Shale Gas Geochemistry Mythbusting*

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Abstract

Our understanding of "unconventional" play types, such as shale gas, is still evolving. We have been developing our scientific concepts and methods for conventional petroleum exploration and development for over 100 years, but the investigation of the concepts and methods for unconventional petroleum has been going on for only about 15 years. As a result, there has been a rush by some to embrace ideas before they have been validated or, in some cases, even tested. This has led to a large portion of shale gas dogma being based on personal opinions that often reference others who share these beliefs, but are not necessarily supported by data. We need to guard against allowing such myths from sneaking into our understanding of unconventional plays. So let us do some Mythbusting to see if some of our beliefs are: Confirmed (valid and therefore not myths), Plausible (possible, but there is not enough evidence to validate), or Busted (false and they truly are myths). We will begin the process with these three concepts: The TOC Misunderstanding: "TOC, organic matter, kerogen -it's all the same stuff."; The Kerogen Type Conundrum: "What difference does it make if my shale had oil-prone or gas-prone kerogen in it, I'm looking for shale gas."; and The Maturity Debacle: "I only need to measure the vitrinite reflectance in the shale, that's the only maturity measurement that counts." The roots of these beliefs are examined as well as their validity.

References Cited

Boak, J., 2012, Common wording vs. historical terminology: AAPG Explorer, August 2012. Web accessed 25 June 2013. http://www.aapg.org/explorer/2012/08aug/emd0812.cfm

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Shale Gas Geochemistry

"You can observe a lot by just watching."
- Yogi Berra

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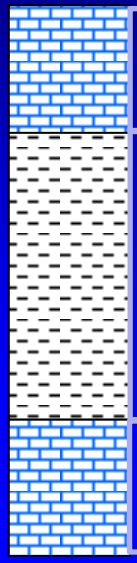
Gas Shale – A Source Rock/Reservoir Petroleum System



Gas Shale

Seal **– competent rock to act as fracture barriers during stimulation**

Source Rock **– an organic-rich shale in the gas window**
Reservoir **– a shale with some porosity and permeability that can be fractured to recover the gas**
Trap **– essentially a stratigraphic trap**
Seal **– minimal open natural fractures to leak off gas**

Seal **– competent rock to act as fracture barriers during stimulation**

Source Rock Properties:

- Sufficient organic richness
- Proper kerogen type
- High enough thermal maturity
- Adequate thickness/volume

Recognize the potential for both vertical and horizontal heterogeneity in all these properties.

Reservoir Properties:

- Porosity/Permeability
- Rock Matrix
  - Mineralogy
  - Depositional Fabric
  - Origin of grains - Biogenic vs. Detrital
  - Fluid sensitivity/compatibility

Our Understanding Of "Unconventional" Plays, Such As Shale Gas, Is Still Evolving.

We have been developing our scientific concepts and methods for conventional petroleum exploration for over 100 years.

Extensive industry investigations of the concepts and methods needed for unconventional petroleum exploration have been going on for only about 15 years.

It is important for us to separate Shale Gas Geochemistry myths from facts, so as to avoid embracing new ideas before they have been validated – or in some cases, even tested.

The Problem Of Inaccurate Information Is Pervasive And Can Even Be Found In The AAPG Explorer

The Plays:	The Rock Type:
Avalon Shale	shale?
Bakken	*mixed siliciclastic and carbonate reservoir*
Barnett Combo	shale
Bone Spring	*sands and corresponding carbonates*
Cana Woodford	shale
Cardium	*sand/shale formation, parts are undergoing waterflooding*
Cleveland	*tight gas sand*
Eagle Ford	shale
Exshaw	*mixed siliciclastic and carbonate*
Granite Wash	*granite wash*
Marcellus	shale
Mississippi Lime	*limestone*
Monterey	*porcelanites*
Montney	shale/*siltstone*
Niobrara	*chalk*
Tonkawa	*sands*
Tuscaloosa Marine Shale	shale
Utica	shale
Viking	*sand*
Wolfcamp-Wolfberry-Wolfbone	*limestone/sandstone*

Did they really mean to say plays where horizontal drilling and hydraulic fracturing are needed?

For further discussion about the need for communicating information accurately see

Myths And Mythbusting

A *Myth* is a fiction or half-truth that forms part of an ideology or belief system.

Much of shale gas dogma is personal opinions that often reference others who share these beliefs, but are not necessarily supported by data.

So let's do some Mythbusting to see if these beliefs are:

Valid, and therefore not myths,

Possible, but there's not enough evidence to validate, or

False, and they truly are myths.

MYTH 1

"TOC, organic matter, kerogen - it's all the same stuff."

