Novel Gas Isotope Interpretation Tools to Optimize Gas Shale Production

Yongchun Tang

Power Environmental Energy Research Institute

PEER

RPSEA
Research Partnership to Secure Energy for America

Outline

- Objectives
- Backgrounds
- OGIP assessment
- Sweet spot prediction
  - Fluid properties
  - Production and Recovery
- Conclusions

Project Objectives

The overall objective of this work is to develop novel diagnostic tools for predicting, monitoring, and optimizing shale gas production. There are three primary objectives of this project.

(1) To field-deploy our gas isotope spectrometer for real time measuring carbon and deuterium isotope ratios of nature gas;

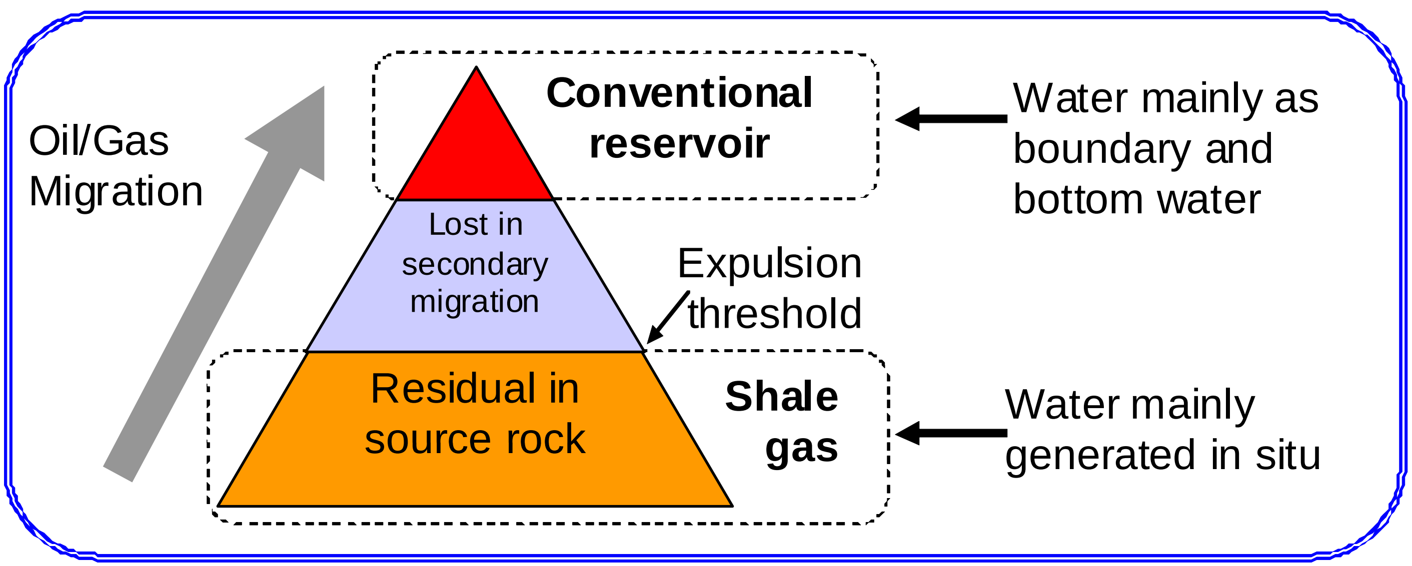
(2) To develop a user friendly interpretive tool to quantify the remaining gas potential (OGIP), amount of free gas and absorbed gas;

(3) To integrate with other field operational data through our industrial partners and to rationalize our results.

Shale Gas Petroleum System

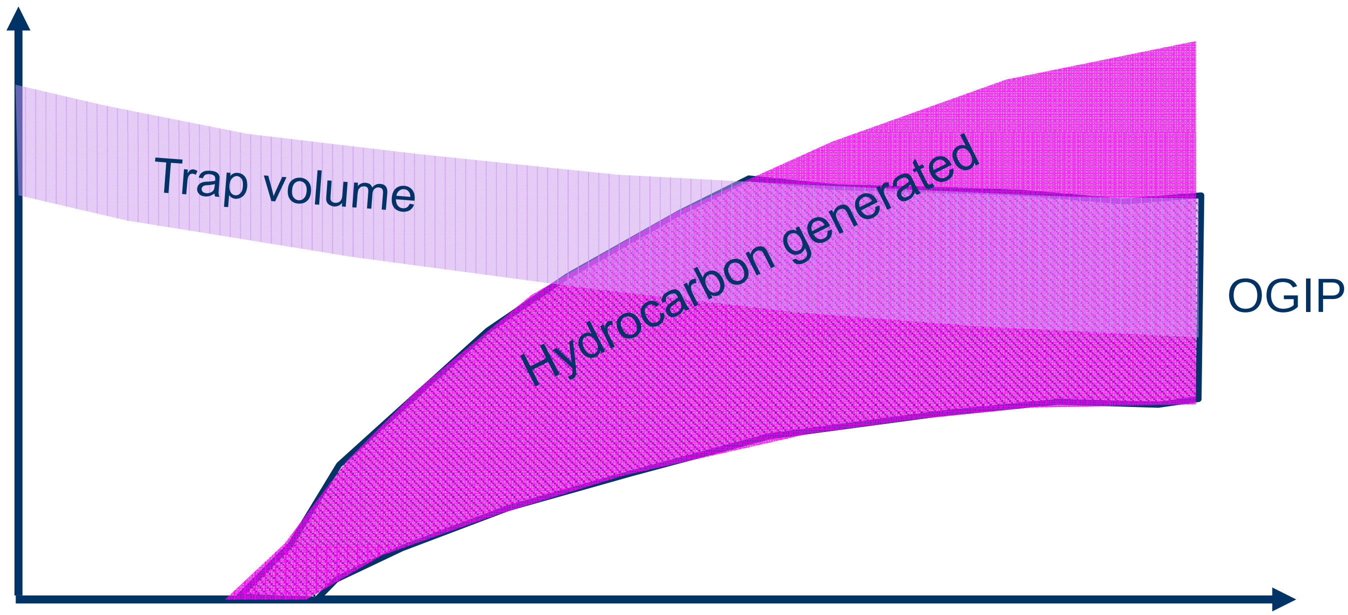
- Source rock as reservoir
  - Shale gas ←→ Conventional gas : Remained ←→ Expelled

→ Need more accurate expulsion threshold
Need to consider water saturation



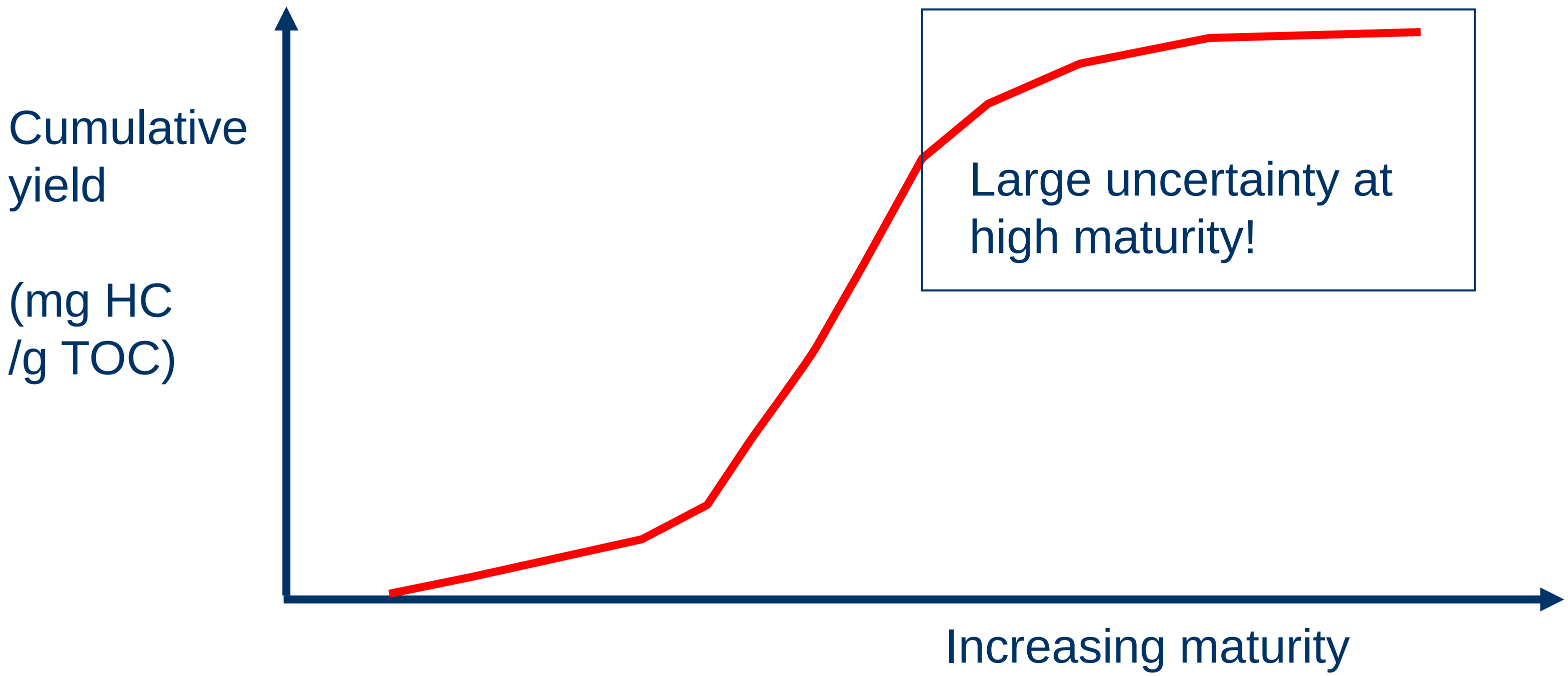
Uncertainties in OGIP assessment

- Uncertainties of generated amount
- Uncertainties of trap volume
- Hydrocarbon/Water saturation



