# Strategy for Assessment of European Gas Shales*

**Donald L. Gautier**[1]

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## Abstract

In cooperation with European geoscience organizations, the United States Geological Survey (USGS) has begun an assessment of potential additions to reserves from continuous-type gas and oil accumulations in fine-grained rocks of Europe. Development of continuous-type accumulations has transformed the energy outlook of Canada and the United States and the degree to which such accumulations can be developed outside North America may determine the future of European and global energy markets. Unlike conventional reservoirs, continuous-type accumulations in mudstones:

1. are laterally extensive,
2. do not necessarily coincide with structural and stratigraphic traps,
3. lack well defined down-dip petroleum/water contacts,
4. do not seem to be localized by buoyancy forces,
5. typically contain both source and reservoir in the same formation.

Drawing on the geological circumstances and well performance observed in analogous North American gas shales, USGS has developed a probabilistic, geology-based methodology with which to evaluate the potential for technically recoverable natural gas and oil in continuous-type accumulations in Europe. Rather than calculating in-place resources and estimating recovery efficiencies, the current USGS methodology is performance-based. Candidate formations are screened for particular geological criteria and geologically defined assessment units (AU) are specified. Potential additions to reserves in each AU are evaluated using four input distributions:

1. play-level risk,
2. volumes of potentially productive formations within the AU,
3. optimal well density,
4. estimated ultimate recovery per well.

The four distributions are combined in a Monte Carlo simulation that yields a probability density of recoverable resources that can be further evaluated for resource/cost relationships.

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# Strategy for Assessment of European Gas Shales

**Donald L. Gautier**

**AAPG – ICE**

**Milan 26 October 2011**

U.S. Department of the Interior
U.S. Geological Survey

# Contents of this Presentation

- Introduction to continuous-type accumulations
- Global screening criteria
- Woodford Shale Example
- Use of analogs
- EURs in Performance-based assessment
- Next steps
- Comment on USGS vs EIA/ARI estimates

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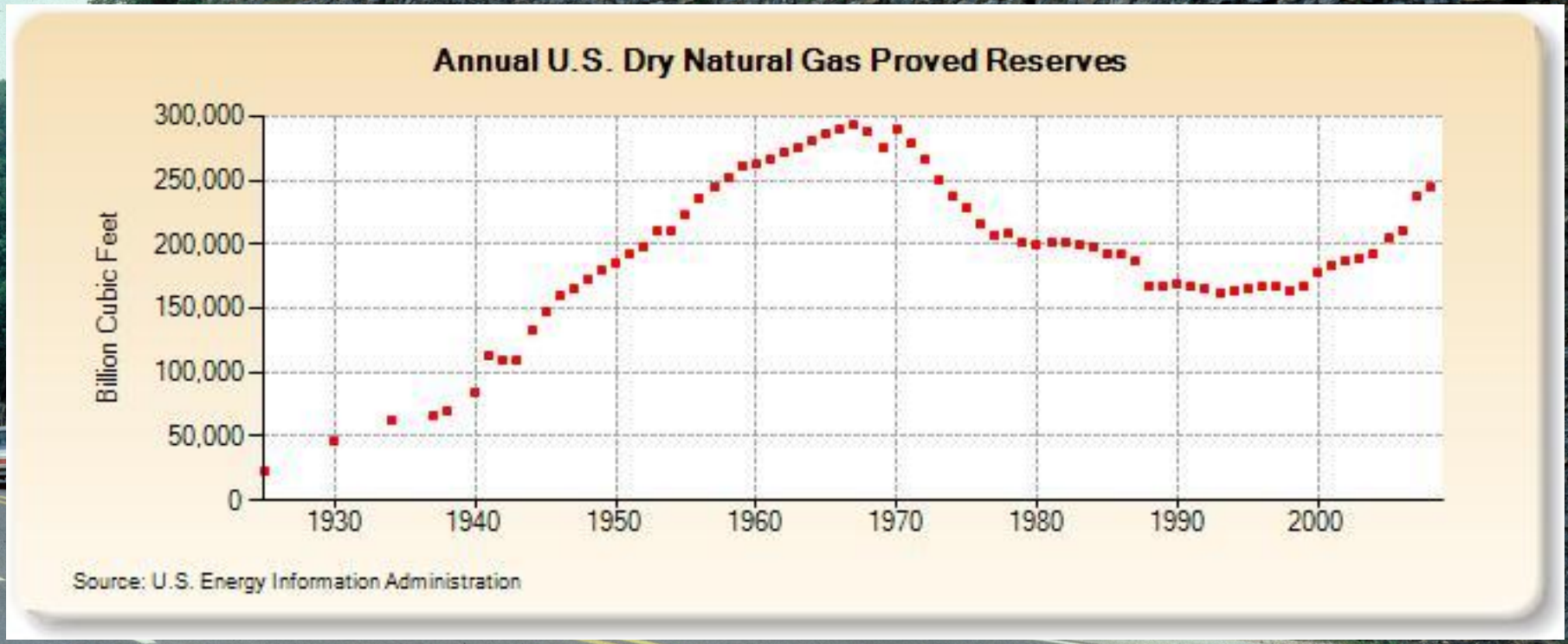
# Continuous Resources Have Changed the Energy Outlook in North America

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# Is the North American Experience Applicable to European Resources?

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# Current Active Partner Institutions for Assessment of Northern Europe

- Denmark:  GEUS
- Germany:  BGR
- Poland:  PGI
- The Netherlands:  TNO

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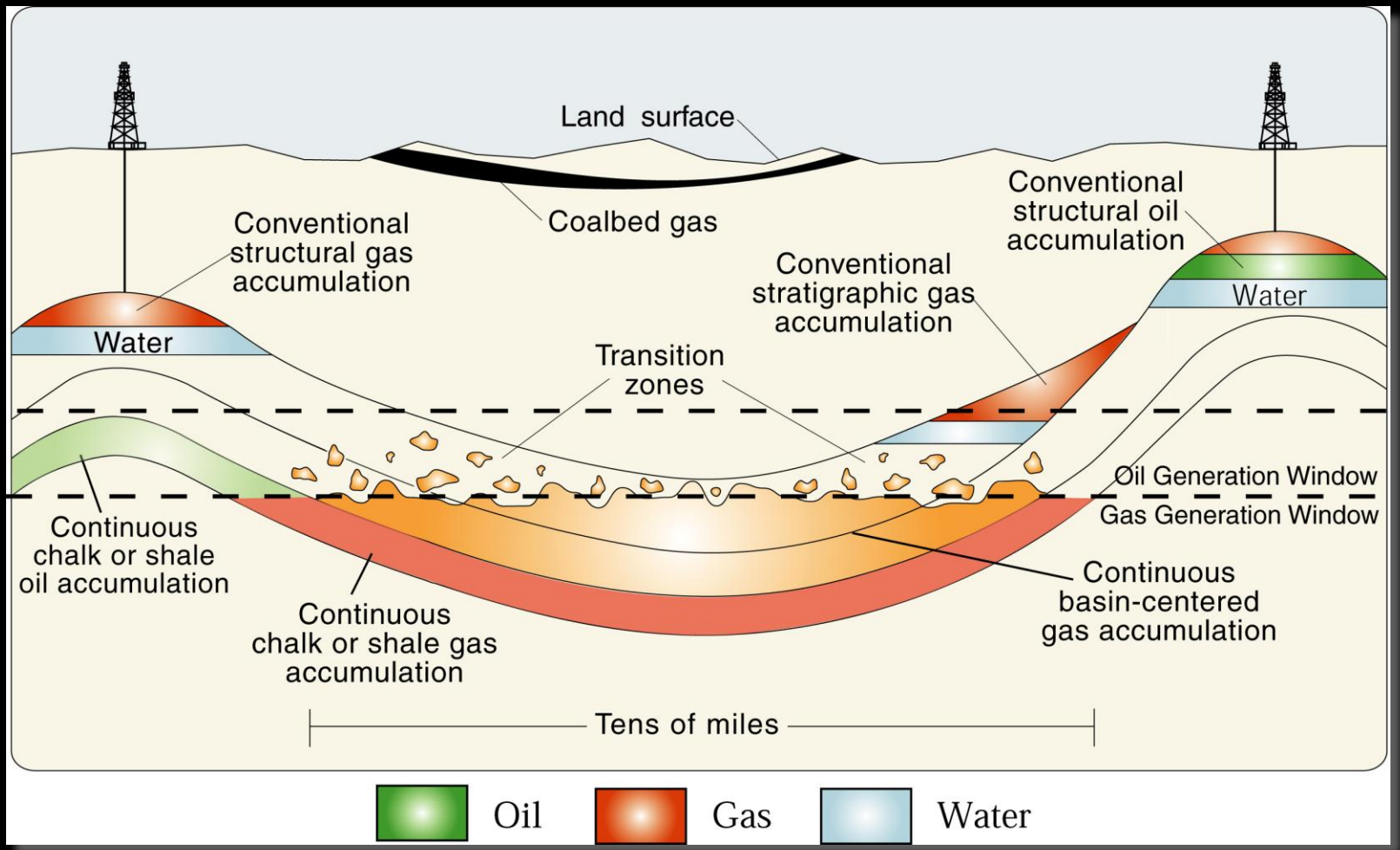
# We Define Resources Geologically

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# Continuous Resources – Geological Criteria

- Laterally extensive
- Not in structural or stratigraphic traps
- Lack down-dip gas- and oil-water contacts
- Not localized by buoyancy forces
- Source and reservoir in the same formation

