Advanced Isotope Geochemistry to Increase Production from Horizontal Wells and Reservoirs*

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Abstract

The efficient and wide use of the isotope analysis has been extensively documented in the reservoir assessment and "sweet spot" identification. However, for a long while isotope analysis could only be performed in stationary laboratory via sophisticated instruments and significant turning-around time. Until very recently the isotope analysis could be done in the field, but only with methane isotope ratios. In this work, we present the novel real-time isotope logging technique for methane, ethane and propane (C1, C2 and C3), and demonstrate how to enhance the "sweet spot" prediction and hydrocarbon production. This new instrument, the Gas Chromatography-InfraRed Isotope Ratio Analyzer (GC-IR2), represents the first of its kind field-deployable isotope ratio analyzer with high accuracy and precision. It is rigorously calibrated with the GC-IRMS (the isotope-ratio mass spectrometry) using standard gas. By field deployment during drilling, we can analyze hydrocarbon gas carbon isotope ratios with only minimal turning-around time. We analyze gases derived from both mud gas and cuttings by using this proprietary design of isothermal grinding. All this new information can be given to producers in a standard log format along with other logging parameters. Our results from field application case studies show that the analytical capacity of this instrument makes it possible for various applications in vertical and horizontal drilling. We demonstrate examples from vertical drilling with pairs of mud-gas and cutting-gas under well-controlled experimental conditions to assess nanoporosity and permeability. We also present the usefulness of this technique to identify hydrocarbon sources for horizontal drilling using isotopes as fingerprinting. We conclude that isotope logging via GC-IR2 provides valuable and quantitative evaluation of the reservoir, and in a timely manner add critical information to the mudlogging and geosteering. This new type of well-site geochemistry makes gas isotope ratios readily and timely accessible to producers and can lead to greater returns from a project.

Reference Cited

Xia, Xinyu, and Yongchun Tang, 2012, Isotope fractionation of methane during natural gas flow with coupled diffusion and adsorption/desorption: Geochimica et Cosmochimica Acta, v. 77, p. 489-503.

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Outlines

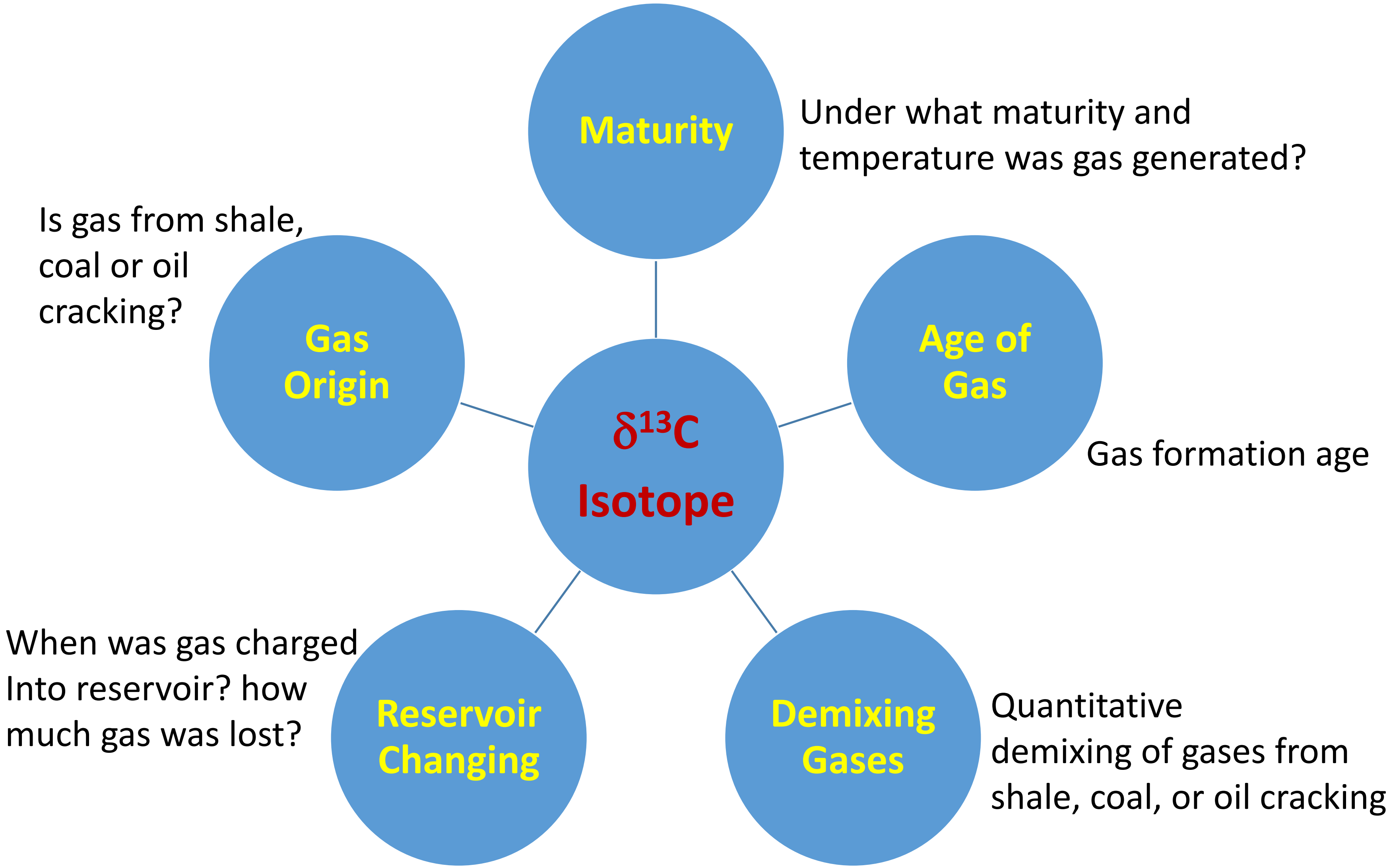
- Recent Advances of Wellside Geochemistry
- Overview of Gas Isotope for Reservoir and Production
- New Applications of Gas Isotopes
- Case Studies