The TOC Misunderstanding

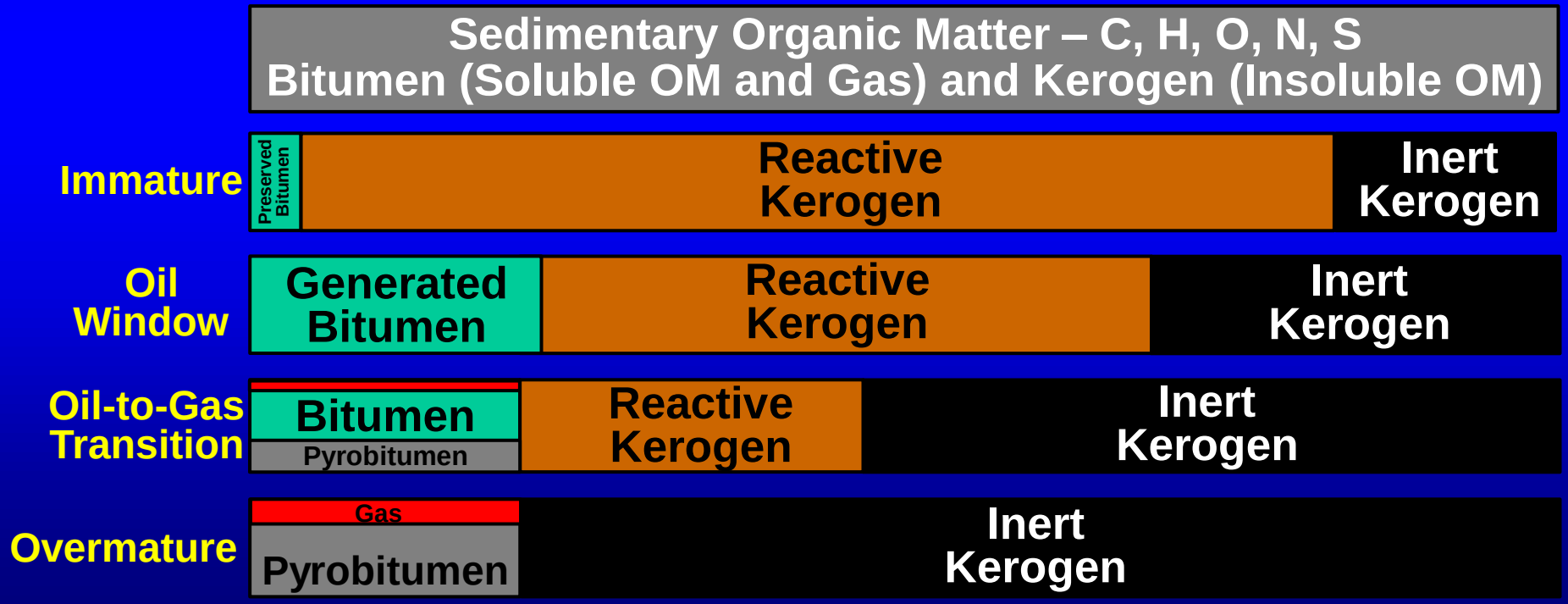
"There are some people who, if they don't already know, you can't tell 'em."
- Yogi Berra

"TOC, organic matter, kerogen -it's all the same stuff." – Not really!

TOC is the Total Organic Carbon content of a sediment expressed as a weight percent.

TOC is a proxy or indicator of the total amount of organic matter present in a sediment.

For organic matter to generate hydrocarbons, the carbon has to be associated with hydrogen - the more hydrogen associated with the carbon, the more it can generate.



MYTH 1

The TOC Misunderstanding:

"TOC, organic matter, kerogen - it's all the same stuff."

TOC, Organic Matter, and Kerogen are related to each other but are definitely not the same thing.

Not only are they not the same thing, they are dynamic materials that change over the maturation history of the sediments.

Understanding what they are and how they change is key to understanding the evolution of source rocks.

MYTH 2

"What difference does it make if my shale had oil-prone or gas-prone kerogen in it, I'm looking for shale gas."