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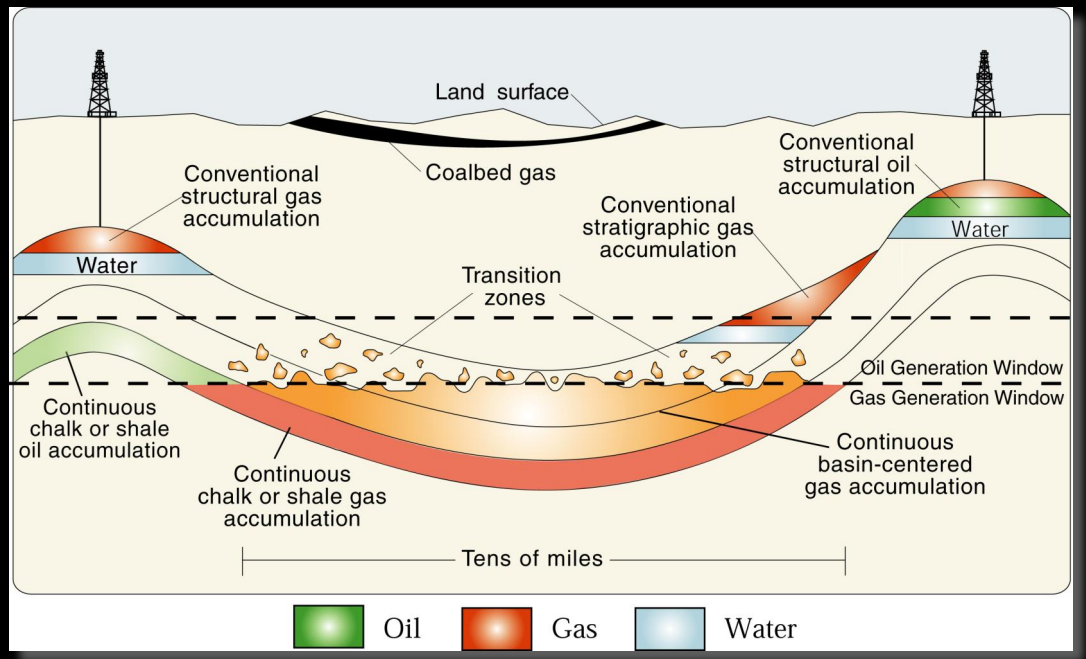
# Types of Continuous Resources

- Gas in source rock systems
- Oil in source rock systems
- Oil in low-permeability reservoirs
- Basin-center gas
- Coal-bed methane
- Methane hydrates
- Heavy oil & tar

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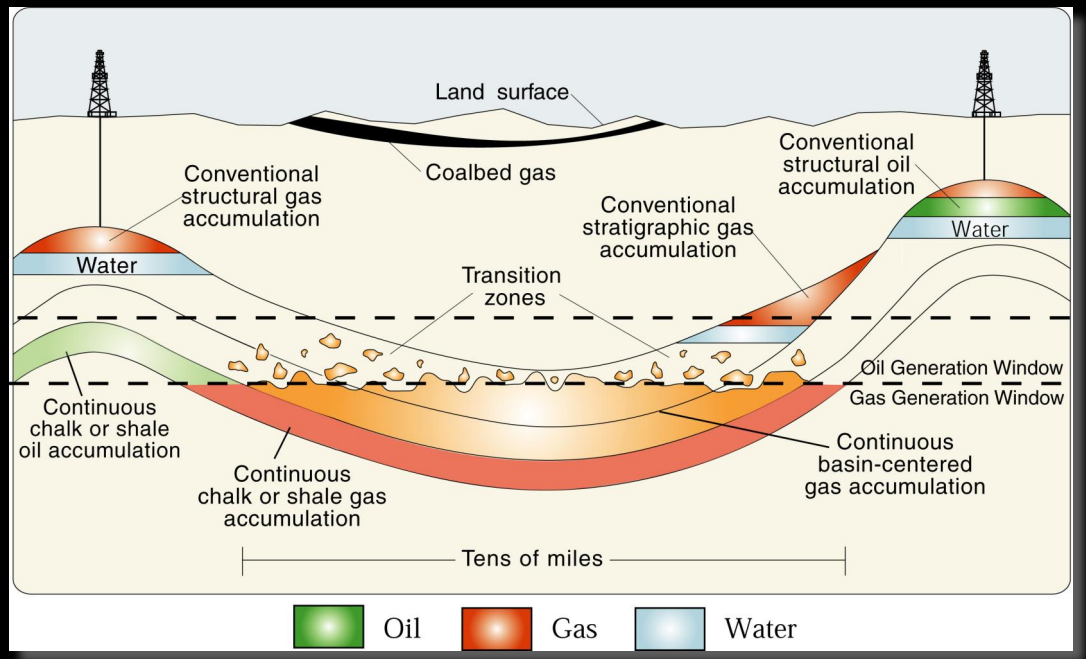


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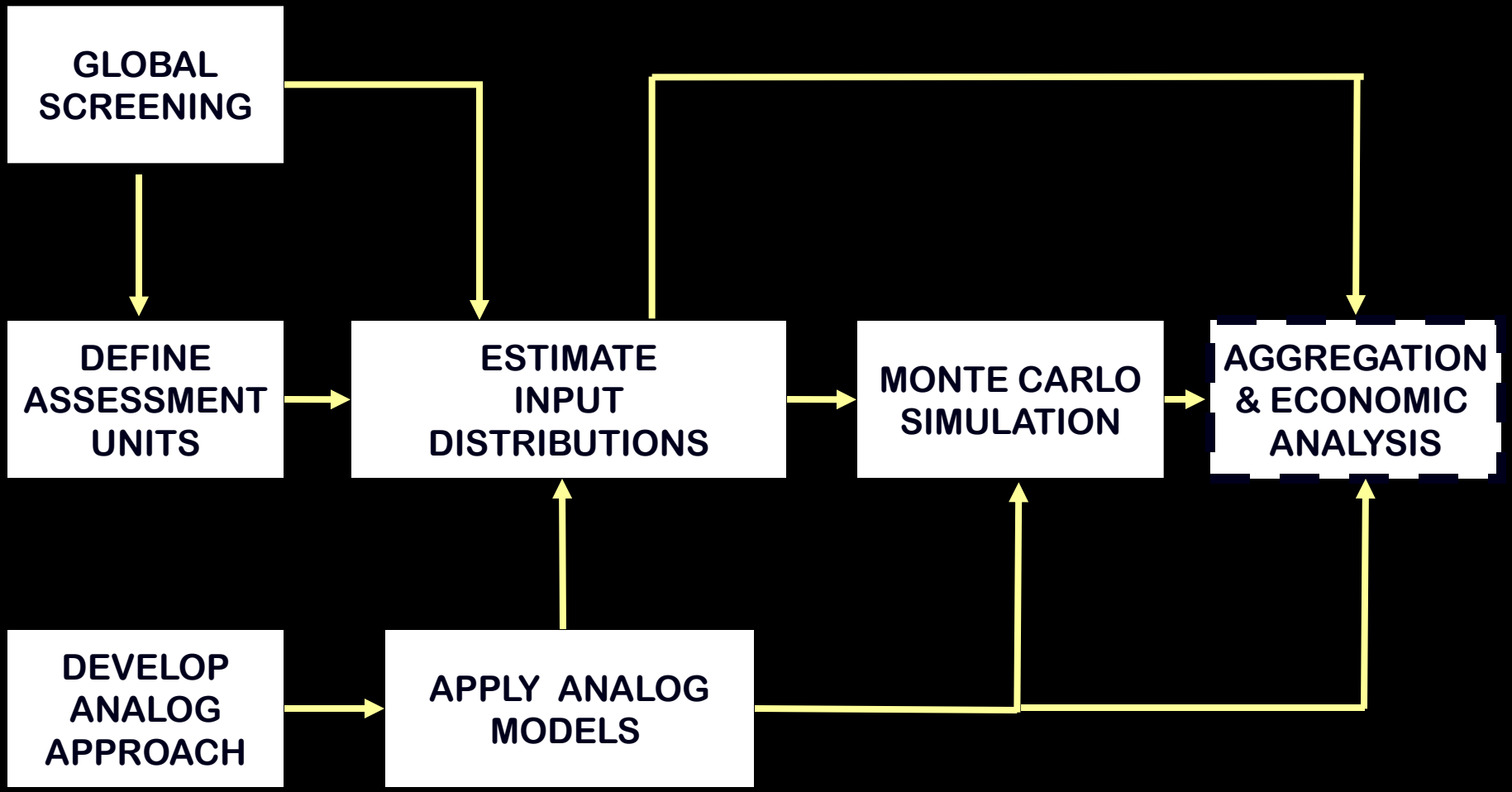
# Assessment of Source Rock Systems

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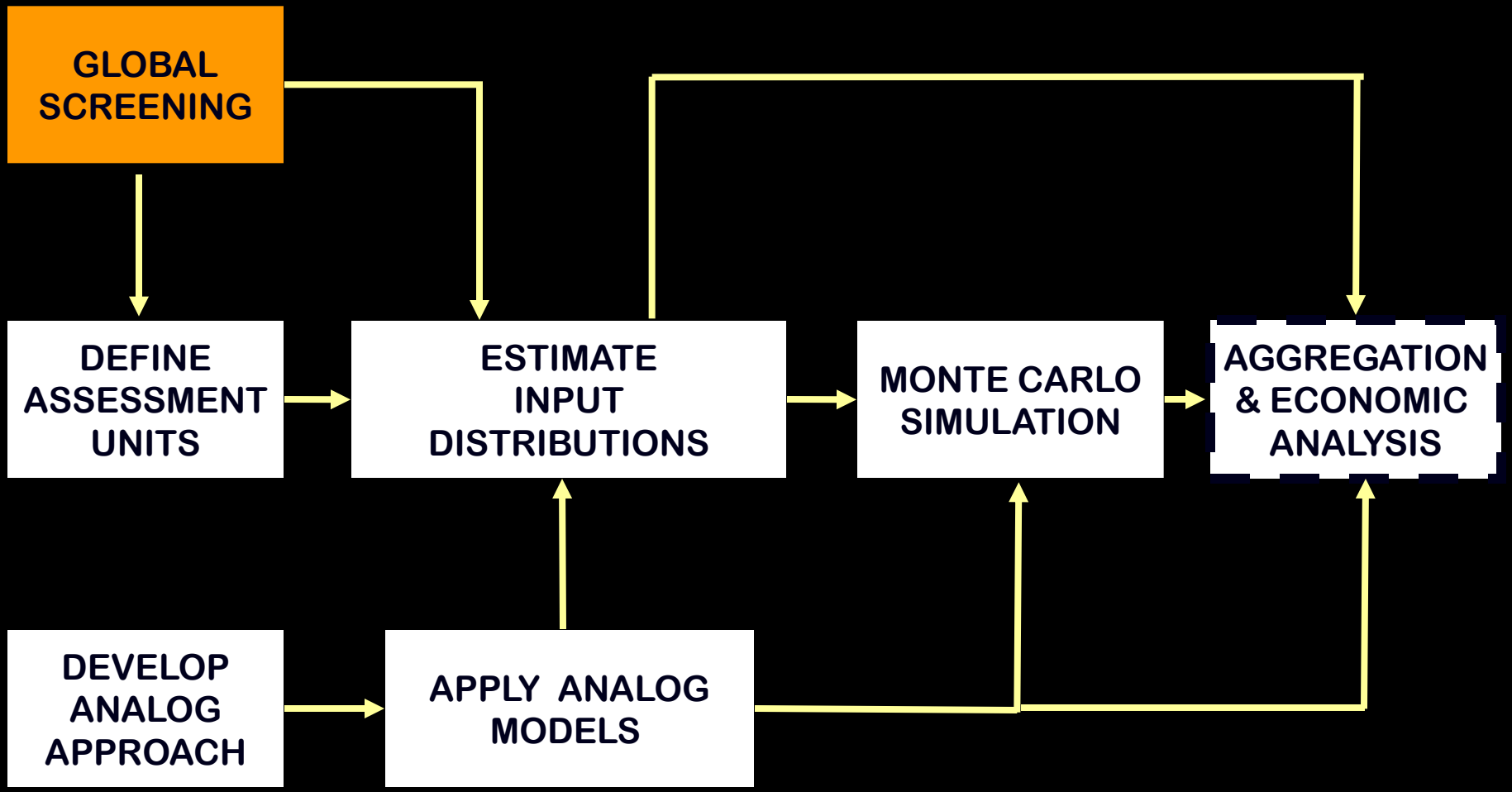


