Integrated Geologic Analysis from Two Marcellus Shale Science Wells in Northeastern West Virginia*

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Search and Discovery Article #51359 (2017)**
Posted February 13, 2017

*Adapted from poster presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016
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Abstract

The Marcellus Shale Energy and Environment Laboratory (MSEEL) consists of four horizontal production wells, and two special purpose vertical science wells to better understand the detailed geology of the Lower Devonian organic-rich Marcellus Shale and other shallower shale units. All activities are in coordination with the Department of Energy and the operator Northeast Natural Energy. Understanding the vertical and lateral distribution of the shale lithofacies is critical to decipher the impact of depositional, diagenetic and geomechanical environments on hydrocarbon generation and production. Integrated geological and petrophysical characterization of the Marcellus and surrounding Onondaga through Mahantango units was performed using core, sidewall cores and well log data. Mineralogy and Total Organic Carbon (TOC) content were estimated using triple combo logs and advanced logging tools (e.g., spectral gamma, lithoscanner, and nuclear magnetic resonance) calibrated to core data (XRD and source-rock pyrolysis). A series of multi-mineralogical models were used to understand the petrophysical heterogeneities of the shale units. Based on the mineralogy and organic content the Devonian Marcellus-Mahantango interval is composed of six shale lithofacies. Integrated petrophysical analysis shows that three well-developed organic mudstone facies are present in the Marcellus interval. Correlation of spectral gamma derived uranium content and organic carbon proportion indicates the highly organic mudstone (TOC > 7 weight percent) facies in the lowest part of the Marcellus Shale was deposited in a highly anoxic environment compared to overlying units. Bin porosities from the nuclear magnetic resonance log indicate that organic-rich mudstone facies contains pore sizes greater than 10 nanometers.

References Cited


**Abstract**

Two science wells were drilled to better understand detailed geology of the Marcellus Shale and other shallower shale units, in combination with the Department of Energy and West Virginia University. Understanding the vertical and lateral distribution of the shale lithofacies is critical to decipher the depositional and diagenetic environments and their potential impact on hydrocarbon generation. Integrated petrophysical and geological characterization of the Devonian Mahantangan/Marcellus interval were performed using core and well log data from the two wells.

Mineralogy and Total Organic Carbon (TOC) content were estimated using both triple combo logs and advanced logging tools (such as spectral gamma, lithoacme, and nuclear magnetic resonance) calibrated to core data (XRD and rock-eval pyrolysis). A series of models and multi-mineralogical models were used to understand the petrophysical heterogeneities of the shale units and calculate effective porosity. Preliminary results show that the Devonian Mahantangan/Marcellus interval is composed of six shale lithofacies based on the mineralogy and organic content. Integrated petrophysical analysis shows that three well-developed organic mudstone facies are present in the Marcellus interval. Correlation of spectral gamma derived uranium content and organic carbon proportion indicates the highly organic mudstone (TOC > 6.5 wt%) facies in the lowest part of the Marcellus Shale was deposited in a highly aerobic environment compared to the shallower units.

**Objectives**

1. Identify different geological facies in the Marcellus Formation to better understand their depositional and diagenetic controls on mineral composition and TOC in the shale mass.
2. Investigate vertical and small-scale lateral heterogeneity of the shale lithofacies, based on Total Organic Carbon (TOC), maturity and mineral composition.
3. Interpret relation between shale lithofacies variation and their geomechanical and hydrocarbon production potential.

**Available Data**

- Well Logs Available:
  - Mineralogy logs (ECAL and Lithoacme)
  - Sonic Scanners (Opole sonic, Elastic moduli, Anisotropy stress)
  - Spectral Gamma Ray
  - Nuclear Magnetic Resonance (NMR)
  - Formation Micro-imager (FMI)

**Conclusions and Future Work**

- Marcellus Shale has been divided into 6 different facies units such as Organic Siliceous Shale, Organic Mudstone, Organic Mixed Shale, Gray Siliceous Shale, Gray Mixed Shale and Gray Mudstones. Carbonate interlayers are present sometimes (in Mahantangan).
- Mineralogy controls the brittleness in Shale Lithofacies. Gray Siliceous and Organic siliceous shale are more brittle due to an increase in quartz content and Gray Mudstone and Organic Mixed Facies are more ductile due to an increase in clay content.
- Organic Siliceous Shale lithofacies has high silica and TOC content.
- This analysis is executed using petrophysical data alone, with the addition of the IRD, KF, and core derived TCI will allow us to refine our shale lithofacies model and refine the depositional environment related to each of the shale lithofacies.

Acknowledgments:
- U.S. Department of Energy, National Energy Technology Laboratory (for providing information through 1PM000357-3 Marcellus Shale energy and Environment Laboratory – MSEEL).
- References [archived]