Recent Advances of Wellside Geochemistry

- Geochemical applications on Wellside
  - Real time, shale specific logging while drilling
    - *Permeability, porosity (Gao's Talk on Wed 10 am)*
    - *Connectivity between each formation (between wells)*
    - *Identifying high production wells (isotopes provide key information)*
    - *Determining condensates and producible oil amount*
    - *Gas to oil ratios*
    - *Kerogen maturity (laser nanoparticle light scattering)*
  - Prediction of Condensate Production Decline

Presenter's notes: Developing tight oil and gas-bearing formations often require a dense pattern of wells with long lateral sections. To produce such fields economically, producing sections of the wells must be positioned accurately within the targeted intervals, while minimizing drilling cost.

Stable Isotopes in Petroleum Exploration



Stable Isotopes in Reservoir and Production

Movable Gas Isotope Machine

Shale Gas Sweet Spot

High production and low production wells (How much gas was lost).

Reservoir Properties

$\delta^{13}C$ Isotope

Perm Porosity

Identify where to drill horizontal wells

Real time gas Isotopes for reservoir compartmentalization

EUR

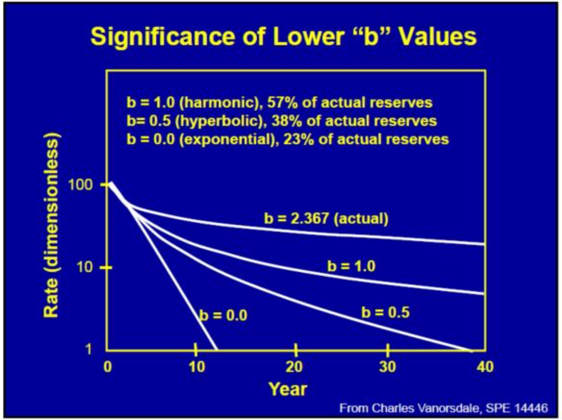
Estimated Ultimate Recovery (EUR) for Gas and condensate

Well Site Gas Isotope Machine Is A Must-Have for Reservoir Applications

Uncertainty for Production Declines

PEERI

Huge Uncertainties to Predict Gas and condensate Production Decline Curves (EUR)



The Arps Equation

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

Presenter's notes: We established our model based on our published work in carbon isotope fractionation during diffusion and desorption (Xia and Tang, 2012). The inputs for our model are carbon isotopes of methane and the production rate record from a production well. The study site was a Barnett shale gas well. The $\delta^{13}C$ values of C1 were measured by our field-deployable gas isotope analyzer (NGIA). The production rates were recorded by our field geologists.

Isotope Fractionation: Diffusion vs. Adsorption

Concen-tration change rate = Flux rate + Reaction rate

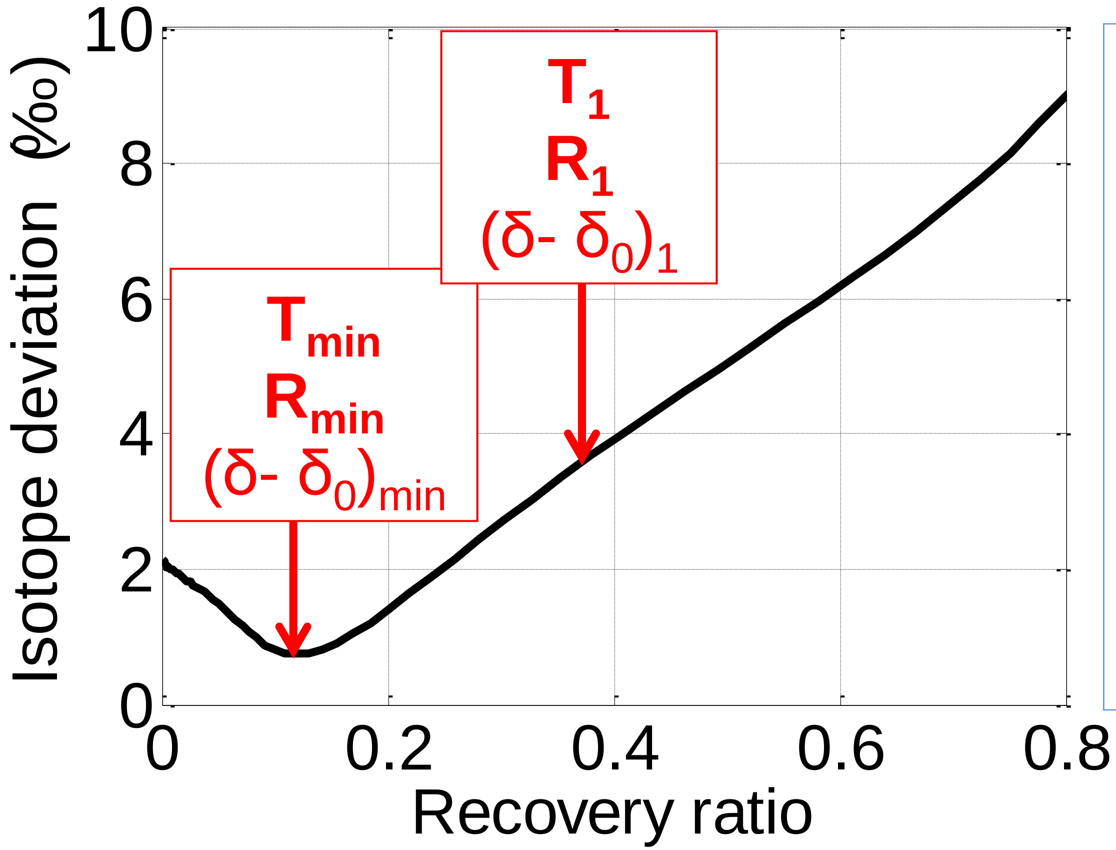
Diffusion | Advection (Darcy flow) | Generation | Adsorption /desorption