Uncertainty in Generation

- Potential of Late Gas
  - Normally the gas generated in late stage is obtained from artificial maturation start from low maturity sample



Uncertainty in Generation

- Contribution of Secondary Gas
  - Residual oil amount after expulsion

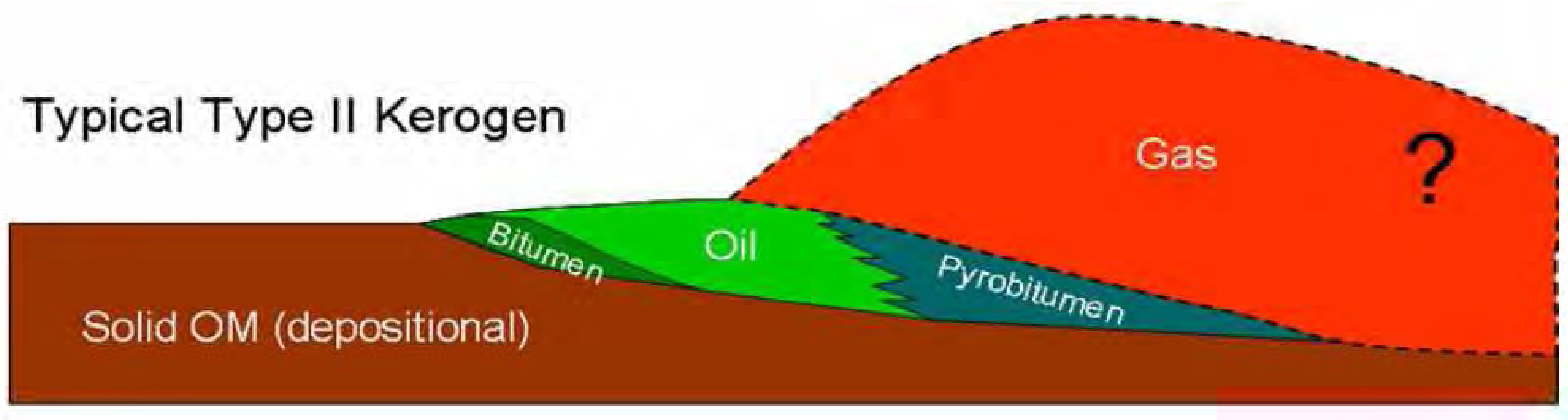
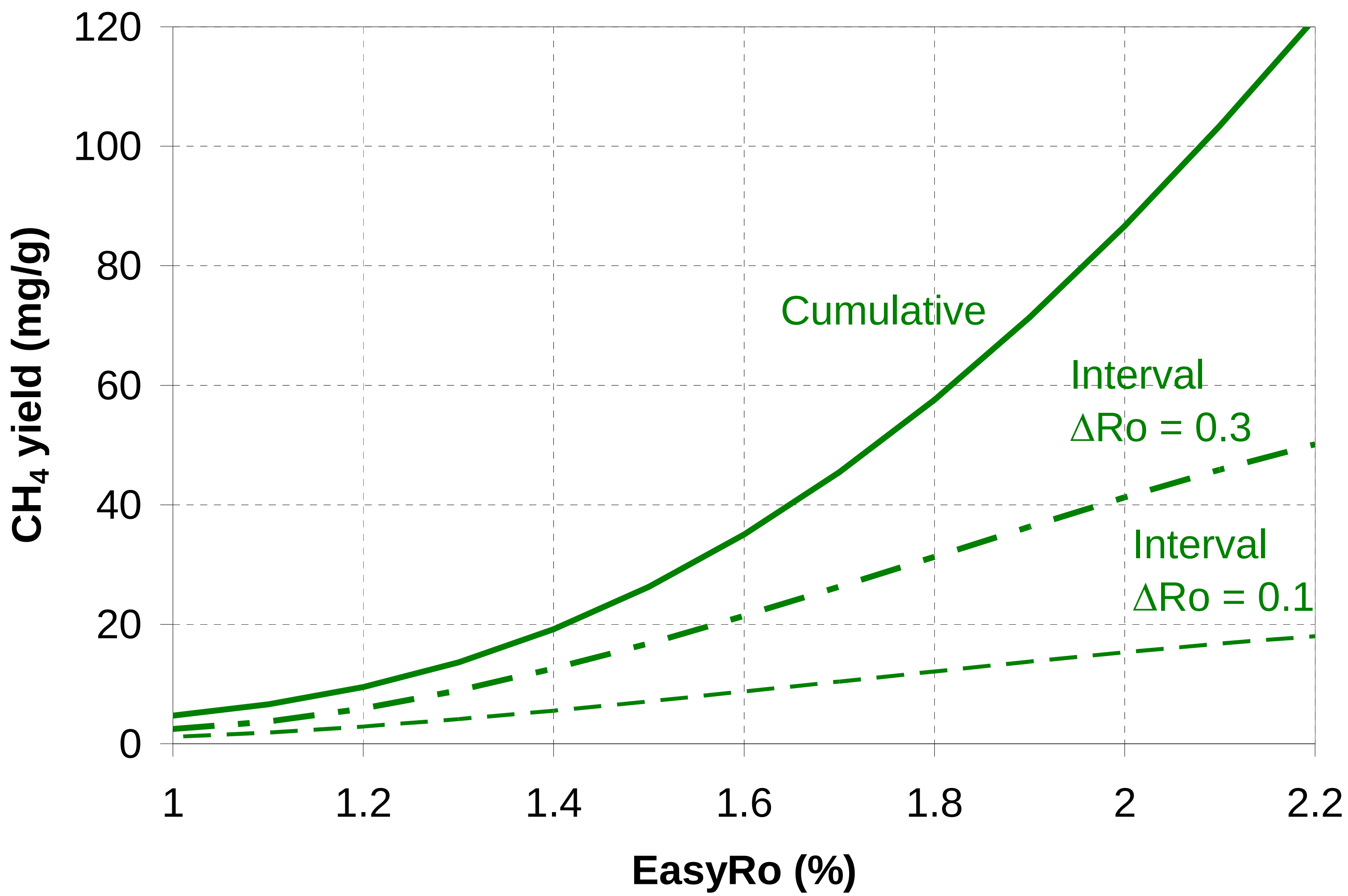


