PS What Are Unconventional Resources? A Simple Definition Using Viscosity and Permeability*

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Search and Discovery Article #80217 (2012)
Posted May 29, 2012

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

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Abstract

There is no formal definition of “unconventional resources” despite the fact that unconventional resources are the most active petroleum play in North America. Meckel and Thomasson, 2008, defined unconventional resources using purely a permeability threshold (< 0.1 md). Yet, coal bed methane plays are considered unconventional and many have permeabilities exceeding 1 md over large portions of the fairway (ex: San Juan Basin, Powder River Basin). Other workers have defined unconventional resources based on an interpretation of the petroleum system and have stated that unconventional resources are “continuous” or “basin centered” and lack traditional traps. While some have restricted the term to product type (i.e. unconventional gas), many shale and tight sand plays have gas, wet gas, and oil fairways and all can be considered unconventional. Heavy oil and oil sands are also unconventional resources and many of these deposits are in reservoirs with permeability exceeding 500 nd. Thus, unconventional resources include both low and high permeability reservoirs with both low and high viscosity fluids. Previous definitions have not accounted for all phases of petroleum in all types of reservoirs in all types of petroleum systems.

This paper proposes a simple graphical definition that incorporates properties of both the rocks and their fluids. All petroleum reservoirs can be plotted on a graph of viscosity versus permeability (both in log scale). On this graph, conventional resources all plot in the lower right quadrant, regardless of fluid phase. All unconventional resources plot outside this quadrant due to a low ratio of permeability to viscosity. Unconventional resources are thus defined as those petroleum reservoirs whose permeability/viscosity ratio requires use of technology to alter either the rock permeability or the fluid viscosity in order to produce the petroleum at commercially competitive rates. Conversely, conventional resources are those that can be produced commercially without altering permeability or viscosity. This simple graphical definition avoids the pitfalls inherent in a petroleum system interpretation (i.e. basin centered or self-

sourced versus migrated petroleum). The graphical definition accommodates and delineates tight gas, tight oil, shale gas, shale oil, heavy oil, coal bed methane, and even offshore reservoirs with low k/viscosity ratios.

Selected References

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Hill, R.J., E. Zhang, B.J. Katz, and Yongchun Tang, 2007, Modeling of gas generation from the Barnett Shale, Fort Worth Basin, Texas: AAPG Bulletin, v. 91/4, p. 501-521.

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WHAT ARE UNCONVENTIONAL RESOURCES?

A simple definition using viscosity and permeability

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Purpose

- Define *"Unconventional Resources"*

Why?

- No simple definition exists
- Current definitions depend on interpretations of geology or the petroleum system
- Current definitions do not always consider fluid properties (viscosity)

Solution

- Graph **k** vs μ (permeability vs. viscosity)
- Ratio of **k/μ** defines unconventional resources

Why is this definition helpful?

- Differentiates all unconventional reservoirs from all conventional reservoirs
- Encompasses all petroleum phases
- Uses quantitative properties of both *reservoirs and fluids and the ability of fluids to flow*