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# Screening Criteria for Gas Plays in Siliciclastic Source Rocks "Shale Gas"

- Net thickness > 15 meters
- Present day total organic carbon > 2.0 %
- Type I or II kerogen ($HI_{(original)}$ > 250 mg/g)
- Minimum thermal maturity: $R_o$ > 1.1 %
- Maximum thermal maturity: $R_o$ < 3.5 %

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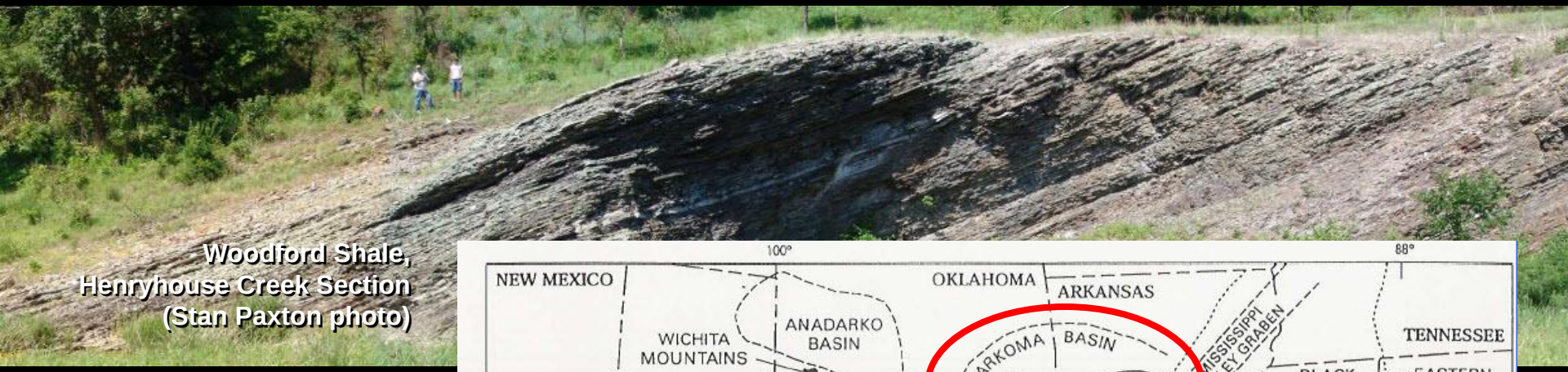
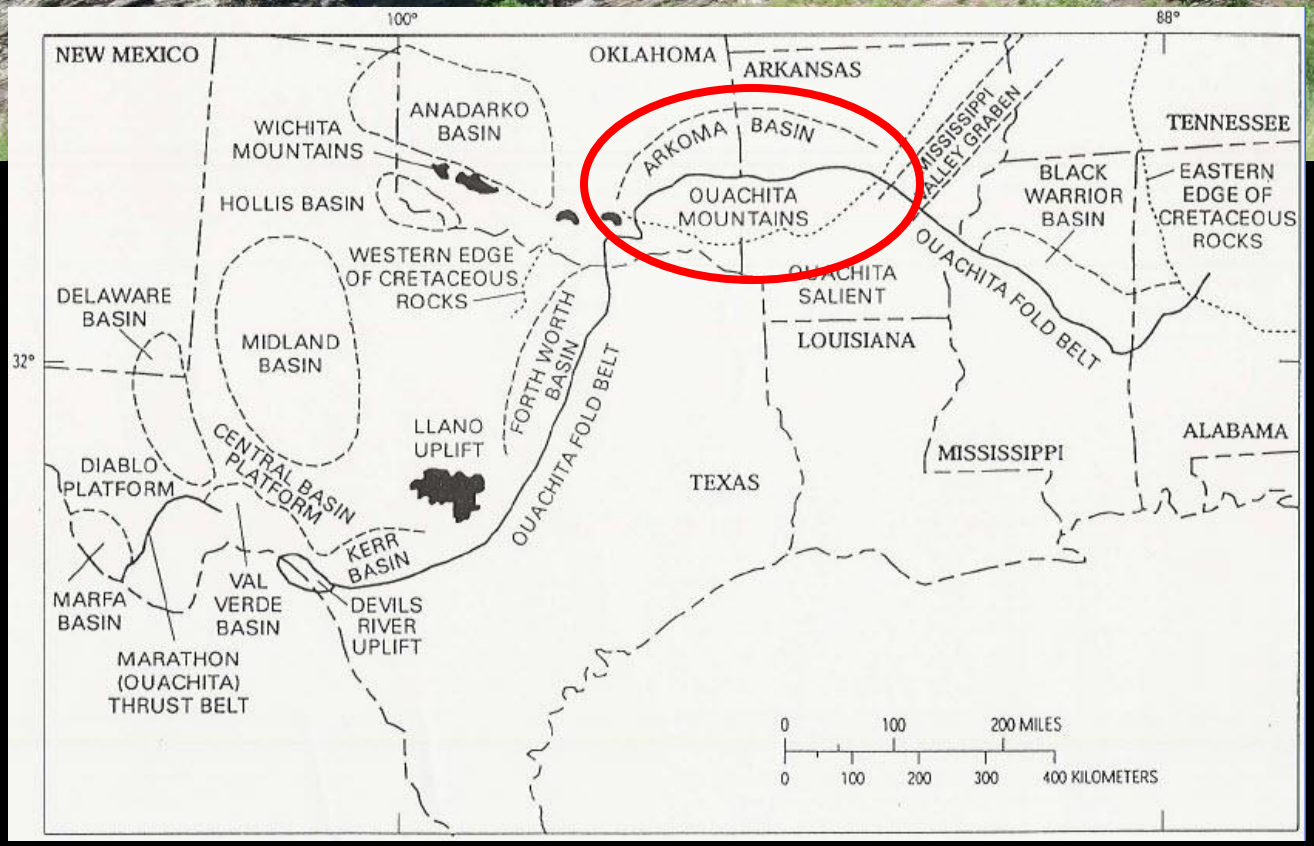
# North American Example - Woodford Shale in the Arkoma Basin



Woodford Shale,
Henryhouse Creek Section
(Stan Paxton photo)