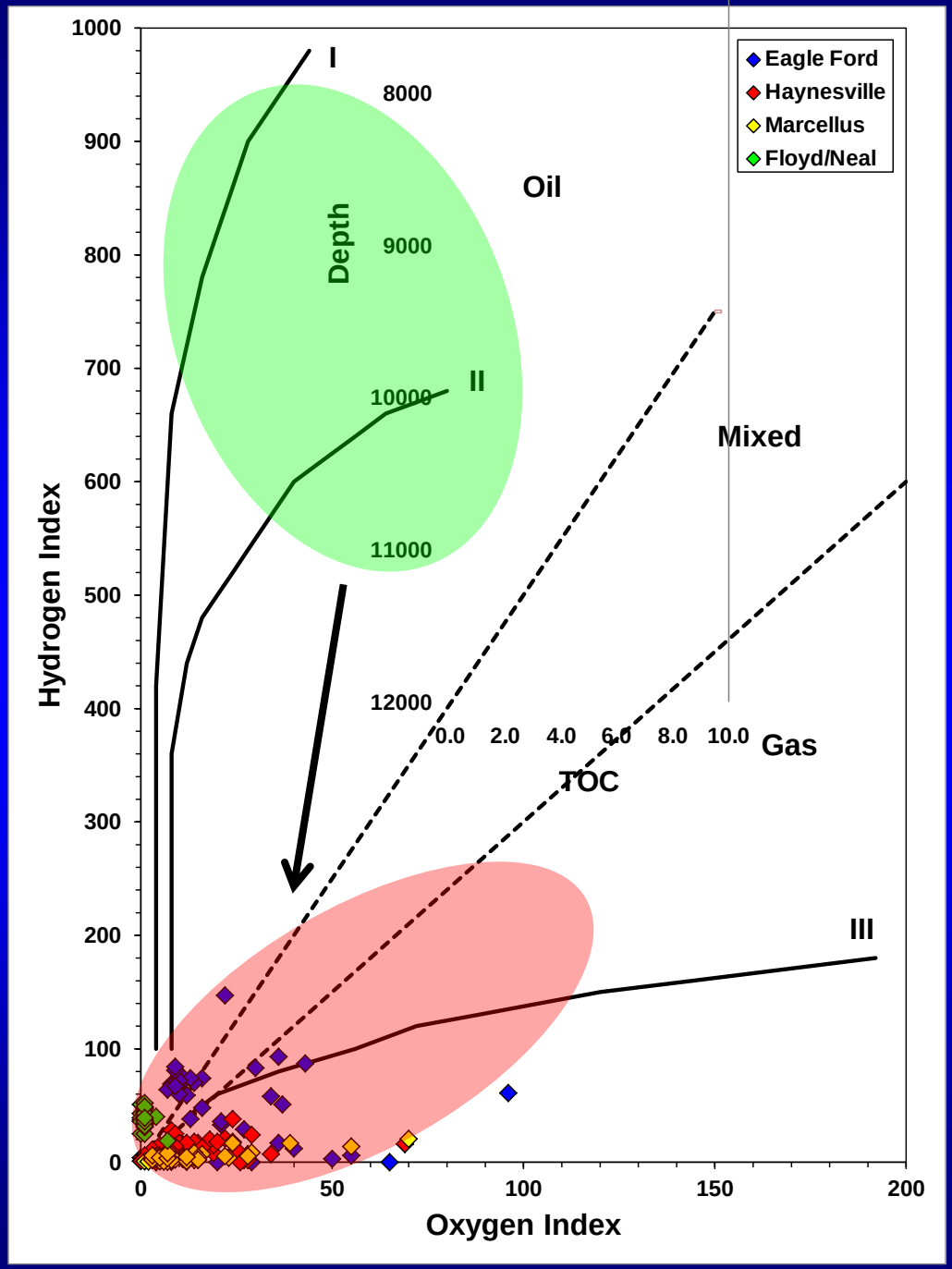
The Kerogen Type Conundrum

"In theory there is no difference between theory and practice. In practice there is. "
- Yogi Berra

Oil-Prone Source Rocks As Gas Sources

	Maximum Kerogen Generation Potential		Expelled Oil	Residual Oil	Residual Oil Cracked To Gas	Total Gas Potential
	mg Oil per g TOC	mg Gas per g TOC	mg Oil per g TOC	mg Oil per g TOC	mg Gas per g TOC	mg Gas per g TOC
Type I	~800	~150	~550-650	~150-250	~65-110	~215-260
Type II	~500	~150	~350-400	~100-150	~45-65	~195-215
Type III	~45	~125	0	~45	~20	~145
			Assuming 70-80% expelled for Type I and II, and 0% for Type III		Assuming 45% conversion of oil to gas	

- Although gas-prone source rocks can generate large amounts of gas at high maturity, they may not be the major source of gas in the subsurface.
- As oil generation nears completion, oil-prone kerogen still has a significant capacity for generating hydrocarbon gas.
- In addition, between 20 and 30% of the oil/bitumen generated by oil-prone kerogen may be retained in the source rock and eventually crack to form significant amount of gas.
- As a result, late stage gas generation and cracking of residual oil/bitumen in oil-prone source rocks can account for more gas generation than gas-prone source rocks.



But if we look at the Rock-Eval data, all the gas shales look gas-prone?

- Looks are deceiving.
- The Rock-Eval data reflects the current state of the kerogen in the source rock.
- We need to look at what the kerogen's original hydrocarbon generation potential was.
- Because as maturity increases, oil-prone kerogen eventually looks like gas-prone kerogen.

MYTH 2

The Kerogen Type Conundrum:

"What difference does it make if my shale has oil-prone or gas-prone kerogen in it, I'm looking for shale gas."

Oil-prone kerogens have higher capacities for hydrocarbon generation per unit organic carbon than gas-prone kerogens.

In addition, residual oil/bitumen in oil-prone sources will eventually crack to form a significant amount of gas.

As a result, oil-prone kerogens will generate more gas during late stage generation than gas-prone kerogen.

MYTH 3

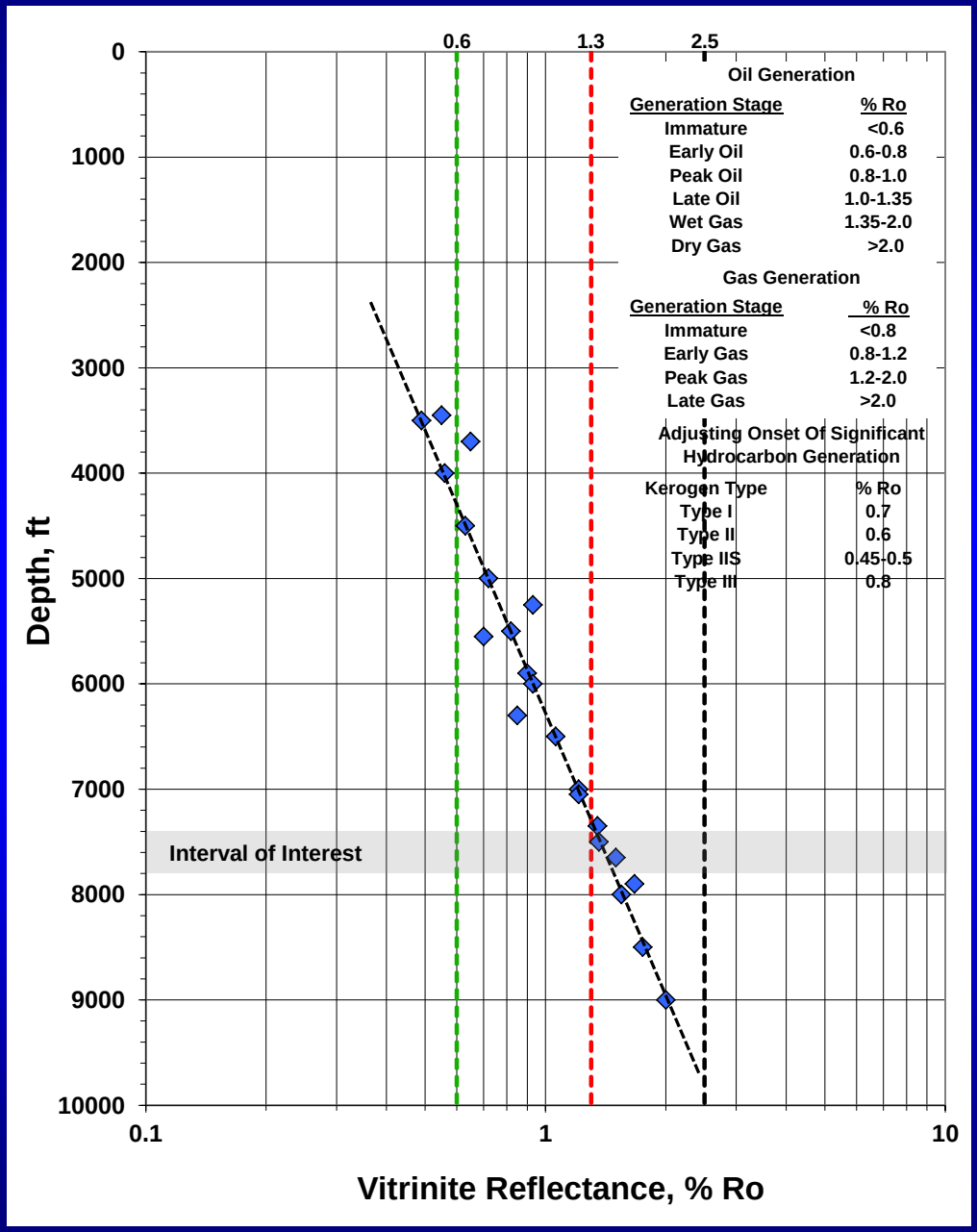
"I only need to measure the vitrinite reflectance in the shale, that's the only maturity measurement that counts."

