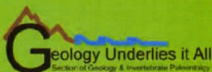


# HISTORY AND GEOLOGY OF PENNSYLVANIA PETROLEUM



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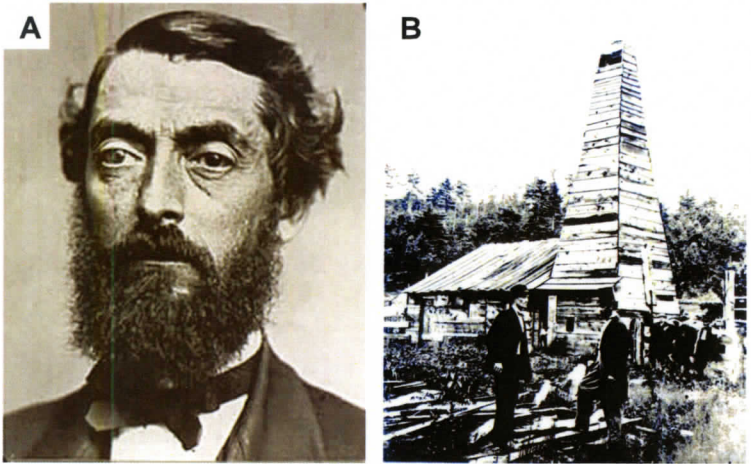


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## The Drake Well

Many history books describe how “Colonel” Edwin L. Drake drilled the world’s first oil well near Titusville, Pennsylvania in 1859 (Figure 1). This “fact” is only one of many things wrong with the whole story. Drake wasn’t the first to discover crude oil, nor was he the first to drill a well and produce oil. He wasn’t even the first to sink a well specifically to produce oil. So, if Drake was not the first to do any of these things, what makes him and his well so special? The answer lies in the vagaries of timing and vision. In brief, Drake began the modern age of petroleum-related energy, industry, and transportation.



**Figure 1. Historical photographs of Edwin L. Drake and his famous oil well. A—Portrait of Drake. B—Drake and his friend Peter Wilson standing in front of the second engine house and derrick of Drake's famous well, circa 1865. The first building burned down in October 1859. Photos courtesy of the Drake Well Museum.**

Actually, the petroleum industry was already well under way at least 4,000 years before Drake was born. The Sumerians, Assyrians, Persians, Egyptians, and other ancients dealt in crude oil and oil products for building, burial rites, waterproofing, lubrication, and even lighting and heating. The Greeks and Romans used oil for warfare by spreading it on the sea and setting fire to it when enemy ships came near. Native Americans on both continents were using petroleum products for waterproofing, embalming, and medicine when the first Europeans arrived, and instructed settlers in finding and using oil. Renaissance scholars were aware of oil’s history and its occurrences throughout the world. Pennsylvania salt well drillers found oil and natural gas in their salt wells in the early 1800’s; one of them, Samuel Kier, had a thriving business in Pittsburgh selling oil, first as a medicine and later refined to kerosene as an illuminant. In fact, Drake used salt-well drilling technology to establish the modern petroleum age. Oil historian Edgar W. Owen indicated that the cumulative experience of 4,000 years of petroleum knowledge had been mostly forgotten. The fact that it finally reached maturity at Titusville in 1859 is one of the greatest paradoxes of

economic history. When Drake's well came in on August 27, 1859 at a paltry 69½ feet, Drake's place in history became sealed. The reservoir rock was only a minor sandstone lens near the Devonian/Mississippian boundary (Figure 2), and Drake's well produced only a few thousand barrels of oil in its lifetime, but it set in motion the search for energy sources that exists to this day.

### Pennsylvania – Leading in Oil and Ideas

Before Drake, the primary source of fuel for illumination was whale oil. Because the world's supply was being depleted rapidly as a result of excessive whaling, the price for whale oil was as high as \$100 per barrel. The only other readily available illuminants were tallow candles and oil and gas distilled from coal, both of which were very expensive as well. In Drake's day, crude oil basically was a source of rustic medicine and waterproofing that was just beginning to be recognized as an illuminant. Today, in its many refined forms, oil provides almost 40 percent of the world's energy, lubricates most of our machinery, and is raw material for many products essential to our everyday lifestyles, from household chemicals and plastics to synthetic fabrics and medicines.

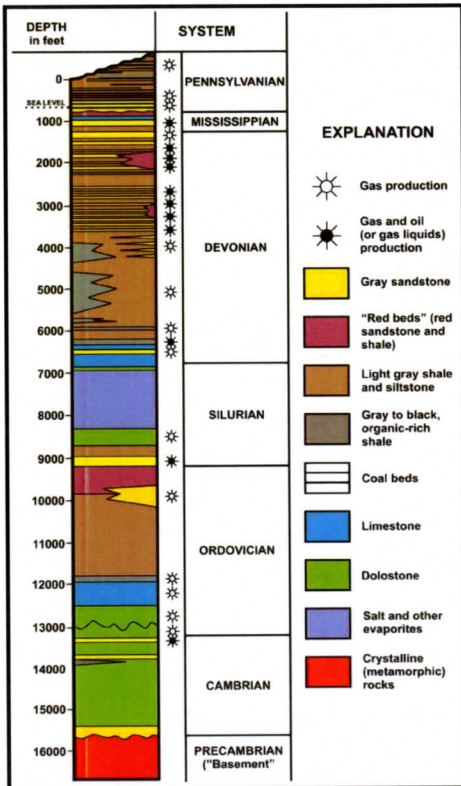


Figure 2. Generalized stratigraphic column for western Pennsylvania showing reservoir strata that have produced crude oil, natural gas, and/or natural gas liquids.