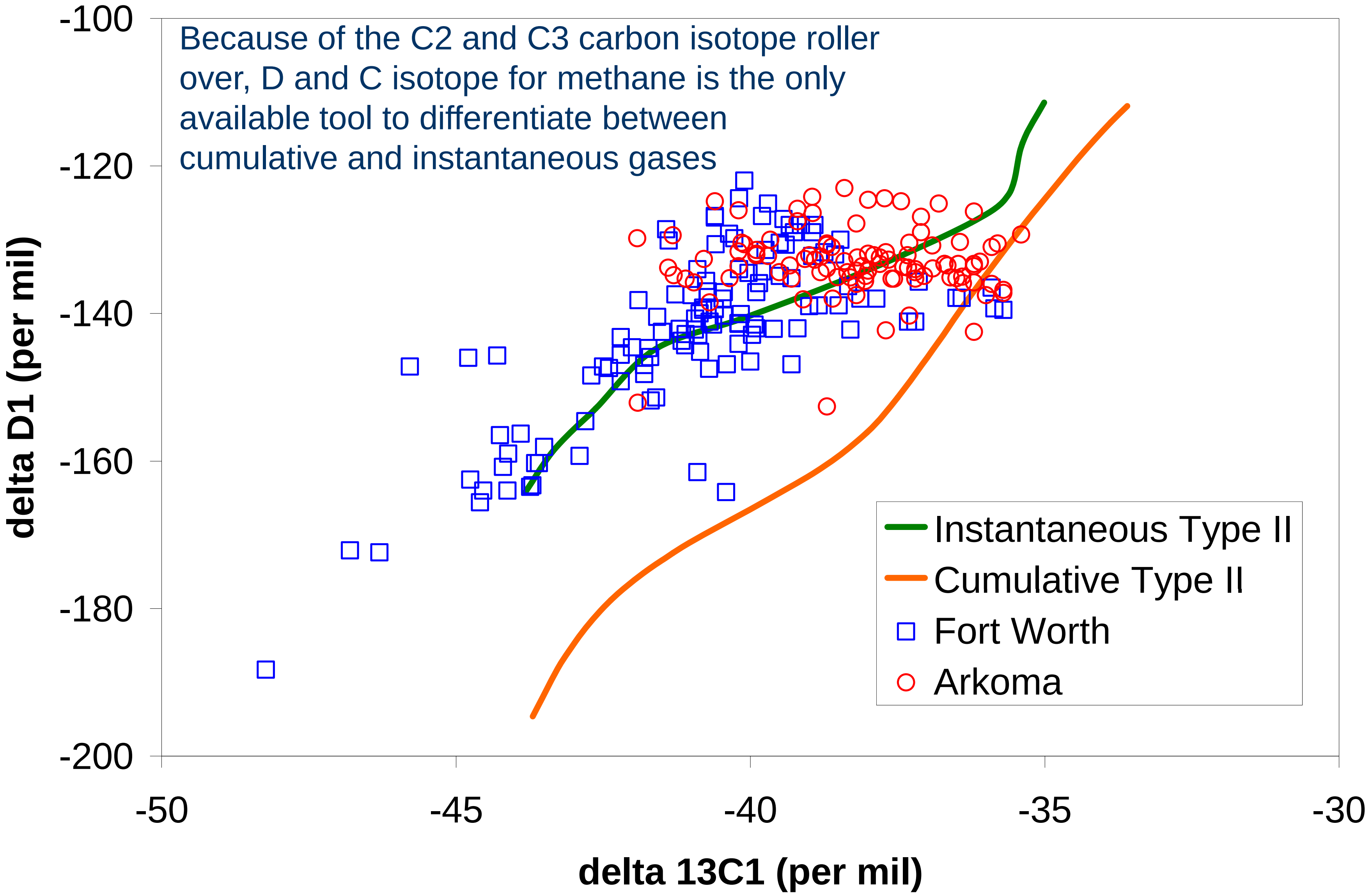
Figure: Passey et al., 2010

Gas Volume Depend on Degree of Instantaneous Model

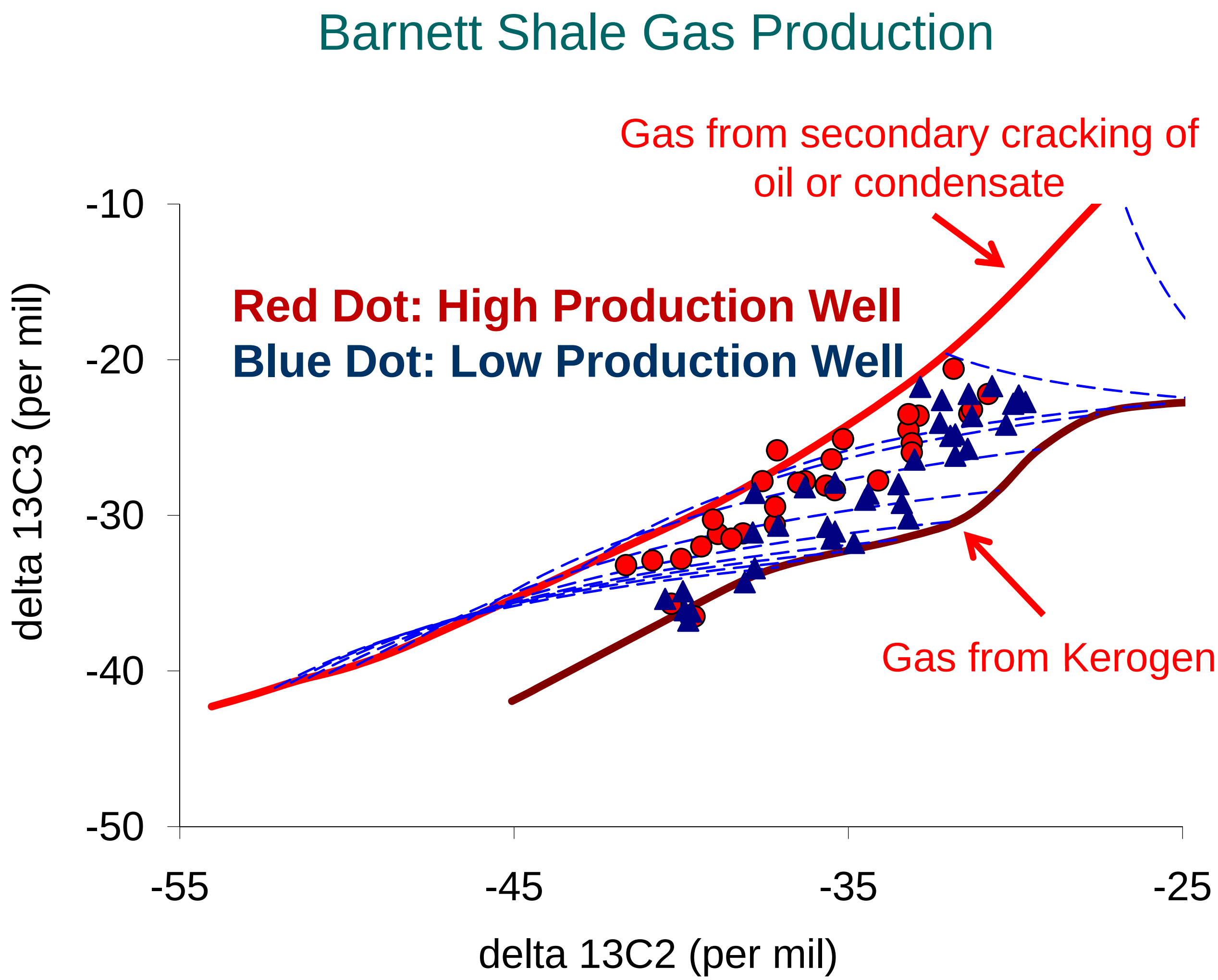


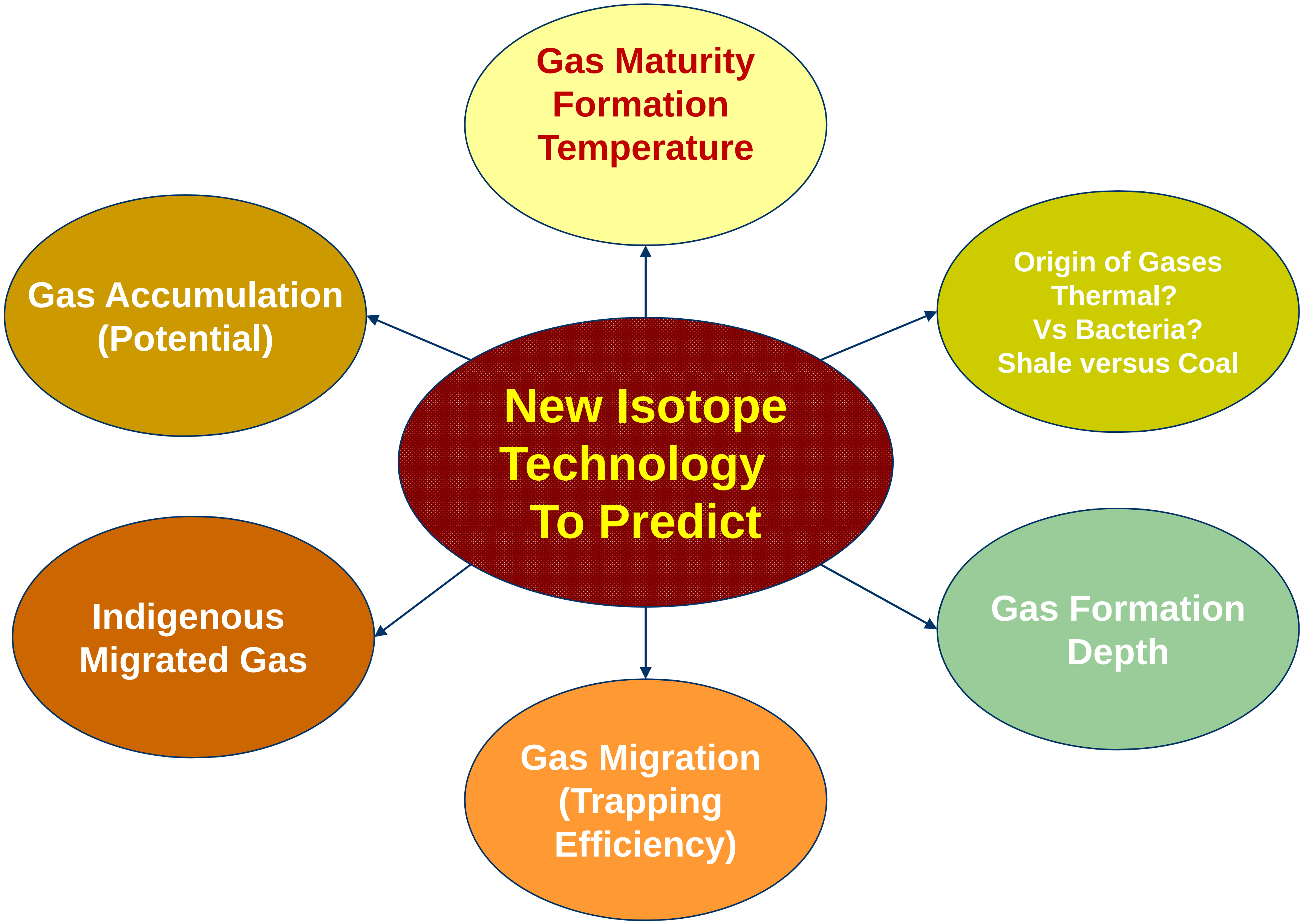
Raw Data from Hill, Tang et al, 2007

Barnett Shale Gas between Instantaneous Model and Cumulative Model



De-mixing gas from oil/condensate and kerogen correlates with high production wells




Gas Maturity
Formation
Temperature
Gas Accumulation
(Potential)
Origin of Gases
Thermal?
Vs Bacteria?
Shale versus Coal
New Isotope
Technology
To Predict
Indigenous
Migrated Gas
Gas Formation
Depth
Gas Migration
(Trapping
Efficiency)

Uncertainty in Generation

- Mechanism of later-gas generation: water involvement?

