A Preliminary Geology-Based Natural Gas Resource Assessment of the Marcellus Shale for West Virginia

AAPG 2013 Annual Convention & Exhibition
Pittsburgh, PA

Susan Pool

WVGES

Ray Boswell

USDOE/NETL

J. Eric Lewis

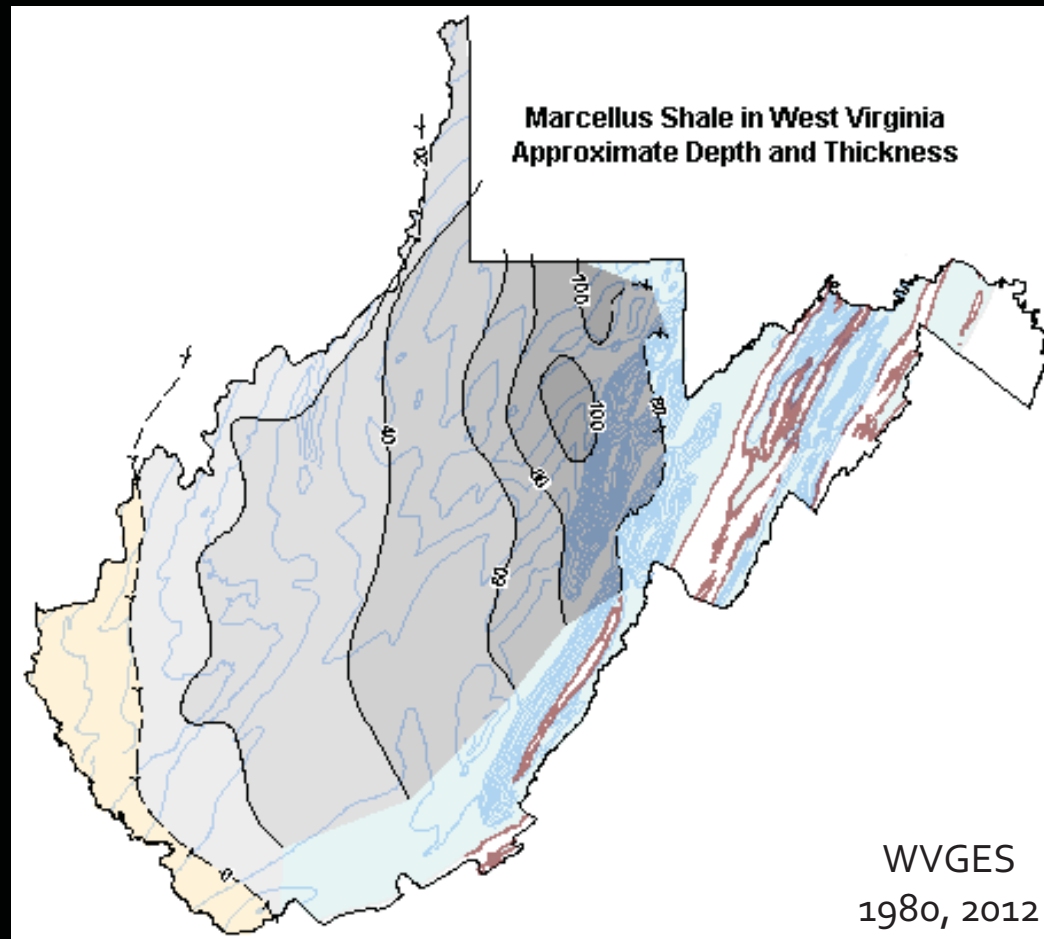*WVGES*

Jonathan P. Mathews

Penn State

Presentation Outline

- Background

- Purpose

- Methodology and Data

- Preliminary Results

- Future Work

Background

Because of interest in and activity related to Marcellus Shale, WVGES is examining basic data, much of which is new, as well as updating and developing Marcellus-specific materials.

Marcellus Shale in West Virginia
Approximate Depth and Thickness

WVGES
1980, 2012

Example of some current WVGES materials

which are a mix of newer and older data and maps.

Purpose

The *purpose* of the study is to:

- Collect and investigate basic geologic data

- Conduct preliminary resource assessment

- Identify requirements to improve assessment

- Make selected data and maps available and provide an up-to-date web-based GIS map application

- Investigate development of a framework for the State to evaluate other petroleum resources

Purpose

Key research questions for the project include:

How much natural gas is likely to be contained
in the Marcellus Shale underlying West Virginia?

How is the gas distributed?

How do the key parameters that affect
gas recoverability vary geographically?

Methodology and Data

Approaches to estimating natural gas resource volumes for continuous unconventional reservoirs include:

those that use *production data*
to estimate *technically-recoverable* resources directly

and

those that use *geologic data*
to estimate total *original gas-in-place*.

Methodology and Data

Both methods have advantages and disadvantages, but ultimately the two approaches can be *combined*
to obtain a fuller understanding of the resource and its potential.
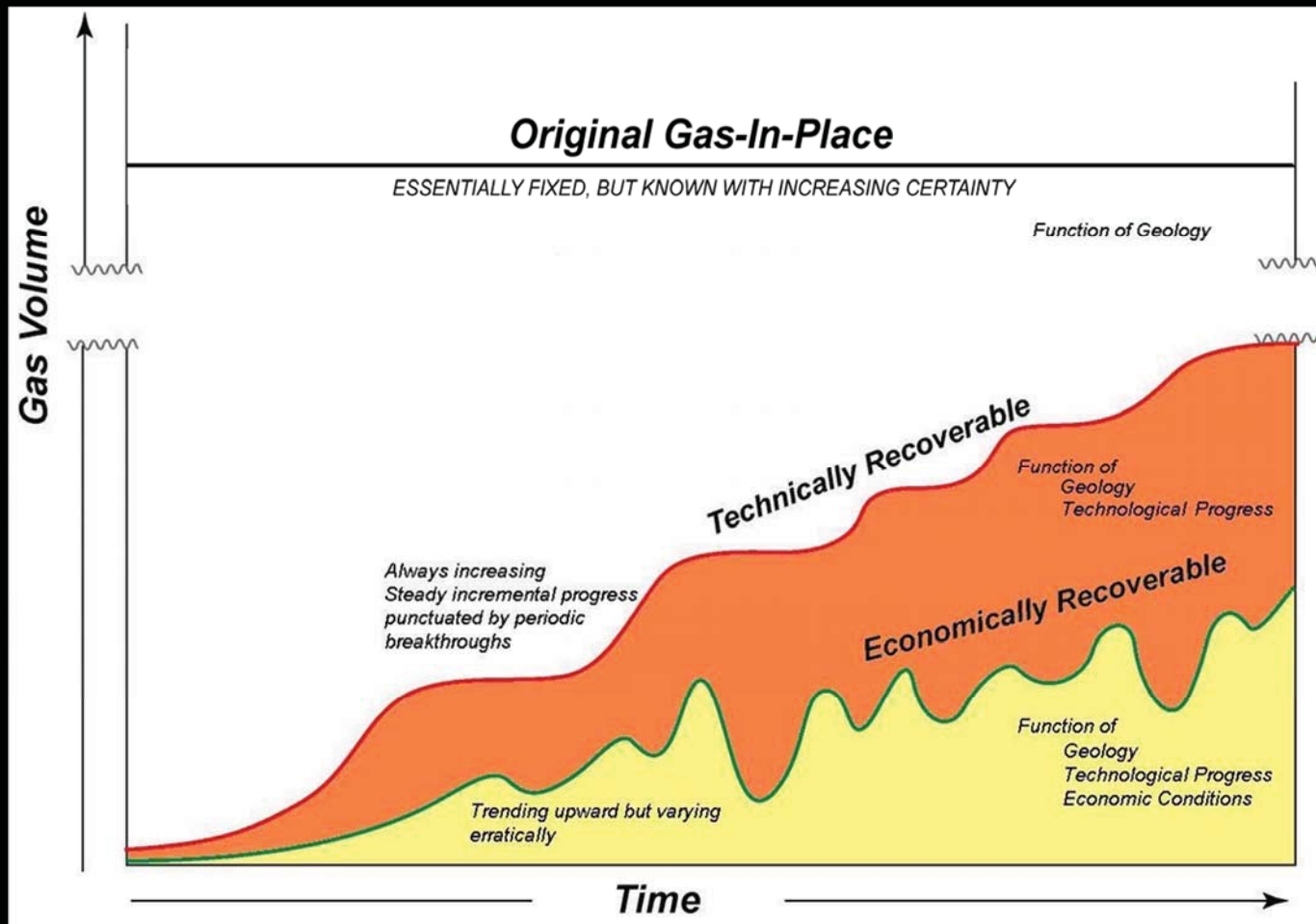
By using both approaches, we may be able to estimate and capture the evolution of recovery factors.