The Maturity Debacle

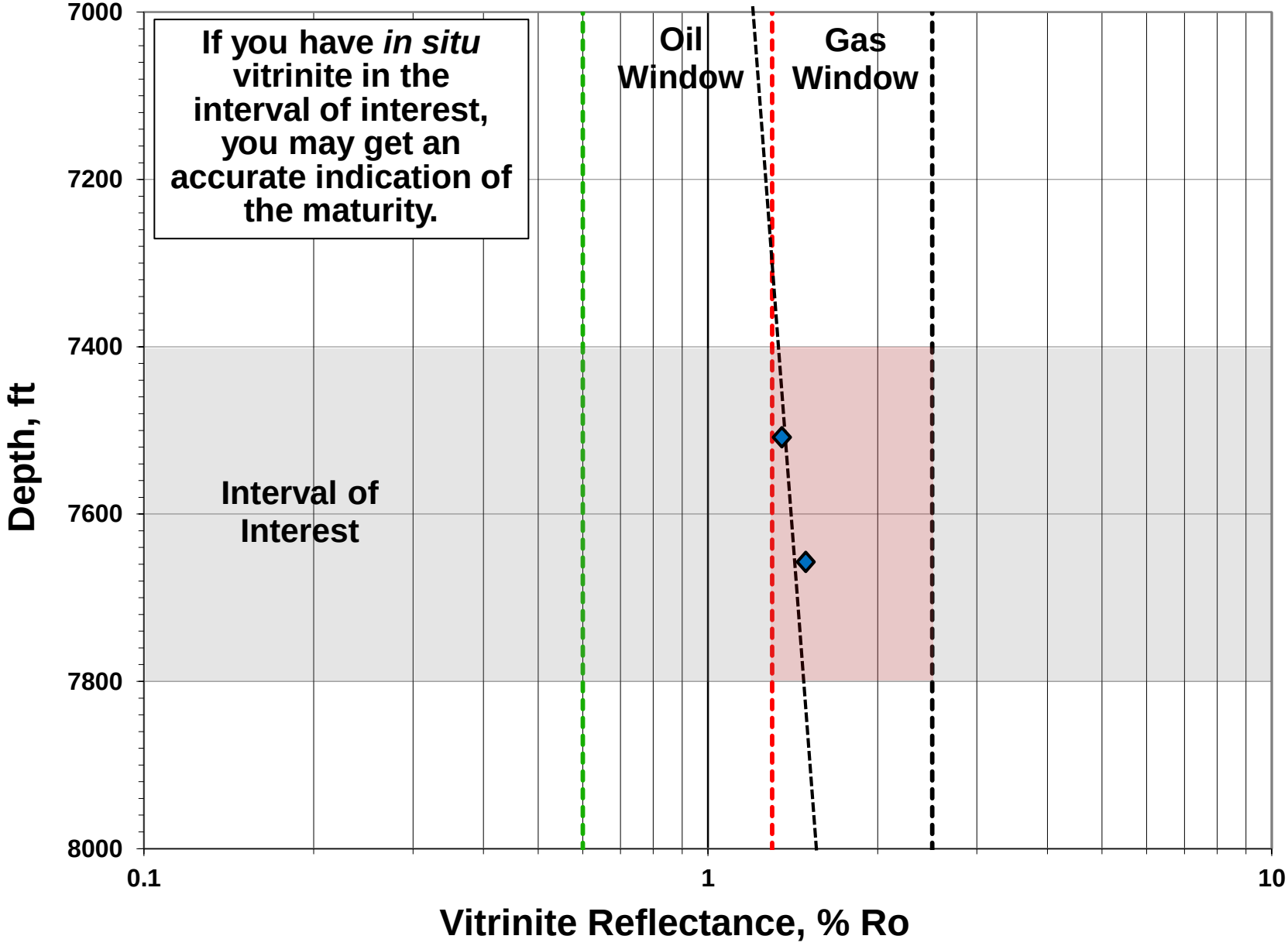
"You've got to be very careful if you don't know where you are going, because you might not get there." - Yogi Berra

Vitrinite Reflectance

- The reflectance of vitrinite increases with increasing time and temperature in a predictable manner that can be related to the generation history of sediments.
- The change in reflectance is a kinetic process so the log of vitrinite reflectance plotted versus linear depth often gives a straight line.
- Vitrinite reflectance is a trend tool. It requires more than just a few samples be measured and a minimum depth range of 4000 feet should be covered in order to establish the trend.
- However, shale gas projects tend to focus on only the interval of interest. As a result maturity data is often collected from only the target shale.