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

(Xia and Tang, 2012 GCA)

Change of $\delta^{13}C$ of Methane with Recovery %

Diffusion Controlled Gas Isotope Fractionation Process



Under a certain geological setting, the minimum value of $\delta- \delta_0$ will appear with a fixed recovery ratio (R_{min}).

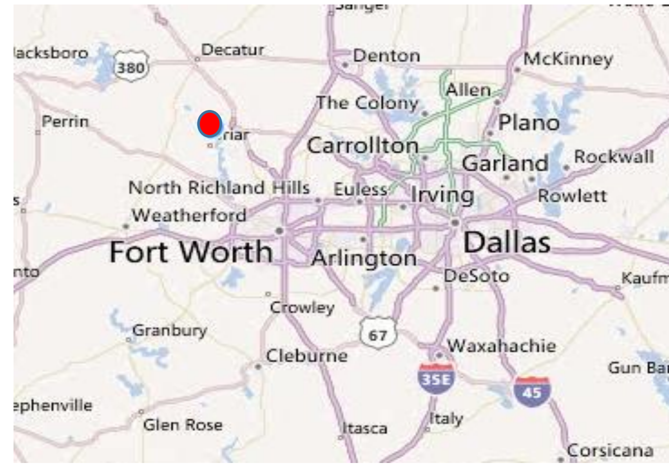
Geological settings: porosity, TOC, Bottom Pressure, etc.

The total reserve equals to the cumulative production by a certain time divided by the recovery ratio at his time.

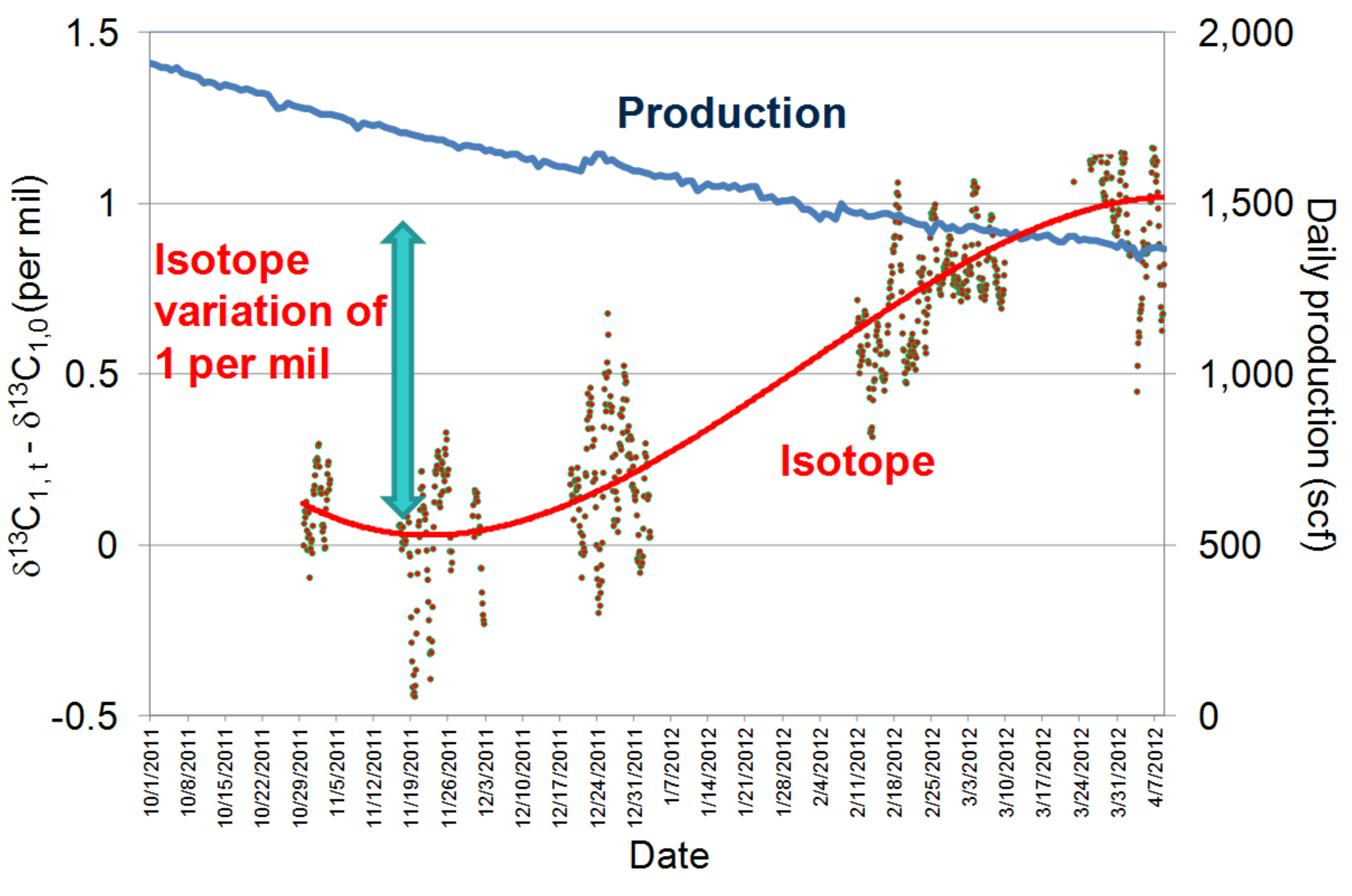
(Gao et al, submitted AAPG Bulletin)