Methodology and Data

The study will be divided into 2 phases to accomodate both approaches.

Phase 1 will use the **geology-based approach** to estimate total **original gas-in-place**.

total original gas-in-place =
free gas-in-place + **adsorbed** gas-in-place

Free Gas-In-Place

$$GIP_{free} = (\phi_{eff} * (1 - S_w) * H_{fm} * A_{gc}) / FVF$$

Adsorbed Gas-in-Place

$$GIP_{adsorb} = G_c * \rho_{fm} * H_{fm} * A_{gc}$$

Methodology and Data

Where will all of the data be obtained?

H_{fm}, ρ_{fm}, ϕ, and S_w
are derived from well logs
with
ϕ and S_w adjusted for V_{sh} and V_{ker}

TOC
is taken from published core-based studies

G_c
is determined from TOC and pressure

FVF
is derived from temperature, pressure, and gas compressibility

Methodology and Data

The study is being conducted using *public data from*:

- Well logs (WVGES, IHS)
  - Depth / Thickness / Extent
  - Porosity
  - Resistivity
  - Temperature

- Literature (WVGES, USGS, U.S. DOE/EGSP, WVU)
  - Vitrinite reflectance data
  - Core data
    - Volume of shale
    - Volume of kerogen
    - Total organic carbon

Source: IGT, 1986

- Operator reports (WVGES)
  - Pressure
  - Production volumes
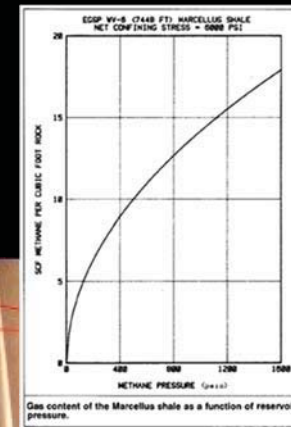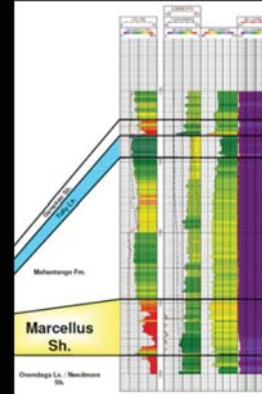
PRD_YEAR	ANN_GAS
2005	12556
2006	6047
2007	5803
2008	8272
2009	7720

Methodology and Data

However, the study could be improved with
additional data from core related to:

Porosity

Volume of shale -
Volume of kerogen -
Total organic carbon

Gas content and
Total organic carbon-gas content functions

Methodology and Data:
Phase 1 Assessment Steps

1. Select wells

   Marcellus Shale
   Resource Assessment
   Study Wells

2. Correlate well logs

3. Extract data from well logs

4. Derive additional required data

5. Characterize reservoir

6. Estimate volumes

7. Correct and refine data as necessary

Methodology and Data:
Step 1—Select Wells

Marcellus Shale
Reservoir Characterization
Study Wells in Gray
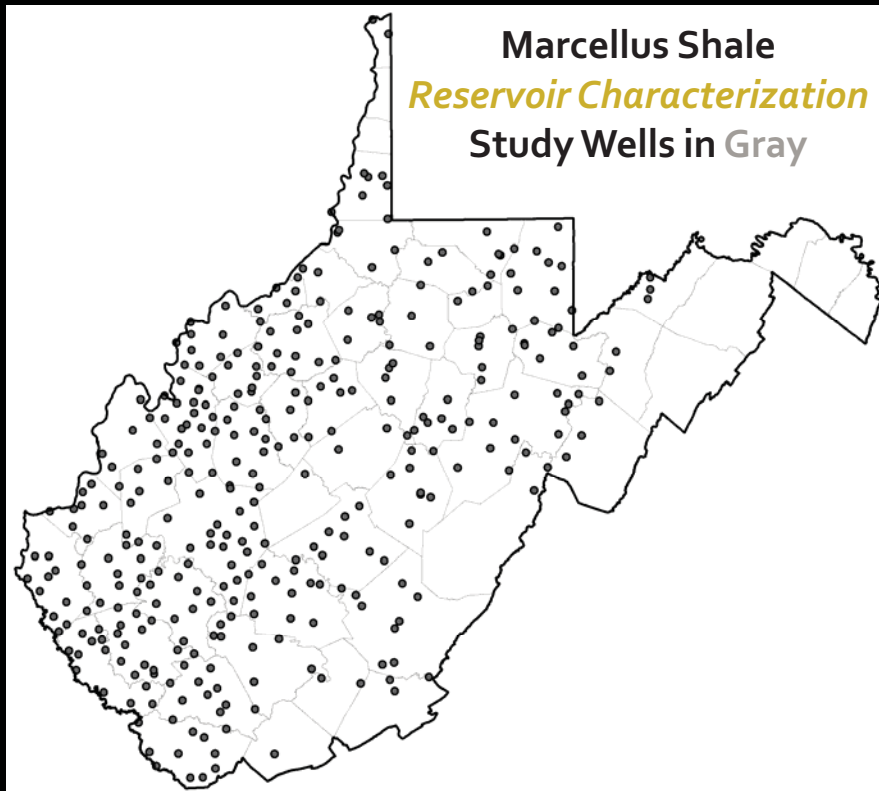
Based on
- Vertical wells
- Geographic distribution
- Log availability
  - GR, POR, RES
  - Newest vintage
  - Digital data