Focused Sampling Only In The Interval Of Interest



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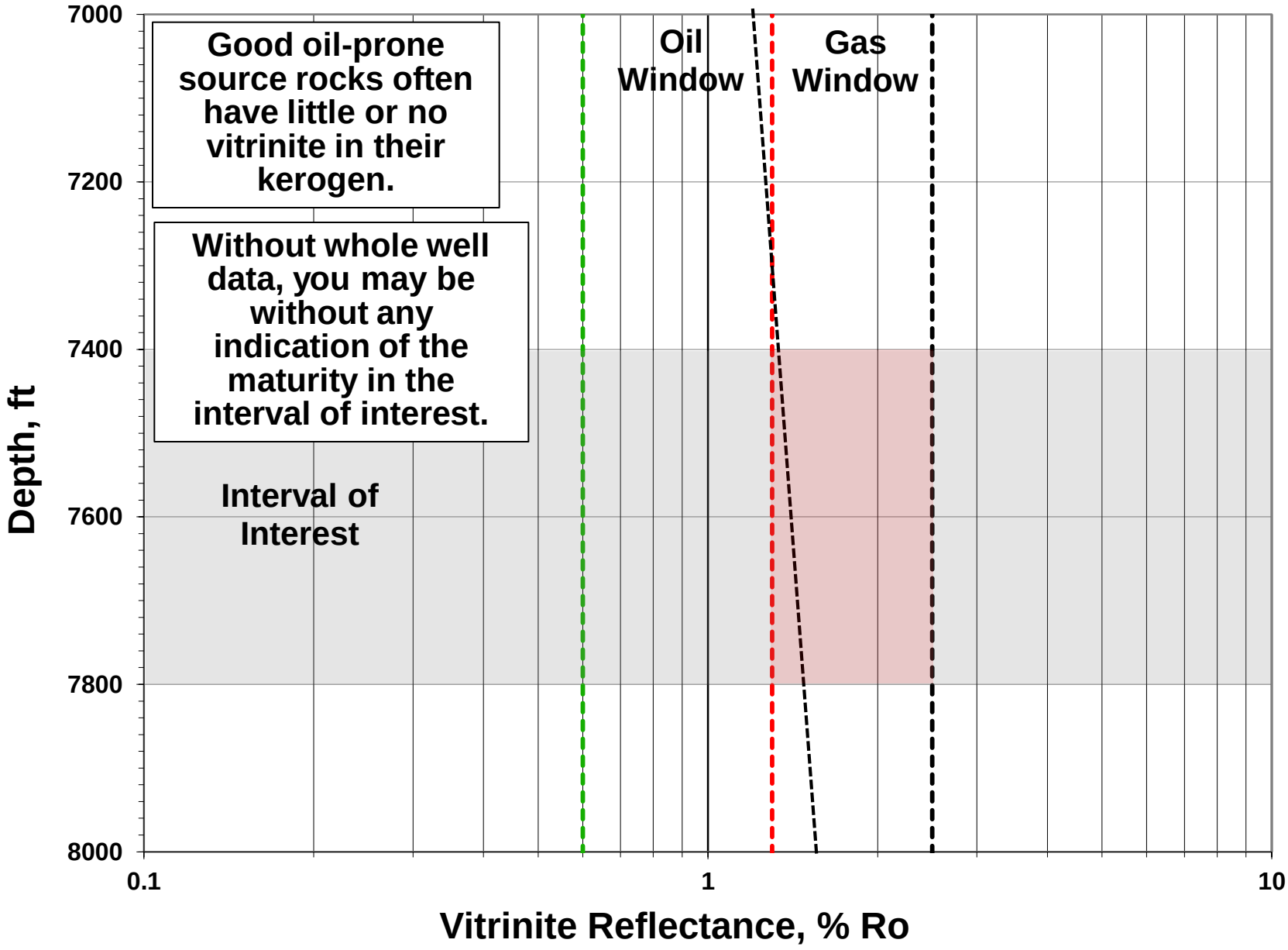

