Introduction to the Marcellus Shale

An introduction to the geological characteristics and considerations of the Marcellus Shale, as well as its cultural history and major topics of scientific interest.

What is the Marcellus Shale?

Shale is a sedimentary rock formed from fine, clay-like particles deposited in low energy water environments and compressed into rock.

![Image of the Marcellus Shale](image_url)

The Marcellus Shale is a dark shale, commonly called a black shale, that can be found in parts of Ohio, West Virginia, Pennsylvania, and New York. It was deposited in what was a shallow sea around 390 million years ago during the Devonian period. Marcellus Shale is mostly located deep beneath Earth’s surface, but because the layers of rock are tilted toward the south, the Marcellus is deeper in the south and is exposed at the surface near the north end of the Finger Lakes region.

Shale is only one type of sedimentary rock in the Hamilton Group. Important properties of all sedimentary rocks are their porosity and permeability. Porosity is the amount of space available between grains in a sedimentary rock, and permeability is the ability of anything trapped between grains in a sedimentary rock to flow between pores. When natural gas is trapped in a sedimentary rock with high porosity and permeability, like a sandstone, it has the ability to flow through the rock to pockets of relatively low pressure. When natural gas is trapped in a sedimentary rock with low porosity and permeability, like the Marcellus

Important properties of all sedimentary rocks are their porosity and permeability.

Marcellus Shale • Issue Number 1 • November 2011
Shales, and create shallow seas. New York, as well as Pennsylvania, Ohio, and West Virginia, were all covered by a shallow sea around 390 million years ago, and this sea deposited Marcellus Shale and many other rock units. Rivers and streams fed into this basin, and brought with them small quantities of clay-like sediments. Algae and other planktonic organisms inhabited the surface waters of this sea, and, as they died, sank to the bottom and mixed with the sediment. The Marcellus Shale's characteristic dark color and natural gas abundance is due to the high concentration of organic matter trapped with the sediment that eventually became rock.

1 The deepest part of this sea was located in the eastern part of the basin, so more sediment and organic matter was able to accumulate eastward. As a result, the Marcellus Shale today is thickest in the east and thins westward. Because of the quantity of organics in the shale, where the Marcellus Shale is thicker it is likely to contain a large amount of natural gas and be of the most interest for economical extraction.

**Natural Gas in a Tight Shale**

The natural gas in the Marcellus Shale is a type of fossil fuel, like coal and oil. While coal is formed from the concentration of fossilized land plant material, oil and gas are formed by the concentration of vast numbers of tiny, ocean-dwelling organisms like zooplankton, phytoplankton and algae. In all cases, organic tissues become fossil fuels because they were buried by sediment before they decomposed. Over long periods of time, the trapped carbon compounds from the organic material were subjected to heat and pressure, creating coal, oil, or natural gas.

Natural gas from Devonian shales is usually composed primarily of methane (80-95%), with a small
mix of ethane and propane (3-15%) which require processing before commercial sale. When natural gas and other fossil fuels are burned to produce energy, the amount of energy produced is measured in BTUs (British thermal units) per standard cubic foot (scf), with higher BTUs indicating greater energy production. One BTU is the amount of energy it takes to heat 1 pound of water by 1°F. Because of the composition of the natural gas varies, the potential energy production from Devonian natural gas ranges from 900-1300 BTUs per scf.

What is an Unconventional Natural Gas Resource?

The Marcellus Shale is referred to as an unconventional source of natural gas because of the way natural gas is trapped within the rock. Conventional sources of natural gas are often found in permeable, porous rocks (like sandstones), where natural gas or oil flows toward an area of lower pressure and eventually can consolidate the resource in ‘pools’ or ‘pockets.’ Extracting conventional resources requires locating a pocket and removing the oil or gas.

In unconventional resources like the Marcellus Shale, the natural gas is stored within the pores of the shale and unable to flow because of the very low permeability of the shale. Therefore, extracting unconventional resources requires both horizontal drilling and hydraulic fracturing to create pathways that increase the porosity and permeability of the shale, and allow the natural gas to travel to the wellbore. Because natural gas trapped in the Marcellus Shale has not migrated outside of the shale, gas companies drilling into the Marcellus are guaranteed to drill into commercial quantities of natural gas, however the extraction methods are more expensive and labor intensive.

The Reason for the Boom

Scientists have been aware of the natural gas in sedimentary rocks of the Appalachian Basin for over 150 years. Fredonia, NY began to run gas-powered streetlights and to power local establishments in town as early as 1825. Geographically, the Marcellus Shale gas basin is the largest in the U.S. However, because of the lower permeability and porosity of the Marcellus, the natural gas has been impossible to extract in commercial quantities with conventional technology. For this reason, it was not considered a potential source for fossil fuel extraction until recently, and is called an “unconventional” resource.

Gas drilling activity in the Marcellus has emerged rapidly in our region due to three separate, coincident developments: rising natural gas prices and increased commercial demand, revised estimates of the amount of natural gas stored in the Marcellus Shale basin, and advances in drilling technology. Around 2000, natural gas prices began to rise dramatically, and have remained relatively high to date. Considering that national predictions expect the demand for natural gas in the U.S. to rise by 20% by 2035, finding an economical way to extract natural gas contained in unconventional resources became more important to oil and gas companies.

In 1980, the National Petroleum Council estimated that, on average, gas content in the Marcellus Shale was about 0.5 trillion scf (standard cubic feet). In 1988, this estimate was dramatically revised to 26.5 trillion scf, and in 2008 the estimate
rose again to about 50 trillion scf.\footnote{Engelder, T., and G. Lash, 2008, Marcellus shale play’s vast resource potential creating stir in Appalachia, American Oil and Gas Reporter, 51:6, p. 76-87.}

Most recently, based on actual production data in the Marcellus Shale gas play, the amount of natural gas estimated to be extractable in the Marcellus increased again to 363 trillion scf.\footnote{Esch, M., 2008, Estimated gas yield from Marcellus shale goes up, International Business Times, November 4, 2008.}

Concurrently with the increasing price of natural gas and the exponential growth of estimated gas extraction potential in the Marcellus, two separate existing drilling technologies – hydraulic fracturing and horizontal drilling – began to be successfully combined for extracting natural gas from low permeability, ‘tight’ shales like the Marcellus. Horizontal drilling allows a well to be drilled along nearly horizontal layers of rock. Hydraulic fracturing is a method of cracking the rock with high volumes of water along the well bore to release the natural gas from the shale, a process sometimes called “stimulation.” Water used in hydraulic fracturing contains chemicals that play an important role in the extraction of the natural gas, and a large quantity of water (3 to 5 million gallons) is used per well during the process. Together, the process is called high-volume, slickwater hydraulic fracturing.

**Summary**

Considering the rapid pace of Marcellus Shale development in Pennsylvania, and of unconventional resources throughout the U.S., it is becoming increasingly important to understand the scientific issues associated with development. This is the first issue in a series of papers addressing Marcellus Shale natural gas origins, distribution, exploration and removal, and the associated environmental impacts.

**References**