Marcellus Shale
Volumetric Estimation
Study Wells in Red
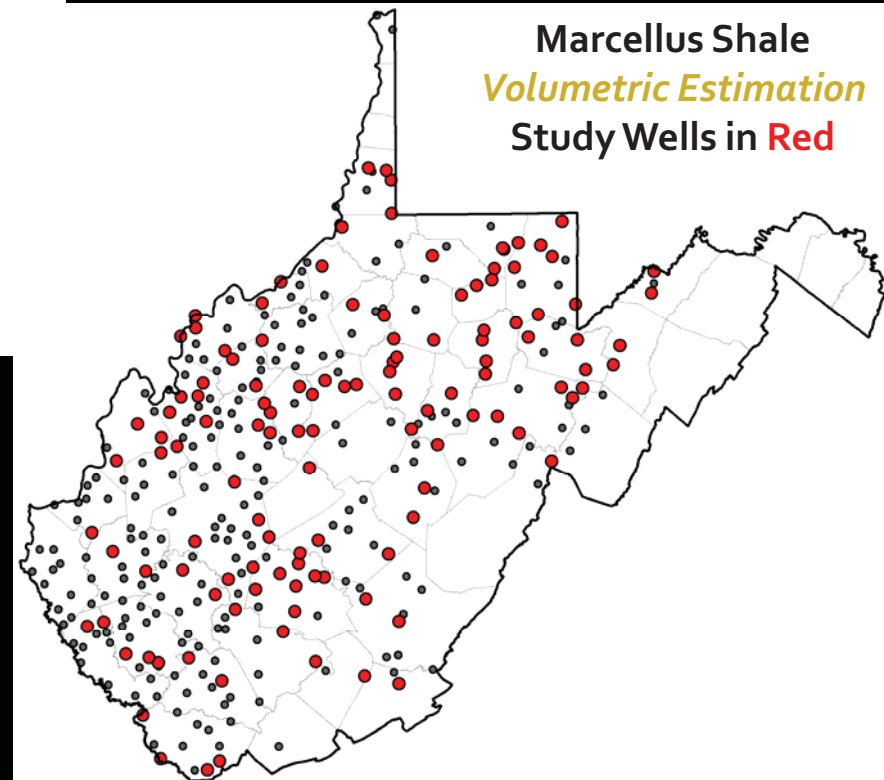
Methodology and Data:
Step 2—Correlate Well Logs
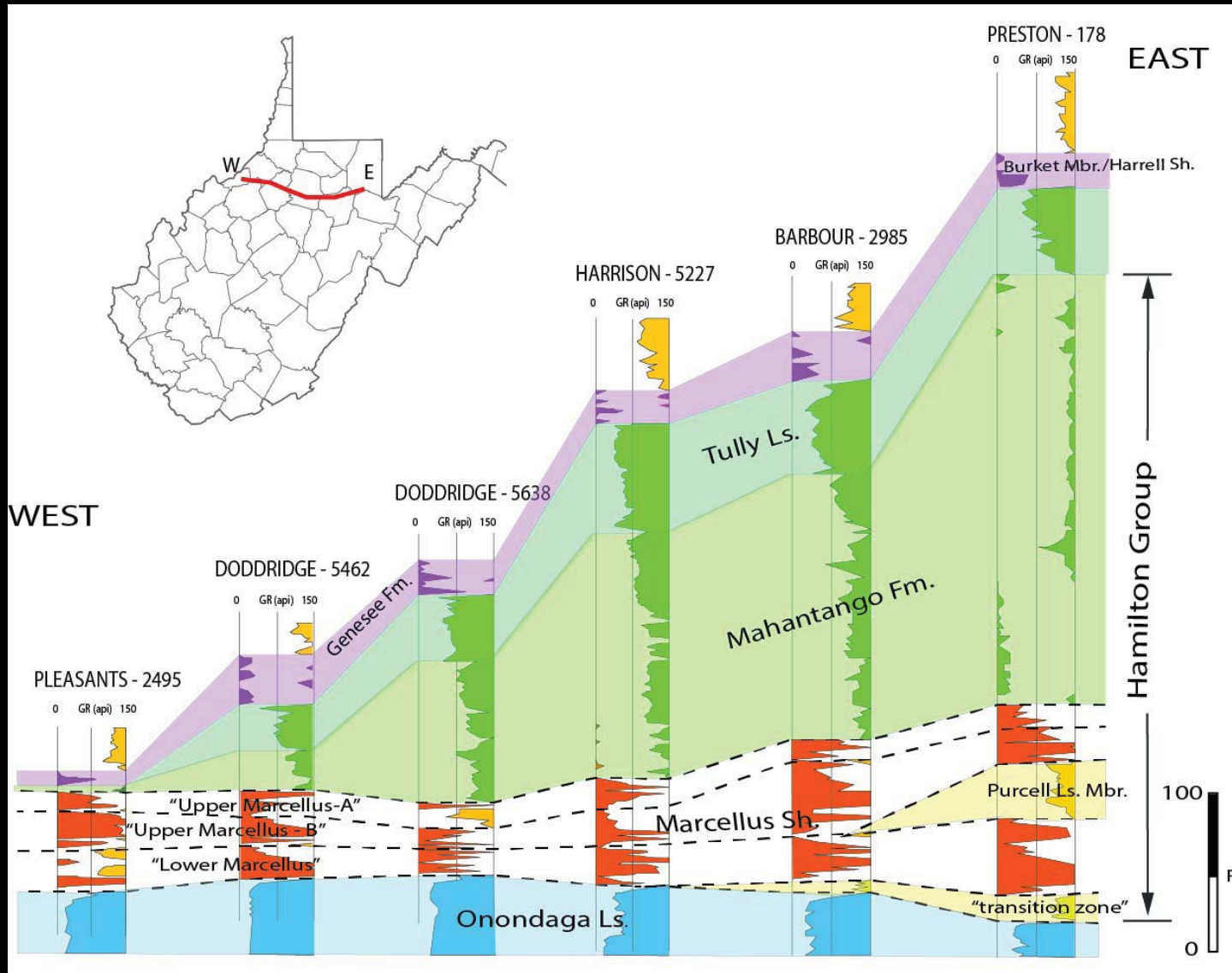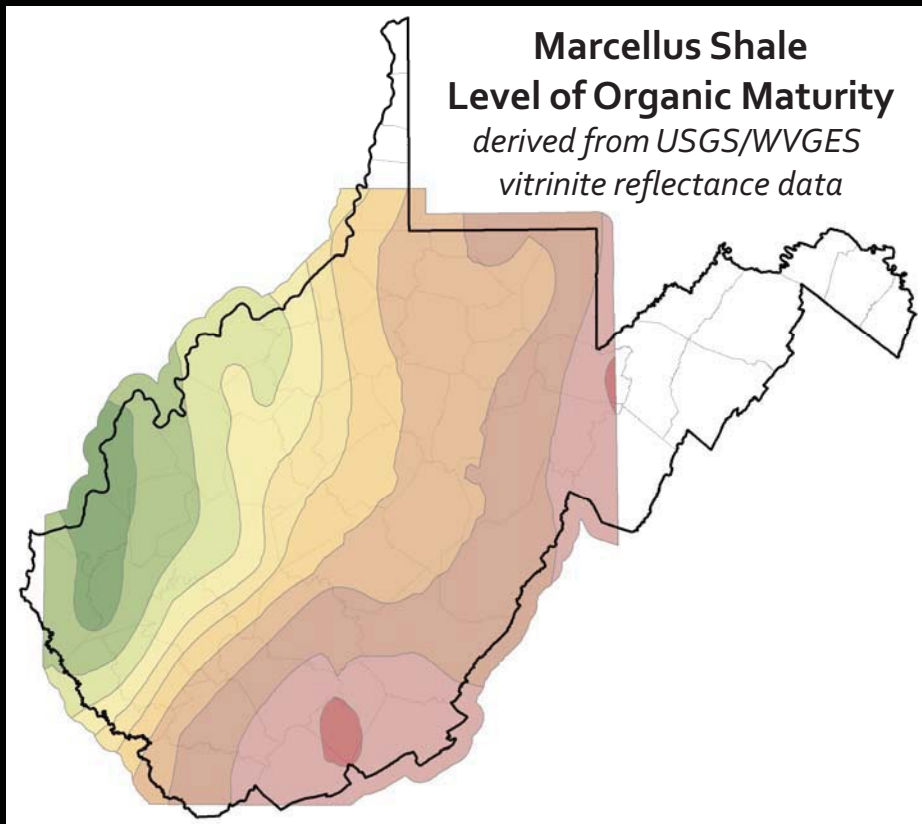
Methodology and Data:
Step 3—Extract Data from Well Logs
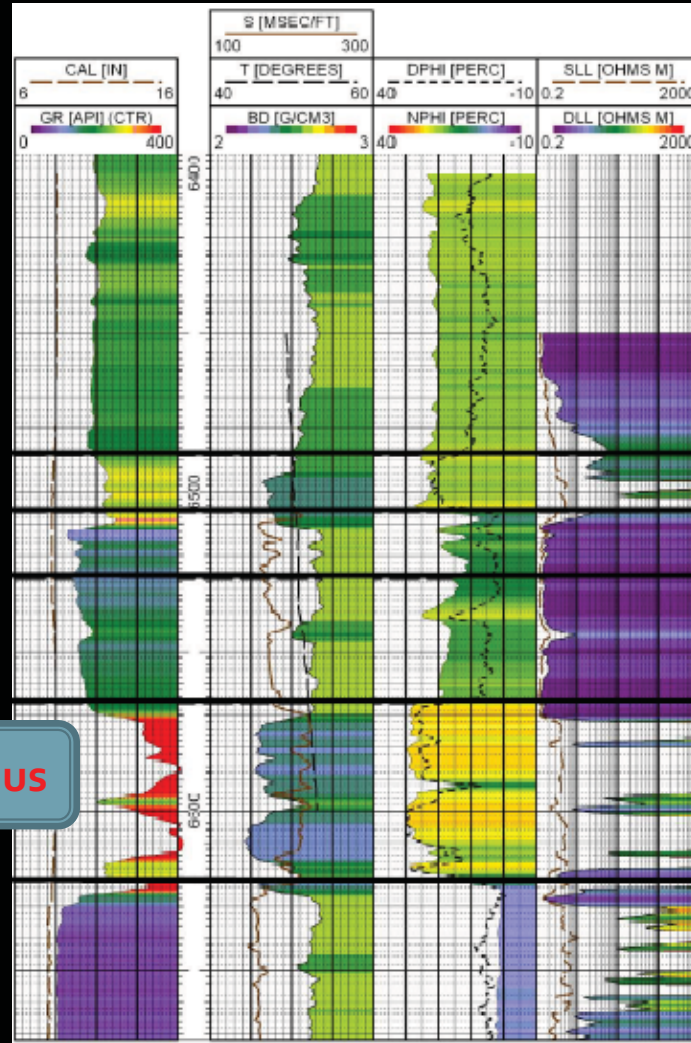
- Depth