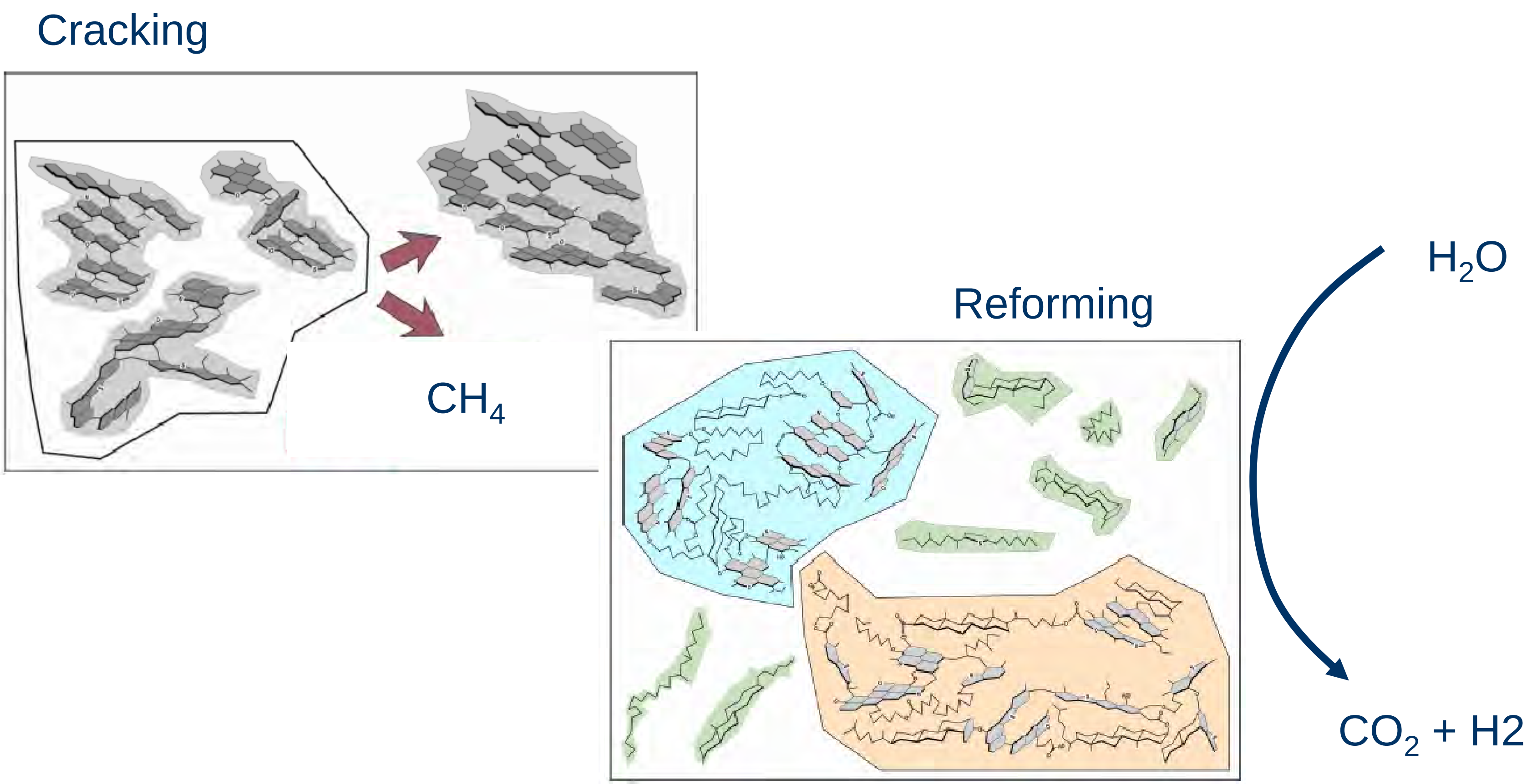
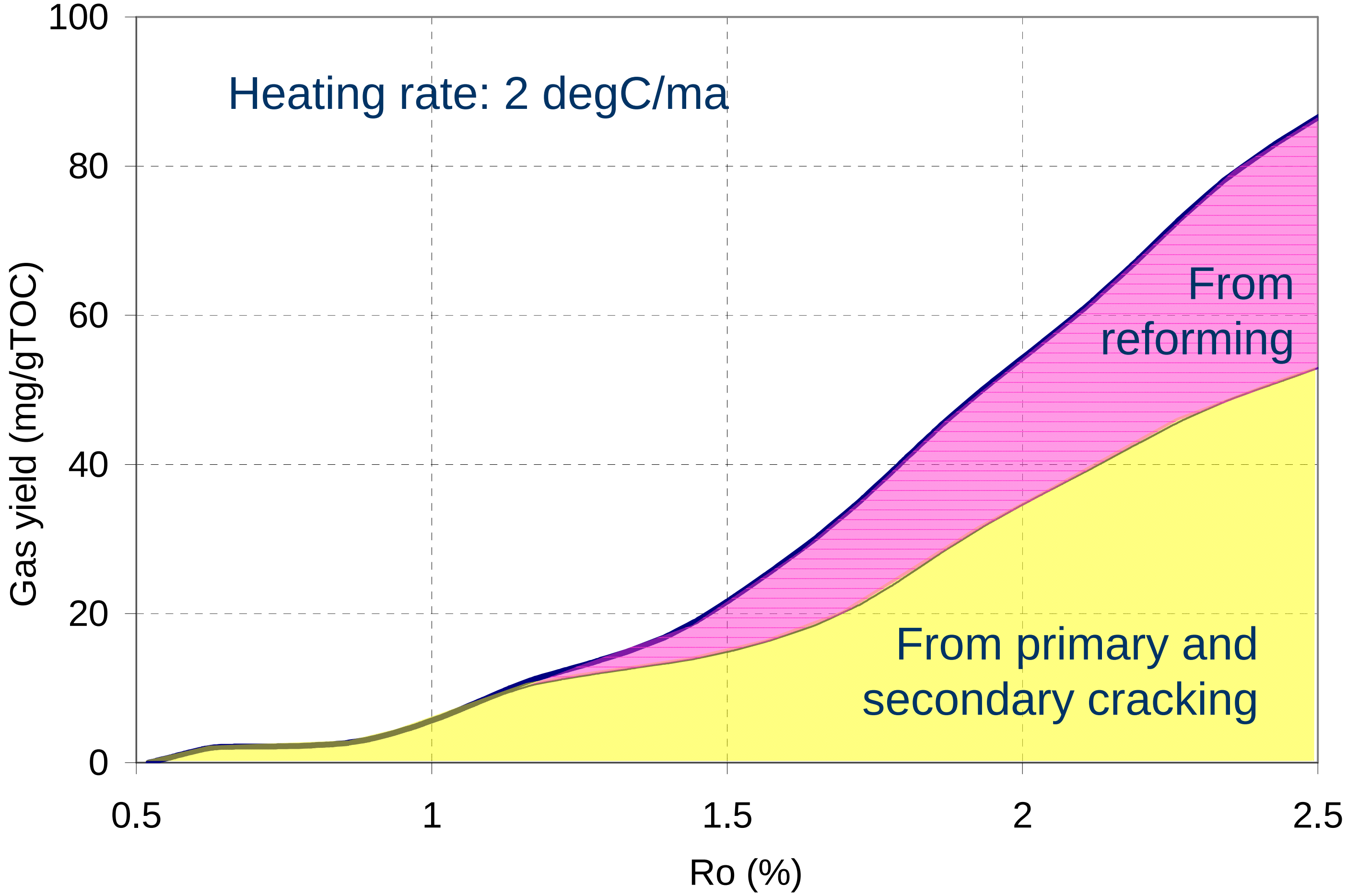


Figure of organic matter: Behar et al., 2010

Towards a more accurate assessment on OGIP



Our Effort Is Now Working on the Detailed Kinetics of This Reforming Reactions

Uncertainty in Fluid Property Prediction

- Water saturation and water hydrocarbon reactions
- GOR
- Producible oil properties
- Wetness of gas
- Condensate
- Non-hydrocarbon

