Organic Porosity Study: Porosity Development within Organic Matter of the Lower Silurian and Ordovician Source Rocks of the Poland Shale Gas Trend*

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Abstract

Porosity in organic matter is often the predominant type of total porosity development in shale rocks. Due to the hydrophobic nature of organic matter, organic porosity is in most cases fully occupied by hydrocarbon where water resides in intraparticle and intergranular pores of inorganic material. Therefore, understanding of porosity development in organic matter could help better describe a total porosity distribution in mudrocks and improve understanding of fluid saturation.

Organic porosity was calculated from FIB SEM images taken for the Lower Silurian and Ordovician source rock samples of the shale trend in Poland. The observation was made that organic porosity is a function of not only thermal maturity but also original organic composition. The transform was developed allowing for organic porosity determination where it is represented as the function of present day and original hydrogen indices. The results were integrated with petrophysical interpretations of well logs to validate gas filled porosity calculations and verify desorption analysis data.

References Cited

Loucks, R.G., R.M. Reed, S.C. Ruppel, and D.M. Jarvie, 2009, Morphology, genesis, and distribution of nanometer-scale pores in siliceous mudstones of the Mississippian Barnett Shale: JSR, v. 79/12, p. 848-861.

Modica, C.J., and S.G. Lapierre, 2012, Estimation of kerogen porosity in source rocks as a function of thermal transformation; example from the Mowry Shale in the Powder River basin of Wyoming: AAPG Bulletin, v. 96/1, p. 87-108.

Organic Porosity Study

Porosity development within an organic matter of Lower Silurian and Ordovician Source Rocks of Poland Shale Trend

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Content/Highlights

- Organic Porosity Development
  - General Assumptions
- Poland: Case Study
  - Samples from Lower Silurian and Ordovician Source Rocks
- Organic Porosity Analysis Results from FE SEM* Images:
  - Organic Porosity Increases with maturity and depth
  - It also depends on kerogen type/composition
  - Correlation of Organic Porosity with Hydrogen Index
- Potential Application
  - Validation of Total Porosity and Water Saturation in a Source Rock
- Summary

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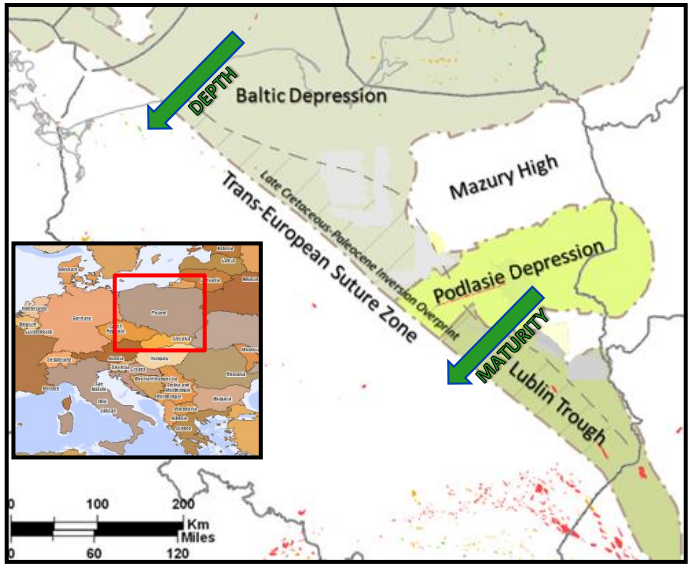
**FE SEM - Field Emission Scanning Electron Microscope*

Case Study: Poland Shale Trend

- The shale resource trend in Poland comprises three tectonic basins: Lublin, Podlasie and Baltic
- Most resource potential in the shale trend lies in Lower Paleozoic: Lower Silurian and Ordovician source rocks represented by organic rich mudstones:
  - Lower Silurian (Wenlock and Low Llandovery): calcareous, laminated to nodular mudstones
  - Ordovician (Upper Caradoc): pelagic to hemipelagic radiolarian to skeletal mudstones



SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

- Variable TOC, source rock thickness, and maturity across three basins

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Organic Porosity Development

General Assumptions

- Porosity in organic matter is often the predominant type of total porosity development in source rocks

- Due to hydrophobic nature (oil-wet) of organic matter, organic porosity is in most cases fully occupied by hydrocarbons with water residing in intraparticle and intergranular pores of inorganic material