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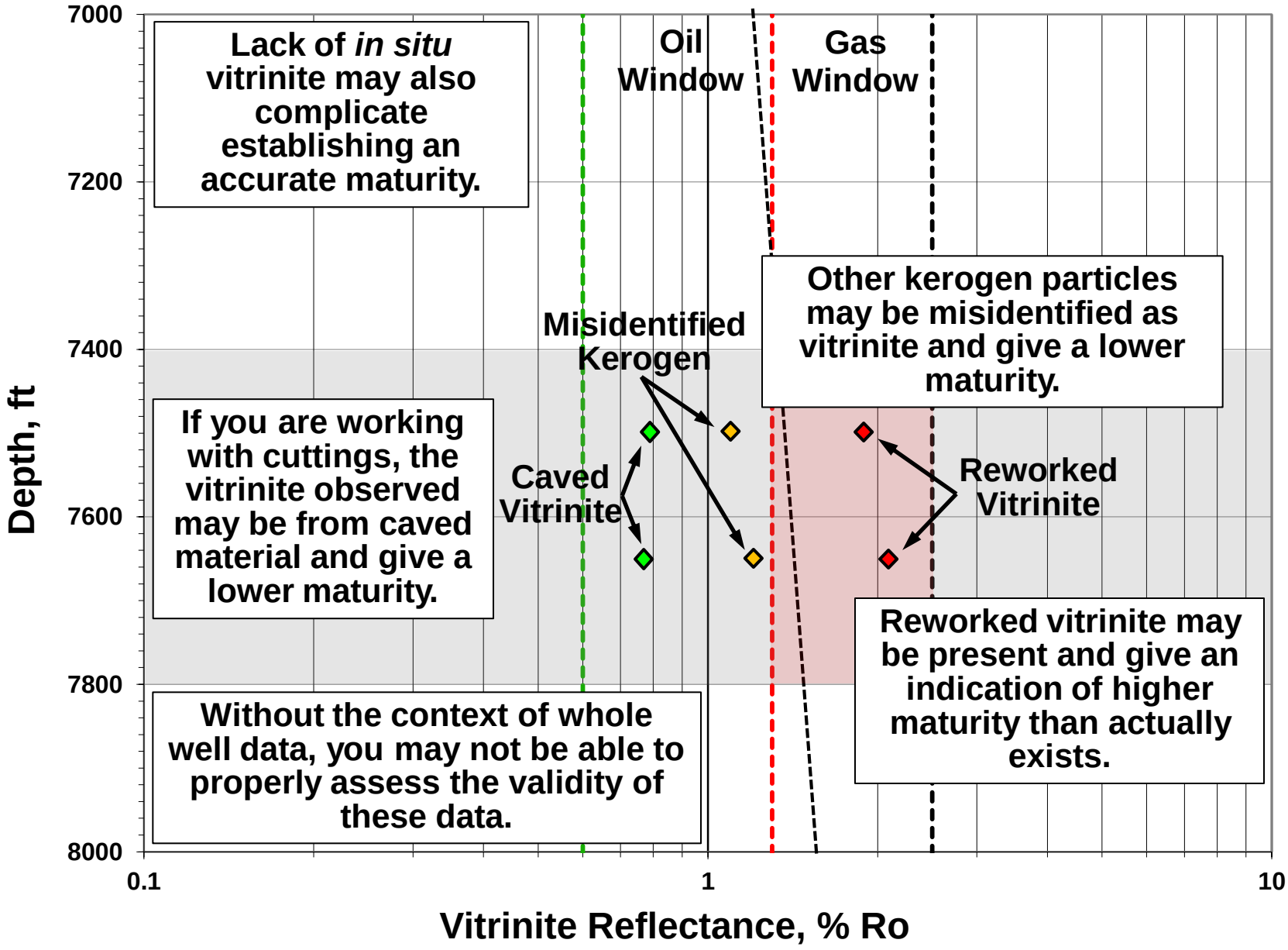