Uncertainties: Production prediction

The Arps Equation

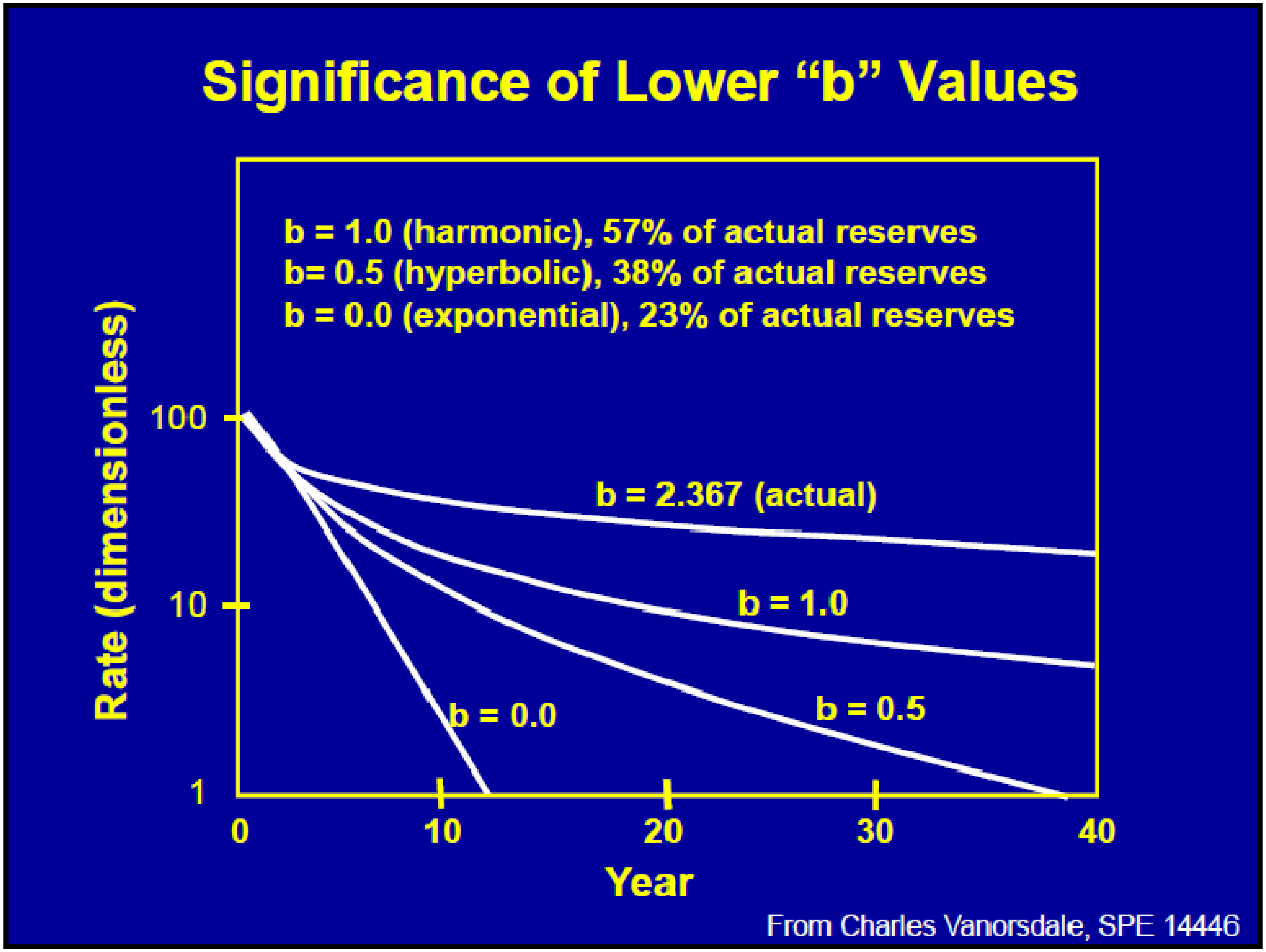
$$q_g = \frac{q_{gi}}{(1 + bD_i t)^{(1/b)}}$$

Where:

- q_g = gas production rate
- q_{gi} = initial gas production rate
- D_i = initial decline rate, percent per year
- t = cumulative time since start of production, days
- b = hyperbolic decline exponent ($0<b<1$)

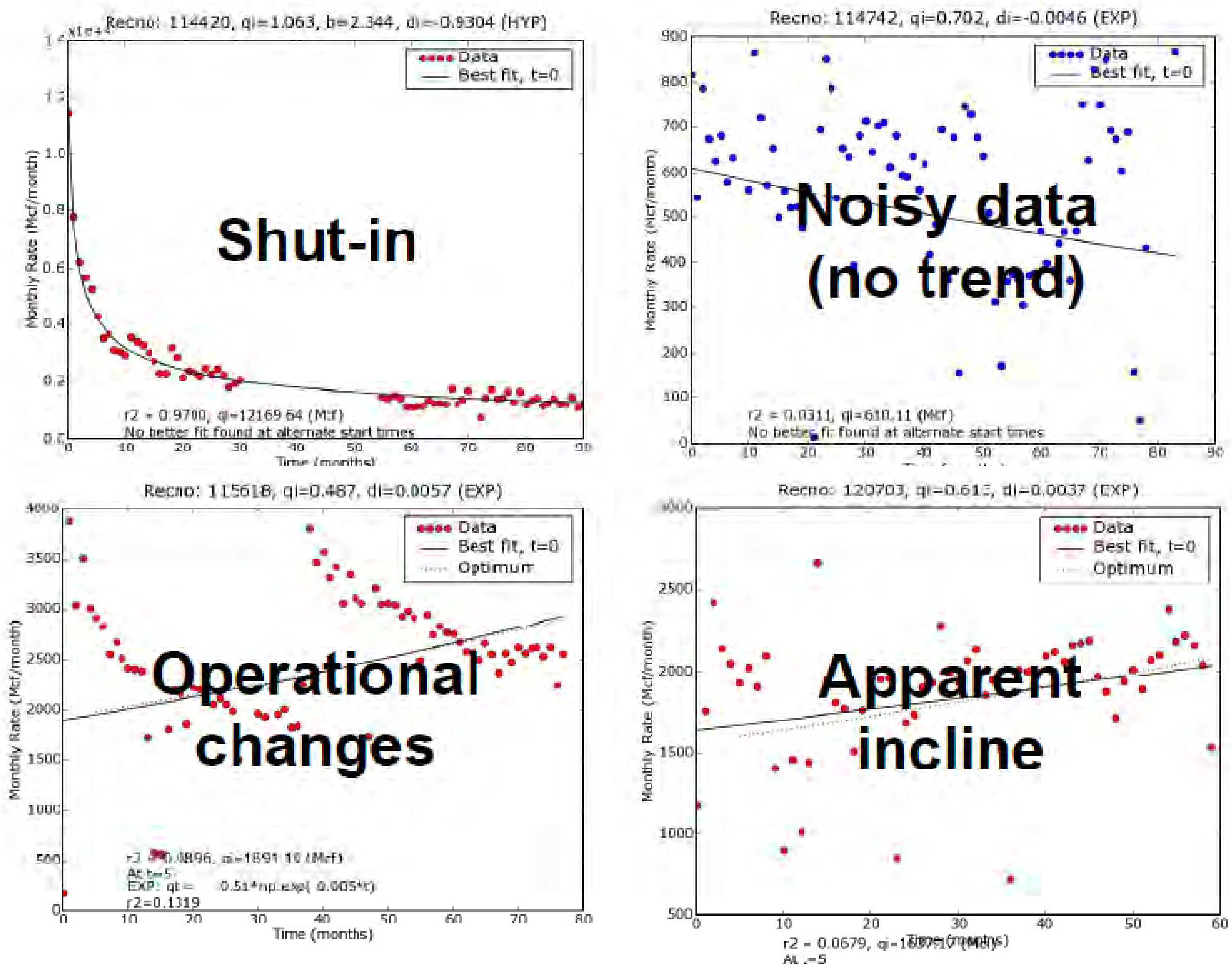
- **Key Assumptions:**
  - Well is producing at a constant bottomhole pressure
  - Well is producing from an unchanging drainage area with no-flow boundaries

Uncertainties: Production prediction



Jenkins et al., 2010

Uncertainties: Production prediction



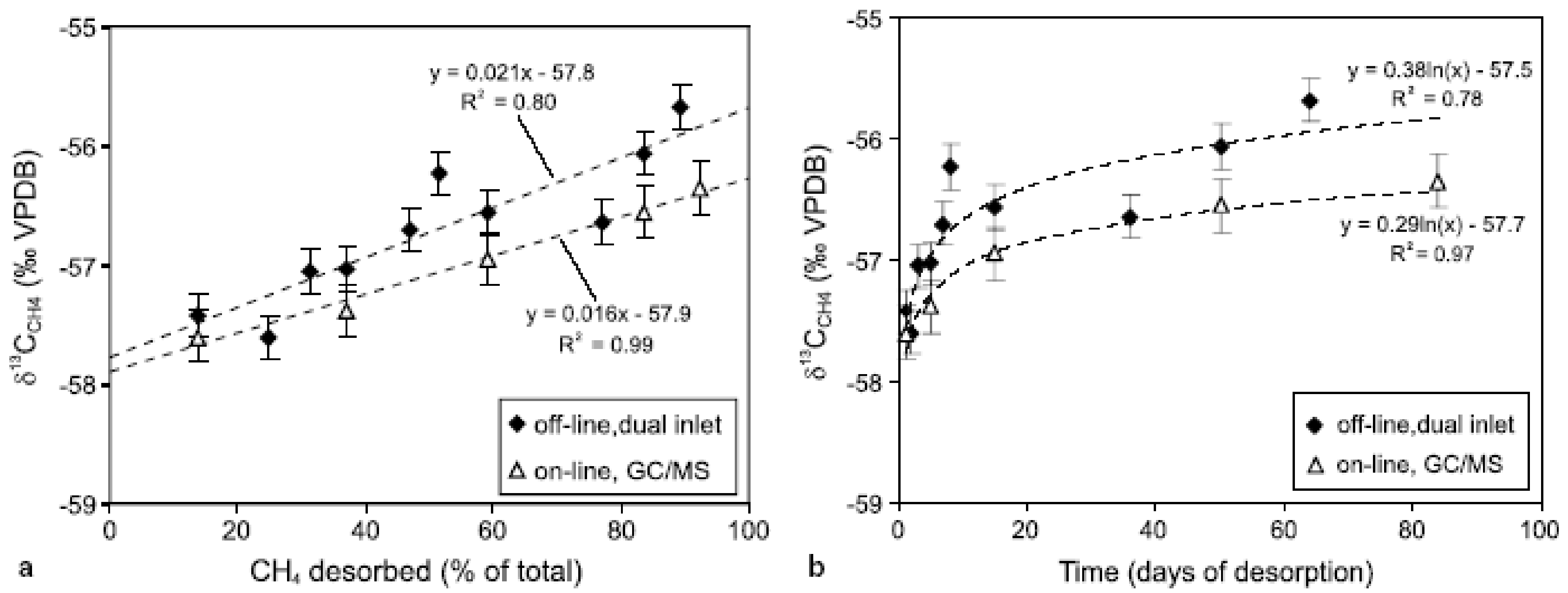
Nuttall, 2007

Production prediction

- Shale production data is messy
- Decline projection is an art
- Need a long period of data
  - First 6 months is an adequate indicator

