[PS]Deciphering Interplay of Tectonism and Redox Conditions on Temporal Variation in Total Organic Carbon Content in the Marcellus Shale: Evidence from Multiple Geochemical Proxies*

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Abstract

The Marcellus Shale is an unconventional shale-gas reservoir that has been a major target of gas production in the Appalachian Basin of the United States. The total organic carbon (TOC) plays a key role in determining hydrocarbon potential of shale gas reservoirs. This study focuses on analyses of stable isotopes, geochemical elements on samples collected from a 30-m core of the Marcellus Shale obtained from Greene County, Pennsylvania to understand dominant controls on temporal variations in TOC. The geochemical proxies reveal that tectonic activity related to Acadian orogeny plays a key role in the deposition of the most organic-rich (OR) interval. The OR interval likely represents a deposition during the tectonically active period of the Acadian orogeny (ca. 395-380 Ma). Highly variable light rare earth elements (LREE) observed in this interval might correspond to the development of finer-scale tectophases, resulting in variations in water depth and sediment sources. Highly variable trace element contents (e.g. V and Mo) in the OR and a wide range of d15N and d34Spyr values towards the top of the OR interval also suggest alternating redox conditions in the water column. Such conditions are favorable for nutrient regeneration and enhancing primary production, resulting in higher concentration of organic matter in the OR interval of the Marcellus Shale.

In contrast, subsequent deposition of the organic-poor (OP) sediments in the Upper Marcellus Shale occurred synchronously with a tectonic quiescent period (ca. 380-370 Ma) during the Acadian orogeny. During this time period, the Acadian orogen might have slowly lowered due to weathering and erosion, resulting in more precipitation and increased clastic input into the basin. The higher LREE and Ti and/or Al concentrations could possibly suggest increased influx of siliciclastic materials into the basin. In addition, d13Corg values increase up-section, suggesting a higher contribution of terrestrial sources to the organic matter towards the top of the section. The d15N and d34Spyr values and concentrations of redox-sensitive trace elements in sediments indicate that the bottom water was predominantly suboxic during deposition of the OP interval, which was not that favorable for higher accumulation of organic matter. All these geochemical proxies provide evidence for the role of tectonism and redox conditions in the temporal variation of TOC content in the Marcellus Shale.

Deciphering Interplay of Tectonism and Redox Conditions on Temporal Variation in Total Organic Carbon Content in the Marcellus Shale Evidence From Multiple Geochemical Proxies

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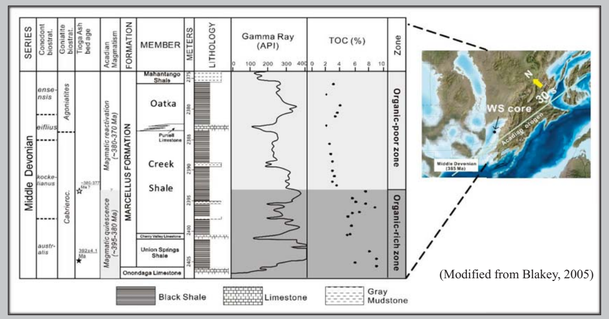
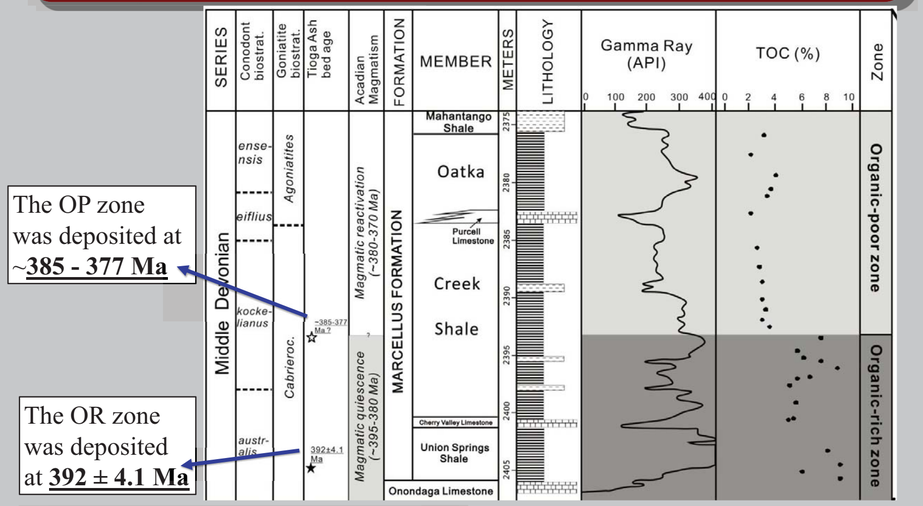
Introduction