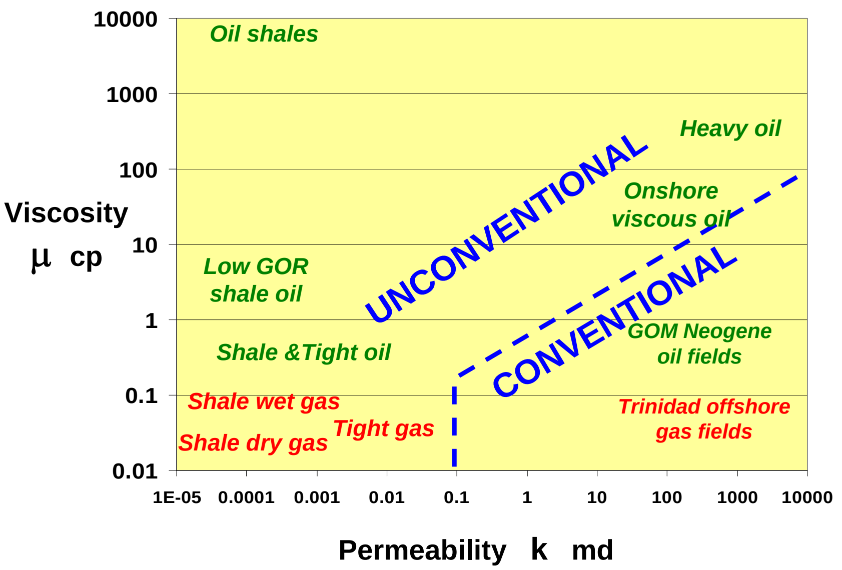
Problems with existing definitions

- "k < 0.1 md" was a political definition for purposes of tax credits
- Usually focus only on gas and omit liquids
- Treat unconventionals as obeying different rules of entrapment or seal (basin-centered or continuous)
- Fail to recognize continuum from "conventional" to "unconventional"
- Qualitative rather than quantitative

Masters and Gray, 1979

"Resource Triangle" defines unconventional qualitatively as difficult to develop

Unconventionals can be defined on a graph of viscosity (μ) vs. permeability (k)



Some common Viscosity values

Water	1.0 cp	
Bitumen	5000 -1mm cp	API 4-10
Heavy oil	100 - 5000 cp	API 10-20
Black oil	2 - 100 cp	API 20-45
Volatile oil	0.25 - 2 cp	API 30-55
Natural gas	< 0.25 cp	

Unconventionals are resources in which technology must be used to increase k/μ ratio in order to achieve commercial rates of flow

- k is usually increased by fracking
- μ is usually decreased by heat

•Graphical definition translates to all languages

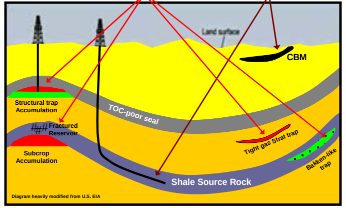
•Does not require interpretations of the petroleum system
- Avoids debate over "continuous" or "basin-centered" petroleum

Unconventionals do not have different petroleum system rules

- Fluid movement is governed by buoyancy, capillary pressure, and hydrodynamics (pressure).
- Petroleum is either retained in source rocks (shale and coal) via absorption and adsorption or migrated and accumulated in structural, stratigraphic, and diagenetic traps
- See also Edman, 2012, World Oil; Hill et al., 2007 AAPG; Shanley et al., 2004

Migrated & Accumulated
Petroleum is allochthonous
Usually extra-formational

Retained
Generated in situ
Rock saturates itself

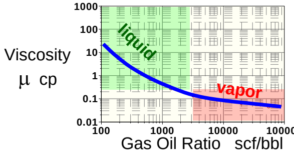


μ/k relates Unconventionals to flow

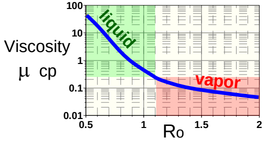
- Must increase k and/or decrease μ to achieve commercial flow rates (Q).
- But, not all flow in nanopores is purely Darcy flow

$$Q = \frac{k * H * \Delta P}{\mu}$$

Viscosity matters for fluid flow in shales… even for gases



Viscosity of petroleum retained in shales is mostly a function of GOR…



…so μ correlates with Ro and continues to decrease even in the gas window

Summary Points

- Unconventional resources are not defined by the type of petroleum system nor by rock properties alone.
- Unconventional resources can be defined using a graph of viscosity vs. permeability (**μ vs. k**) which differentiates all unconventional from conventional reservoirs
- In unconventional resources, technology is required to increase **k** and/or decrease **μ** in order to achieve commercial flow rates (**Q**)
- Unconventionals obey the same rules of physics as conventional resources
  - Fluid movement is still governed by buoyancy, capillary pressure, and pressure
- Petroleum in unconventionals is either retained or migrated
  - Most petroleum in shales and CBM was generated in situ and retained