[PS]Improving Hydrocarbon Resource and Fluid Property Prediction with a Coupled Generation/Expulsion Model*

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Abstract

The recent extensive exploration in gas shales provides unprecedented opportunities to understand the hydrocarbon retained in source rock. In a newly developed modeling method, we coupled both generation and expulsion processes for hydrocarbon in source rock. The generation processes, including both primary-cracking (generation of hydrocarbons from kerogen) and secondary-cracking (generation of light hydrocarbons from heavy ones), are well described by a group of parallel first-order reactions with kinetic parameters calibrated by gold-tube pyrolysis. The extent of expulsion processes is based on the evaluation of maximum amount of water, oil, free gas and adsorbed gas in the pore system and on the matrix surfaces of source rock.

The results revealed following interesting phenomena, which has not been paid enough attention in previous work on hydrocarbon resource evaluation:
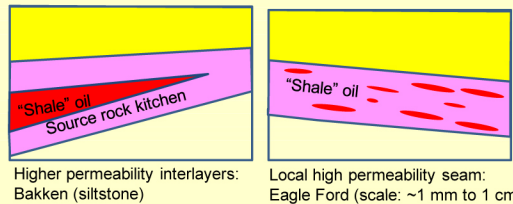
1. There is remarkable oil and condensates retained in source rocks even at high maturity of Ro > 1.5%, which contribute to the formation of shale gas at high maturity.

2. Retained and expelled gas content is not only a function of organic matter properties, but also remarkably influenced by burial history and paleopressure profiles.

3. There is obvious compositional fractionation between retained and expelled hydrocarbon; this fractionation need to take into account for fluid property prediction of both conventional reservoirs and shale gas.

Our quantitative method illustrated that the estimation on oil/gas amount, composition and fluid property can be largely improved considering the residue hydrocarbon components retained in source rock. This is important to for both shale gas and conventional oil/gas appraisal.

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Problems in resource estimation of shale plays

- ❑ Amount of hydrocarbon generated /expelled/retained
- ❑ Composition of expelled /retained hydrocarbon
  - ➢ Gas to oil ratio
  - ➢ Gas wetness
  - ➢ Condensates
  - ➢ Oil composition

Expulsion depending on heterogeneity scale

"Shale" oil
Source rock kitchen

"Shale" oil

Higher permeability interlayers: Bakken (siltstone)

Local high permeability seam: Eagle Ford (scale: ~1 mm to 1 cm)

Model

Retained = Generated – Cracked – Expelled

Kinetic description

Expulsion due to
- o Exceeding threshold
- o Dissipation

- ❑ Quantifying the threshold
  - ➢ Formation of nanopore in kerogen due to gas generation
  - ➢ Hydrophobic surfaces of kerogen and pyrobitument
  - ➢ Free gas: Peng-Robinson Equation
  - ➢ Adsorbed gas: competitive Langmuir Model

Kinetic network

- ❑ Kinetics of group composition (Saturates, Aromatics, Resin and Asphaltnene) applied
  - ➢ Advantages:
    - o More reliable for compositional fractionation during expulsion
   - o Applicable for fluid property prediction
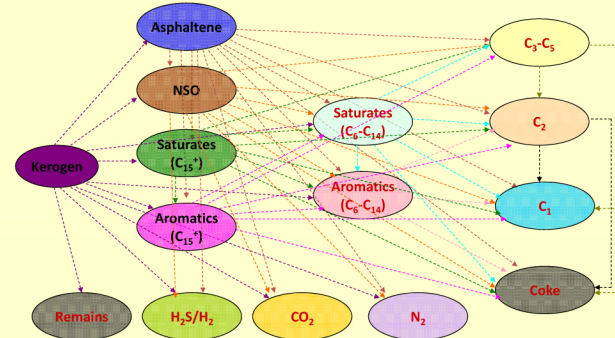
- ❑ Kinetic model optimization
  - ➢ Calibration with high-pressure isobaric gold-tube pyrolysis results (Tang et al., 1996)
  - ➢ Pyrolysis on both immature and post-mature samples to calibrate both primary and secondary generation
  - ➢ Gas isotope kinetics and fractionations calibrated simultaneously
  - ➢ Optimization software: GeoIsoChem Kinetics05[TM], Isotopes[TM], OptimRx[TM]

Uncertainties of residual hydrocarbon potential

The parameter sensitivity test and investigation on typical shale oil/gas systems (Barnett, Eagle Ford, Woodford, Marcellus, New Albany, Posidonia etc.) reveal a large variation of residual hydrocarbon potential at high maturity, depending on:

- ➢ TOC, organic type, maturity
- ➢ Burial history (paleopressure)
- ➢ Oil expulsion efficiency (amount of pyrobitumen as gas precursor)

Equivalent to 200 scf/ton rock for TOC = 4%
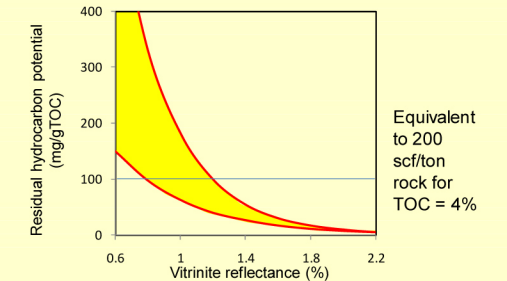
Case study: Eagle Ford shale at Skelly well
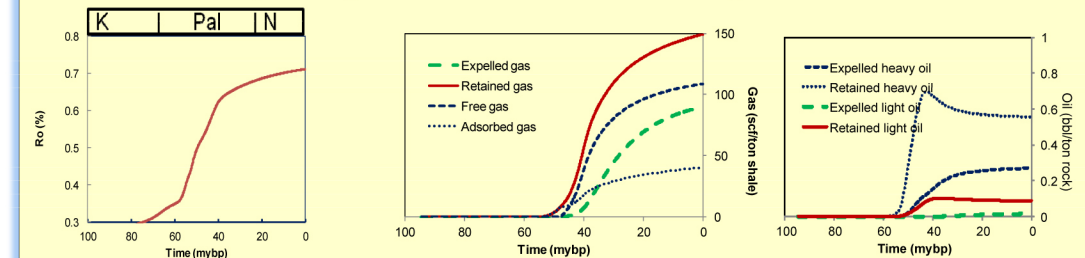
Conclusions

Using the well-established basin modeling tool coupling generation/expulsion, one can quantitative predict:
(1) Amount of hydrocarbon retained in and expelled from shale source rocks
(2) Composition and fluid properties of retained and expelled hydrocarbon