Models and the Field Trial

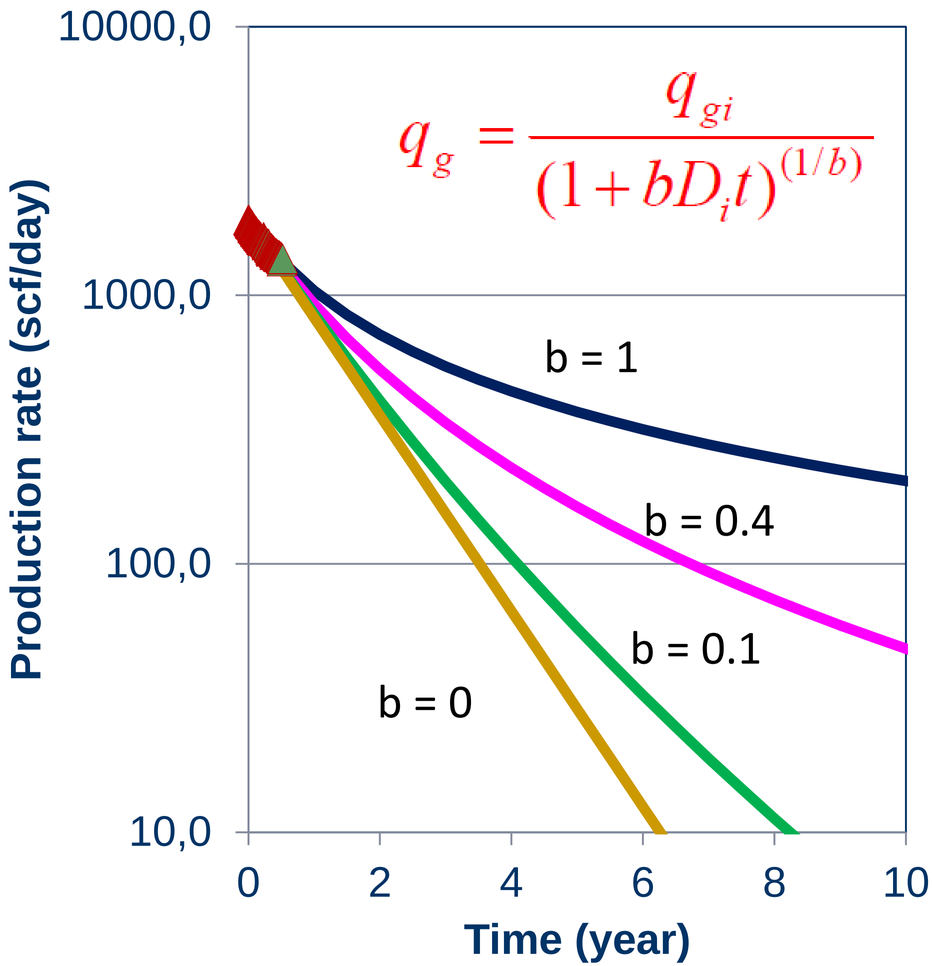
- Field trial started on October 28, 2011
- Barnett Well @Ft. Worth Basin
- Devon Energy



Field-testing result



Determining the decline curve



b	Current recovery ratio	Current isotope fractionation
1	5.9%	Should become more negative
0.4	12%	1.0 per mil
0.1	31%	2.0 per mil
0	34%	2.5 per mil

Driving Force for High Oil Production

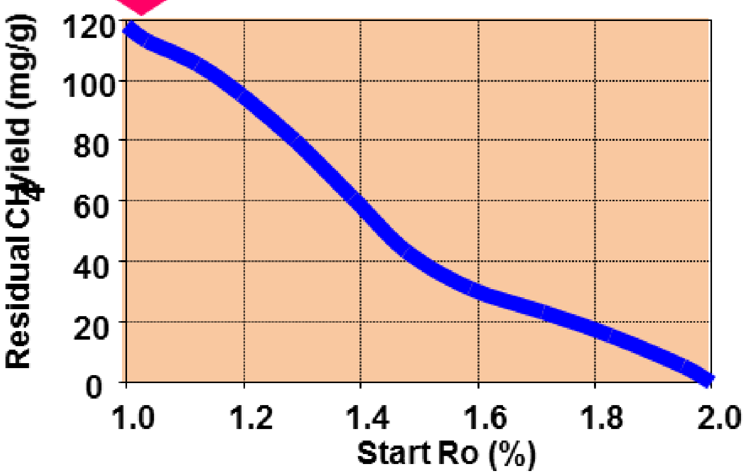
$$\frac{\delta F}{\delta t} = \frac{k * H * \Delta P}{\mu}$$