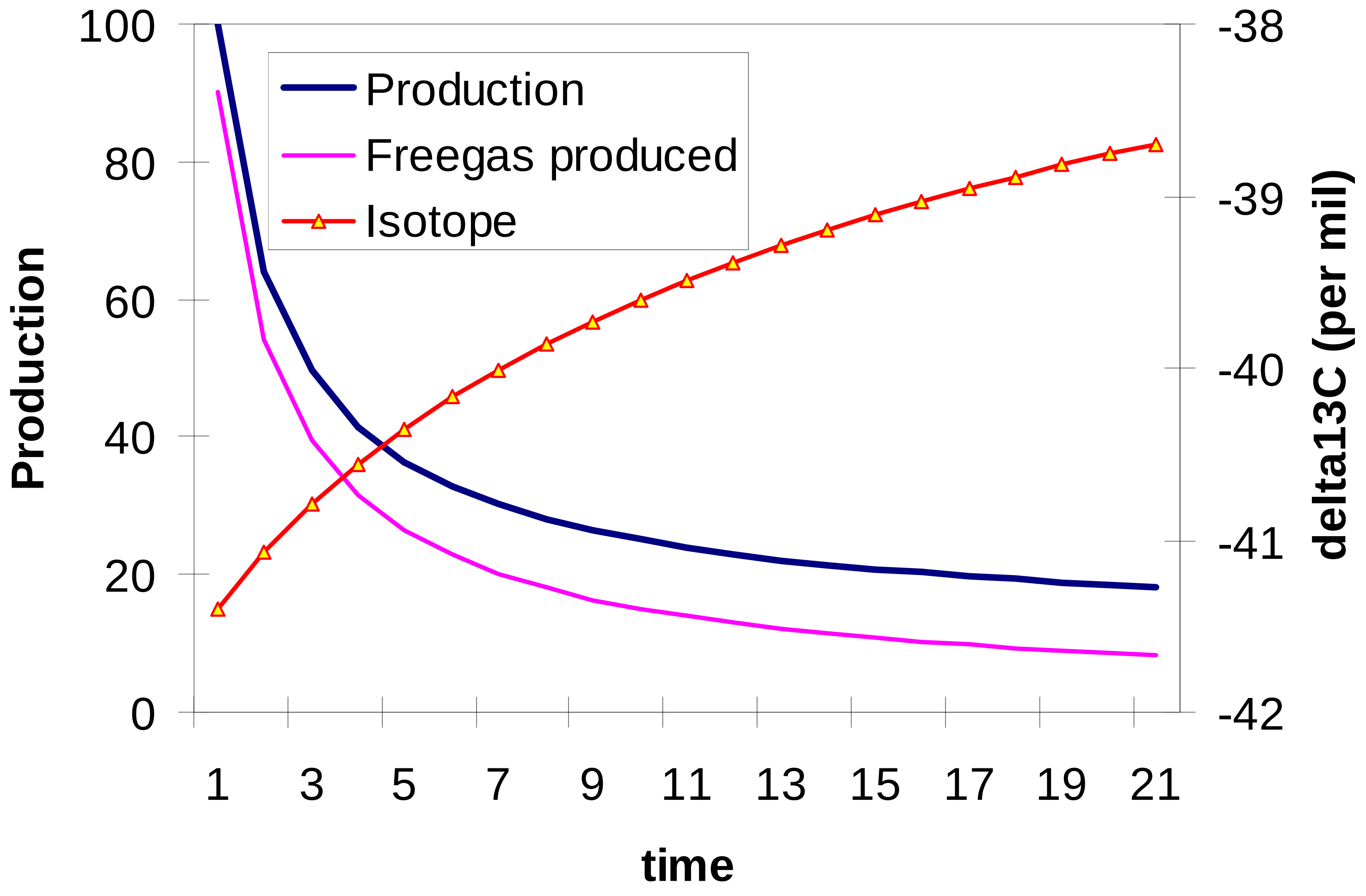
Predict from Isotope change?

