The Marcellus: An Analogue for the World's Gas Shale Plays?*

Terry Engelder

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*Adapted from 2013-2014 AAPG Foundation Distinguished Lecture
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Abstract

Challenges for global gas shale production include infrastructural and geological with the Marcellus providing an analogue for both.

**Infrastructural:** The production from the Marcellus gas shale presents unique challenges that include issues associated with leasing, geology, landowners, virtually no deep disposal wells, state governments without a severance tax, several river basin commissions, an infrastructure designed for shallow gas production, an emotional group of environmentalists, and one state that has yet to permit horizontal well stimulation. This combination of challenges makes for a very interesting set of lessons that operators will face elsewhere in the world when attempting to play gas shales.

**Geological:** The Appalachian Basin is characterized by 2nd order depositional sequences (approximately 10's of million years duration) that make up thousands of feet of strata in this basin, 3rd order sequences (1-10 million years) with up to several hundred feet of strata, and parasequences, that comprise tens of feet of strata. Middle Devonian Marcellus Formation encompasses two third order transgressive-regressive (T-R) sequences, MSS1 and MSS2, in ascending order.

Compositional elements of the Marcellus Formation crucial to the successful development of this emerging shale gas play, including quartz, clay, carbonate, pyrite, and organic carbon, vary predictably within the proposed sequence stratigraphic framework. Tops of the parasequences commonly contain a calcareous interval, commonly containing shell debris, overlain by a sharp transition into the high TOC mudrocks of the next overlying parasequence. Thickness trends of Marcellus T-R sequences
and lithostratigraphic units reflect the interplay of Acadian thrust-load-induced subsidence, short-term base-level fluctuations, and recurrent basement structures. Rapid thickening of both T-R sequences, especially MSS2, toward the northeastern region of the basin preserves a record of greater accommodation space and proximity to clastic sources early in the Acadian orogeny. However, local variations in T-R sequence thickness in the western, more distal, area of the basin may reflect the reactivation of inherited Eocambrian basement structures to form a carbonate bank.

References Cited


The Marcellus: An analogue for global gas shale plays?

Terry Engelder, Distinguished Lecturer
Department of Geosciences
The Pennsylvania State University
Regional Extent of Devonian Marcellus Fracking in North America
U.S. Natural Gas Shale Plays are World-Class Resources

Outcome of the PSU Board of Trustees Meeting:

Conventional

Unconventional

** Dr. Terry Engelder, Penn State University
Some have predicted that the Appalachian Basin stacked play will yield 30 Bcf/d by 2020.
Christopher Joyce
Correspondent: Science Desk
National Public Radio (NPR)

• I have been in science journalism for more than 30 years and I have never seen more **scientific disinformation** on any topic as **fracking**. I am amazed at the level of both inadvertent and purposeful disinformation.

• There is such an agenda on everyone’s mind.

http://www.youtube.com/watch?v=giCRpuI-YBA

**Fracking in North America**
There are some people who really want it (i.e., production of oil and gas) to fail!

Scott Perry,
Undersecretary for Oil and Gas
Pennsylvania Department of Environmental Protection
Shale gas estimate in North West 'bigger' than previously thought

By Matt McGrath
Environment correspondent, BBC News
“Members of AAPG try to manipulate science!”

- Engelder notebook #43, page 119.

Frack Free Romania - We will not buy your corporate half truths that try to manipulate science! Romania and Europe will not be fracked Mr. Dr. Strangelove of fracking !!!

Frack Free Romania is the science
“Some Europeans fear the propaganda in the movie, *Gasland*, more than the hand of Vladimir Putin on the valve that supplies natural gas to Central Europe.”

Terry Engelder, Malostranski Namesti, Prague
May 17, 2012
• “Anyone who speaks in favor of fracking must be highly paid by industry (i.e., a shill)!”
  • Evidence for this found on many websites like ‘Fracked’.

Disclaimer: NO business (i.e., Shell) and no government (i.e., EU) will pay me a single Euro for giving this talk!
Google: Engelder the fracking debate

http://www.youtube.com/watch?v=BBSVLGf7zPl
Objective of Talk:
To understand the general infrastructural and geological characteristics of a successful black shale play
Qualities of a prospective gas shale

1. Public Domain Data Base
2. Free Market (Floating-Price) Commodity
3. Total Organic Carbon Content
4. Kerogen Type
5. Thickness
6. Depth
7. Thermal Maturity
8. Porosity
9. Pore Pressure
10. Low Clay Content
11. Total Technically Recoverable
12. Slight Structural Complexity
   i. Natural Hydraulic Fractures
   ii. No Thief Faulting
Public Domain Data Base