- Understanding porosity distribution in organic matter may help us better describe a total porosity distribution in source rocks and improve understanding of fluid saturation

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Organic Porosity Development

General Assumptions

- Porosity in organic matter is a function of the degree of thermal maturity and the resultant decomposition of organic material during hydrocarbon generation process

- It has been confirmed by various studies* where evaluation of SEM images showed that the abundance of pores in organic matter is directly related to thermal maturity
  - * e.g. R. G. Loucks et al. in Barnett shales study, 2009; Christopher J. Modica and Scott G. Lapierre (Kerogen porosity estimations in Mowry Shales, 2012); others

- Organic porosity development may also depend on kerogen type (organic composition)

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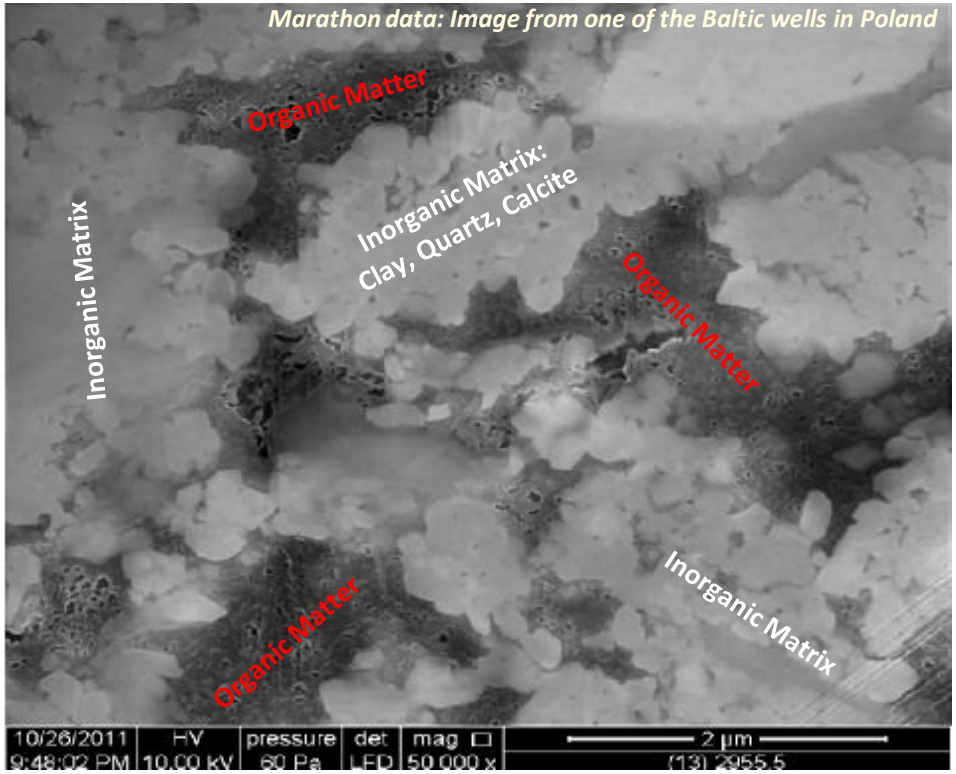
Organic Porosity Development



- Organic Porosity was evaluated using FE SEM images from legacy wells from Poland
- Data from 7 wells from 3 basins (Lublin, Podlasie and Baltic) in Poland have been used in the analysis
- The samples for analysis were selected (as available) to cover various maturities and kerogen types