- Thickness

- Porosity

- Resistivity

- Temperature

Methodology and Data:
Step 4—Derive Additional Required Data

**Marcellus Shale
Level of Organic Maturity**
*derived from USGS/WVGES
vitrinite reflectance data*

**"Upper Marcellus"
Total Organic Carbon
(*in Percent*)**
*extrapolated from data in
Wang 2012*

>10%

7-10%

<3%

**"Lower Marcellus"
Total Organic Carbon
(*in Percent*)**
*extrapolated from data in
Wang 2012*

>10%

6-8%

< 6%

< 6%

8-10%
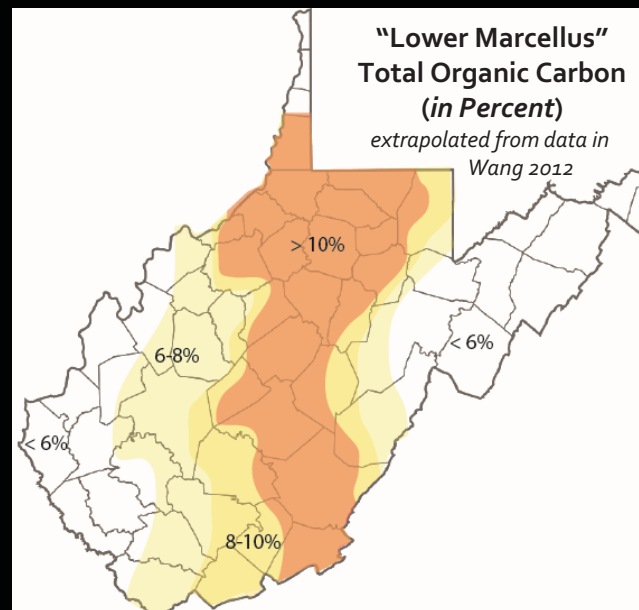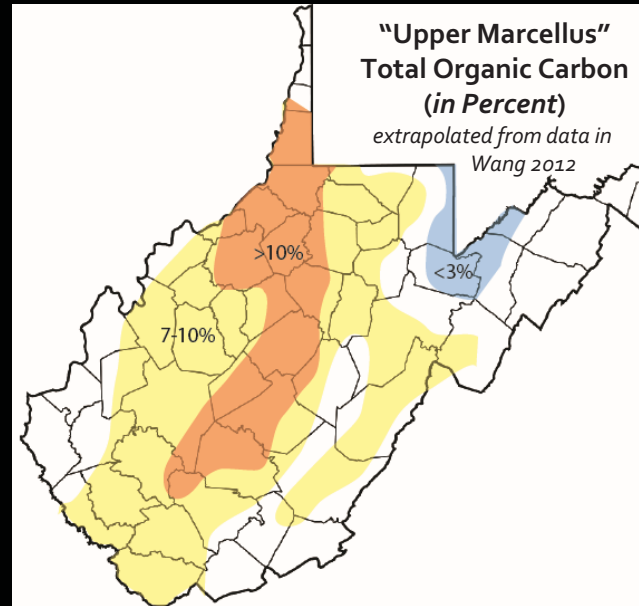
Derive:
*LOM
TOC*

*Derived from
data in USGS/WVGES
(2005)*

*Extrapolated from
data in Wang
(2012)*

*Calibrated to
limited public
core data*

EGSP WV#6

EGSP WV#7

Others

Methodology and Data:
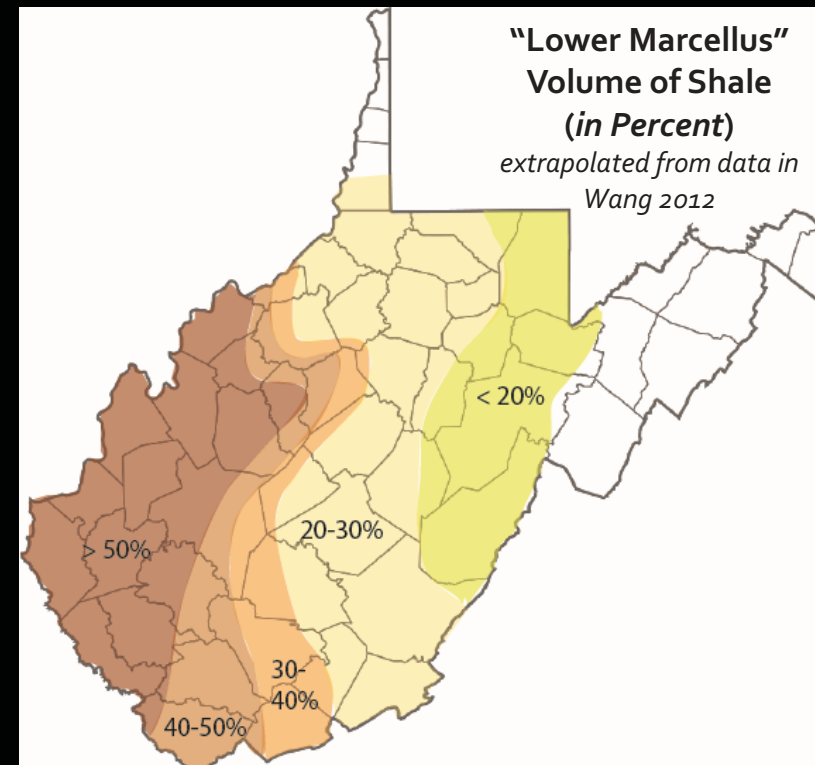## *Step 4—Derive Additional Required Data*

"Upper Marcellus" Volume of Shale (*in Percent*) extrapolated from data in Wang 2012
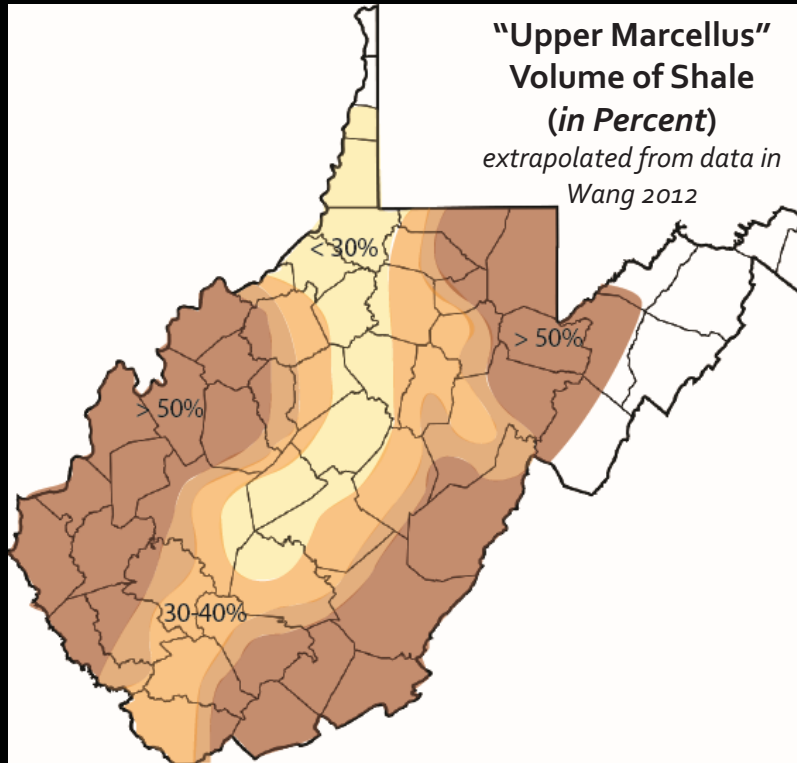
And, derive: V_{sh}

Extrapolated from data in Wang(2012)

