ePS A Petrophysical Model to Estimate Free Gas in Organic Shales*

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Abstract

A method is presented whereby conventional open hole logs -density, neutron, Pe, GR, and resistivity - can be used to quantify the volume of free gas in organic shale. The calculations involve determining silt and clay mineral volumes in the shale fraction of the rock. Porosity associated with the clay minerals is subtracted from total porosity, and the difference remaining is silt porosity. Silt porosity is added to any, usually very small, amounts of clean formation porosity which might exist when shale volume is less than 100%. This summed porosity is then combined with water saturation to determine free gas volumes. A summation of free gas-filled shale porosity can then be compared with cumulative adsorbed gas volume to yield a comprehensive petrophysical analysis.

Gas in shale reservoirs is composed of two distinct types. Adsorbed gas is attached to the rock surface, and is gradually released to the wellbore as pressure is released. Free gas is located in the (small) volume of shale porosity, and behaves in the same way as in conventional reservoirs when pressure is reduced. Both types of gas will produce over time, but at different rates. Therefore, it is desirable to distinguish between adsorbed and free gas if possible. Most prior work in the petrophysical field has been directed towards quantification of total organic carbon (TOC), from which gas content and adsorbed gas volume is available. Often, it is assumed that the volume of free gas is about the same as adsorbed gas. Any free gas in an organic shale is located within small to very small volumes of porosity in the silt fraction. Typical values are in the 2% to 6% range, and rarely exceed 10%. The method presented here is based on a component analysis of the rock. The clean and silt fraction is typically quartz, calcite, and dolomite, and other components such as plagioclase. Shale components are clay minerals - typically illite, smectite, kaolin, etc. - and silt. If XRD data are available, the components can be defined. If not, reasonable estimates can be made from porosity cross plots. Using the porosity of individual clay minerals, total clay porosity can be calculated, subtracted from total shale porosity, to yield silt porosity. Hydrocarbon

saturation is determined by comparing shale apparent water resistivity with the value of apparent water resistivity in a shale interpreted to be low in TOC.

Reference

Passey, Q.R., S. Creaney, J.B. Kulla, F.J. Moretti, and J.D. Stroud, 1990, A Practical Model for Organic Richness from Porosity and Resistivity Logs, AAPG Bulletin, v. 74/12, p. 1777-1794.

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A Petrophysical Model to Estimate Free Gas in Organic Shales

Presented at the

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Introduction

- Conventional reservoirs can be easily analyzed to define porosity accessible to hydrocarbons (often termed effective porosity), and its contained fluids – water, oil, and gas.

- By contrast, petrophysical evaluation of shale gas reservoirs is in its infancy. Procedures applicable to conventional reservoirs cannot be applied, and new approaches need to be developed.

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Introduction

- Shale gas is comprised of two quite different types of gas:

ADSORBED GAS
Gas adsorbed onto the rock surface, and concentrated in the TOC (total organic carbon) fraction of the shale

FREE GAS
Gas located in the small to very small volumes of porosity dispersed within the shale reservoir

Introduction

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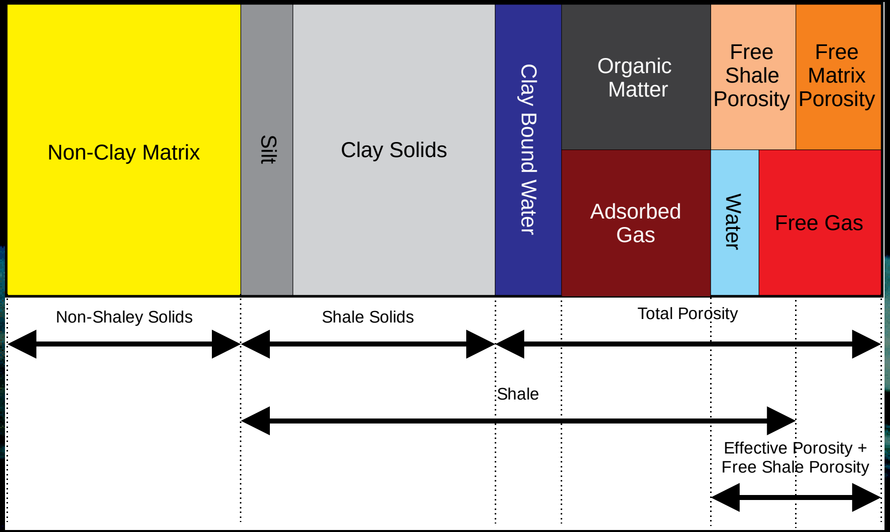
- The challenge we currently face is how to calculate the small volumes of free shale porosity
- The proposed approach is to segment the reservoir into a number of compartments, and then to determine petrophysical properties for each compartment.