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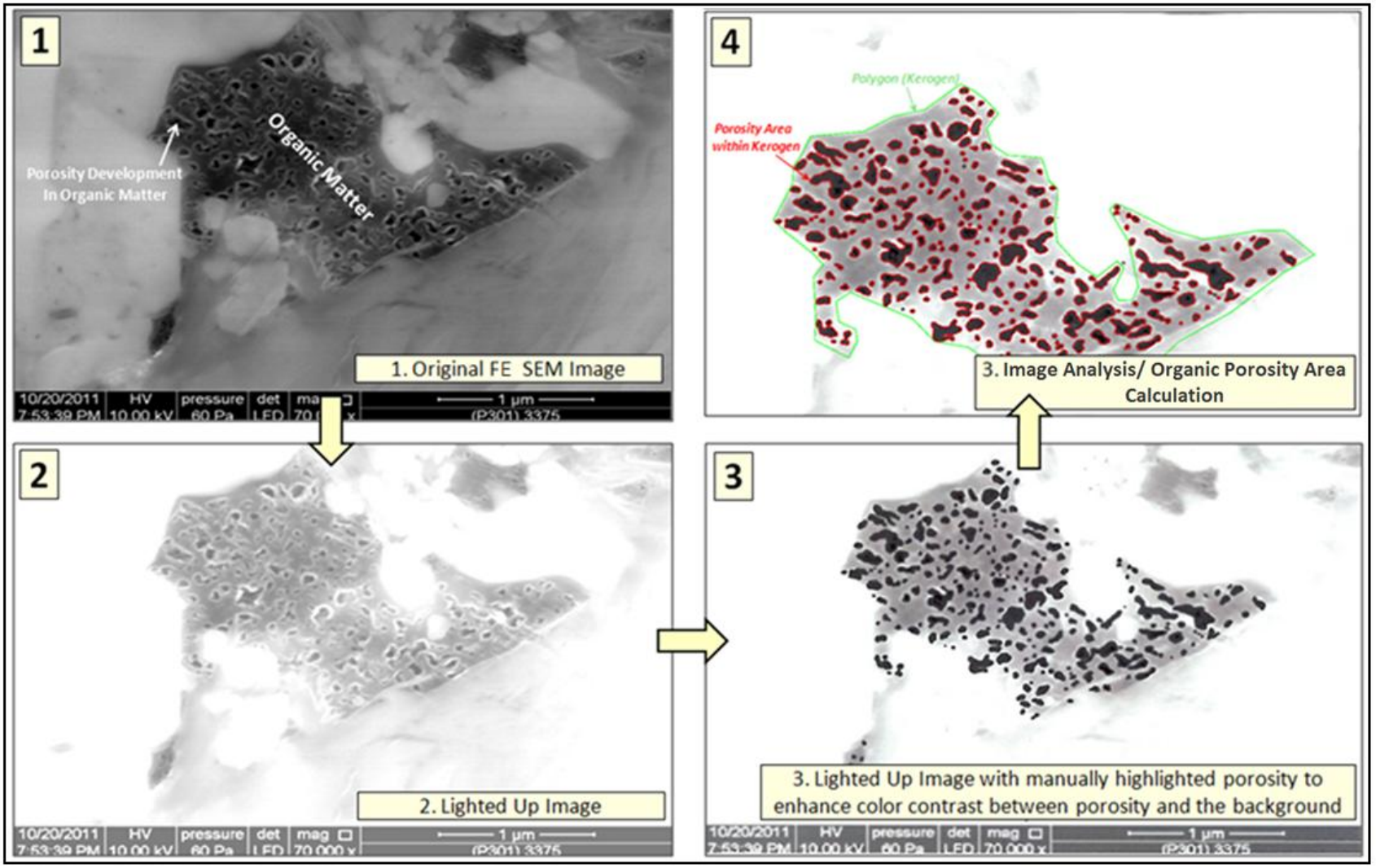