When Drake showed that a plentiful, reliable supply of illuminating oil could be obtained simply by drilling a hole in the ground, "black gold fever" took hold in Titusville and throughout western Pennsylvania. As oilmen found success after success, wooden drilling rigs quickly dotted the hillsides in New York, Ohio, West Virginia, and many other parts of North America, and throughout the world. Oil towns like Pithole, Venango County sprouted like weeds and just as quickly vanished when the oil played out just a few years later.

Pennsylvania became the leading oil producer in the 1880's, providing about 85 percent of the world's total (Figure 3). Although oil production decreased in the 1890's, and Pennsylvania quickly lost its dominance in the world oil market, many of the geological and

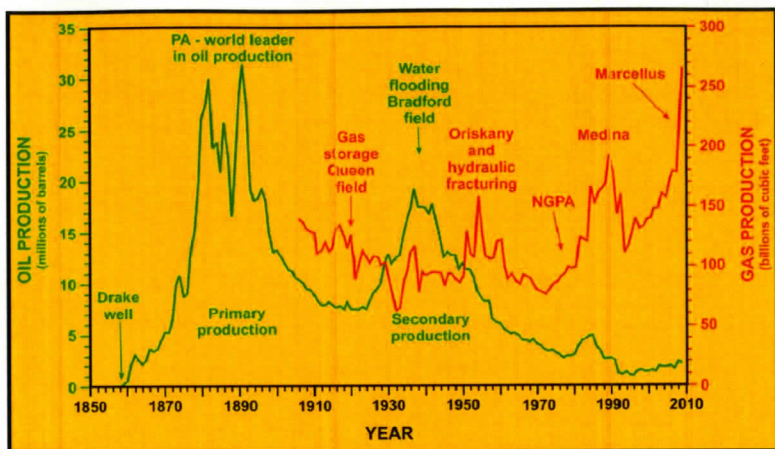


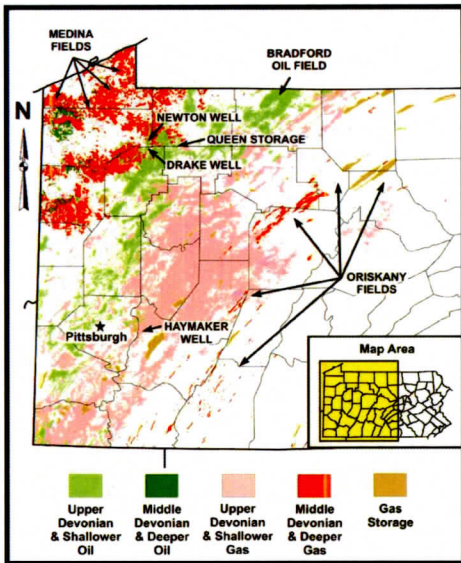
Figure 3. Oil and gas production in Pennsylvania, 1859-2009.

engineering concepts and practices that are still used in oil fields the world over can be attributed to the early days of work in Pennsylvania's oil fields. One of these practices, which eventually became a standard technique for stimulating oil production, was water flooding.

When the natural (primary) production of an oil well declines, operators look for ways to increase production. Wells can be pumped; the reservoir can be fractured by exploding nitroglycerine (this is called "shooting" a well); the well bore can be swabbed to remove the buildup of paraffin that clogs pores in the rock. Beyond these techniques are ways to improve recovery by introducing fluids such as air, natural gas, water, or chemicals into the reservoir that will help both to reduce the viscosity of oil in the reservoir and to flush it out. These are all examples of enhanced oil recovery (EOR). In the 1870's, the oil industry noted an increase in production in some wells in Venango County after rain water ran into nearby unplugged holes. For many years, this was thought to be harmful to the reservoir, and in the 1890's the state of Pennsylvania actually banned the intentional flooding of oil reservoirs. When science and engineering demonstrated that flooding a reservoir with water did not harm it, the ban was finally lifted in 1921. After that, the occurrence of water flooding increased dramatically, particularly in the Bradford oil field of McKean County (Figure 4), which oil historians consider to be the world's first giant oil field. This resulted in a spike in Pennsylvania's oil production that lasted for decades (Figure 3). Since the 1950's, however, Pennsylvania's oil production has declined dramatically. Today, the state's oil fields supply only a few million barrels of Penn Grade crude oil, as it is called, to the world market. This accounts for less than 1 percent of the total US production of crude oil. Most of this oil is used to make high-quality motor oil, but it also provides the basis for waxes, resins, chemicals, and even some gasoline.