Proposed Modified Shale Petrophyscial Model:



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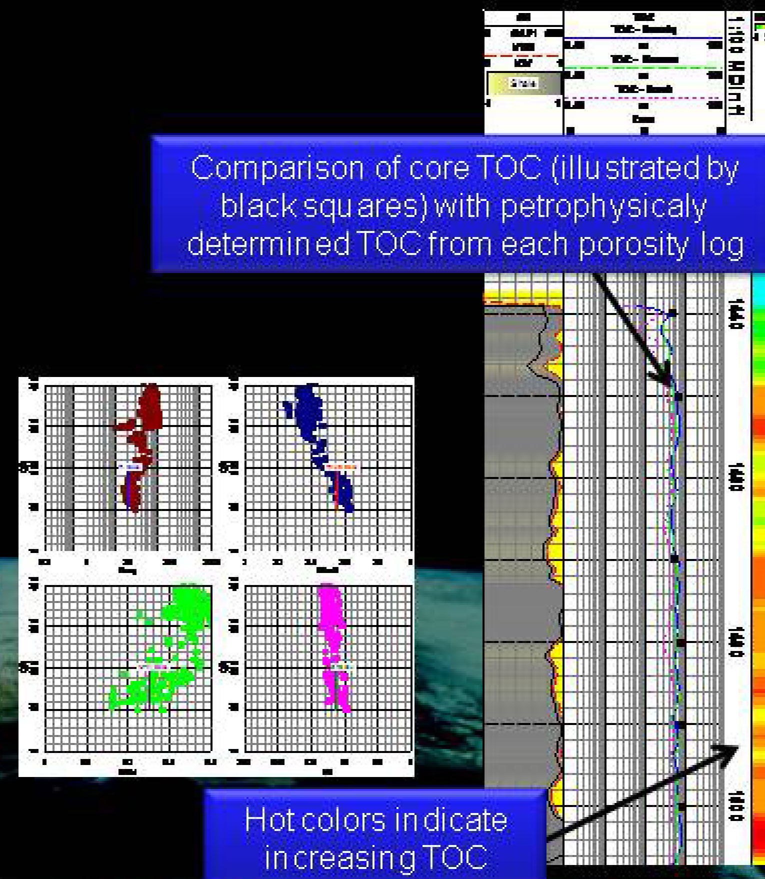
Petrophysical Calculations – Adsorbed Gas

- The first part of the analysis is to calculate the amount of Adsorbed gas-in-place:
    1. The identification of organic rich shale sequences contrasted with organic lean shales using the ΔR technique of Passey et al.
    2. TOC values in weight percent are then calculated
    3. TOC is then converted to volumes of Adsorbed Gas
    4. Adsorbed gas-in-place is then calculated



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Petrophysical Calculations – Free Gas

- The second part of the proposed analysis uses a novel technique, which has been developed over the past few years:

  1. Correct the Density and Neutron logs for gas effects

  2. Using the corrected logs, determine the following component volumes:

     Matrix

     TOC Volume

     Effective Porosity

     Shale Volume

Petrophysical Calculations – Free Gas

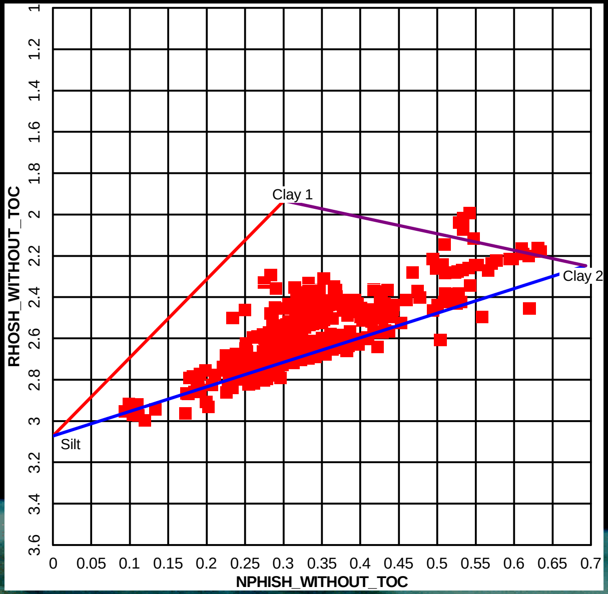
3. From density and neutron responses in shale volume cross plot, determine the volumes of:

Silt

Clay #1

Clay #2

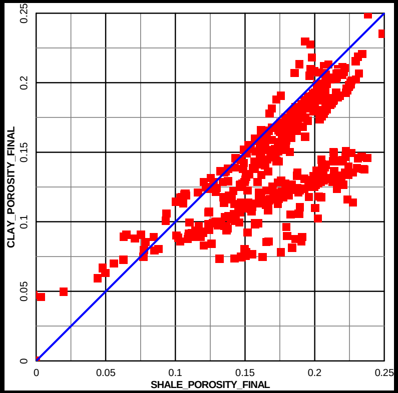
Shale Porosity



4. From input porosity values of Clay #1 and Clay #2, determine Clay Porosity

Petrophysical Calculations – Free Gas

3. The majority of the calculated Shale Porosity should be greater than or equal to Clay Porosity as shown in this example:



4. Now, calculate Free Shale Porosity and Free Available Porosity. Compare calculations with core measurements if they exist, repeat first steps in the case of a mismatch.
5. Calculate Water Saturation
6. Calculate Free Gas Porosity and finally, Free Gas-in-Place

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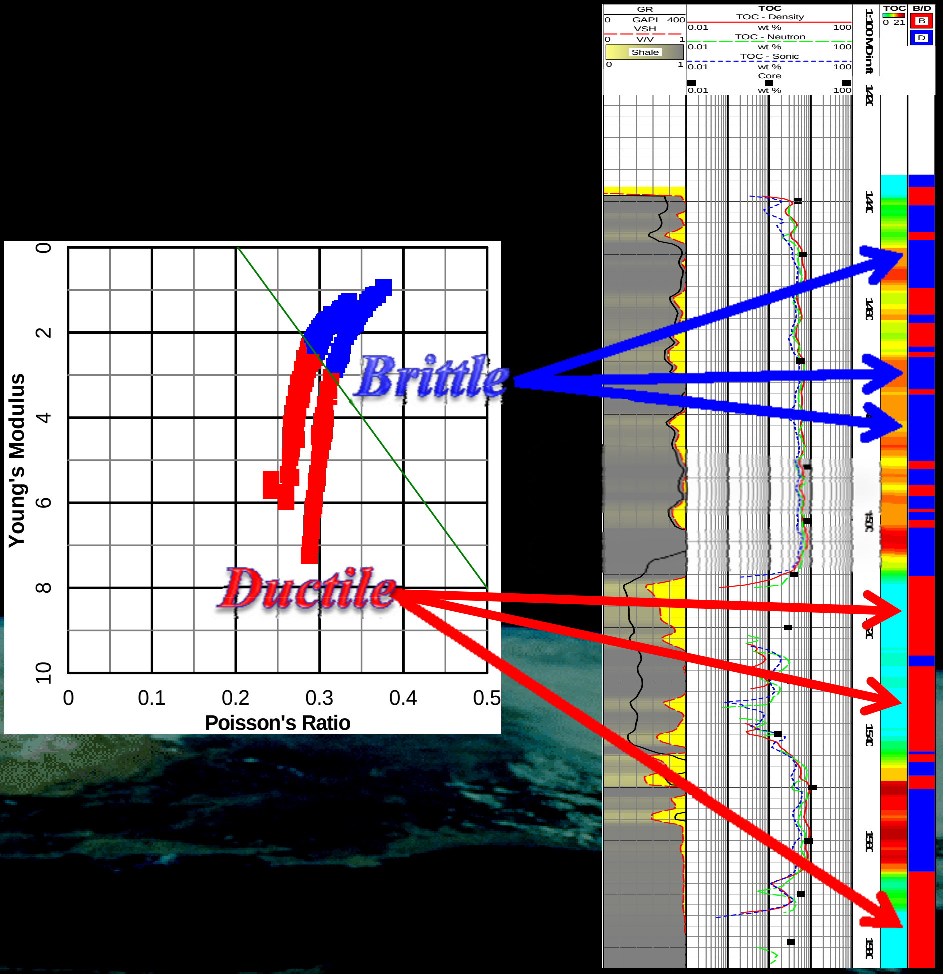
Mechanical Properties