$\delta F/\delta t$:	Gas Flow Rate
K	Permeability
H	Thickness
ΔP	Reservoir Pressure – Wellbore Pressure (Controlled GOR)
μ	Viscosity of Fluid (controlled by GOR)

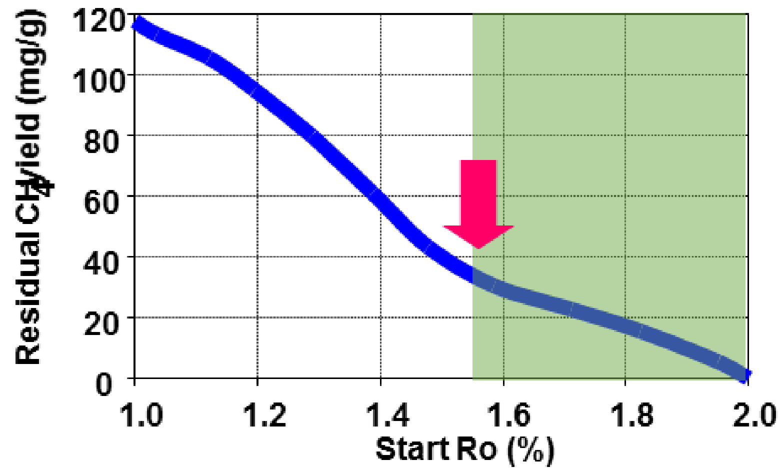
GOR Is A Key toward condensate and oil production

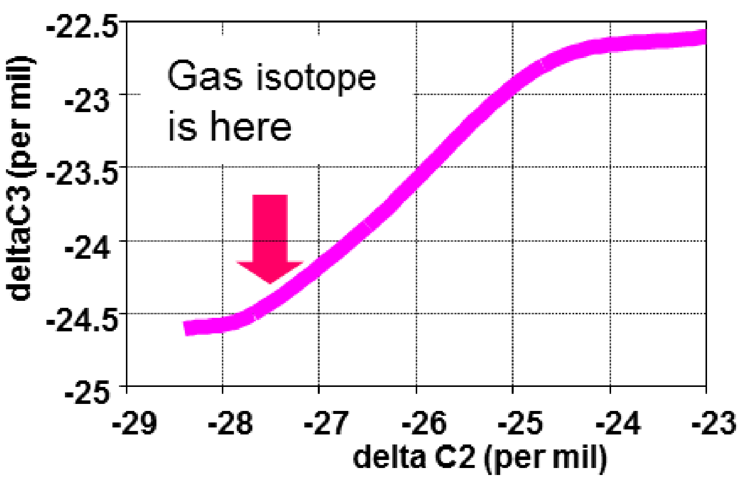
Gas Isotope as Indicator for gas/oil storage history