• **Small operators plus capital markets** can compete with majors (Exxon Mobil, Shell, Chevron, Total, BP, Statoil)
  – Mitchell Energy
  – Range Resources
  – Devon
  – Chesapeake
  – East Resources
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2. Free Market (Floating-Price) Commodity

High energy density reduces production cost by 50%
High permeability reduces production cost by 50%
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3. Total Organic Carbon Content

Schlumberger ELAN log
Background: Depositional Environment

- Carbonates dominated in west, associated with paleo-topographic high (Findlay Arch)
- Clastics dominated in east; derived from Acadian highlands and deposited in foredeep
- Proto-Mahantango Delta Complex in Central Pennsylvania (Prave et al., 1996)
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4. Kerogen Type
These are gas charged in situ (otherwise they would be veins)! These are the high permeability channels necessary for rapid production of gas but only when propped with sand!
Upper Devonian Coal in Fluvial Beds

Interpretation: Brent Wilson
J₂ Joints are restricted to the green rocks!
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5. Thickness

Marcellus Shale Thickness
- 0 - 50 feet
- 50 - 100 feet
- 100 - 150 feet
- 150 - 200 feet
- 200 - 250 feet
- 250 - 300 feet
- 300 - 350 feet
- 350+ feet

Marcellus Shale thickness is an MCOR interpretation based on multiple data sources.
Penn State research south of Sunbury, Northumberland County, PA
Marcellus (Three Members)
20-foot sections (NX core)
View: Looking downhole

Oatka Creek

Union Springs

Bottom

Machannango Fr

Purcell Ls

Onondag Ls
4. Thickness

local complete erosion of MSS1

Cross-Section 4

4. Thickness
Outcrop to SW PA

- Union Springs Mbr. (~1.5-2 Ma duration, 390 – 388 ma)
- Six parasequences
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6. Depth

Depth of Marcellus Shale Base
- 2000 - 3000 ft
- 3000 - 4000 ft
- 4000 - 5000 ft
- 5000 - 6000 ft
- 6000 - 7000 ft
- 7000 - 8000 ft
- 8000 - 9000 ft
- > 9000 ft

Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from Wrightstone, 2009.

Marcellus Shale Extent
(includes non-economic areas)
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7. Thermal Maturity

Wrightstone, 2009, Search and Discovery
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![Image of porosity with labels: Illite, Intra-organic nano-pores, scale 1um]
8. Porosity

Marcellus

Onondaga Limestone

Bound Water $\phi < 1\%$

Note: Bound water can't enter fractures as a free brine

Water Saturation = 2-10% of total porosity

Note: Free water can enter the gas shale along fractures as a free brine but this is not brine native to the gas shale

Free Water $\phi = 2\%$
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Marcellus Shale Asset Optimization through Increased Geological Understanding
Yang, Bowman, Morris, Zagorski (2013)
AAPG ACE
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### 11. Total Technically Recoverable

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<th>Region</th>
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<th>Shale Oil Resources</th>
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</table>

**TOTAL**

Present: Marcellus: 16 bcf/d --- Qatar: 25 bcf/d
Future: Marcellus plus Utica: 30 bcf/d

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Geneseo/Burket gas shale:
Two natural hydraulic fracture sets
Plan View

Acid Injection
Breakdown
Slurry Rate Increases
Maximum Rate

1770'

10H
3H
2H
11H

10H
Stage 4
all events
FEAR OF FrACKING

A key technique in shale drilling is hydraulic fracturing, aka fracking. A fluid mix of water, sand, and chemicals is pumped down the well at high pressure, creating fissures in the shale that let gas flow into the well. But the whole drilling process may also create pathways that allow gas or chemicals to pollute drinking water.

Diagram not drawn to scale

Leaky ponds: Contaminated wastewater from fracking is often stored in surface ponds, which can overflow or leak, polluting streams or groundwater.

Faulty wells: Wells are reinforced with steel casing and sealed with concrete. But poor cementing can leave gaps that allow methane or fracking chemicals to contaminate drinking-water aquifers.

Fractures: Fracking fissures might connect to natural ones, allowing pollutants to migrate. Whether they'd climb thousands of feet to shallow aquifers isn't clear.

National Geographic's version of a lightening bolt

Taughannock Falls State Park, Trumansburg, NY
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Vertical Fracture Zones:

**Zones of No Drilling**: Engelder (2009) resource estimate risked the Marcellus at 30% (i.e., fraction of Marcellus that is too badly fractured to permit economic drilling.

Texas Creek Anticline (thick halite, dolomite)

Engelder (2009) resource estimate risked the Marcellus at 30% (i.e., fraction of Marcellus that is too badly fractured to permit economic drilling.)
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**Gulf of Suez**