- If acoustic data are available, mechanical properties can be calculated using:

  Young’s Modulus
  Bulk Modulus
  Shear Modulus
  Poison’s Ratio

  – Comparisons of Young’s Modulus and Poisson’s Ratio can be used to distinguish brittle from ductile rock, which is valuable when completion intervals are being chosen



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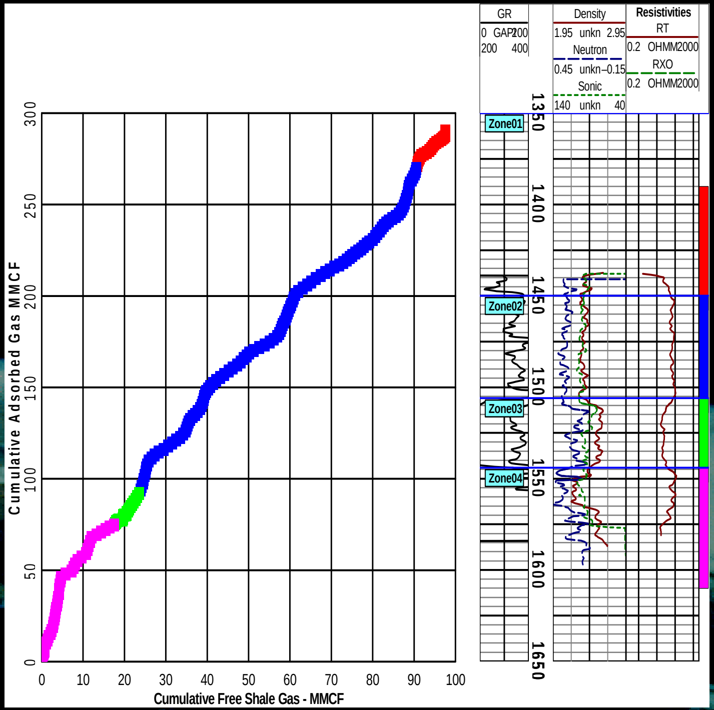
Adsorbed vs. Free Gas

- The distribution of Adsorbed vs. Free Gas can be shown by comparing cumulative values of the two entities.
- Since well productivity is influenced by both types of gas – Free Gas will tend to be produced more quickly than Adsorbed Gas – it is important to understand their relative abundance in the reservoir.

Example from the Antrim Shale, Michigan



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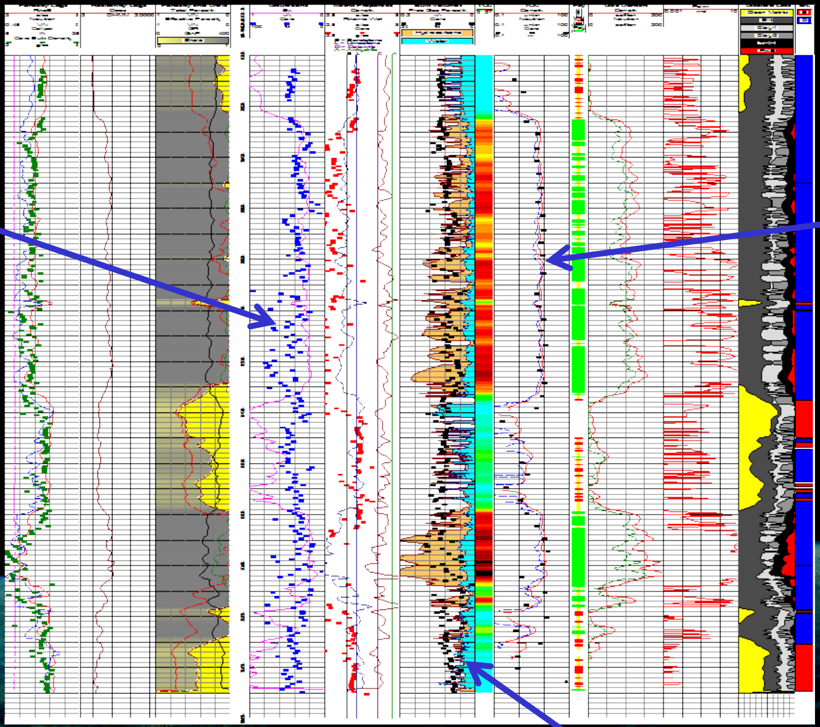
Example