The Marcellus Shale is an unconventional shale-gas reservoir that has been a major target of gas production in the Appalachian basin, United States. The total organic carbon content (TOC) plays a key role in determining hydrocarbon potential of shale gas reservoirs. This study focuses on analyses of stable isotopes, geochemical elements on samples collected from a 30-m core of the Marcellus Shale obtained from Greene County, Pennsylvania to understand dominant controls on temporal variations in TOC. The geochemical proxies reveal that tectonic activity related to Acadian orogeny plays a key role in the deposition of the most organic-rich (OR) interval. The OR interval likely represents a deposition during the tectonically active period of the Acadian orogeny (ca. 395-380 Ma). In contrast, subsequent deposition of the organic-poor (OP) sediments in the upper Marcellus Shale occurred synchronously with a tectonic quiescent period (ca. 380-370 Ma) during the Acadian orogeny.

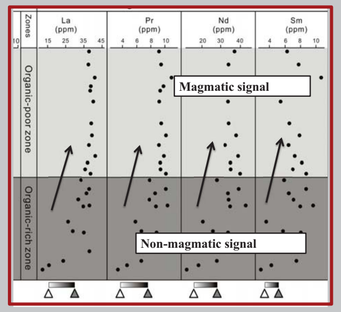
Study area and sampling

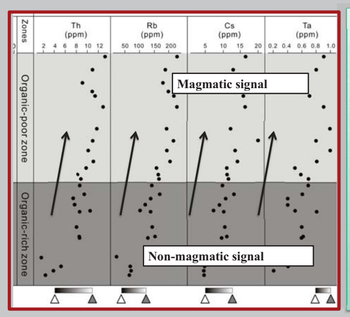


Temporal correlation



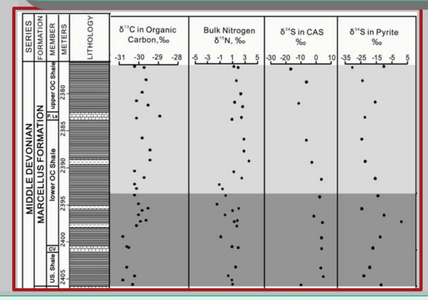
Geochemical correlation

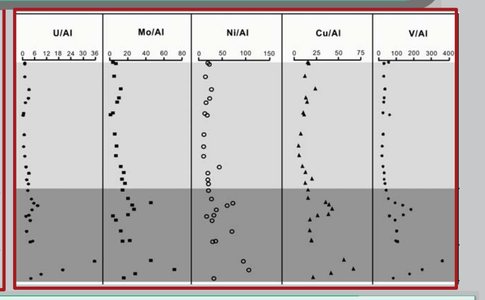




1. Increasing LREEs suggest a compositional shift in sediment source.
2. Increasing LREEs and volatile trace elements indicate magmatic signal during the OP zone.
3. Highly variable LREE might correspond to the development of finer-scale tectophases,

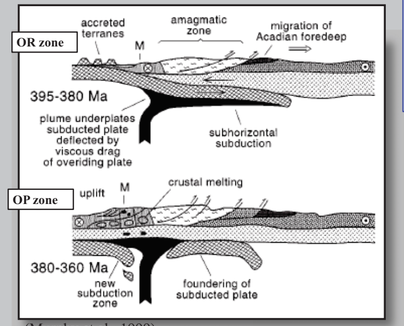
Other geochemical evidences





- Finer-scale tectophases might result in variations in water depth and sediment sources.
- Highly variable N and S isotopic compositions and trace elements the OR suggest alternating redox condition.
- Organic C isotopic compositions ($\delta^{13}C$ = -30.5‰) in the OR zone indicate marine organic matter;, the values increase upward in the OP suggest higher contribution of terrestrial sources to the organic matter.

Conclusions



(Murphy et al., 1999)

- Basin subsidence and water depth increase
- Reduced sediment input
- Alternating redox conditions
- Nutrient regeneration, enhancing primary production

→ OM enrichment

- Acadian orogen might have slowly lowered due to weathering and erosion
- Higher sediment input
- Increased O2
- Subsidence began decrease

→ OM Poor