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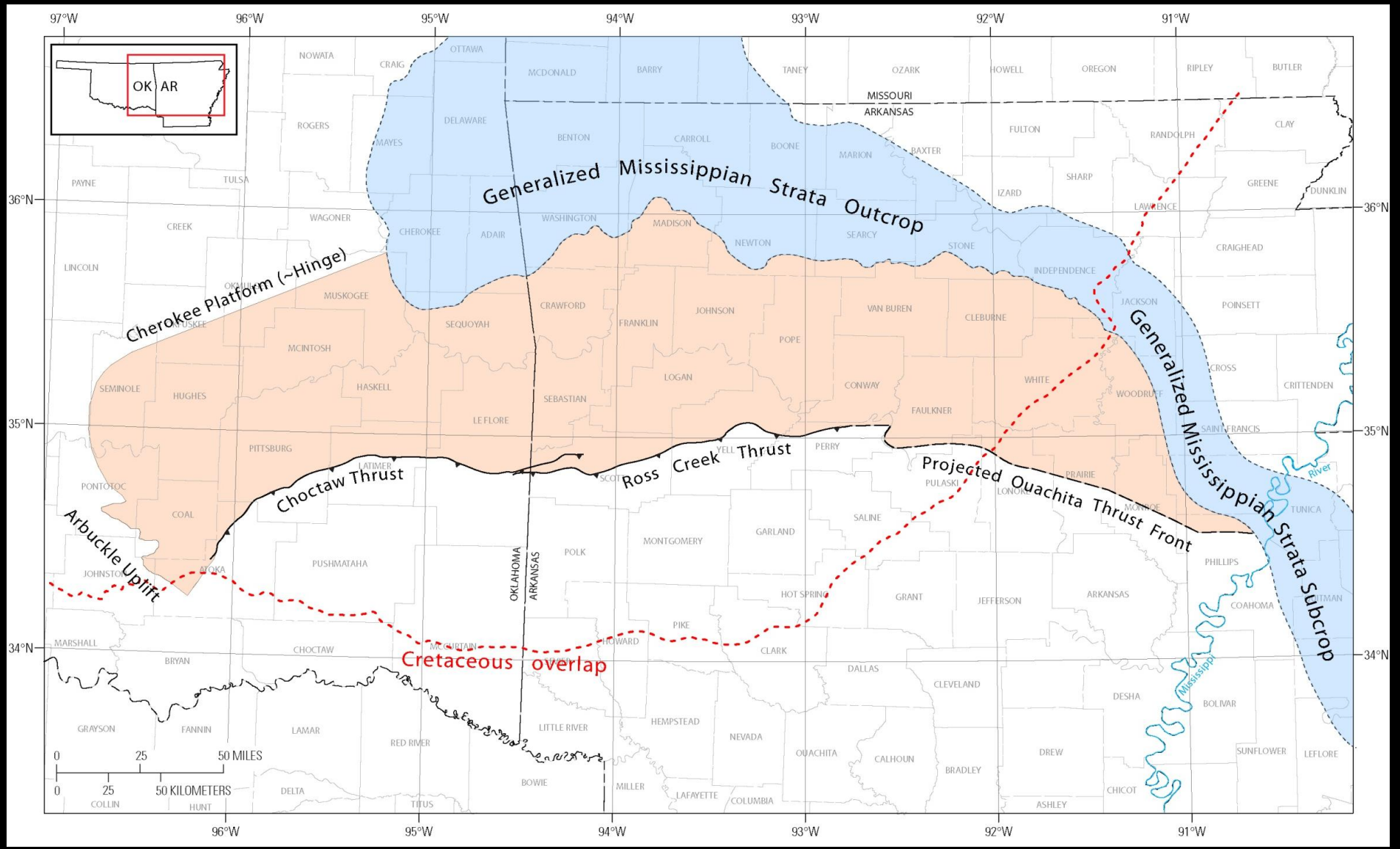
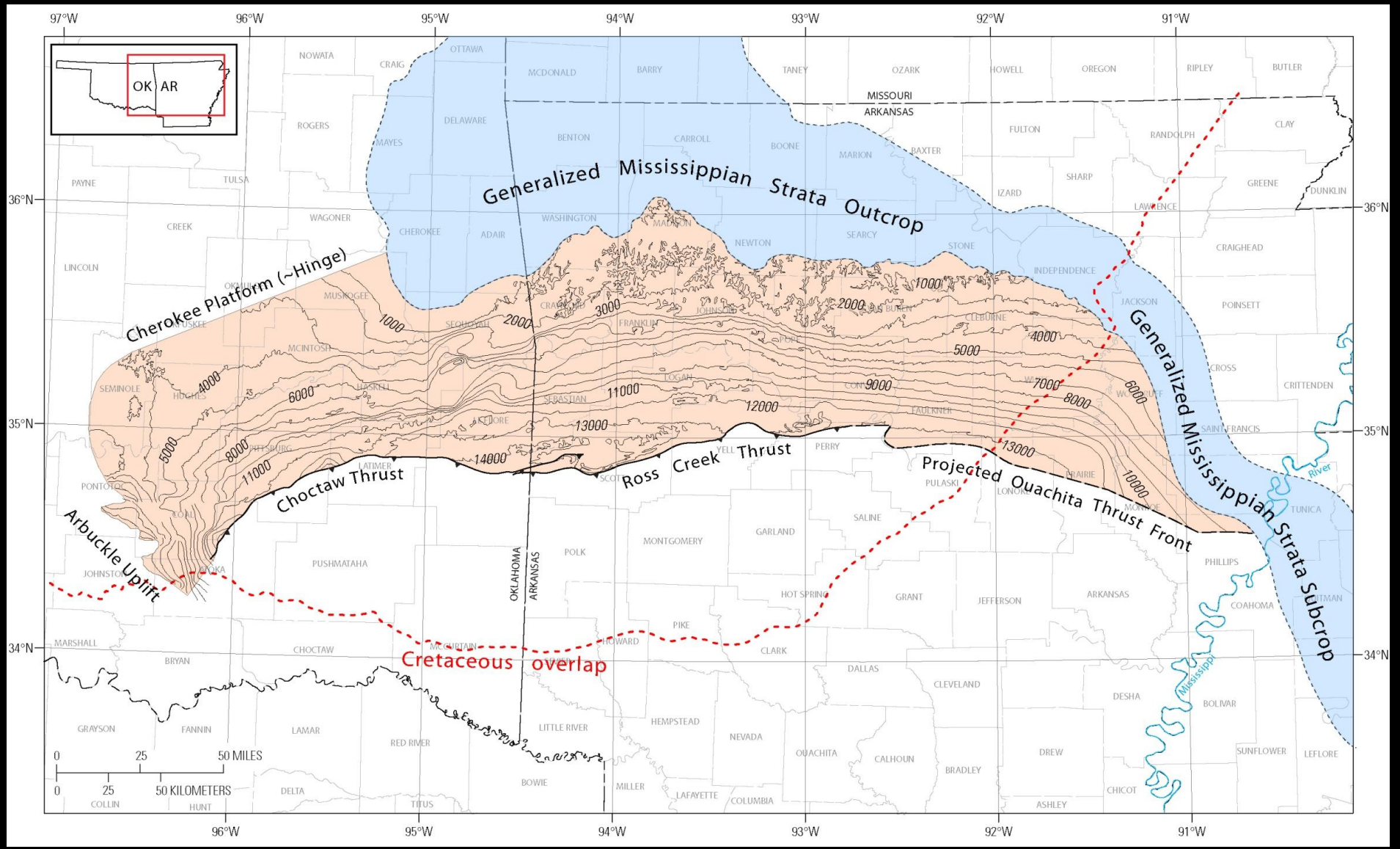
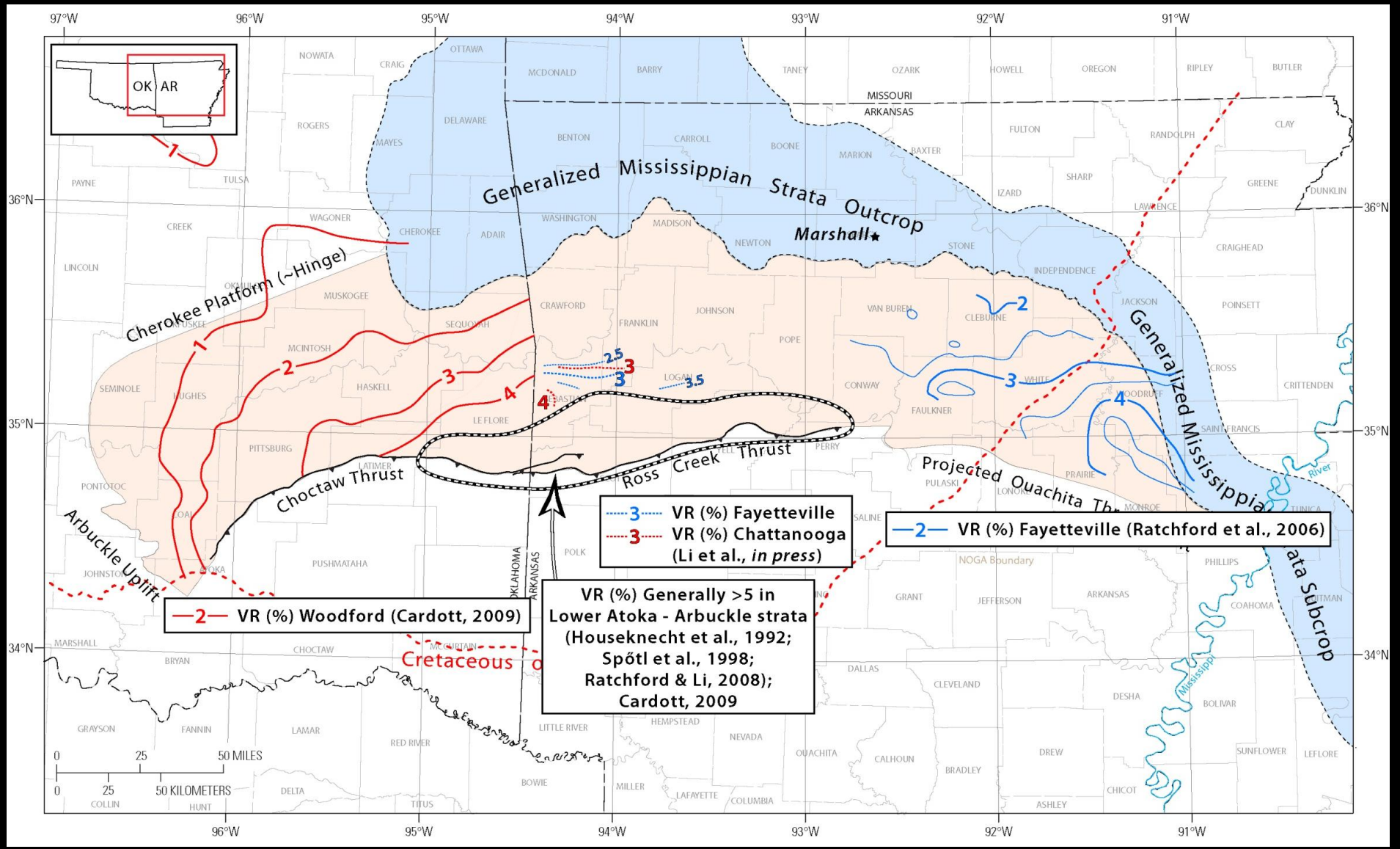
# Woodford-Chattanooga Shale: Extent