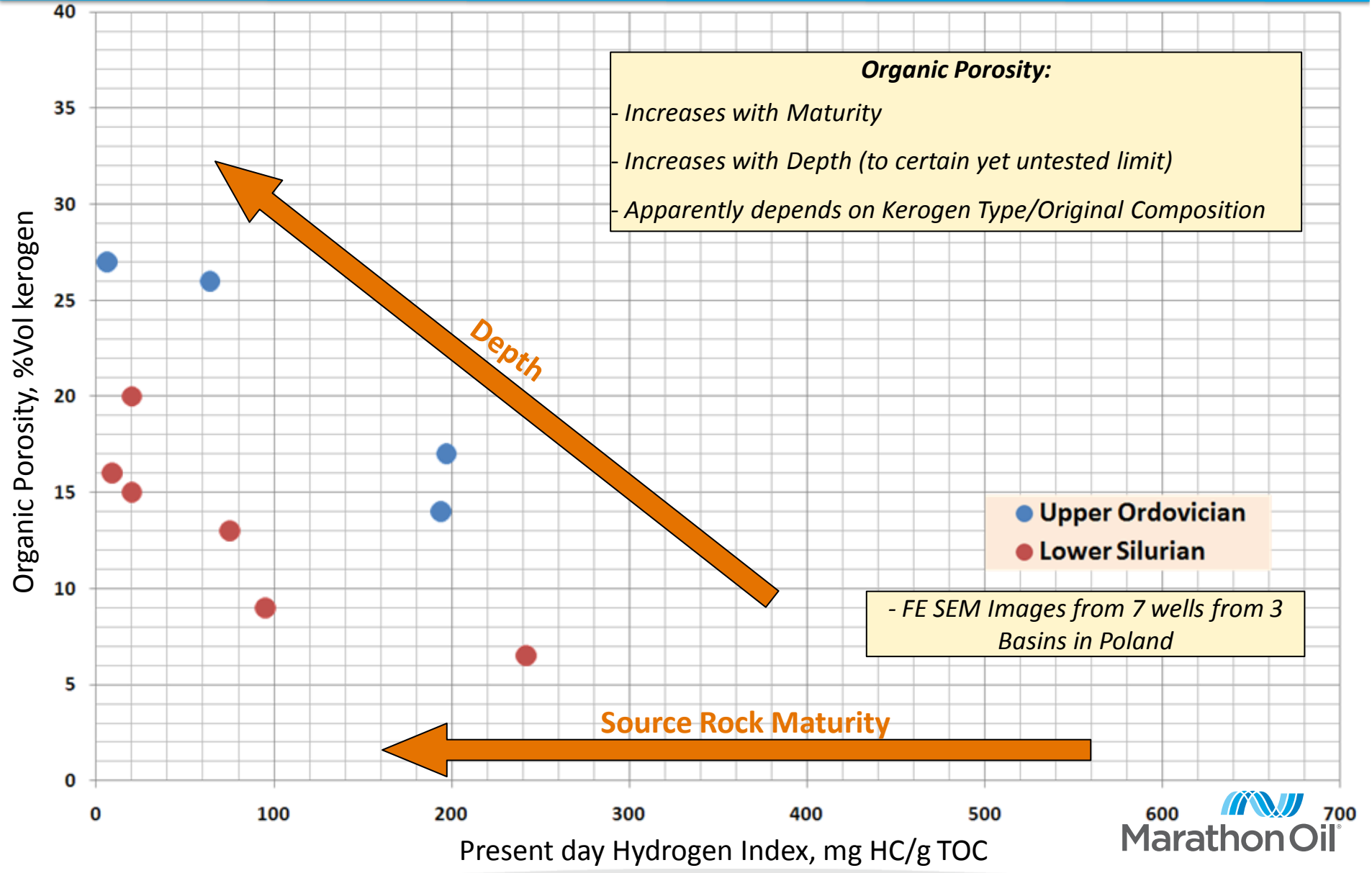
FE SEM Analysis: Image Processing Workflow