Isotope change during coal de-gassing



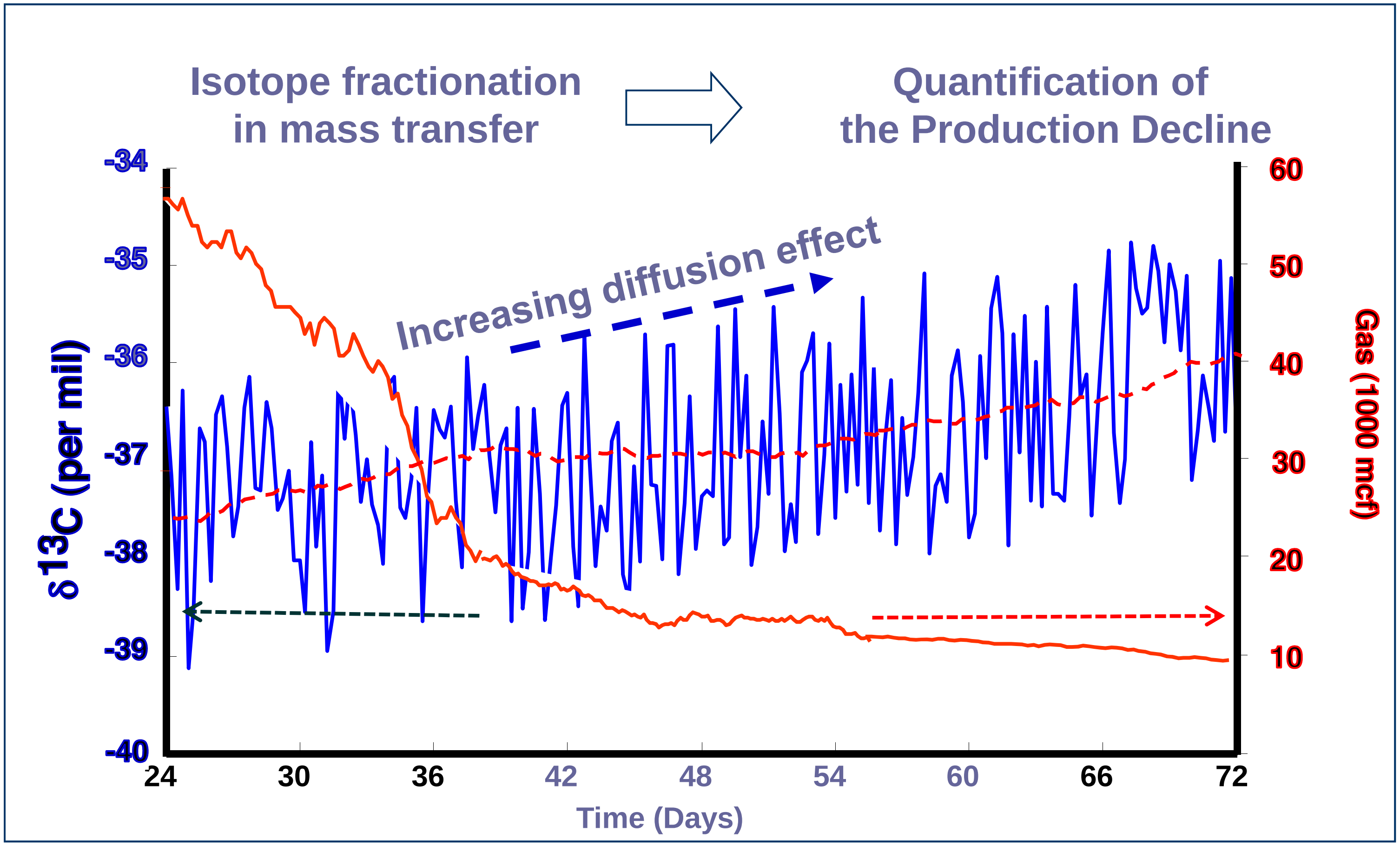
Strapoc et al., 2006

Using Real Time Gas Isotope to Model Gas Production Decline Curve

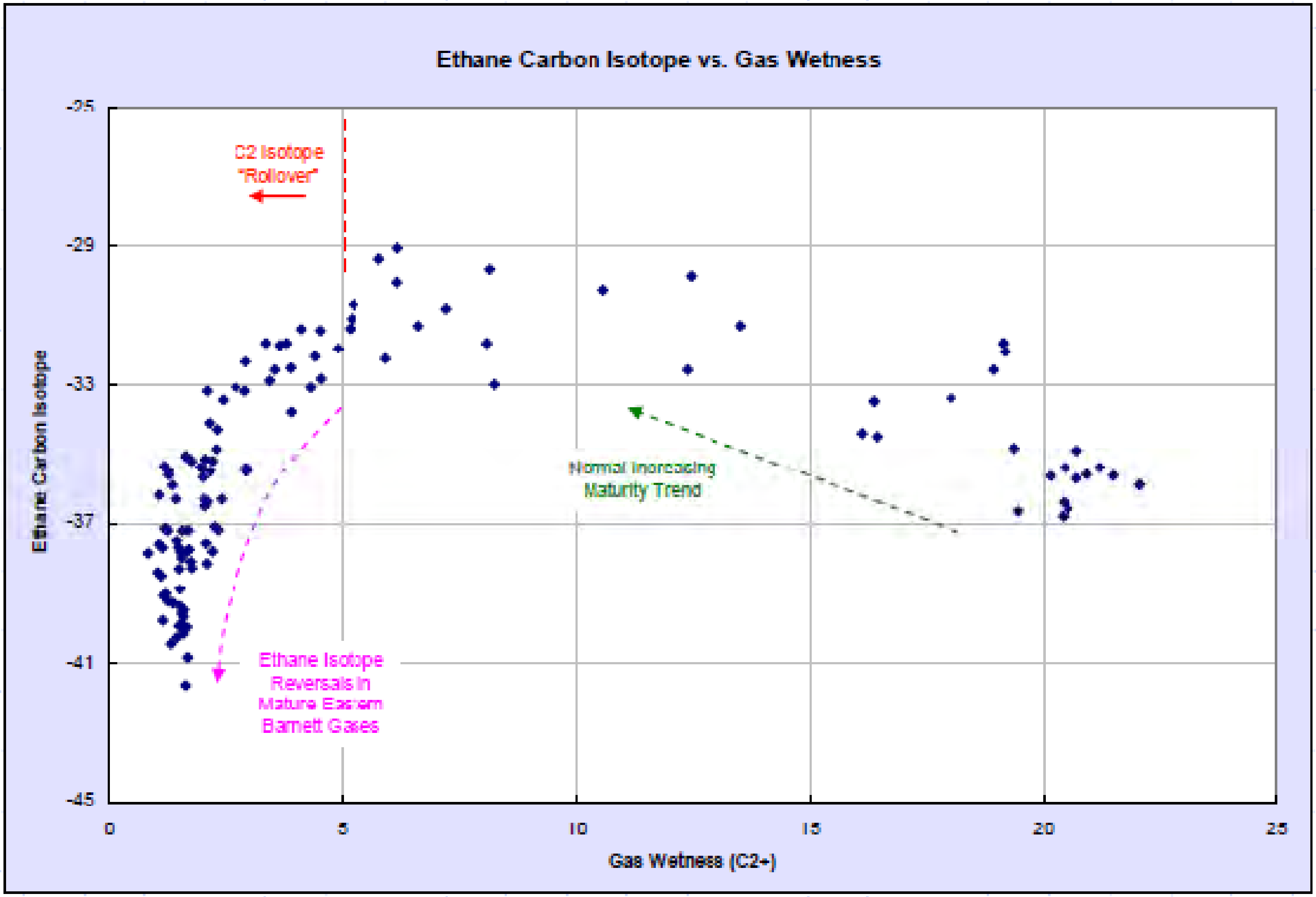


Why we need field deployed measurement?
Importance of high frequency measurement

- Large fluctuations in samples' δ13C values ---- 2 per mil
- Correct trend is established through long term high frequency measurement

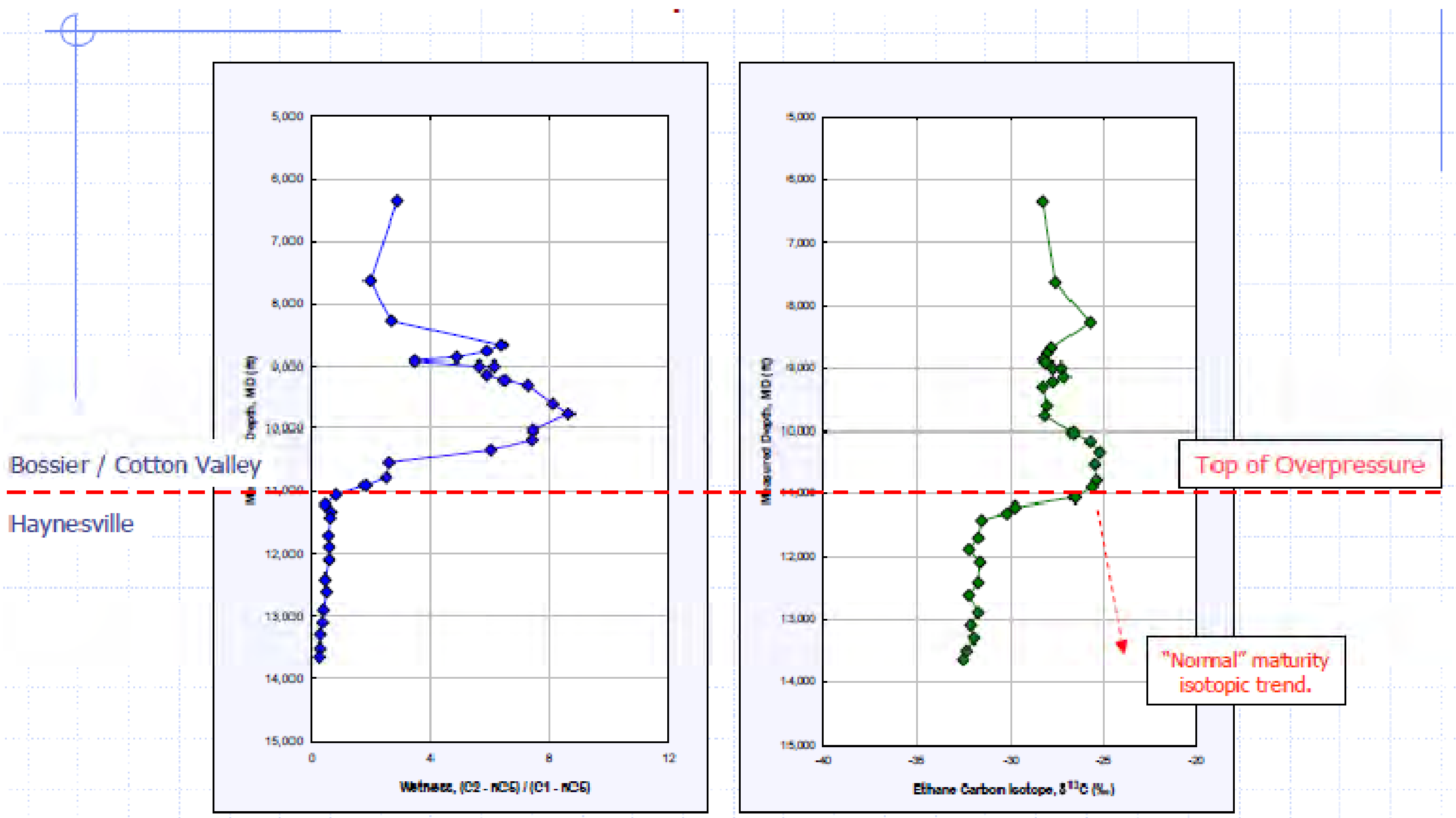


Gas Isotope: directly reflecting generation



Geomark 2008

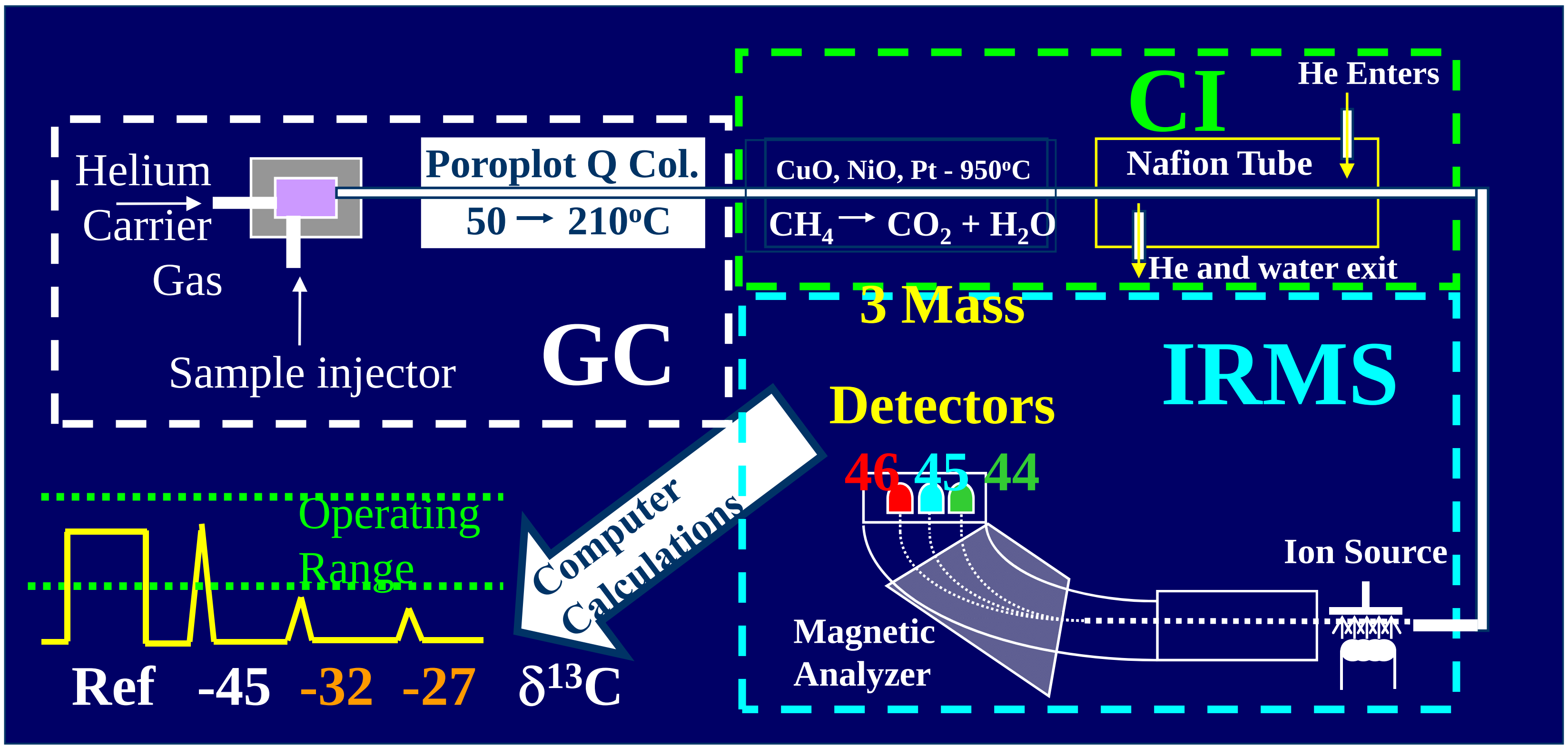
Gas Isotope: related to sealing condition