All gas is accumulated …

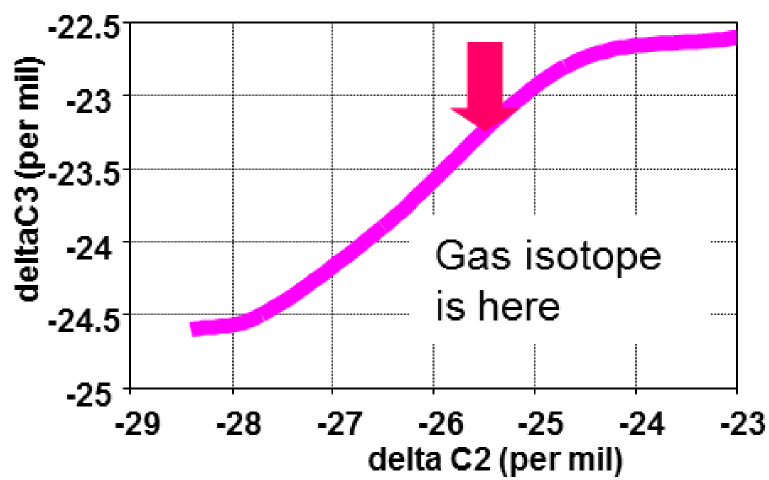


Not all gas is accumulated



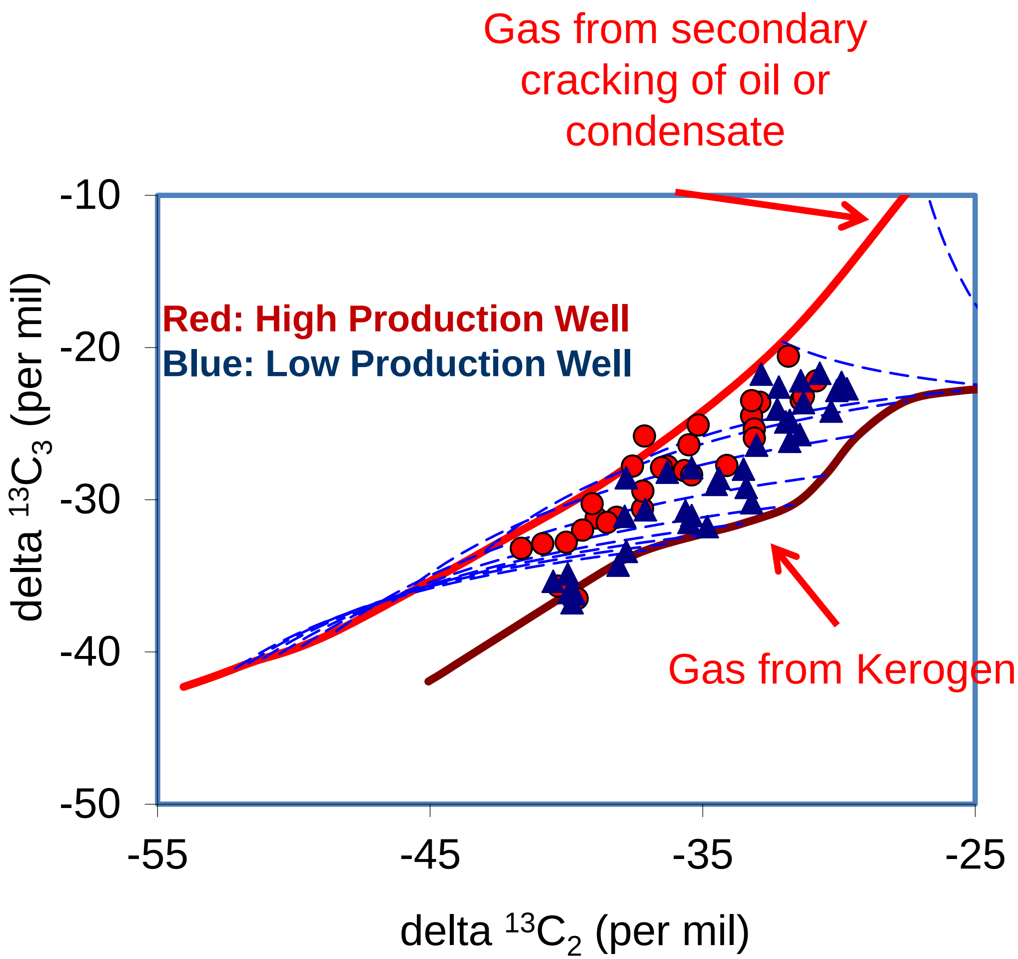


Total Amount of Gas = 120 mg/g(TOC)



Total Amount of Gas = 40 mg/g(TOC)