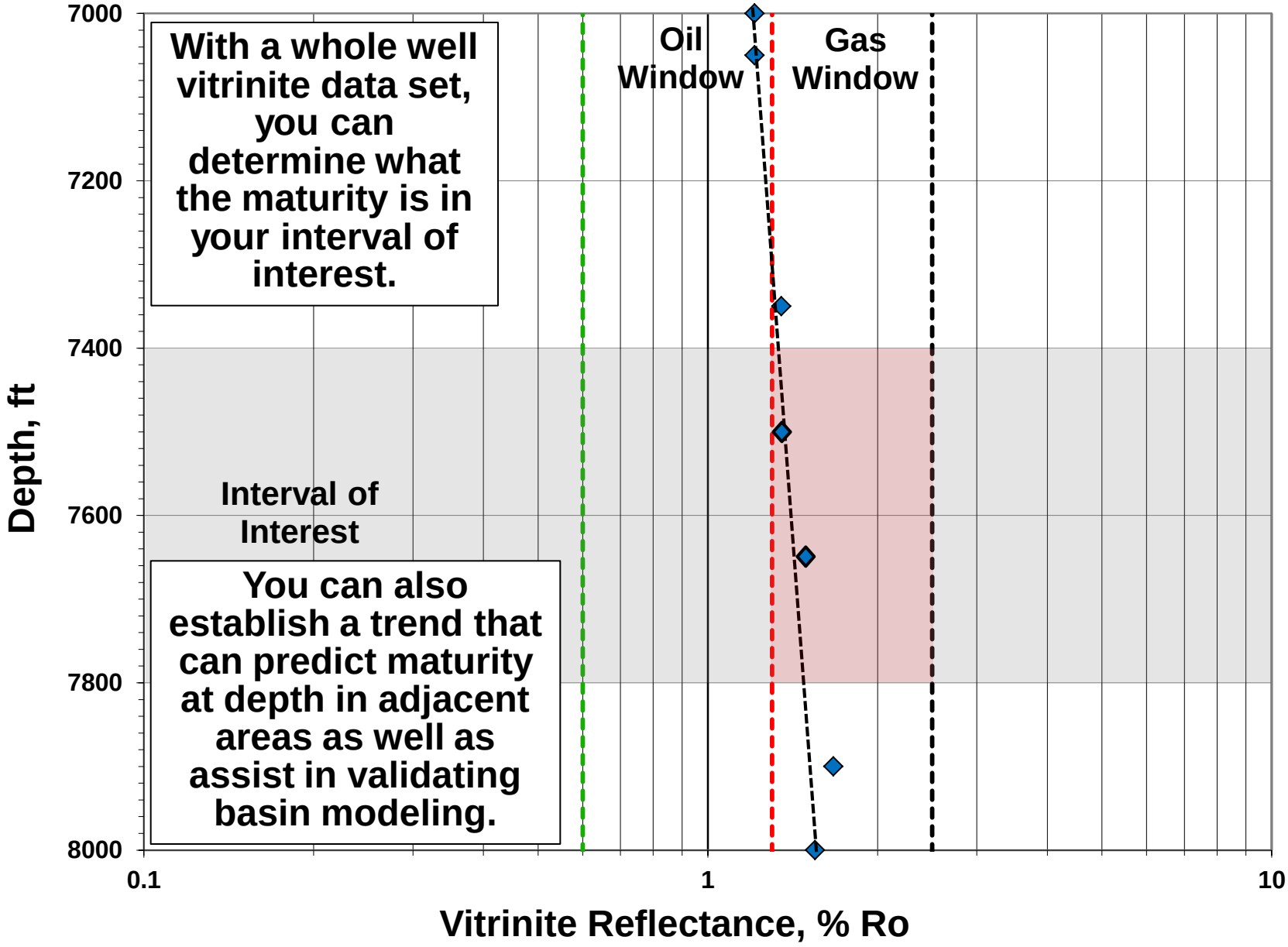
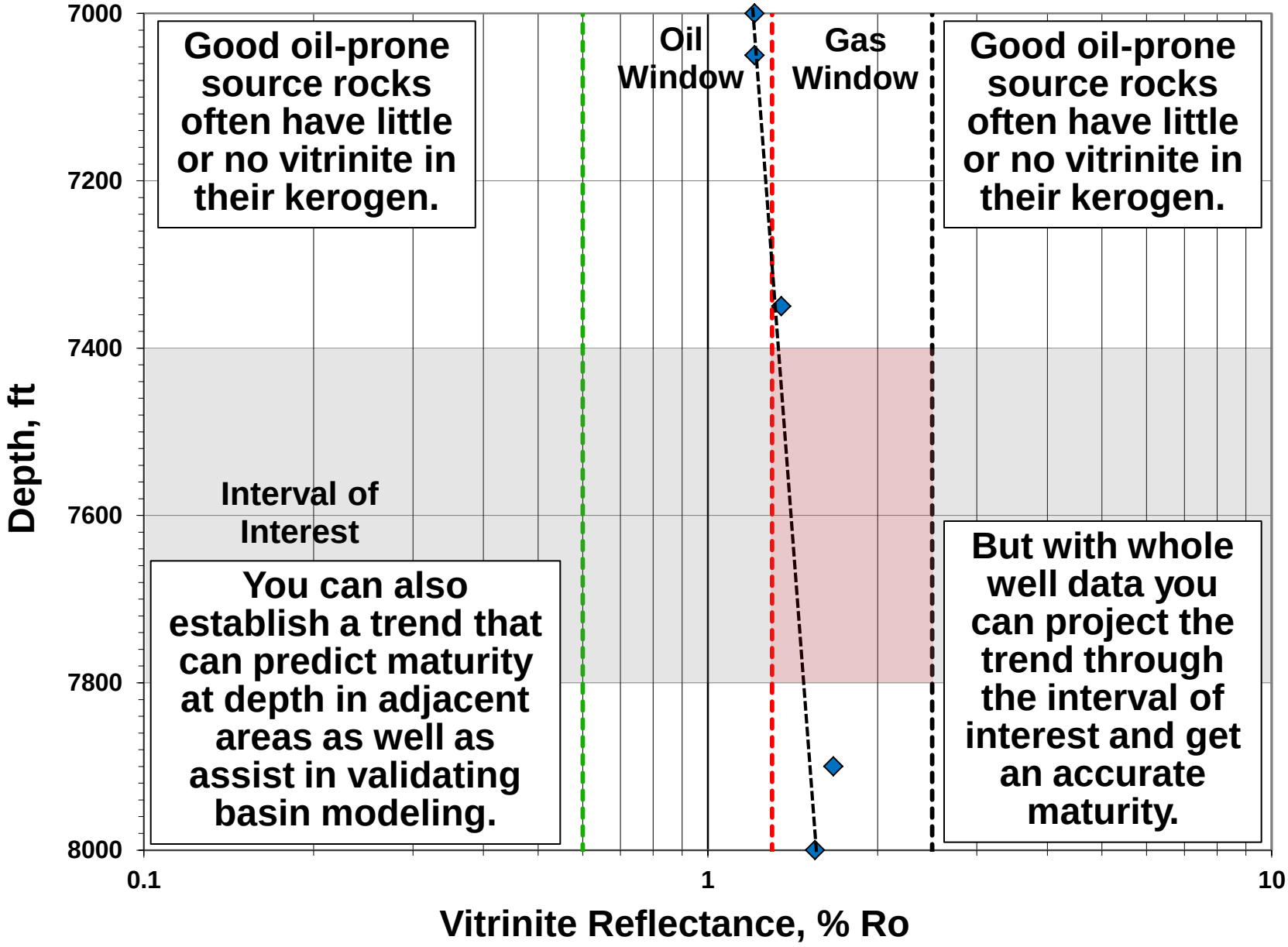