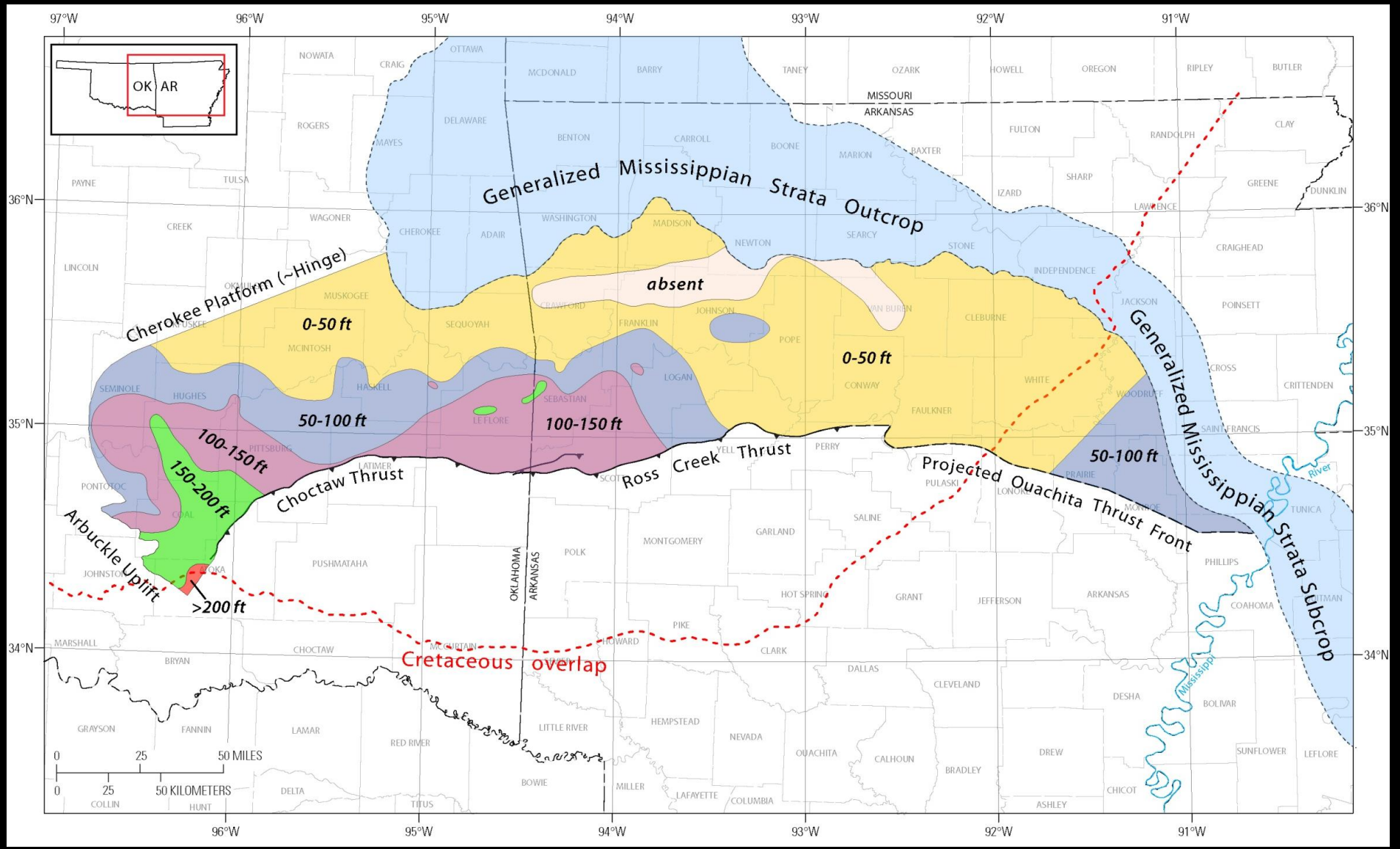
# Woodford-Chattanooga: Depth to Top



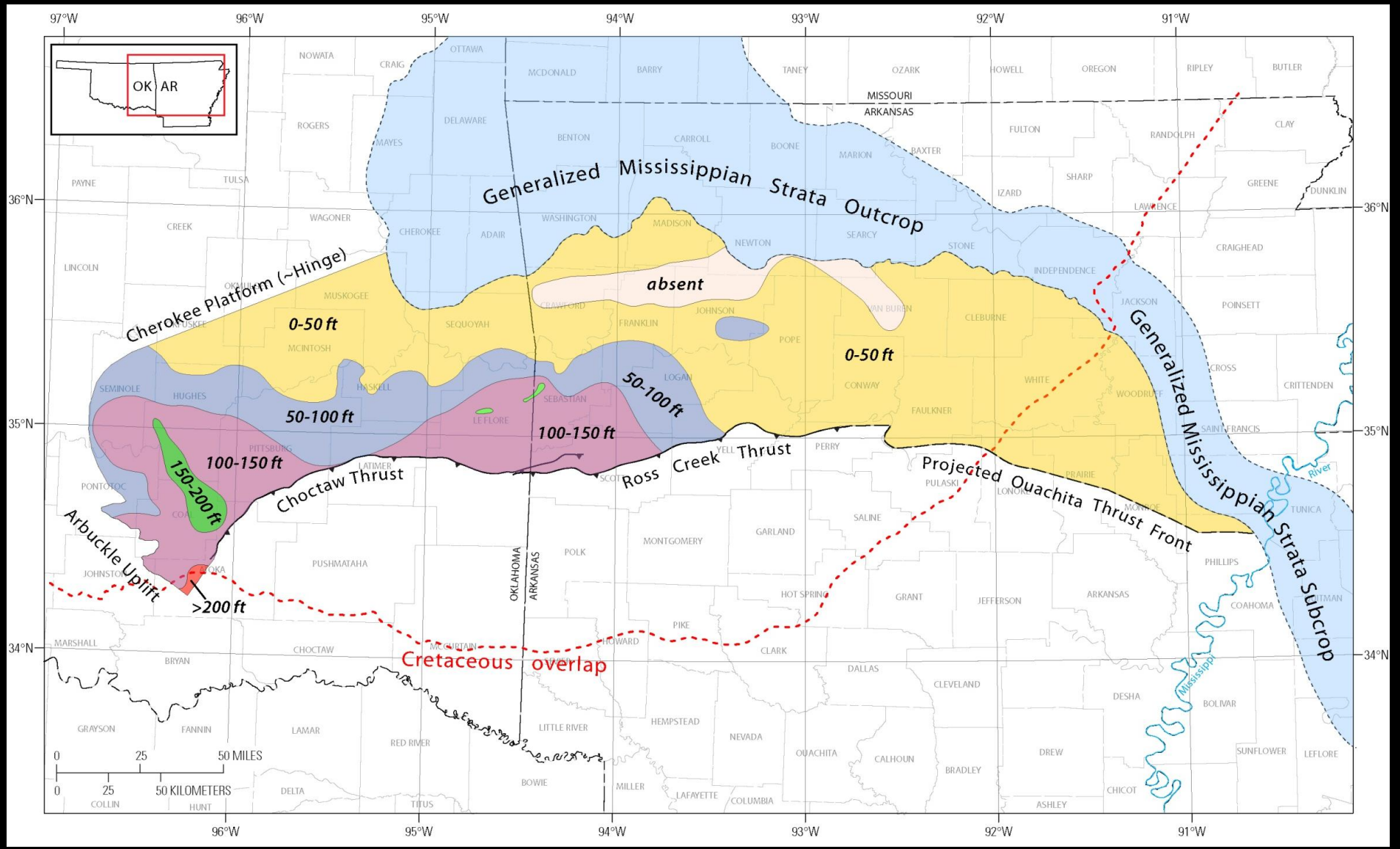
# Woodford-Chattanooga: Thermal Maturity