Antrim Shale, Michigan



Core Water Saturation shows fair to good comparison to petrophysics

Core TOC compared with petrophysical TOC is always very good

Core porosity shows fair to good comparison to petrophysics

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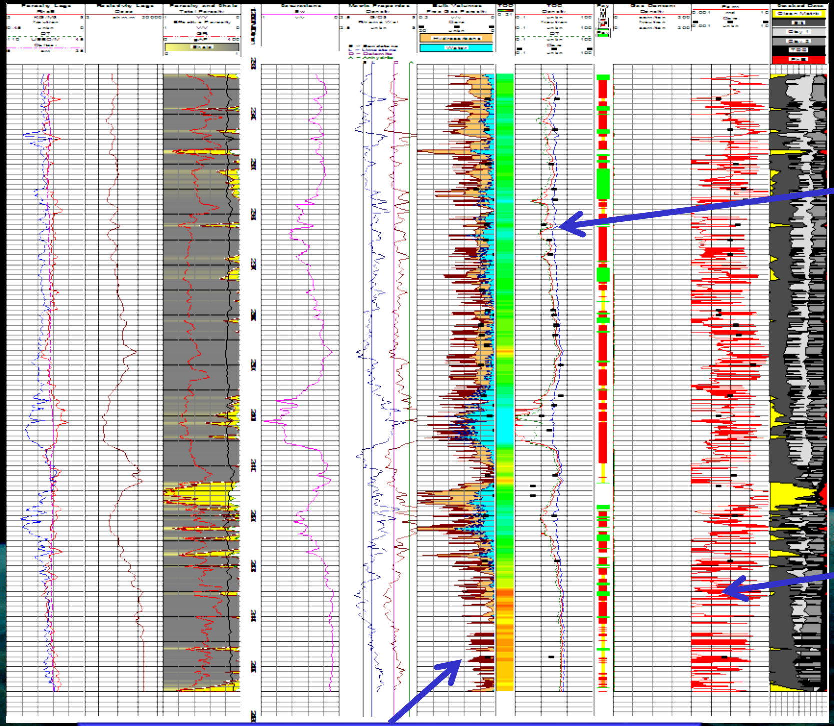
Examples

Devonian Shale, Western Canada



Core TOC compared with petrophysical TOC is always very good

Core permeability data is minimal, but shows fair correlation with petrophyscs

Core porosity shows fair to good comparison to petrophysics

Conclusions

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Advantages of the Petrophysical Model

- The methodology requires a standard suite of open hole logs:

  Density, Neutron, GR, and Resistivity

  Acoustic and Pe – desirable but not essential

- Adsorbed Gas volumes are available from the straight forward technique of Passey et al

- Free Shale Gas Porosity – i.e. porosity available to contain Free Gas – is determined by logical distinction of reservoir components built into the system and checks for impossible results due to unrealistic input

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Conclusions

- If core data are available, additional fine-tuning of procedures is possible. However, the system does not require core data to run.

- Comparison of free gas volumes with adsorbed gas volumes will help in deciding which intervals to complete

- If acoustic data are available or can be estimated from Rock Physics modeling, mechanical properties comparisons can be used to distinguish ductile from brittle rocks. This data is again helpful in deciding when to complete.

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