PS Predicting Shale Gas Content and Productivity Based on Isotope Fractionation*

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Abstract

Carbon and hydrogen isotopic composition belongs to the most important information to determine natural gas reservoir properties; however, the conventional interpretation methods on gas isotopes may not work well for shale gas due to the special isotope fractionation of gas in the micropore systems in the organic-rich shale. Based on the field observation, experimental simulation and theoretical modeling, we developed a systematic approach to evaluate shale gas content and productivity based on gas isotope properties.

Our interdisciplinary research revealed that the isotope "rollover", which describes the reversal trend of ethane carbon isotopic composition against maturity, may be largely attributed to the mixing of gas generated from the cracking of oil and condensates. We solved the "rollover" curves based on the gas end members derived from our kinetic isotope fractionation and gas expulsion models, and established the method to derive the contribution of oil-cracking gas. This deconvolution based on isotopes helps to improve the reliability in the estimation of gas content, oil/gas ratio, gas wetness and condensate amount in shale.

We evaluated gas isotope fractionation during production based on a continuum flow model with coupled adsorption/desorption and diffusion, to describe the isotope fractionation due to gas flow through low permeability organic-rich shale rocks. With this method, we can derive reliable information for shale plays during production:

1. Determine the shale preservation condition based on the methane isotopic composition profile.

2. Determine the reservoir properties with well-controlled isotope measurement of cuttings under laboratorial conditions.

3. Predict gas productivity based on the variation of methane isotopic composition.

4. Diagnose engineering problems based on the variation of methane isotopic composition.

These approaches may remarkably increase the beneficiary of gas isotope applications.

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Introduction

- Productivity of shale plays determined by
  - Original gas/oil in place
  - Reservoir permeability
  - Fluid composition
  - Frackability
- Uncertainty reflected by the low sensitivity of whole production decline curve on initial production
  - Production decline curve described by Arps Equation

$$q_t = \frac{q_0}{(1+bD_i t)^{\frac{1}{b}}}, 0<b<1$$

  - Factor "b" not sensitive to the initial production within the first couple years (Vanorsdale C, SPE 14446)

Our solution

- Quantitative correlating isotope fractionation with permeability and recovery ratio
- Predicting productivity with gas isotope fractionation

Concentration change rate	= Flux rate: Diffusion, Advection (Darcy flow)	+ Reaction: Adsorption /desorption

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

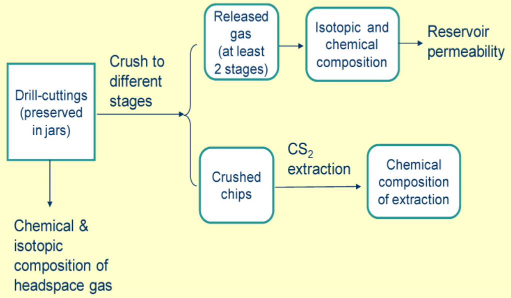
$$\varphi\frac{\partial p^*}{\partial t} = \frac{1}{r^m}\frac{\partial}{\partial r}\left(r^m D^*\frac{\partial p^*}{\partial r}\right) - (1-\varphi)c\frac{\partial \theta^*}{\partial t}$$

Details:Xia and Tang, 2012, Geochimica et Cosmochimica Acta, 77, p. 489-503

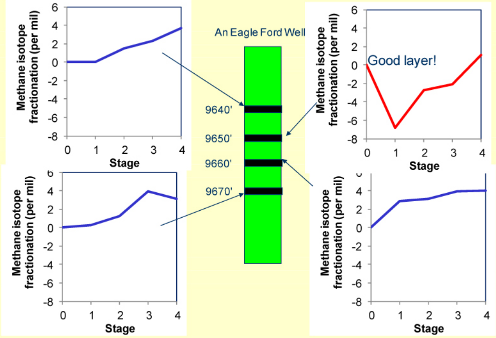
Approach 1: Reservoir characterization

- Correlating isotope fractionation to diffusivity and permeability

  Measuring isotope variation during gas release from cuttings



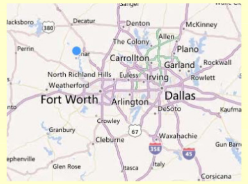
- Distinguish good layer

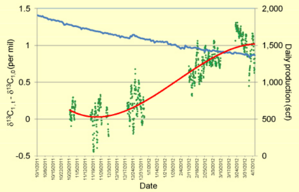


- Advantages
  - Real time gas isotope measurement on well site
  - Informative: more information on gas content, gas wetness and condensates ; Permeability
  - Reliable: overcome the arbitrary error of headspace gas analysis
  - Fast and convenient : several hours vs days (normal nano-permeability measurement) vs months (desorption measurements for gas content)

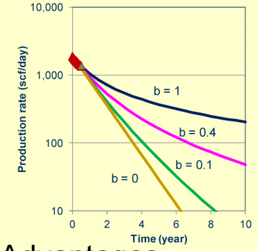
Approach 2: Production monitoring with gas isotope

- Real-time onsite isotope analyzer
  - 15 minute startup + 5 minute averaging
  - Error: $\delta^{13}C$ < +/- 0.5 per mil
    $\delta^{2}H$ < +/- 5 per mil
- Field trial started on October 28, 2011
  - Devon's Well Tin Ft. Worth Basin





- Predicting the production decline:
  Isotope fractionation → recovery ration →"b" value



Current isotope fractionation	Current recovery ratio	b
< 0.5 per mil	< 10%	~1
1.0 per mil	21%	0.4
2.0 per mil	31%	0.1
2.5 per mil	34%	0

- Advantages
  - Real-time; prediction at very early production stage
  - Variation of isotope ratio during production reflects production stage and reservoir permeability
  - Extremely useful toward shale gas exploration and production