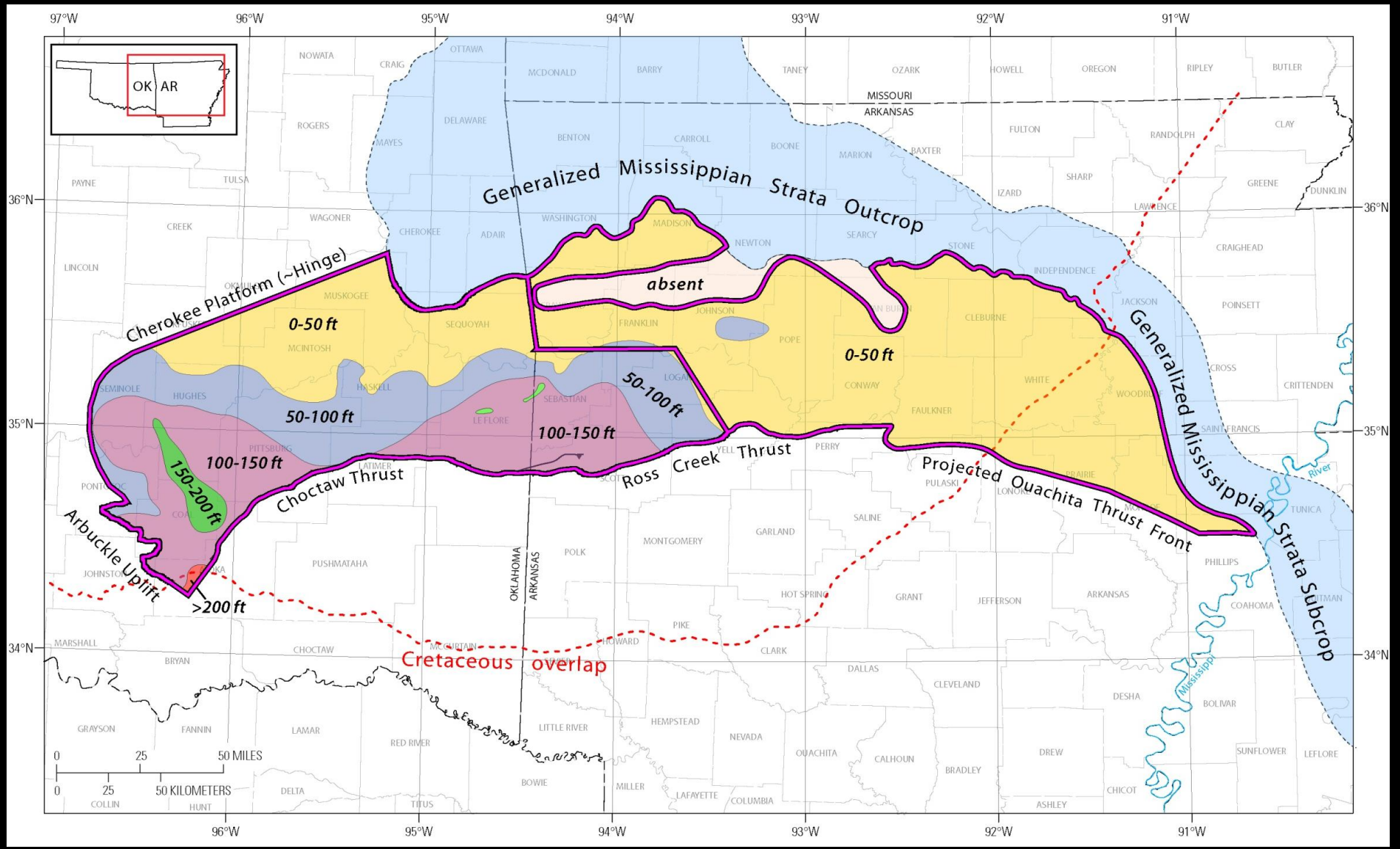
# Woodford-Chattanooga: Gross High GR



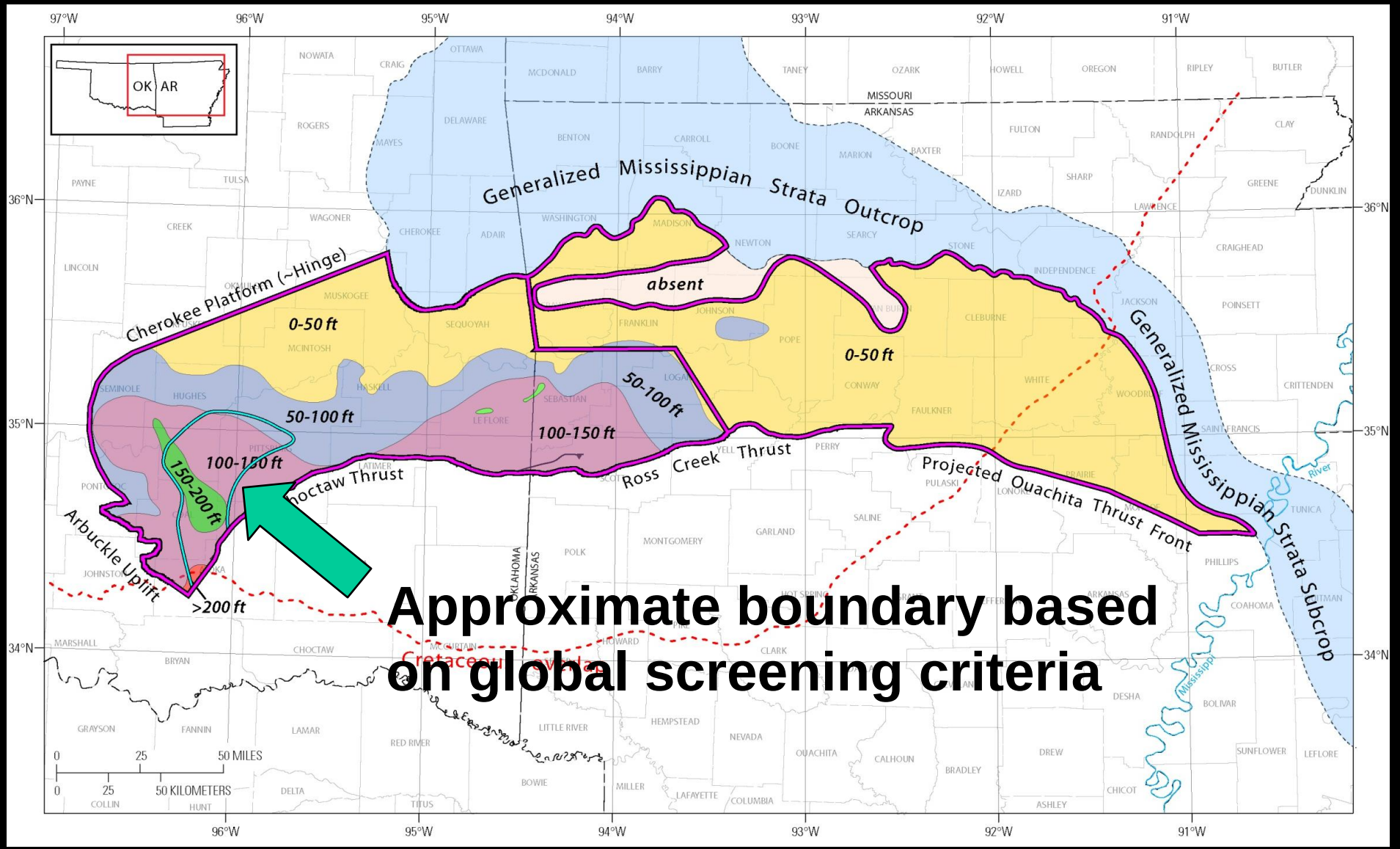
# Woodford-Chattanooga: Net High GR



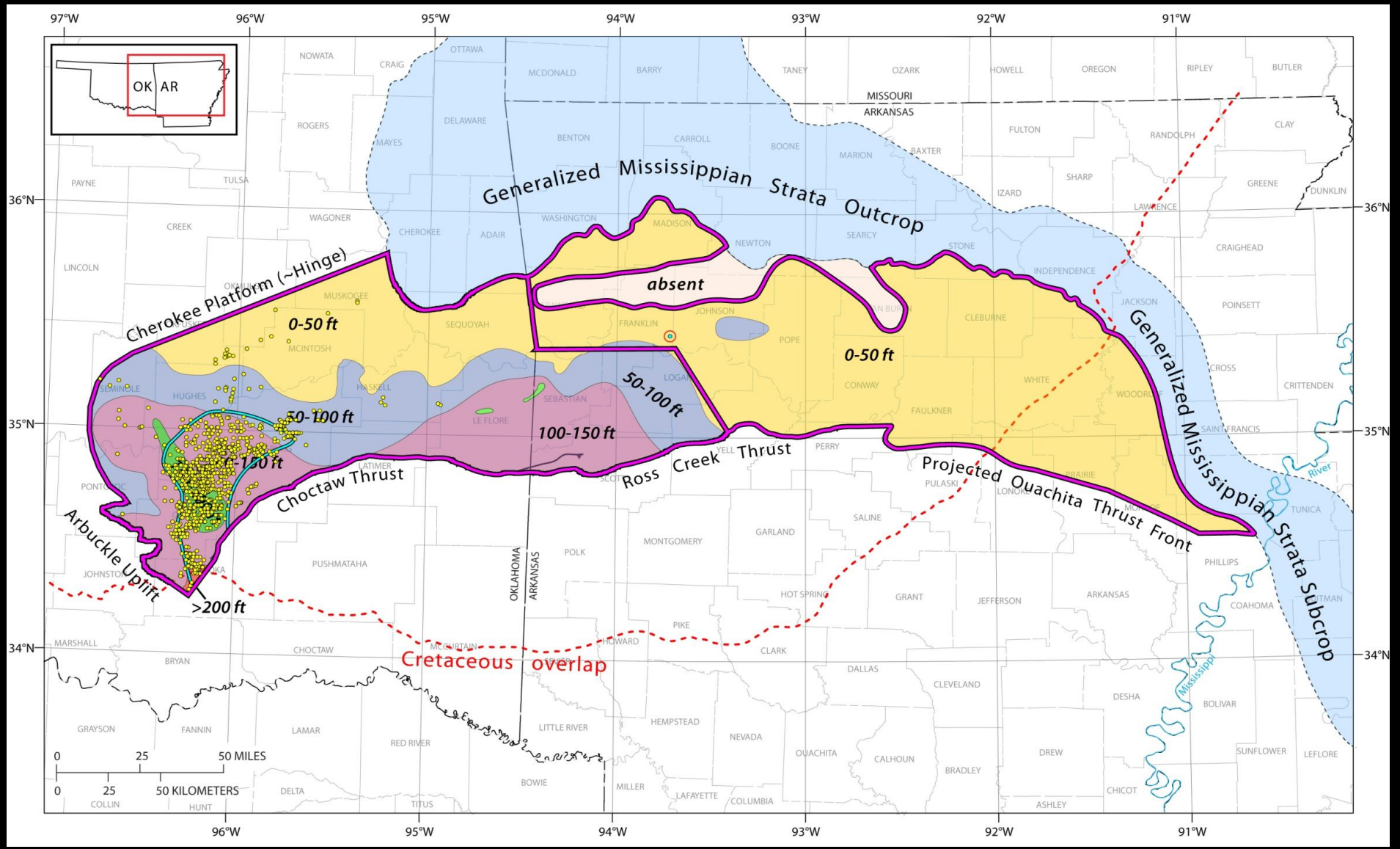
# Woodford-Chattanooga Assessment Units



# Woodford-Chattanooga – Global Screening

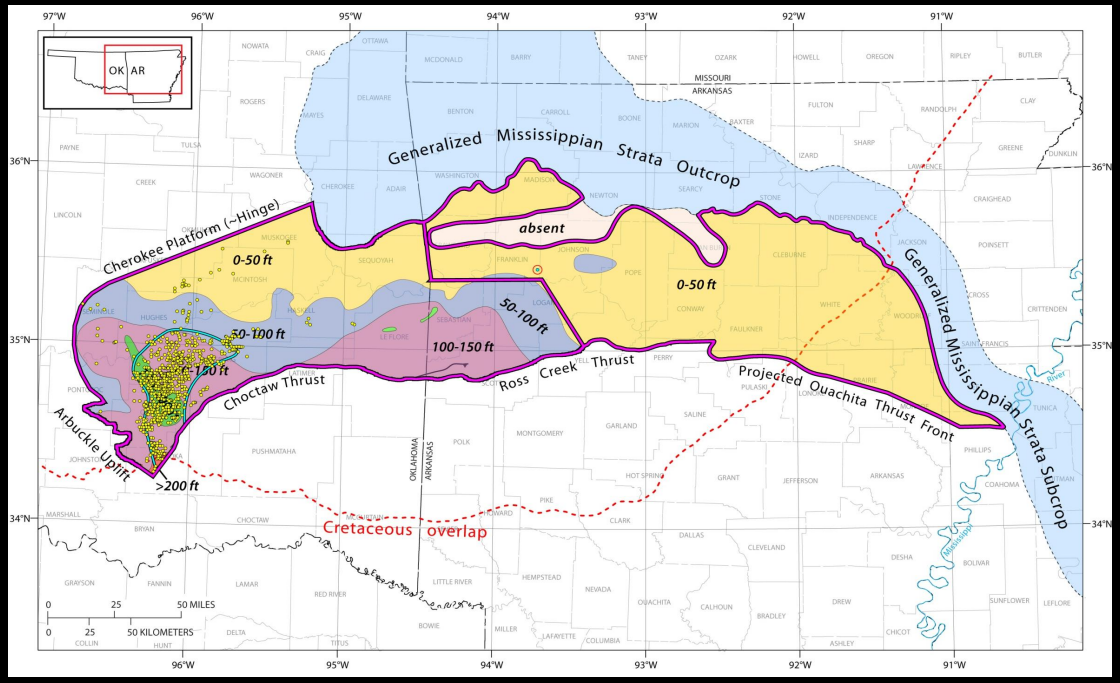


# Woodford-Chattanooga: AUs & Wells



# Effect of Global Screening Criteria on Woodford-Chattanooga Well EURs

- All Horizontals: Mean = 1.135 BCF
- Excluded Horizontals: Mean = 0.662 BCF
- Included Horizontals: Mean = 1.233 BCF