Poland: FE SEM Data Analysis



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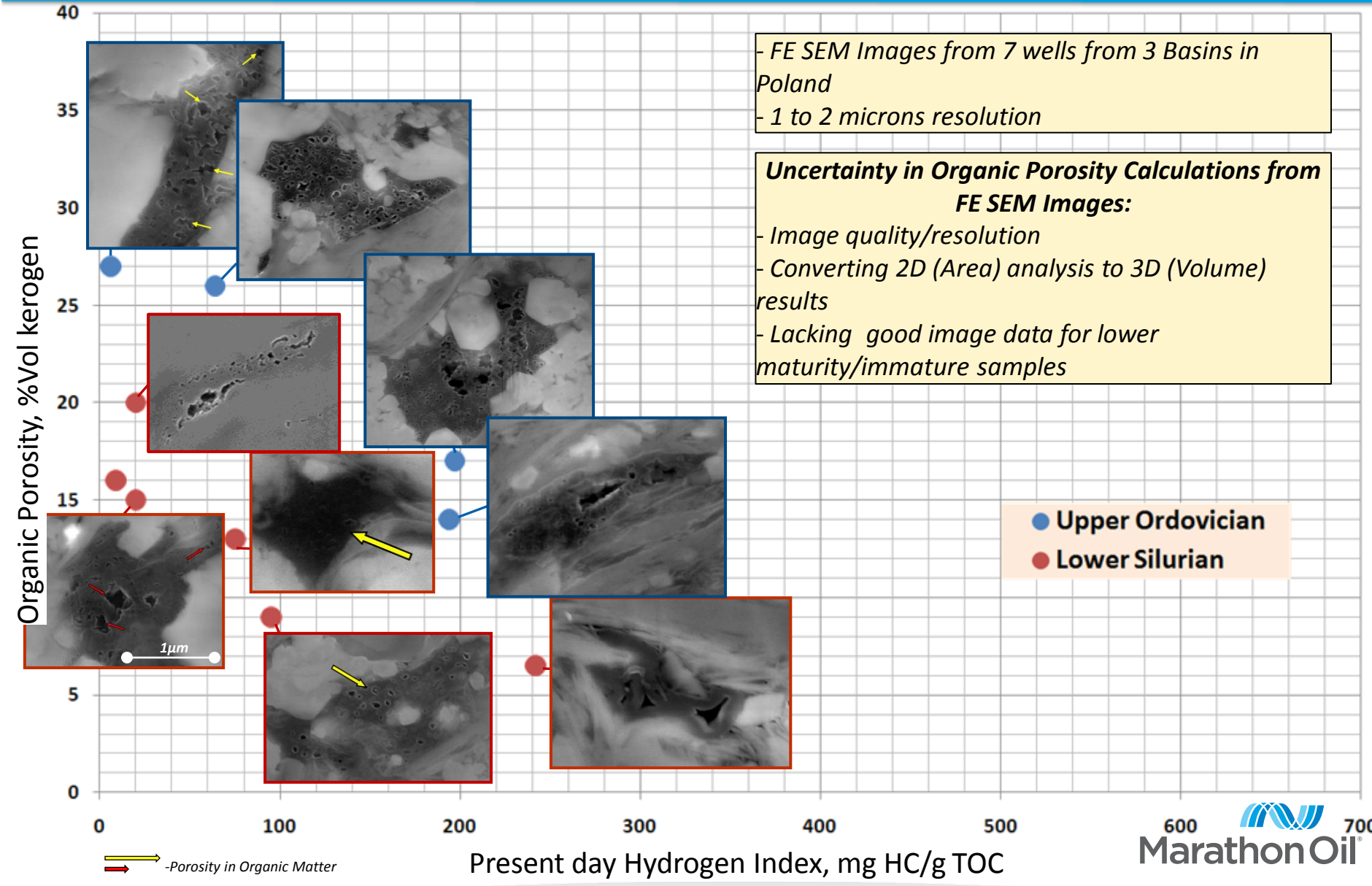
Hydrogen Index defines Remaining Generation potential of a Source Rock

Poland: FE SEM Data Analysis



- *FE SEM Images from 7 wells from 3 Basins in Poland*
- *1 to 2 microns resolution*

Uncertainty in Organic Porosity Calculations from FE SEM Images:

- *Image quality/resolution*
- *Converting 2D (Area) analysis to 3D (Volume) results*
- *Lacking good image data for lower maturity/immature samples*