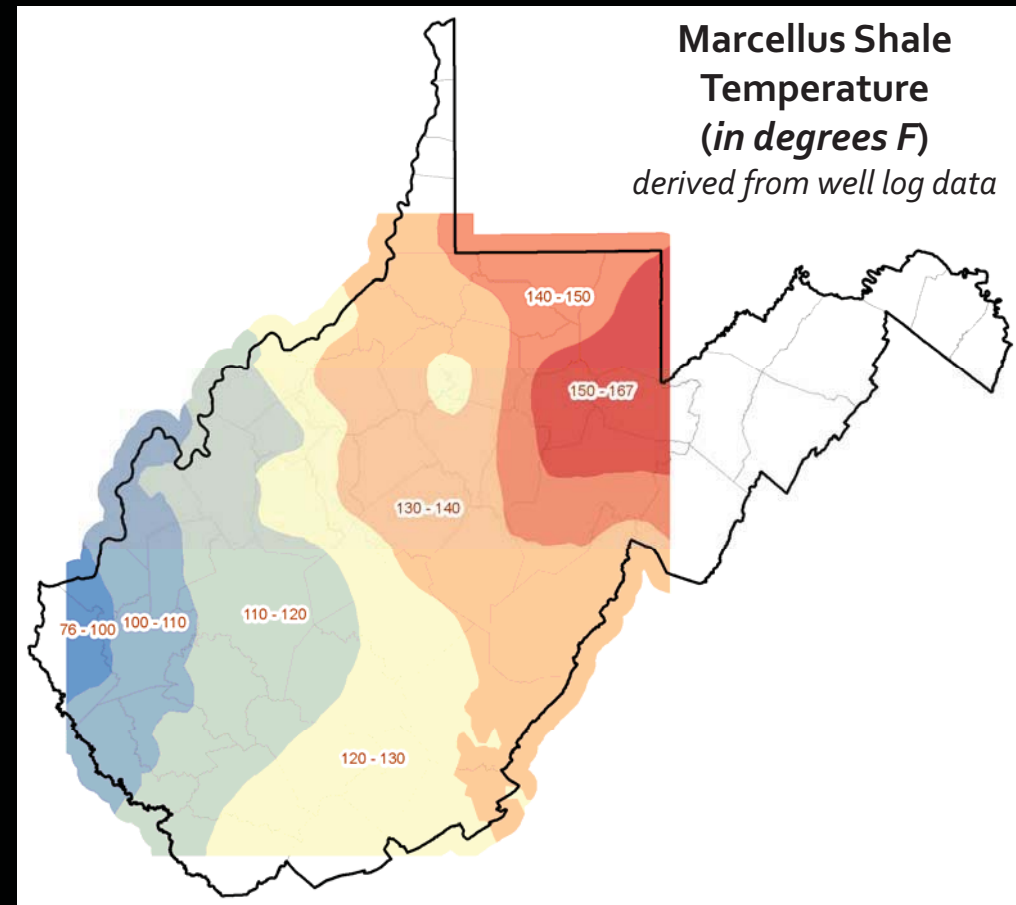*Calibrated to limited public core data*
EGSP WV#6, EGSP WV#7, Others

"Lower Marcellus" Volume of Shale (*in Percent*) extrapolated from data in Wang 2012

Preliminary Results:
Step 5—Characterize Reservoir

Marcellus Shale Pressure Gradient (*in psi/ft*)
from operator–reported data
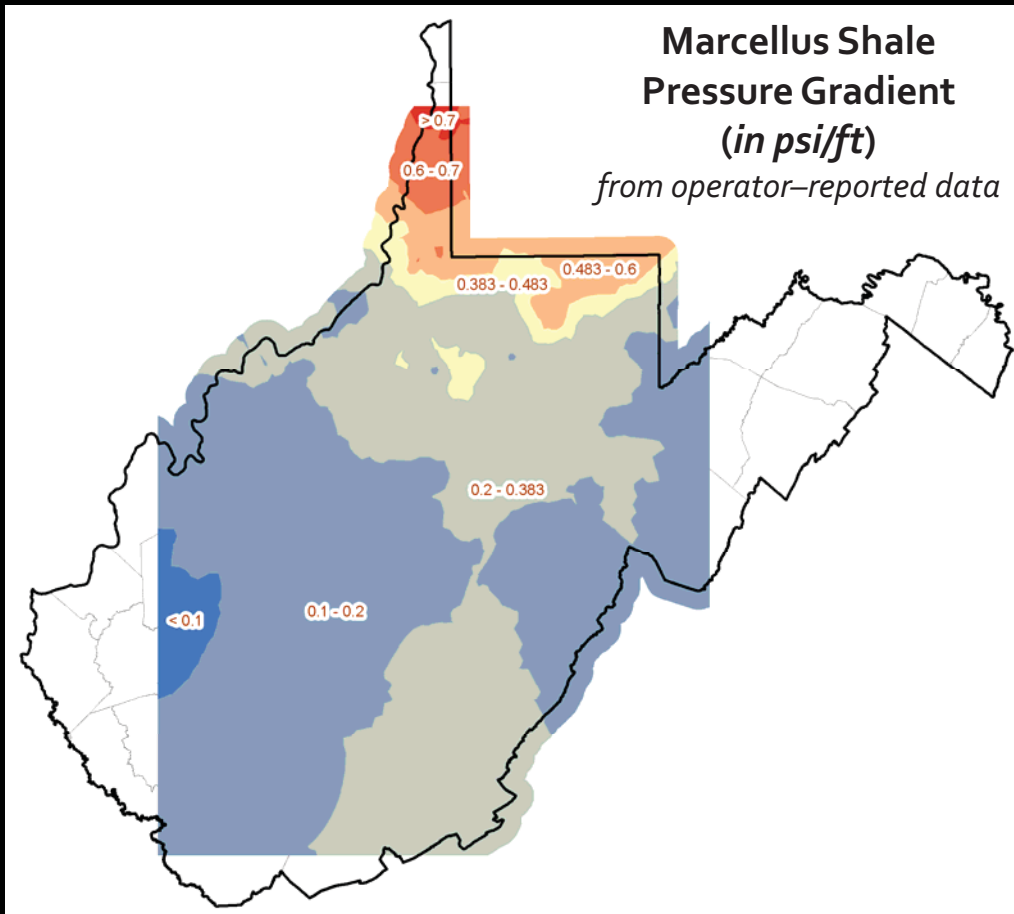
Develop: *pressure* and *temperature maps*

Marcellus Shale Temperature (*in degrees F*)
derived from well log data

Preliminary Results:
Step 5—Characterize Reservoir

**Marcellus Shale
"Upper-A"; "Upper-B" and "Lower"
Thickness (*in feet*)**
derived from well log data

100 - 120
> 200
80 - 100
180 - 200
160 - 180
40 - 60
120 - 140
60 -80
0 - 1
140 - 160
1 - 20
20 - 40
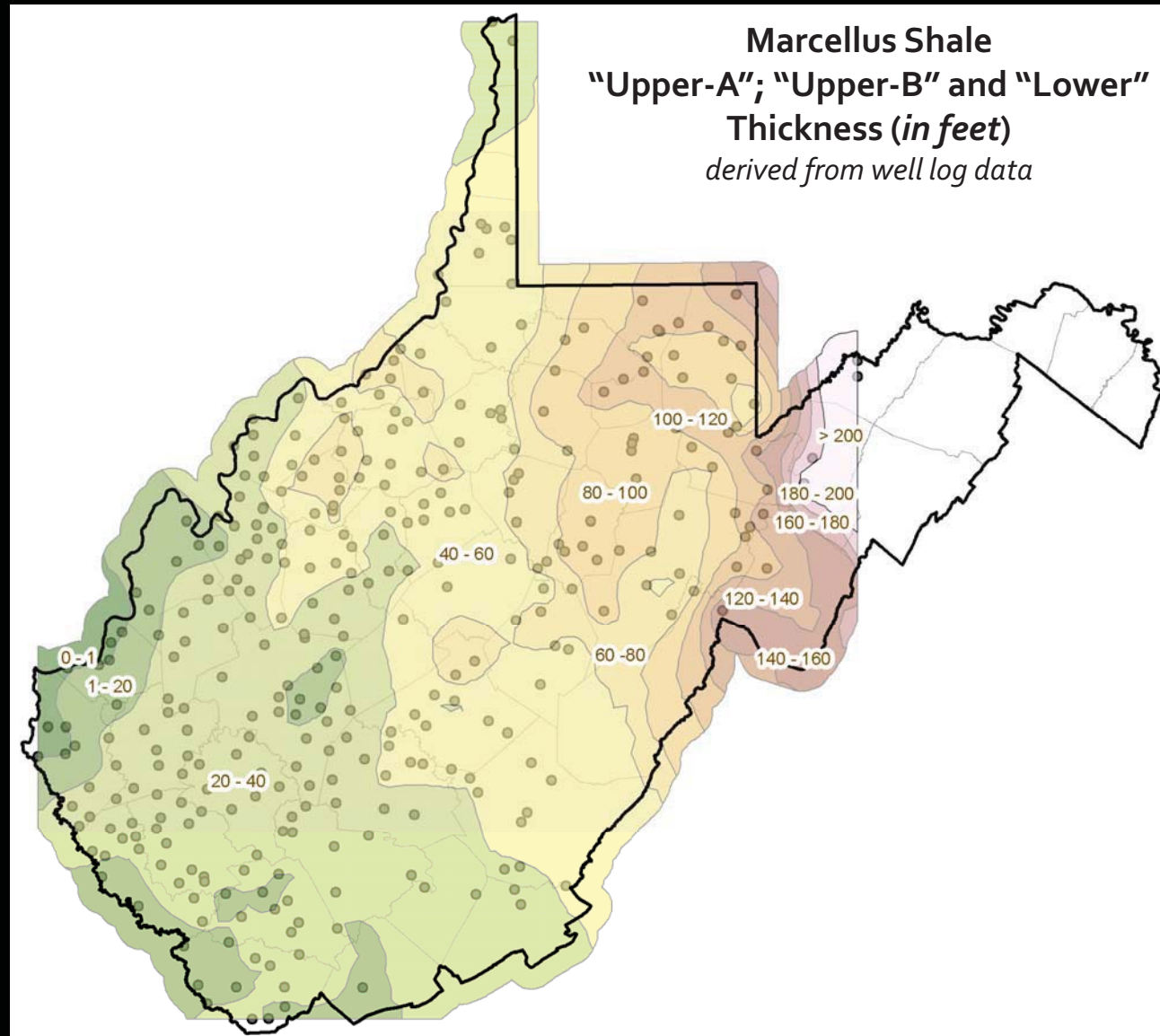
Develop:
*additional
basic
maps
such as
thickness*