Sweet Spot Prediction for Shale Gas/Condensate

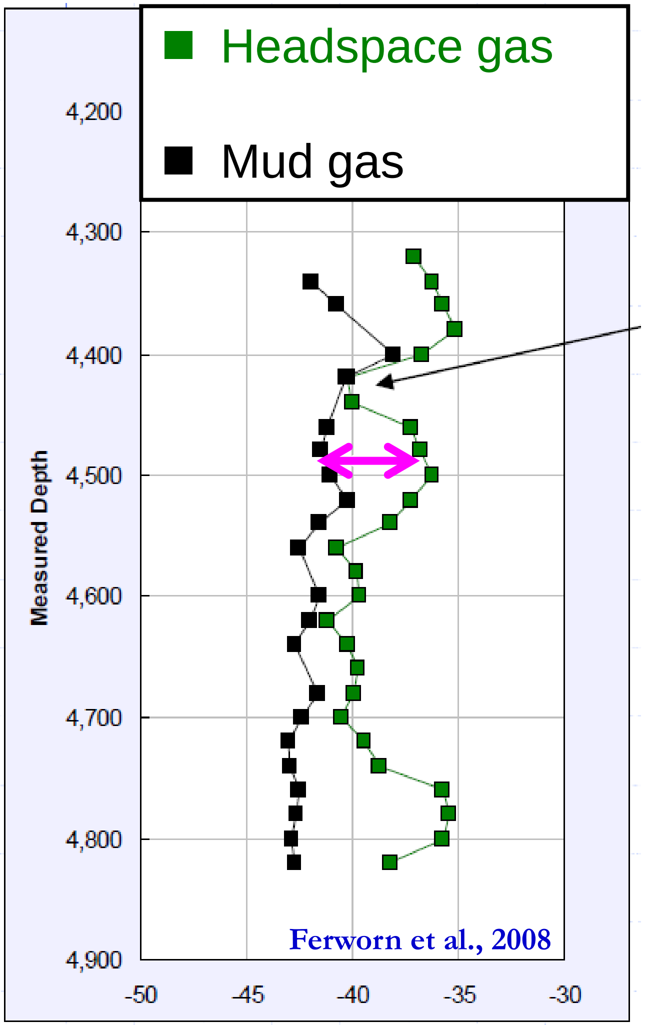


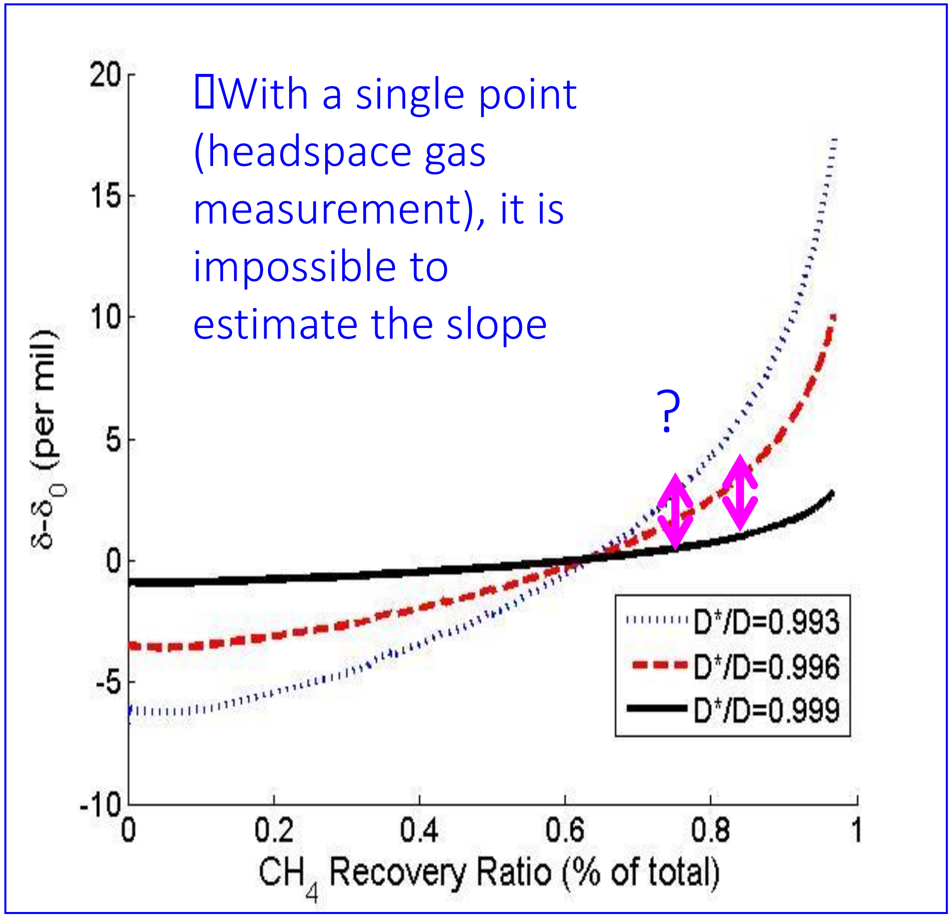
Gas isotopes help differentiate the sources of gases (primary vs. secondary).

Oil-related gas wells are usually of high production rates.

(JIP Report , 2013)

