GEOLOGY OF THE MARCELLUS SHALE IN MARYLAND
Conventional Appalachian Deep Gas Source Bed and Unconventional Gas Reservoir

David K. Brezinski
Maryland Geological Survey
2010
The Appalachian Basin
Grandfather of the World’s Oil and Gas Industry

1859 - Edwin Drake drills first oil well in Titusville, Pennsylvania.

1860 - 1901 - The Appalachian region becomes the center of the American oil industry.

1901 - Spindletop gusher drilled in Beaumont, Texas leads to oil industries migration from the central Appalachians to the Gulf Coast.

2004 – Marcellus unconventional gas play begins in Washington Co. PA.
Conventional versus Unconventional Gas Wells
Conventional “deep” Appalachian gas well
Conventional Reservoir Sandstone, The Oriskany Sandstone
Appalachian Basin’s Prime Deep Gas Reservoir Unit
Appalachian Deep Reservoir Seal or Capping Unit
The Marcellus Shale
Unconventional gas well—Source bed becomes reservoir too
Key to unconventional drilling: The “downhole mud motor” drilling head
Marcellus Shale - Expansive Gas Reservoir and Source

from Milici and Sweezey, 2006
ORIGIN AND STRATIGRAPHY OF THE MARCELLUS SHALE
400 Mya

from Blakey, 2010
Lower Marcellus Shale in sawed slab

1 cm
Weathered pyrite, lower Marcellus Shale

\( \text{FeS}_2 + O_2 + H_2O \rightarrow \text{FeSO}_4 + H_2SO_4 \)
Upper Marcellus Shale in sawed slab

1 cm
PRESERVATION AND MATURATION OF ORGANIC MATTER IN THE MARCELLUS SHALE
Lower Marcellus Deposition—Because of the strongly developed pycnocline, oxygen-free sea waters develop.

organic matter + bacteria + SO$_4$ = H$_2$S + sulfide minerals (e.g. pyrite)
Purcell Limestone Deposition

Middle Marcellus Deposition—Destruction of the pycnocline allows deposition of fossiliferous limestone, the Purcell Limestone.
Upper Marcellus Deposition—Pycnocline redevelops, but lack of pyrite suggests that it is not as strong as it was during deposition of the lower Marcellus
Variations of TOC (total organic carbon) within Marcellus Shale

(POC from Pennsylvania Topographic and Geologic Survey for Allegheny County, Pennsylvania)
Fatty Acids

Temperature & Time

Kerogen ($C_{15}H_{32}$)

octane ($C_8H_{18}$)

butane ($C_4H_{10}$)

propane ($C_3H_8$)

methane ($C_4H_4$)

liquid @ room T

gas @ room T

(= depth of burial)
Appalachian Thermal Maturity of Organic Matter (Measured by Vitrinite Reflectance)
THE MARCELLUS SHALE IN MARYLAND
Distribution of the Marcellus Shale in Maryland

- Keysers Ridge
- Cumberland
- Town Hill
- Sideling Hancock Hill

Legend:
- Gray: Rocks older than Marcellus Shale
- Yellow: Rocks younger than Marcellus Shale
- Marcellus Shale outcrop
- Western Maryland Gas Field (Oriskany)
Preliminary Map Illustrating Thickness of the Marcellus Shale in Maryland
Natural Fracturing of the Marcellus Shale in Maryland
DRILLING FOR THE MARCELLUS SHALE
A. Conventional well is drilled to below lowest fresh-water aquifer, then well bore is cased and cemented.

B. Conventional well is continued down to the KOP (Kickoff Point).

C. Downhole mud motor is inserted into well bore at KOP, and directional drilling to and into the Marcellus Shale continues.
Well Completion

1. Cementing

2. Logging and Perforation

3. Hydraulic Fracturing and Sand Injection
Summary

• The Marcellus Shale is the hydrocarbon source bed for most deep Oriskany gas wells in the Appalachian Basin.

• The Marcellus Shale was deposited in an anoxic (oxygen absent) marine basin that was thousands of feet deep.

• The Marcellus Shale can be subdivided into three subunits, the lowermost containing the highest levels of TOC.

• Current estimates of in-place gas is in excess of 500 trillion cubic feet.

• Fracing (fracking) of a Marcellus unconventional wells requires up to 1 million gallons of water per thousand feet of lateral hole.