Preliminary Results:
Step 5—Characterize Reservoir

Marcellus Shale
"Upper-A"; "Upper-B" and "Lower"
Percentage of the Interval
100 API Over Gamma Ray Baseline
derived from well log data

10 - 20%
20 - 30%
30 - 40%
0 - 10%
40 - 50%
50 - 60%
60 - 70%
70 - 80%
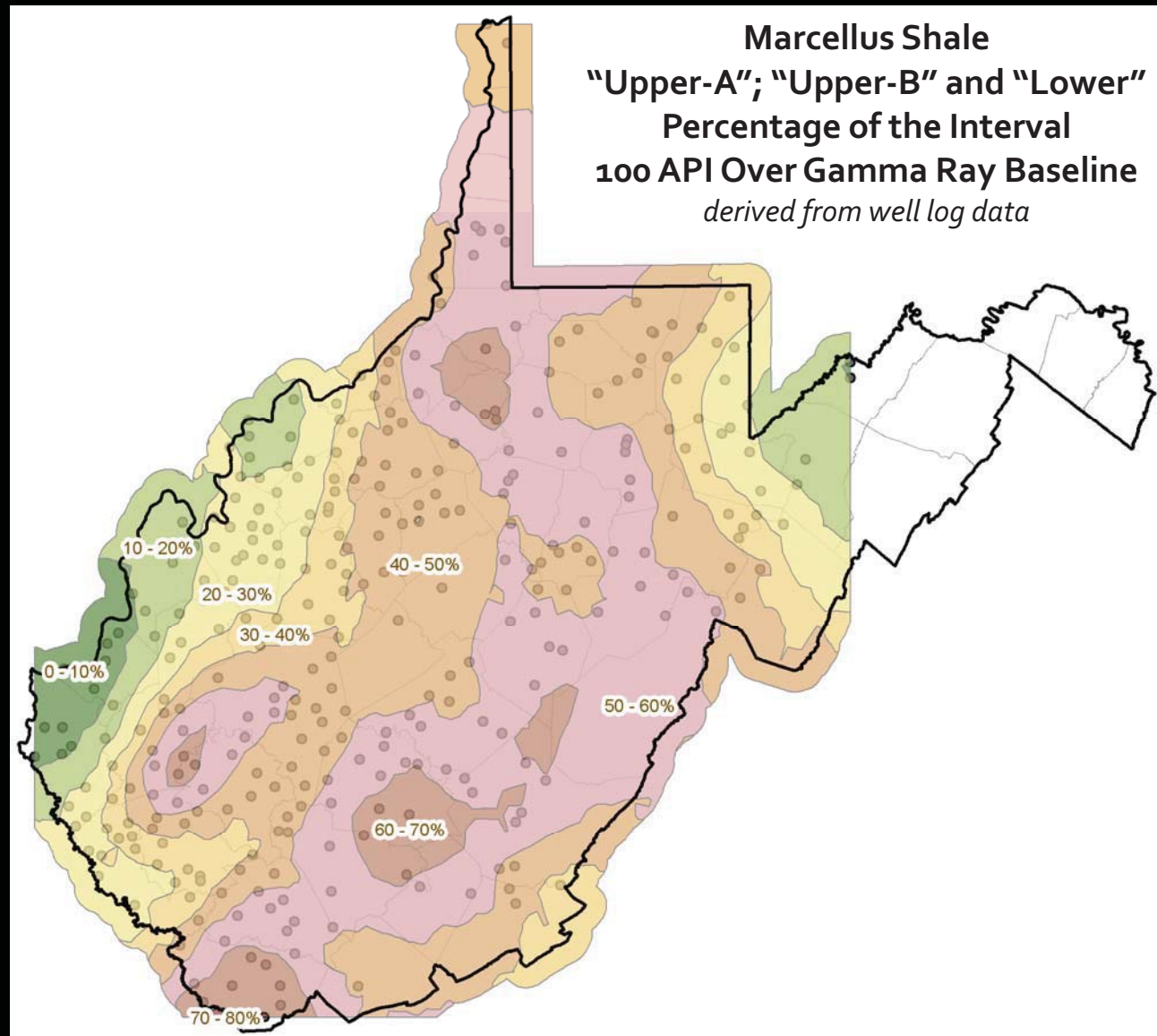
Develop:
*specialized
maps
such as
high
organic
content*