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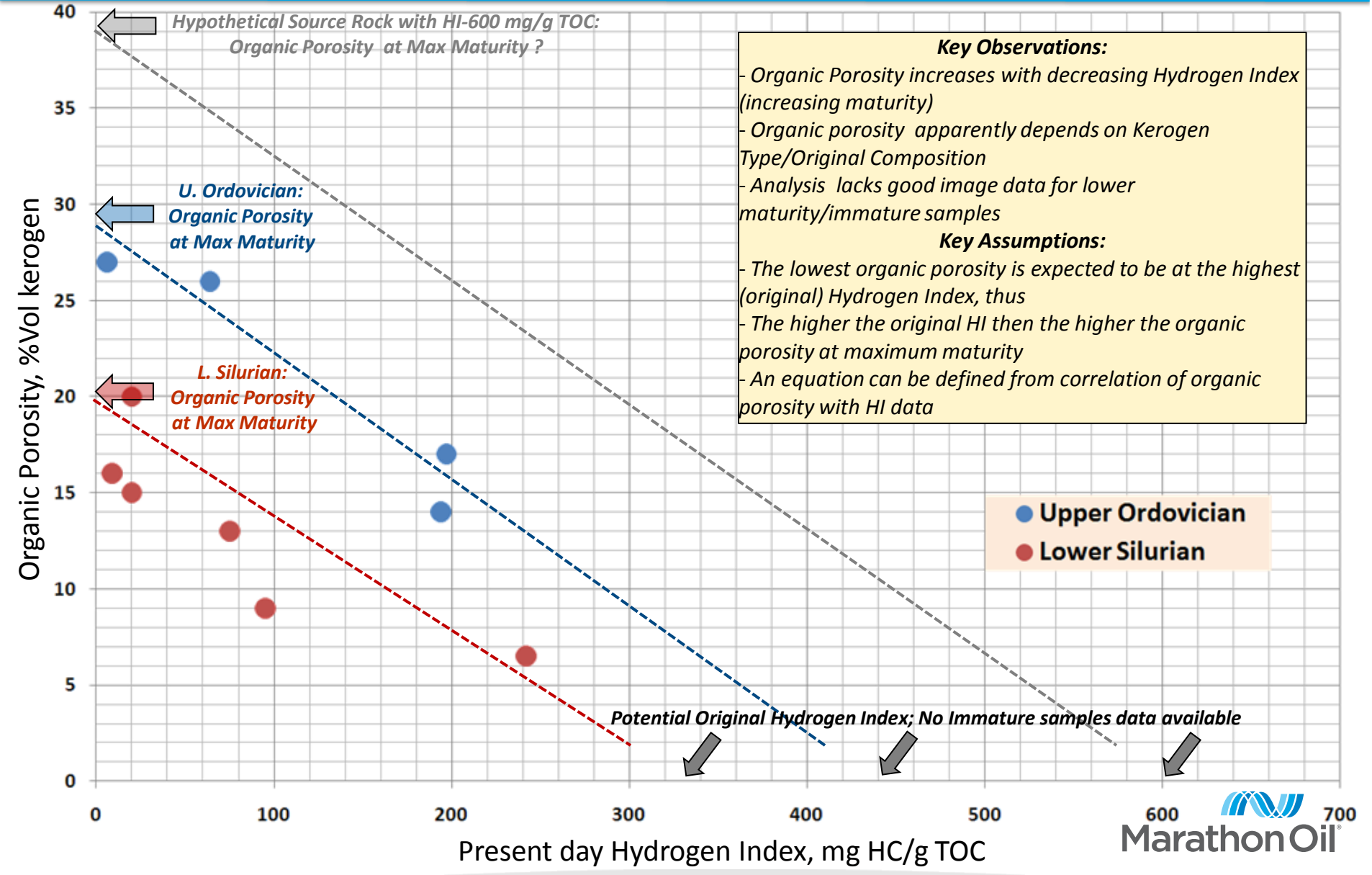
Hydrogen Index defines Remaining Generation potential of a Source Rock