Geomark 2008

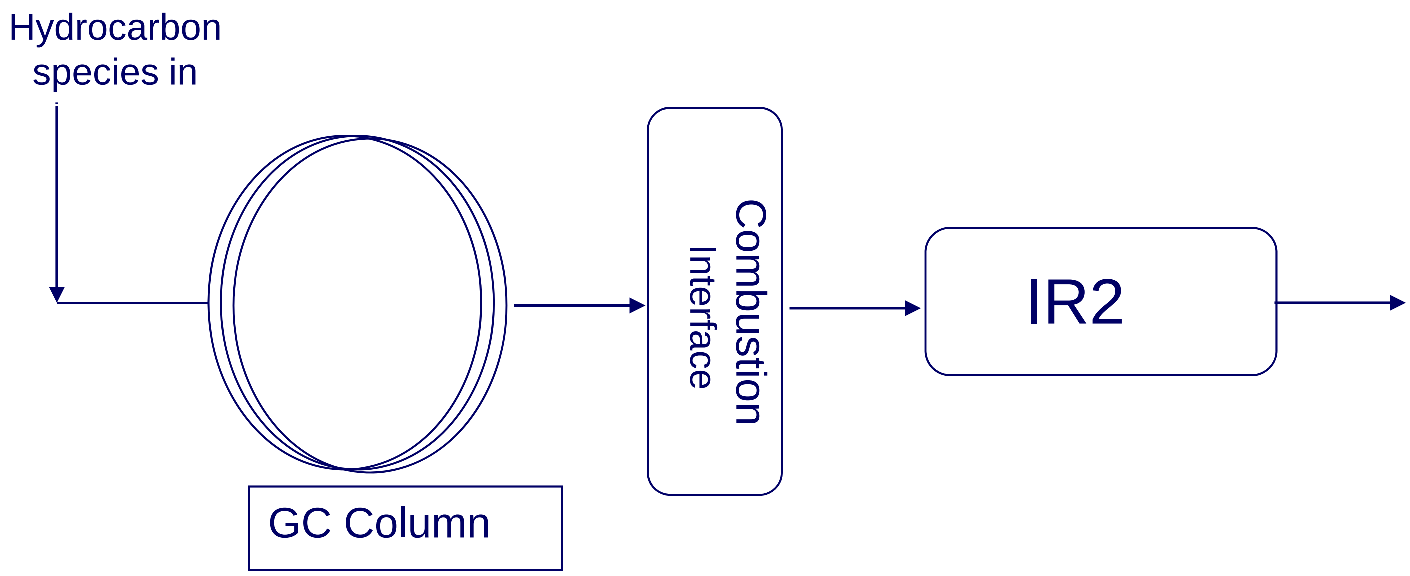
Disadvantages of Current GC-IRMS

- Expensive
- High Vacuum
- Not field deployable
- High maintenance cost
- Constant tuning/Refernce Gas consumption



Isotope Analyzer Solution from New Technology

GC + InfraRed Isotope Ratio Analyzer (GC-IR2)



How we implement it?

- PEER Institute design and fabricate sample preparation and preconcentration unit
- Then interface with the Super Isotope machine (Methane $\delta^{13}C/^{12}C$ & $\delta D/H$, and CO_2 $\delta^{13}C/^{12}C$)
- Then interface preconcentration unit with the GC-IR2 machine from GeoIsoChem (C1, C2, C3's $\delta^{13}C/^{12}C$) --- not needed for shale gas production, but good for other natural gas production

Expect field trial start – June to July!!

Integrated Gas Isotope Model for Gas Shale Production

- Through integration of the gas isotope models for both gas shale generation and gas desorption, a new gas isotope model combining these two isotope fractionation processes will be derived from laboratory's simulation.
- The model also can be calibrated by the field measurement of gas isotope curves during gas shale production.

Improved a previous model of gas isotope fractionation

- … but a non-linear model coupling diffusion /advection and adsorption/desorption

$$\varphi \frac{\partial c}{\partial t} = -\frac{1}{r^m}\frac{\partial}{\partial r}\left(r^m D \frac{\partial c}{\partial r}\right) - (1-\varphi)\, n_A \frac{\partial \theta}{\partial t}$$

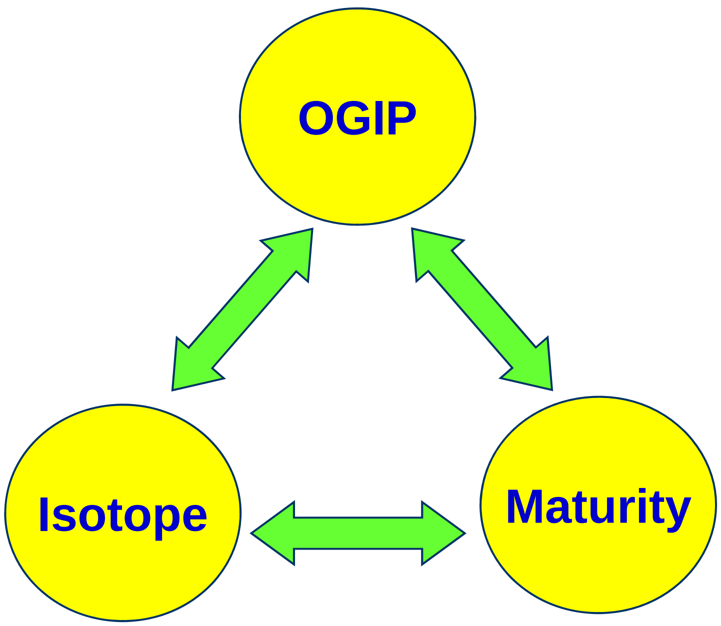
Diffusion and Advection

Adsorption /desorption

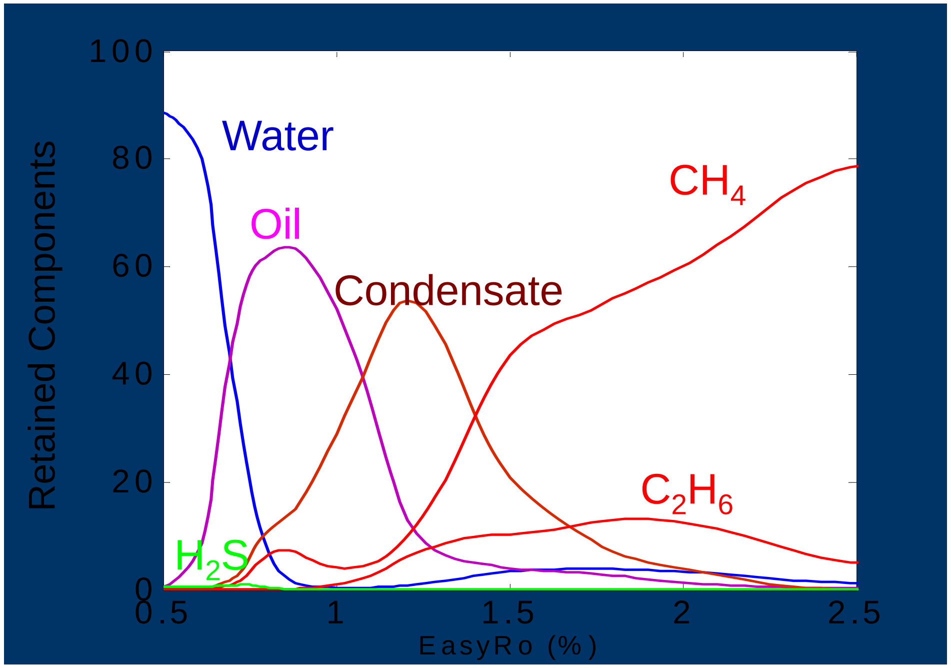
- Diffusion is the reason for isotope fractionation

A Full Paper Submitted to GCA, 2011

Algorithm ready for OGIP prediction



Retained fluid in shale



Conclusions

- Significant progress developed based on carbon and hydrogen isotope to quantify the remaining gas potential (OGIP) and predict "sweet spot" for shale gas production
- Developed a super machine where we can measure both C and H isotope in real time for methane gas
- Isotope ratio of retained gas in shale reflects
  - Generation (maturity)
  - Trapping efficiency
- Variation of isotope ratio during production reflects
  - Production stage
  - Reservoir permeability

Acknowledgement