Preliminary Results:
Step 6—Estimate Volumes
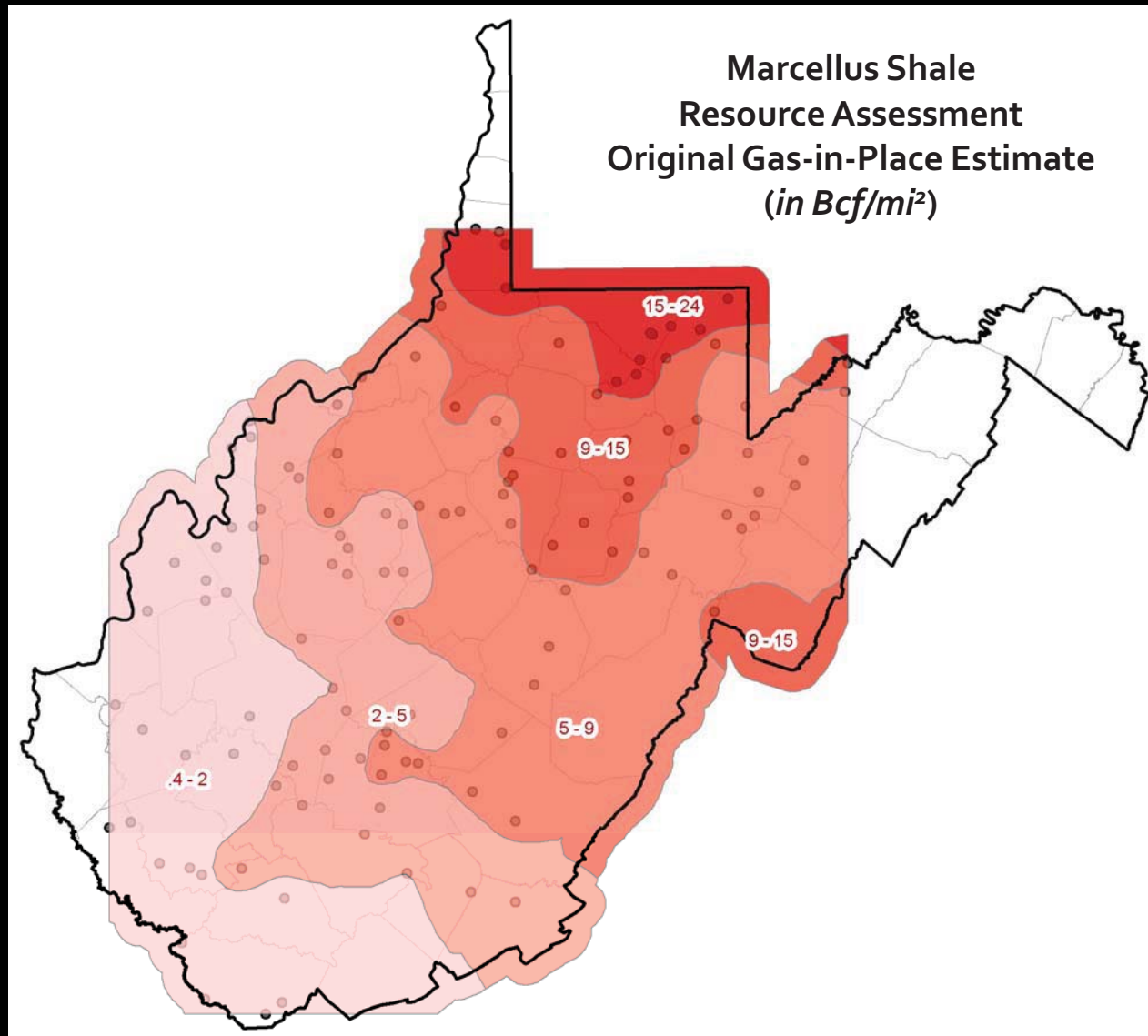
Develop:
*basic
map*
related to
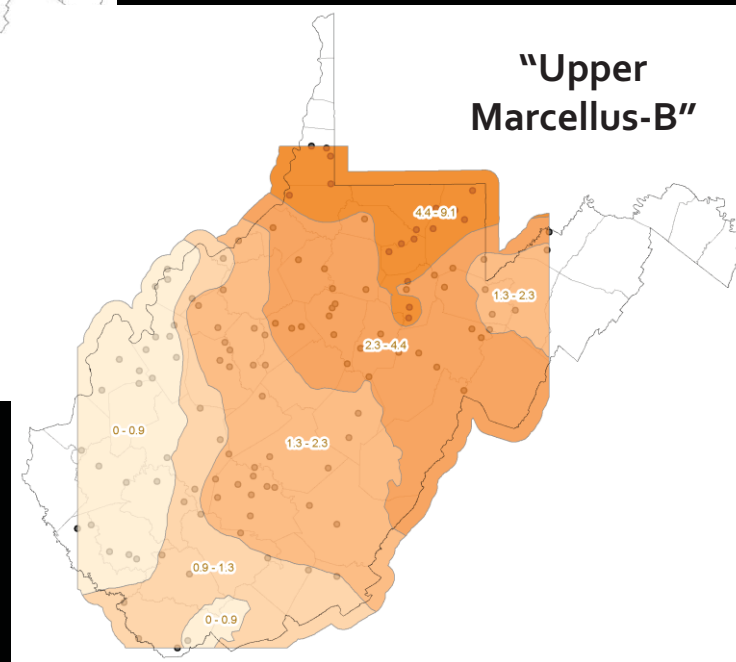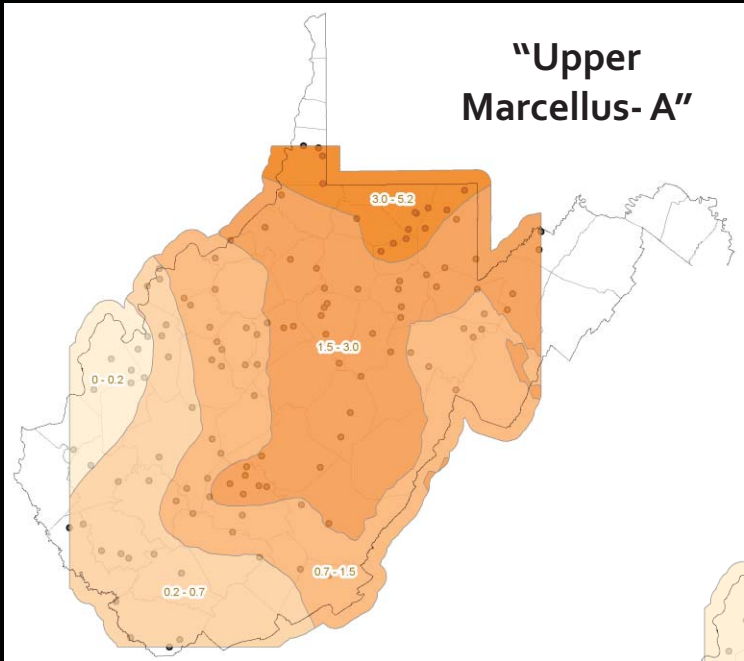*volumes*

Preliminary Results:
Step 6—Estimate Volumes

"Upper
Marcellus- A"

3.0 - 5.2

1.5 - 3.0

0 - 0.2

0.7 - 1.5

0.2 - 0.7
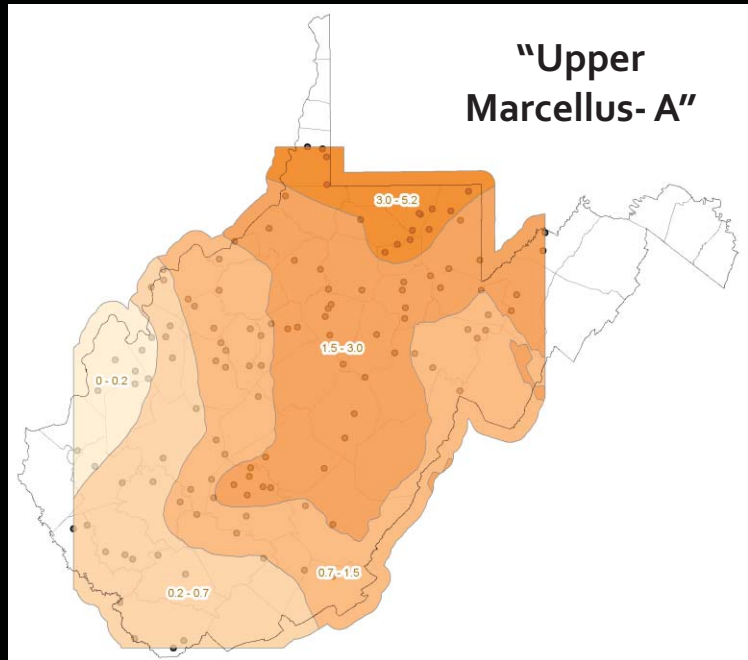
**Marcellus Shale
Resource Assessment
Original Gas-in-Place Estimate
(*in Bcf/mi²*)**

Develop:
*specialized
maps
related to
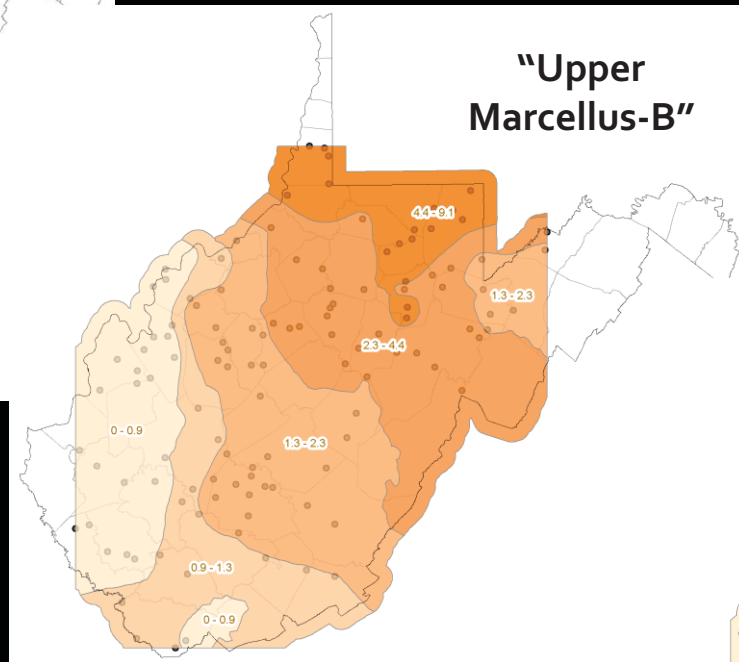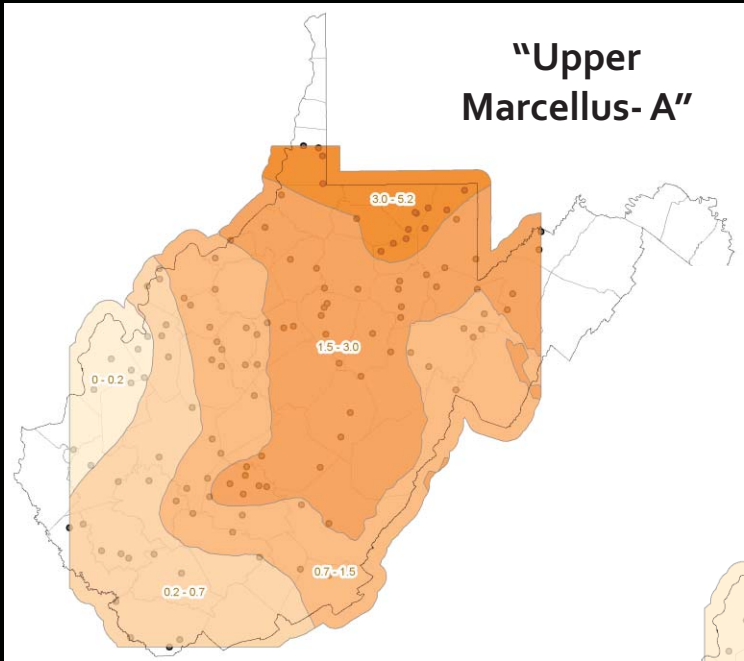volumes*