## Natural Gas Goes Big Time

Even as Pennsylvania's oil fields were making it famous throughout the world, another energy industry began to emerge in the western part of



**Figure 4. Map of the oil and gas fields of Pennsylvania, showing the locations of wells and fields discussed in the text.**

the state – natural gas. It may come as a surprise to some to learn that the natural gas industry began 38 years before the Drake well was drilled. In 1821, William Hart noticed gas bubbling up through the bed of Canadaway Creek at Fredonia, New York. With a pick and shovel, he dug a 27-foot-deep well on the creek bank and was able to supply several users in the area with enough gas for

lighting purposes. Other gas wells were dug along the Lake Erie shore from Buffalo, New York to Sandusky, Ohio until Drake’s discovery. As “black gold fever” settled in, many in Erie County used the new drilling technology to prospect for oil. Instead of oil, however, these wells produced small amounts of gas from the Upper Devonian shales, basically enough to provide heat and light to homeowners, small businesses, and manufacturers alike. The first truly commercial gas well in Pennsylvania, the Newton Well in Crawford County (Figure 4), was drilled in 1872 to the Venango Third sand (Upper Devonian) at a depth of 786 feet. It flowed an estimated 5 million cubic feet per day. The gas was piped to Titusville where it was used by residents, oil refiners, and others as a source of energy.

Natural gas is an integral part of an oil reservoir, with the gas occurring in solution. As such, all early oil wells produced natural gas. Since gas was not the product the operator wanted, however, it was allowed to vent off, sometime with horrifying results. For example, there were many well fires that burned for days, or even months or years. One of these was the famous Haymaker well in Murrysville, Westmoreland County (Figure 4), which was completed in 1878 in the Murrysville sand (Upper Devonian) at a depth of 1,320 feet. The gas came out at 34 million cubic feet of gas per day, the largest gas flow the world had ever seen. When the well caught fire in 1881, the flame shot 100 feet into the air and burned for a year and a half before being brought under control. When George Westinghouse saw the well, he suggested that the gas from this and other wells subsequently drilled in the area should be piped to Pittsburgh for use in manufacturing. Thus began the modern natural gas industry.

Most of Pennsylvania’s natural gas came from Upper Devonian reservoirs until the 1950’s when a flurry of drilling activity targeting the Oriskany Sandstone (Lower Devonian) caused a spike in Pennsylvania’s

gas production (Figure 3). At about the same time, hydraulic fracturing began to replace shooting as the preferred method of stimulating gas reservoirs. Hydraulic fracturing, or “fracing” as the industry calls it, is the practice of pumping large amounts of fluid carrying a proppant into the reservoir rock to fracture it and keep the fractures propped open to let the gas and/or oil flow freely to the borehole. Early frac jobs used gelled kerosene or gelled oil as the fluid, and sand or other coarse material as the proppant. When companies began substituting water for oil products as the fluid, they found that production increased even more and the use of oil products for fracing was generally discontinued.

Gas production in Pennsylvania declined through the 1960’s, mostly as a result of stagnant prices. The “energy crisis” of the early 1970’s, and the subsequent passage of the Natural Gas Policy Act in the late 1970’s, however, increased prices enough to stimulate domestic natural gas exploration and development. This resulted in a significant increase in drilling in Pennsylvania, particularly in Medina Group (Lower Silurian) reservoirs in the northwestern part of the state (Figure 4). Today, Pennsylvania’s natural gas industry produces only a little over 1 percent of the nation’s total. The most recent spike in gas production shown in Figure 3 is mainly the result of the current trend toward drilling in the Middle Devonian Marcellus Formation, which tends to produce large quantities of gas from most wells. For more information on the Marcellus Formation, see PA/S Publication 11.

## **Gas Storage**

The earliest form of natural gas storage was simply keeping a well or pipeline shut-in until the gas was needed. This was not the most practical application, however, so the gas industry devised the process of pumping gas into depleted reservoirs during summer months and withdrawing and shipping it via pipeline to critical markets during winter months. The first such underground gas storage operation took place in Canada in 1915, followed a year later by operations in the Buffalo, New York area. During World War I, serious shortages of natural gas in the United States required curtailment of domestic use. Following the war, natural gas companies realized they would need to increase the amount of natural gas stored underground to accommodate demand during peak periods. National Fuel Gas Company developed Pennsylvania’s first underground gas storage project in the Queen sand (Upper Devonian) in Forest and Warren counties in 1920 (Figure 4). It took another 14 years before the industry began to develop more storage projects in Pennsylvania’s depleted gas fields. The Oriskany gas fields in north-central Pennsylvania, in particular, became major storage areas with huge storage capacities. For many years, gas has been shipped via interstate pipelines from the Gulf Coast and western US to be stored in Pennsylvania before continuing on its way to northeastern markets. Recently, the surge in gas production from the Marcellus Formation has contributed much of Pennsylvania’s own gas to this effort. As of 2007, Pennsylvania had a maximum storage capacity in all reservoirs of almost 750 billion cubic feet of gas. New storage development projects will ensure that this number increases in the future.