Role of Geochemistry in Unconventional Resource Development

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Opportunities have changed. Source = Reservoir

Need for understanding the geological and geochemical heterogeneities in source rock.
1. Source Rock Characterization

1. Modelling Variations in TOC
   - Locating sweet spots
   - Oil vs gas production
   - Frackability
   - Porosity/permeability effects

2. Modelling variations in mineral and elemental composition
   - natural/induced fracture networks
   - rock-fluid interactions

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**Geochemistry Applications**

**2. Chemostratigraphic Correlation**

- Vertical and lateral continuity of reservoirs
- Placement of horizontal wells

Proposed correlations of the New York subsurface based on $\delta^{13}C_{\text{carb}}$ (Mitzger et al., 2013)

Chemostratigraphic correlation of a formation in 2 vertical wells (Hildred & Rice, 2014)

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3. Determining Zonal Isolation

- Gas/fluid migration due to propagation of fractures into overlying or underlying zones
- Production allocation - Quantifying contribution of individual pay zones to comingled produced gas

Modified Schoell & Bernard plots

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4. Assessing Environmental Impacts

- Determine if stray gas and/or pollutants in aquifers are associated with oil and gas development.
What are primary factors controlling variations in the quantity & quality of Total Organic Carbon (TOC) content in Marcellus Shale?
CASE STUDIES
Marcellus Shale
Appalachian Basin

(Modified from Chen, Sharma et. al., 2015)
Role of alternating redox conditions in the formation of organic-rich interval in the Middle Devonian Marcellus Shale, Appalachian Basin, USA

Ruiqian Chen, Shikha Sharma *

Fluctuating N/S isotopic signatures & trace metal ratios in OR zone suggest episodic oxia that might have released & recycled nutrients into water column resulting in elevated primary productivity and higher burial of ORGANIC CARBON

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Comparison of isotopic and geochemical characteristics of sediments from a gas- and liquids-prone wells in Marcellus Shale from Appalachian Basin, West Virginia

Ruiqian Chen\textsuperscript{a}, Shikha Sharma\textsuperscript{a,\textdagger}, Tracy Bank\textsuperscript{b}, Daniel Soeder\textsuperscript{c}, Harvey Eastman\textsuperscript{d}

\textbf{WV-6 core} → basin margin → higher influx of clastic sediment & woody, terrestrial OM → generate gas

\textbf{WV-7 core} → open marine environment → lipid rich marine OM matter → generate gas & liquids
Case Study: Powder River Basin, Wyoming

Determining Reservoir Continuity

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Case Study: Powder River Basin, Wyoming contd....

δ¹³C DIC of produced water can be used to trace the lateral continuity of individual coalbeds.

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Predicting Gas/Water Ratios

Case Study: Atlantic Rim Basin, Wyoming

If $\delta^{13}C$ are directly related to production....

Then we can use $\delta^{13}C$ to predict hotspots!

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Lower $\delta^{13}C_{DIC}$ values in produced water indicate:

- Buried faults were conduits of fresh water recharge hence wells had low gas/water ratios
- Wells with poor cement bond logs had low gas/water ratios
Assessing Environmental Impacts

Tracing Coalbed Natural Gas–Coproduced Water Using Stable Isotopes of Carbon

by S. Sharma$^1$ and C.D. Frost$^2$

High carbon isotope signature of CBNG produced water with can be used to trace its input into surface water streams
Assessing Environmental Impacts

Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing

Stephen G. Osborn*, Avner Vengosh*, Nathaniel R. Warner*, and Robert B. Jackson*bc1

www.pnas.org/cgi/doi/10.1073/pnas.1100682108

Contrasting results highlight need for baseline characterization

Environmental Pollution

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Surface water geochemical and isotopic variations in an area of accelerating Marcellus Shale gas development

Adam J. Pelak, Shikha Sharma*

Environmental Pollution 195 (2014) 1–10

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Presence of overlying producing wells (~4000 ft above Marcellus) which can be used as monitoring wells to test for changes in hydrologic connectivity.
Presence of overlying producing wells (approximately 3000-4000 ft above Marcellus)

Presence of natural faults that can augment hydrologic connectivity

Multiple Monitoring Tools:
1) 3-D numerical modeling of fracture propagation
2) Long-term seismic monitoring
3) Artificial PFC tracers
4) Isotope monitoring

Case Study: Marcellus Shale Greene County, PA

Presence of natural faults could augment connectivity
Numerous microseismic events were observed above the Tully Limestone, which is thought to be an upper barrier to fracture growth from hydraulic fracturing in the Marcellus Shale.

No evidence of gas or brine migration from the Marcellus Shale to the Upper Devonian/Lower Mississippian gas field during the monitored period after hydraulic fracturing.
Gas isotopic composition consistent before & after hydraulic fracturing
The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.
What are geological controls on microbial distribution, diversity and function?

- Gas productivity and well infrastructure
- Potential for fracture and pore clogging
- Microbial life/adaptations

CSIA & Fatty Acid biomarker distribution

- Ratios of physiological stress
- DGFA/FAME lipid biomarkers
- Changes in the PLFA and DGFA profiles during nutritional & thermal stress
- CSIA will be used to identify microbial populations involved in methanogenesis, methanotrophy, sulfate reduction etc.

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Initial $\delta^{13}$C$_{DIC}$ enrichment trend in wells 5H and 3H during first few hours to days indicates dissolution of carbonates in reservoir after injection of hydraulic fracturing fluids. High $\delta^{13}$C$_{DIC}$ values indicate carbonates were precipitated during initial phase of biogenic methanogenesis in the reservoir. The C and S isotope trends will be monitored over several months to understand microbial reactions induced in the reservoir after injection of hydraulic fracturing fluids.
Decoding Kerogen structure and its interactions

- Changes in kerogen structure and composition on interaction with frac fluids
- Effect of changes in kerogen on chemistry and flow of produced water and gases

MSEEL Contd......

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Behar & Vandenbroucke, 1987

Collaborators:
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NATIONAL LABORATORY

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