Source: WVGES
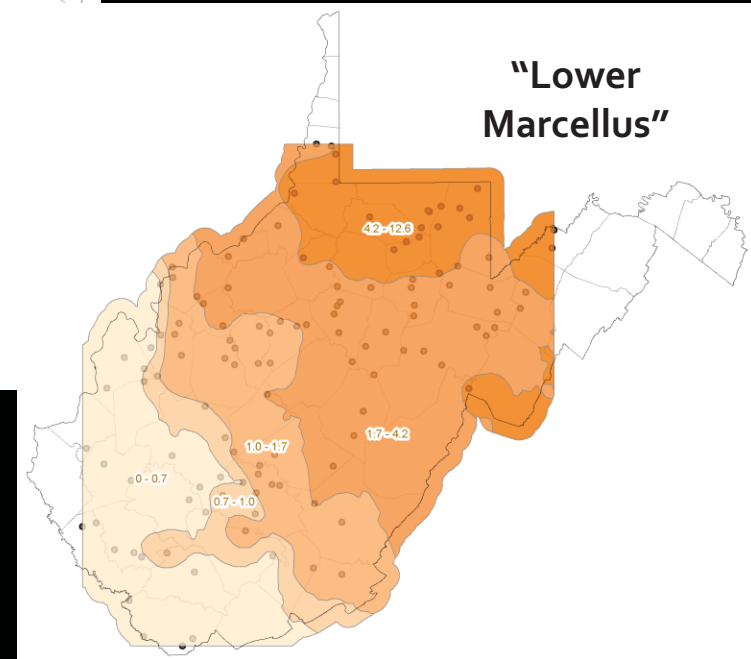Date: May 17, 2013

Preliminary Results:
Step 6—Estimate Volumes

"Upper Marcellus- A"

3.0 - 5.2

1.5 - 3.0

0 - 0.2

0.2 - 0.7

0.7 - 1.5

**Marcellus Shale
Resource Assessment
Original Gas-in-Place Estimate
(*in Bcf/mi²*)**

"Upper Marcellus-B"

4.4 - 9.1

1.3 - 2.3

2.3 - 4.4

0 - 0.9

1.3 - 2.3

0.9 - 1.3

0 - 0.9

Source: WVGES
Date: May 17, 2013

Preliminary Results:
Step 6—Estimate Volumes

"Upper Marcellus- A"

"Upper Marcellus-B"

"Lower Marcellus"

Marcellus Shale
Resource Assessment
Original Gas-in-Place Estimate
(*in Bcf/mi²*)

Preliminary Results:
Step 6—Estimate Volumes

Marcellus Shale
"Upper-A"; "Upper-B" and "Lower"
Ratio of Adsorbed to Free Gas
derived from well log data
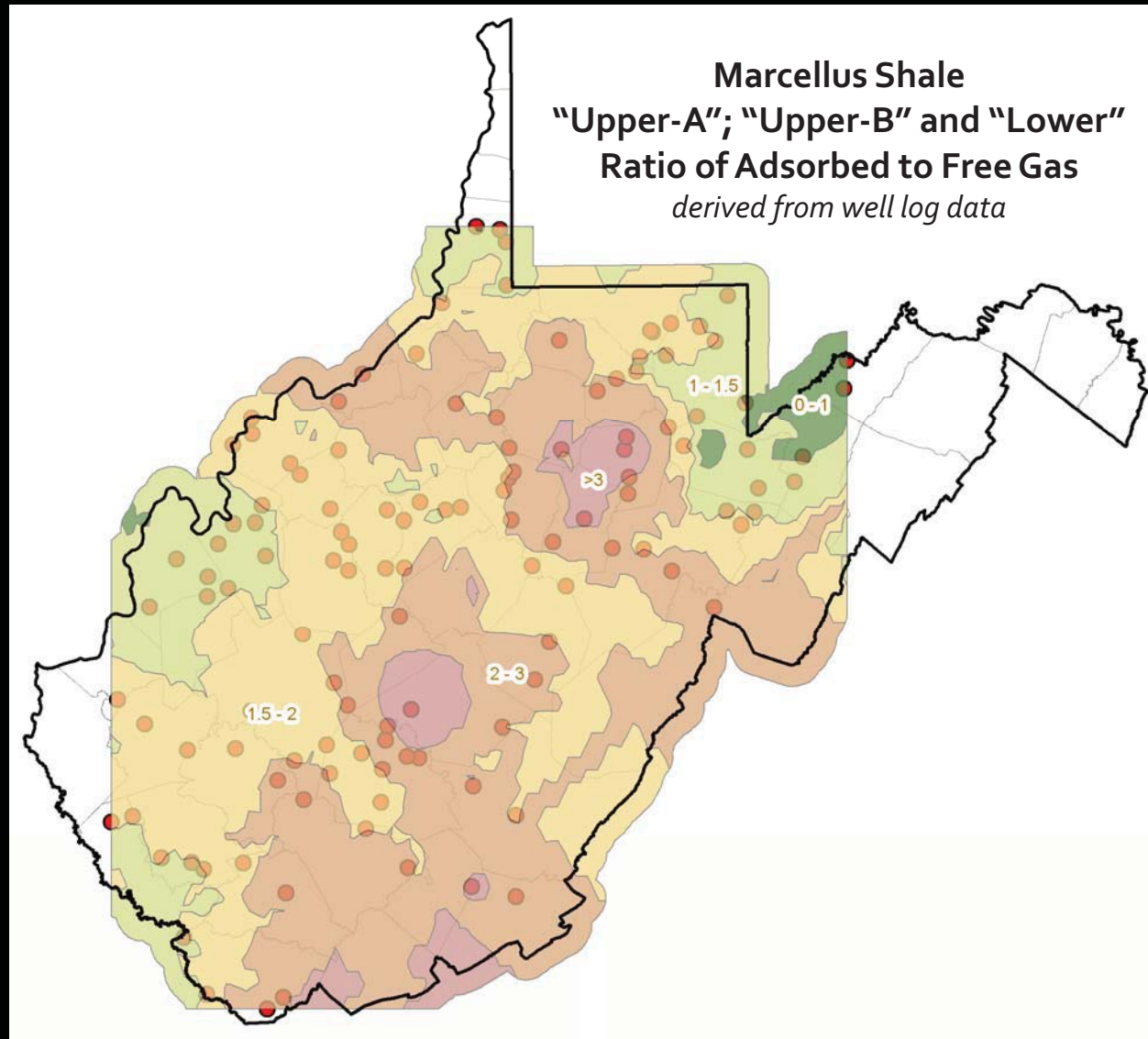
Develop:
*additional
specialized
maps*

Preliminary Results:
Step 6—Estimate Volumes

And the ***preliminary*** number is:

Source: WVGES
Date: May 17, 2013

Preliminary Results:
Step 6—Estimate Volumes

And the *preliminary* number is:

122 Tcf
gas-in-place

Source: WVGES
Date: May 17, 2013

Future Work:
Finalize Assessment

- Incorporate additional well data

- Recalibrate all well data to core
    Investigate further:
    1. porosity
    2. V_{sh}-V_{ker}
    3. G_c and TOC-G_c functions

- Refine volume estimates

- Investigate production and recovery factor(s)—Phase 2 of Study

Future Work:
Release Results and Products

For the Marcellus Shale in West Virginia:

- estimate of **total original natural gas-in-place volume (refined)**

- estimate of **current recoverable natural gas volume**

- **cross-sections** and **maps** including maps for:
wells, location / extent, thickness, depth, pressure, and volumes

- up-to-date, publicly-accessible **web-based map application**

Future Work:
Release Results and Products

Data will be updated and new maps and features will be added to the ***Marcellus Shale web-based map application***.

Acknowledgements

IHS

Mike Hohn, Mary Behling, Jessica Moore, Susan Kite, Sam McCreery, John Bocan, John Saucer, Phil Dinterman, Ron McDowell, and Tom Repine
West Virginia Geological and Economic Survey

Doug Miller, Beth King, and Kelly Moran
Penn State

Questions, Comments, or Suggestions?