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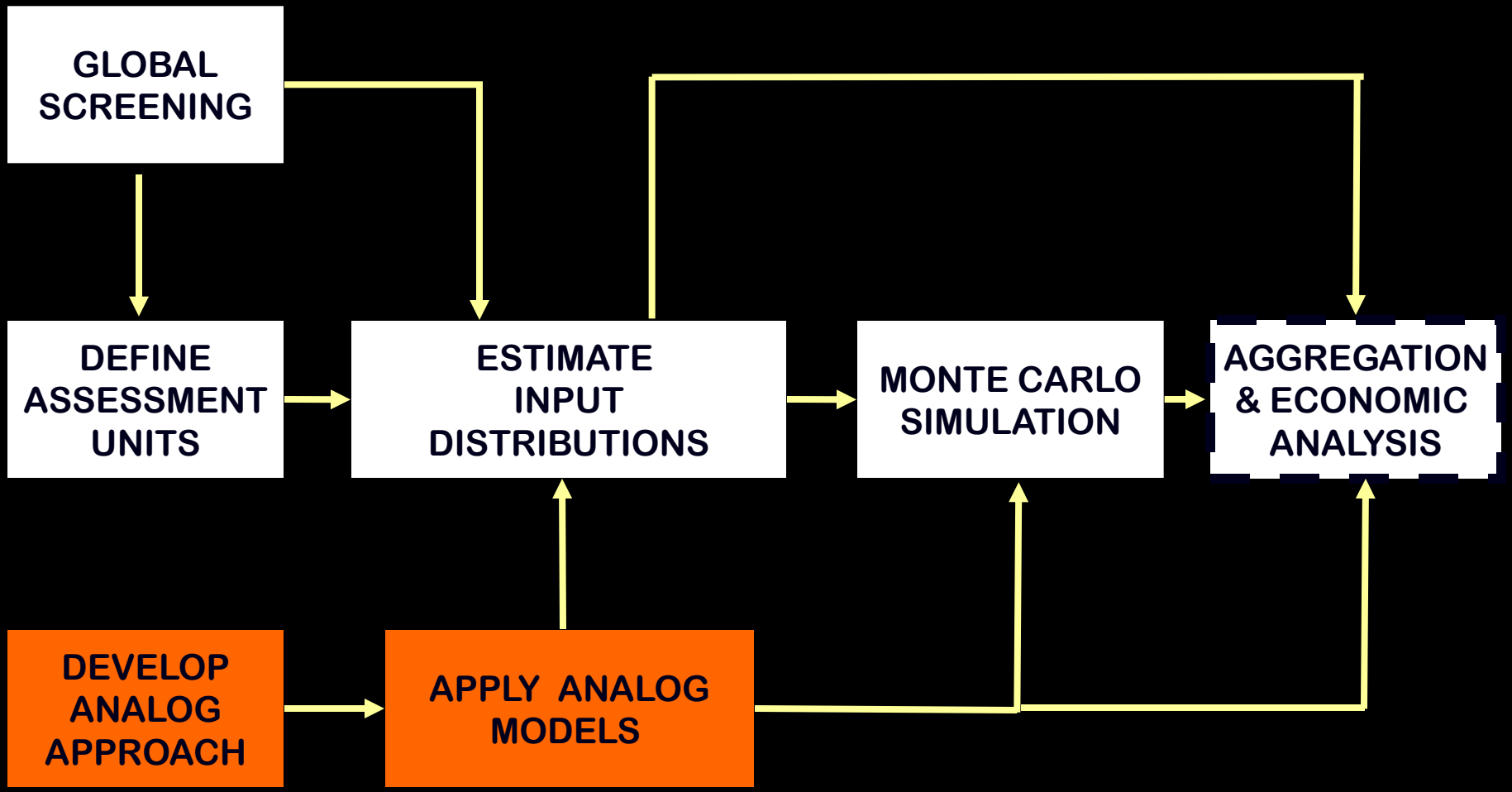
# Assessment of Source Rock Systems

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# Analogs May Be Needed to Evaluate Several Crucial Input Parameters

- Assessment Unit probability
- Numbers of untested wells
- Well Success Ratio
- Well EUR
- Development costs

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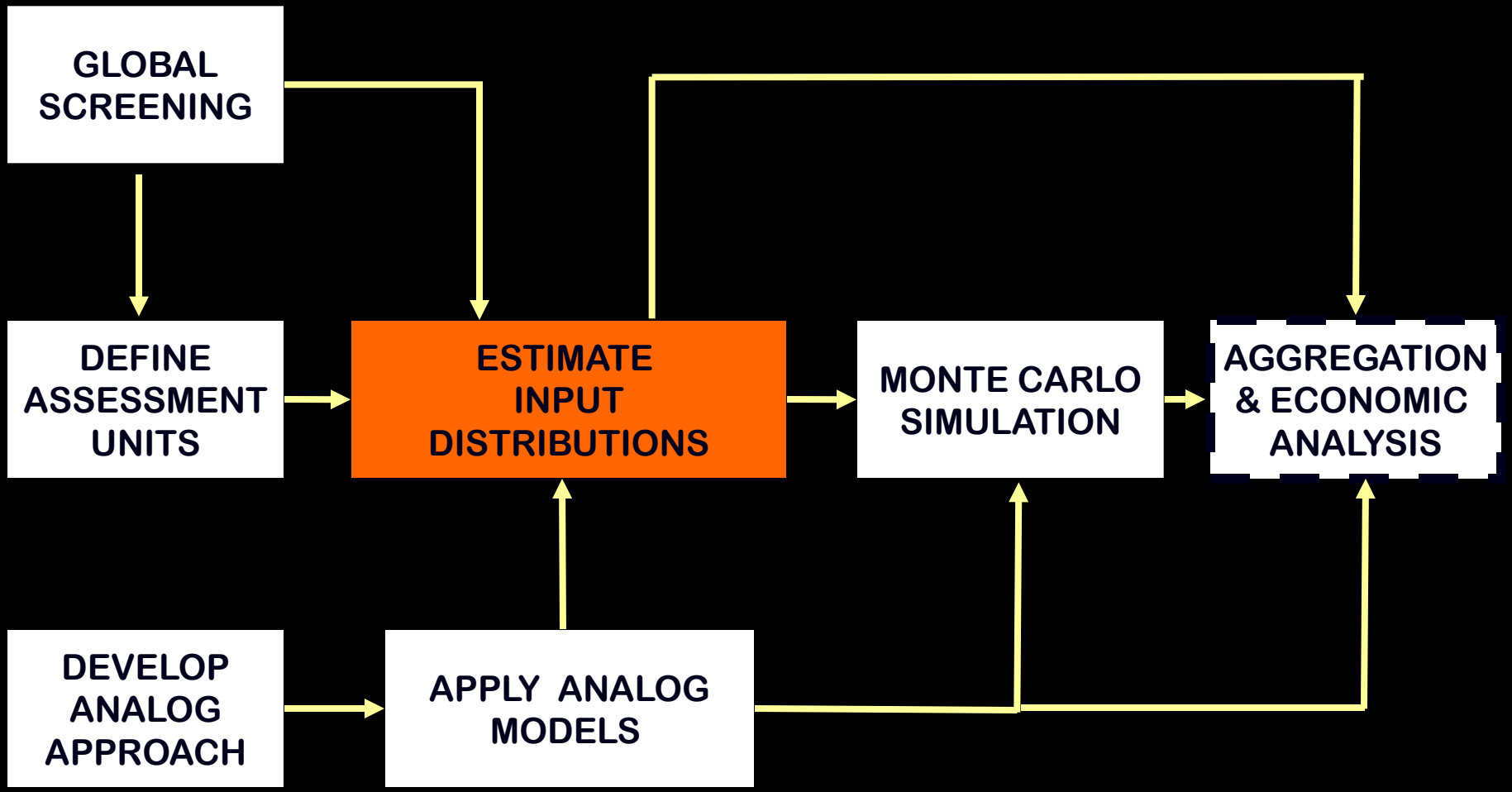
# Assessment of Source Rock Systems

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# Input Distributions
# Used in the Global Assessment

- Assessment unit probability
- Oil vs gas based on maturity, kerogen type
- Number of undrilled wells based on area, optimal spacing
- Estimated ultimate recovery (EUR) per well
- Ancillary data for cost analysis