Isotope Diffusion Can Lead to Nano Porosity

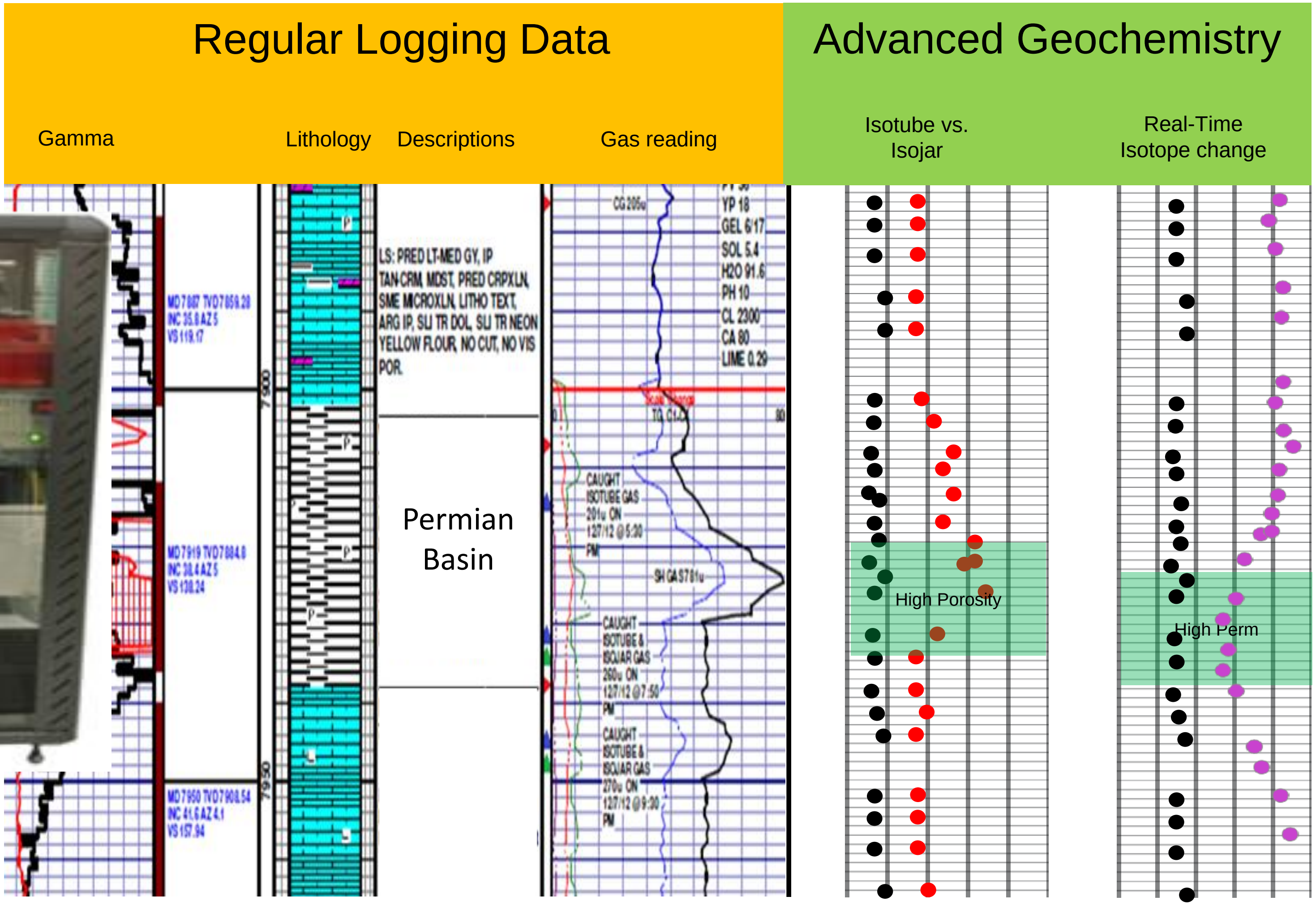




(modified from Xia and Tang, 2012 GCA)

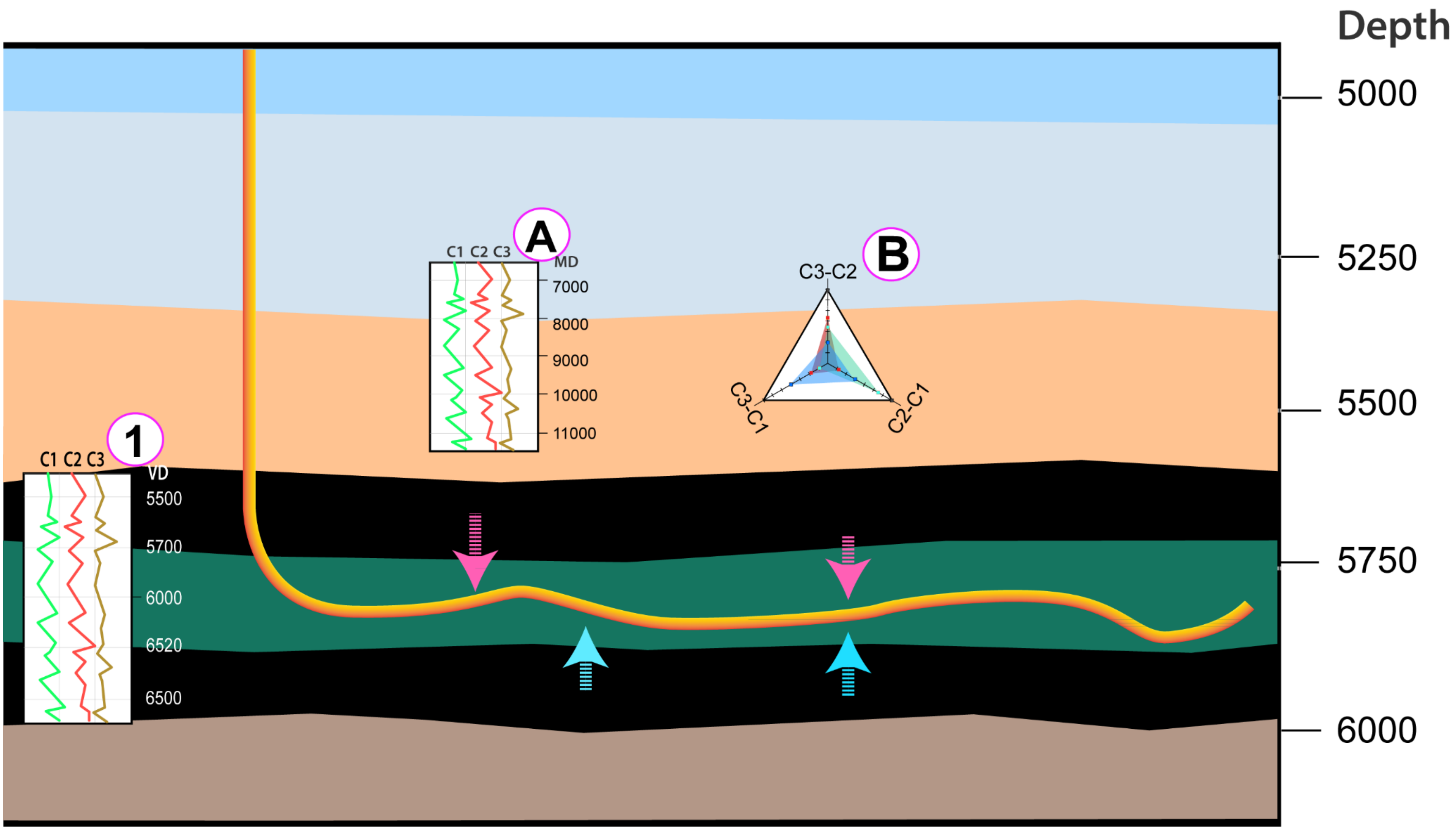
Requires Well Site Gas Isotope to Determine Porosity of Rocks

Using GCIR², Isotope Mud Logging Is Possible



Dr. Gao will present using isotope for permeability on Wed 10 am

Where is the oil/gas from?



New Applications of Gas Isotope

(1) Quantify gas production decline curves

(2) Real time gas isotope for on-site mud logging

- Reservoir compartmentalization
- Sweet spot prediction
- Gas isotope for horizontal wells

(3) Using isotope to measure rock porosity/permeability

Acknowledgement for Our JIP Members

devon

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Shell

bhpbilliton

MARATHON

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Saudi Aramco

Statoil

noble energy

TALISMAN ENERGY

TOTAL