Poland: FE SEM Data Analysis



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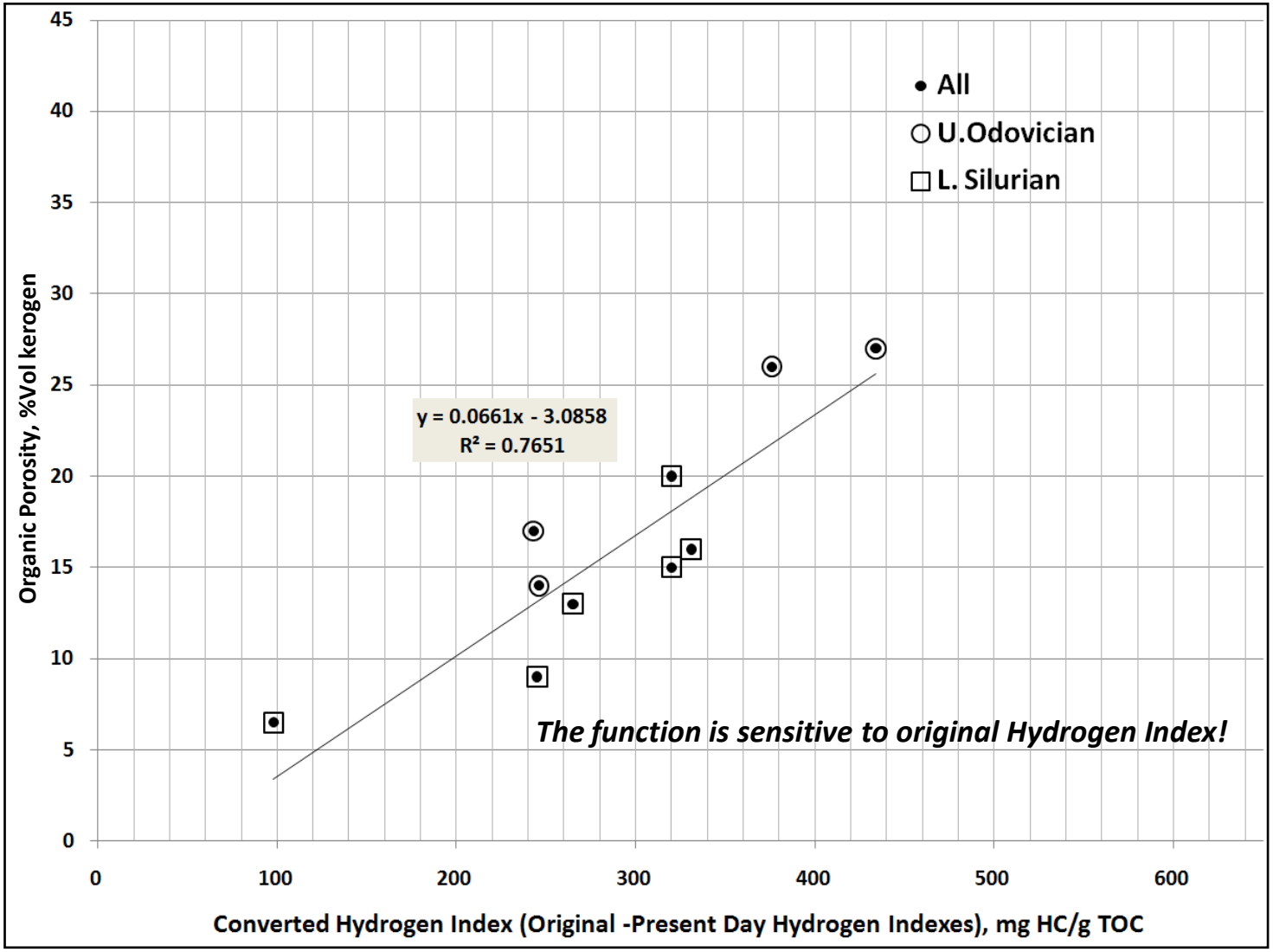
Hydrogen Index defines Remaining Generation potential of a Source Rock

Correlating Organic Porosity with Hydrogen Index



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Organic Porosity:

Application in Source Rock Petrophysics

$$\text{Organic Porosity } (\%V_{ker}) = (0.066^{x}(HI_{original} - HI_{present}) - 3.01)$$

$$\Downarrow$$

$$\text{Organic Porosity } (\%V_{bulk}) = \text{Porosity } (\%V_{ker})\ ^{X}\ V_{ker}(V_{bulk})$$

- Due to hydrophobic nature of organic matter, organic porosity is mainly occupied by hydrocarbon with water residing in intraparticle and intergranular pores of inorganic material
- Additional analysis is required (e.g. pore size distribution, clay content, etc) to evaluate percentile of total hydrocarbon which can be trapped in inorganic pore space
- Since majority of hydrocarbons are most likely to occur within organic matter of a source rock, the ratio of organic porosity to total porosity is essential information in understanding the hydrocarbon saturation value

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Summary

- **Organic Porosity is confirmed to be a function of thermal maturity**
  - Samples from Poland demonstrate organic porosity increases with maturity
  - Organic porosity increases with depth (to a certain limit that is yet to be tested)
- **Organic Porosity is also a function of kerogen type**
  - Porosity in Organic Matter within Lower Silurian and Ordovician source rocks in Poland reaches 20 to 30% of Kerogen Volume at maximum maturity
  - The uncertainty in organic porosity measurements exists due to image quality/resolution
- **The organic porosity can be correlated to the difference between original and present day Hydrogen Indexes**
  - The function is sensitive to original Hydrogen Index
  - The derived equation is yet to be confirmed by studying other source rocks
- **Organic porosity can be used to validate petrophysical parameters such as total porosity and saturation**

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