nearly all formations are known to contain hydrocarbons at one location or another within the Greater Green River Basin.

Weber Sandstone showing dune-scale cross stratification, Irish Canyon, CO. Photo by R. Lynds.

Hydrocarbon source rocks vary by location within the section and within the basin. The U.S. Geological Survey (USGS Southwestern Wyoming Province Assessment Team, 2005) determined nine regional total petroleum systems in the southwestern Wyoming province (the bulk of which includes the Greater Green River Basin of Wyoming). These nine systems imply source rocks in the Phosphoria Formation, Mowry/Aspen Shale, Hilliard/Baxter Shale, Niobrara Formation, Mesaverde Group, Lewis Shale, Lance and Fort Union formations, and the Wasatch and Green River formations. Excluding the Phosphoria (Permian), Wasatch and Green River formations

(Eocene), and Fort Union Formation (Paleocene), all other source rocks are Cretaceous—primarily Upper Cretaceous.

The source rock facies within the Phosphoria Formation are contained within the Meade Peak and Retort members. The Phosphoria was deposited in a sediment-starved, restricted basin on the western edge of the Wyoming shelf (Piper and Link, 2002). Within this complex, the Meade Peak and Retort members were formed in areas that were favorable for upwelling, high organic productivity, and preservation of organic matter (e.g., Piper and Link, 2002). Total organic content values are as high as 30 weight percent in this organic-rich source rock. High amounts of sulfur suggest original oil composition within the Phosphoria was Type-IIS kerogen, with oil generation beginning during the Late Cretaceous (Johnson, 2005).

The Cretaceous source rocks resulted from relative transgressions and regressions within a foreland basin that was progressively subsiding from the advancing Sevier orogen. These source rocks are all marine shales, some of which were deposited under anoxic conditions that preserved an unusual amount of carbonaceous matter. Of the Cretaceous shales, the Mowry/Aspen Shale has the highest total organic content (Burtner and Warner, 1984) and is primarily responsible for charging the Dakota Sandstone and Frontier Formation reservoirs throughout the Rocky Mountain region (Warner, 1982; Burtner and Warner, 1984), with additional gas locally sourced from the Frontier coals.

Eocene Wasatch and Green River source rocks are lacustrine organic-rich shales and marginal marine and terrestrial coal and carbonaceous mudstones (Roberts, 2005). Lacustrine source rocks contain Type-I and mixed Type-I and Type-III kerogen, while the coal and carbonaceous units contain Type-III kerogen (Grabowski and Bohacs, 1996; Carroll and Bohacs, 2001). These source rocks are responsible for significant oil shale deposits in the Green River Formation and biogenic gas accumulations (i.e., coalbed natural gas) in both the Wasatch and Green River formations.

Cathedral Bluffs Tongue of the Wasatch Formation, eastern Washakie Basin. Photo by R. Surdam.

Production

The Greater Green River Basin is a mature hydrocarbon province that has been under production since the early twentieth century. Since that time, the Greater Green River Basin has produced over 929.2 million barrels of oil and 24.6 trillion cubic feet of gas. There are 283 producing fields in the basin, 252 of which have produced oil and 267 have produced gas. The basin is home to an accumulation of CO_2 greater than 100 trillion cubic feet on the crest of the Moxa arch, as well as the nation's primary helium reserve. Twelve of the top 100 highest-producing oil fields in Wyoming are in the Greater Green River Basin. More than half of the most productive gas fields in the state (58 of the top 100) are also in the Greater Green River Basin. In 2013, the Greater Green River Basin produced 22.5 percent of Wyoming's oil and 59.1 percent of Wyoming's natural gas.

The production of oil and gas in the Greater Green River Basin has not declined as much as it has in other Laramide basins throughout Wyoming, in part due to the discovery of the giant Jonah gas field, and also due to the success of CO_2-EOR projects in the Lost Soldier and Wertz fields, and the Monell unit in the Patrick Draw field. Since 1980, oil production throughout the basin has remained relatively steady, fluctuating from below 10 million barrels per year to over 16 million barrels per year. 2013 production was 14.1 million barrels of oil. Gas production has generally increased since 1978, to a maximum of 1.4 trillion cubic feet in 2010. 2013 natural gas production was 1.2 trillion cubic feet. Increased gas production with time is mainly due to the discovery and development of the Jonah and Pinedale anticline fields. Hydrocarbon exploration and production is alive and well in the Greater Green River Basin, and many new large projects are currently applying for permits.

Future development

There are presently five large natural gas projects in various stages of the federal review process in the Greater Green River Basin. The largest of these projects, including Continental Divide – Creston and Hiawatha, are in the eastern Greater Green River Basin. These projects, operated by BP and QEP, respectively, plan to drill more than 10,400 wells in Wyoming. The primary drilling targets include the Cretaceous age sandstones and shales of the Frontier Formation, Mesaverde Group, and Lewis Shale. BP forecasts production of more than 12 trillion cubic feet of natural gas from the Continental Divide – Creston project; production forecasts are not available for the Hiawatha project.

Drilling rig in the Greater Green River Basin. Photo by E. Campbell-Stone.

The Labarge and Moxa Infill projects are generally targeting the Cretaceous section with plans to drill 2,700 wells. Although information is not available for the Labarge project, the Moxa Infill project, operated by EOG Resources, forecasts production of 1.8 trillion cubic feet of gas and 12.5 million barrels of oil. These projects should come online in the next few years.

The Normally Pressured Lance project, operated by Encana, is a neighbor of the giant Jonah gas field. Production from the Jonah field is in overpressured sandstones of the fluvial Lance Formation. The Normally Pressured Lance project seeks to produce gas from analogous Lance sandstones with less pressure than the Jonah field. Forecasts are for 3,500 wells and 5.52 trillion cubic feet of gas.

Other projects in the Greater Green River Basin include infill drilling in the Monell and Arch units of the Patrick Draw field as well as the Bird Canyon project east of La Barge. More information on these, in addition to other projects in the early or proposed stages of development, can be found at www.wsgs.uwyo.edu/development-areas/.

In general, drilling has decreased in the Greater Green River Basin over the past few years and production has followed this trend. In 2013, there were 1077 applications for permits to drill,

half of 2010 applications (WOGCC, 2014). Production of both oil and gas also declined since 2010, down from a high of 17.5 million barrels of oil and 1.4 trillion cubic feet of gas, to 14 million barrels of oil and 1.2 trillion cubic feet of gas (WOGCC, 2014). However, there are plans to produce oil and gas from more than 18,000 additional wells in the Greater Green River Basin over the coming decades. Production from these future wells should offset the declining production in the Green River Basin.

A handful of small and interesting developments have occurred in the eastern Greater Green River Basin over the past few years. Horizontal drilling and hydraulic fracturing has made for productive natural gas wells in the Paleocene Fort Union Formation in the Washakie Basin and the Mesaverde Group on the far eastern flank of the basin. Improved drilling and production technologies may further increase production from what were historically thought of as tight and unproductive sandstone or shale reservoirs, but are now rather typical unconventional reservoirs.

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