Whole Well Vitrinite Reflectance Trends

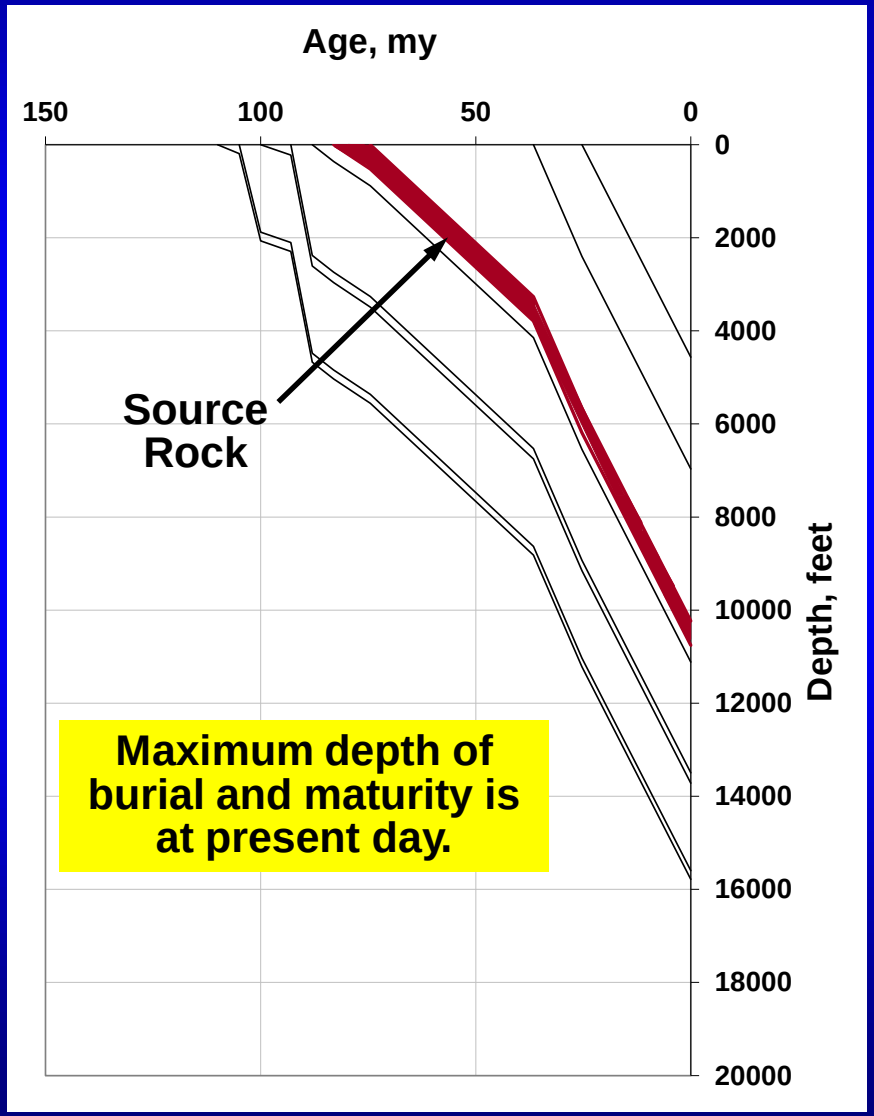


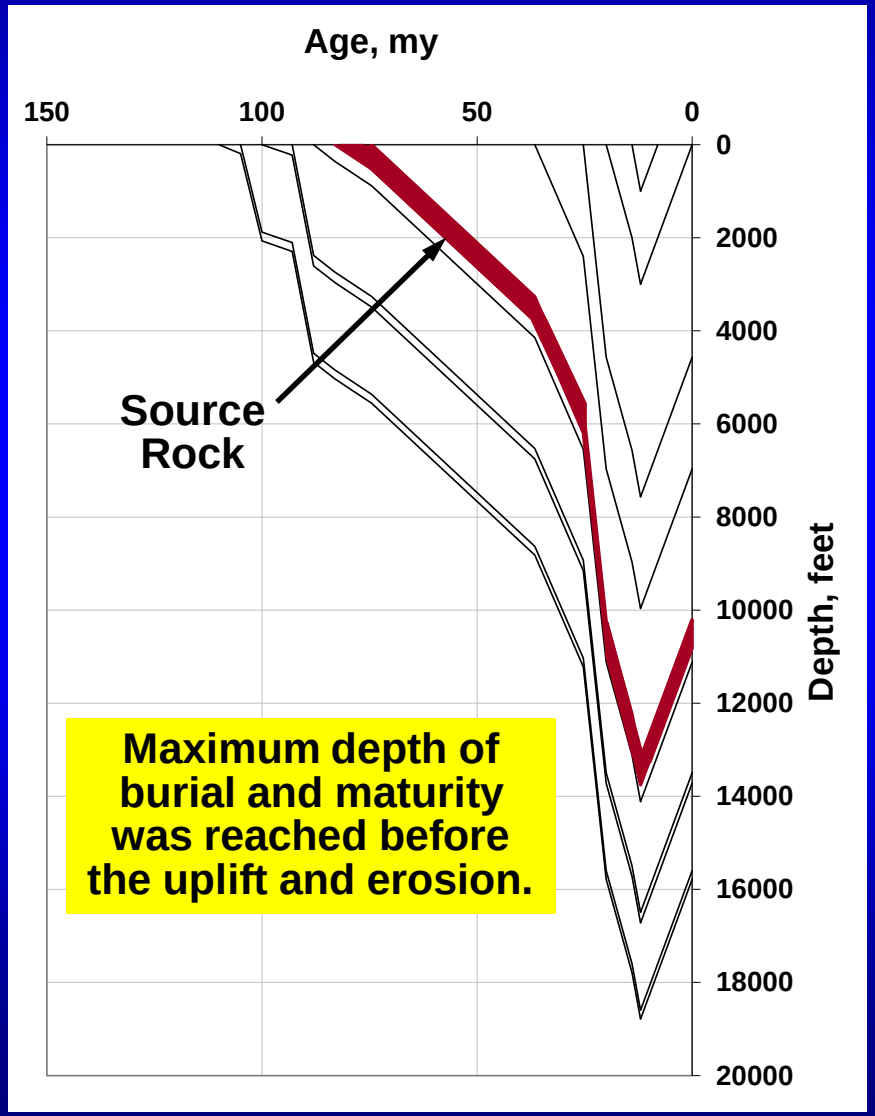
Whole Well Vitrinite Reflectance Trends



Burial History And Thermal Maturity

It is always better to place the thermal maturity data in the context of the sediment's burial history for proper interpretation.





MYTH 3

The Maturity Debacle:

"I only need to measure the vitrinite reflectance in the shale, that's the only maturity measurement that counts."

Vitrinite reflectance is a trend tool requiring multiple data points collected over a large depth range.

A few data points collected over a few hundred feet may not represent true maturity, especially in very good oil-prone source rocks that may contain little or no *in situ* vitrinite.

It is best to use whole well vitrinite reflectance profiles and build a burial history for the sediment column for context.

We may have been led astray in the past by...

… The TOC Misunderstanding,
The Kerogen Type Conundrum, and
The Maturity Debacle…

…but armed with this information, we can avoid these errors in the future.

We also need to be vigilant and guard against allowing other myths like these from sneaking into our understanding of unconventional plays.

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"I just want to thank everyone who made this necessary." – Yogi Berra