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- Assessment unit probability
- Oil vs gas based on maturity, kerogen type
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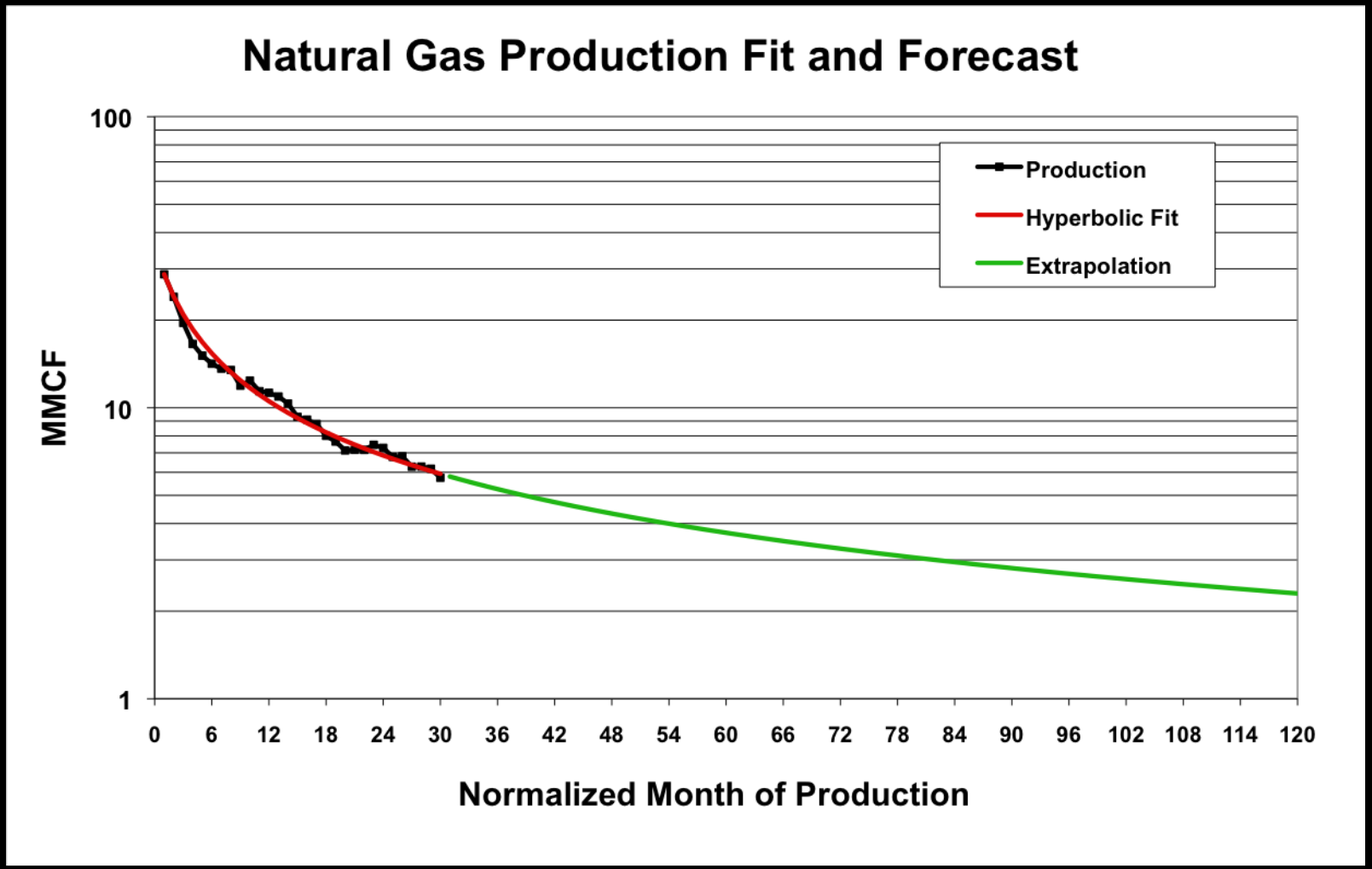
# Creating an EUR from a Decline Curve

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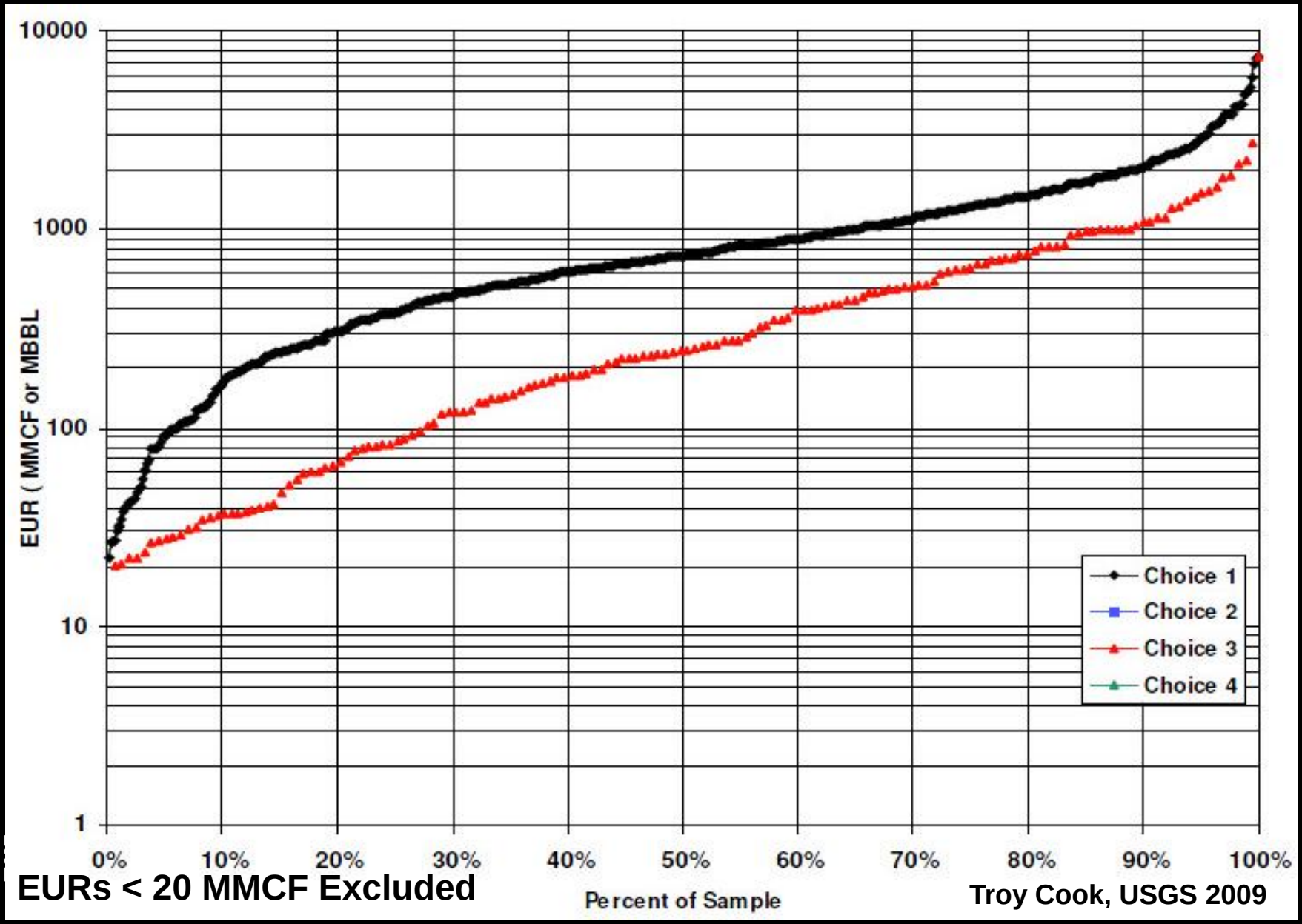
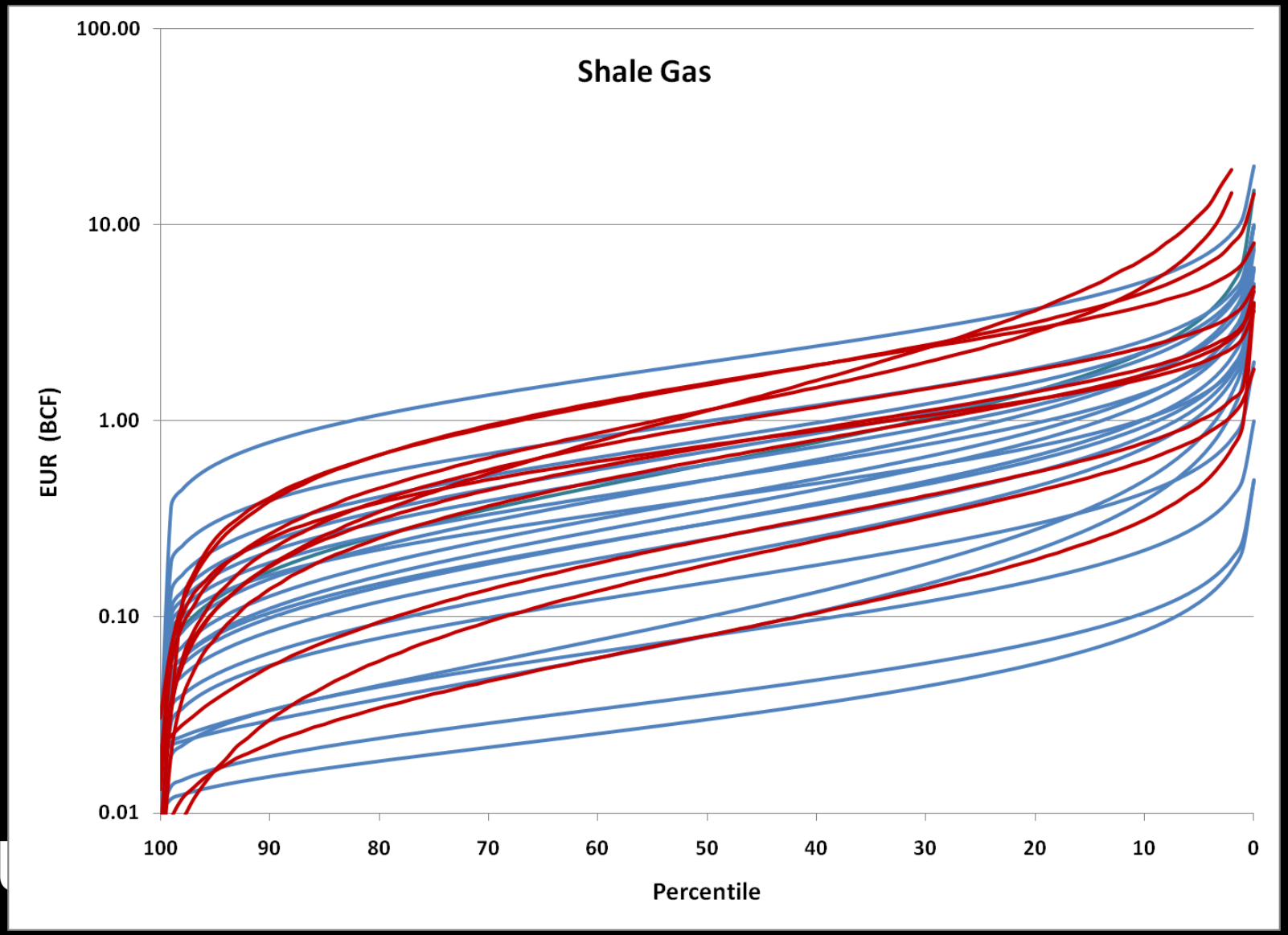
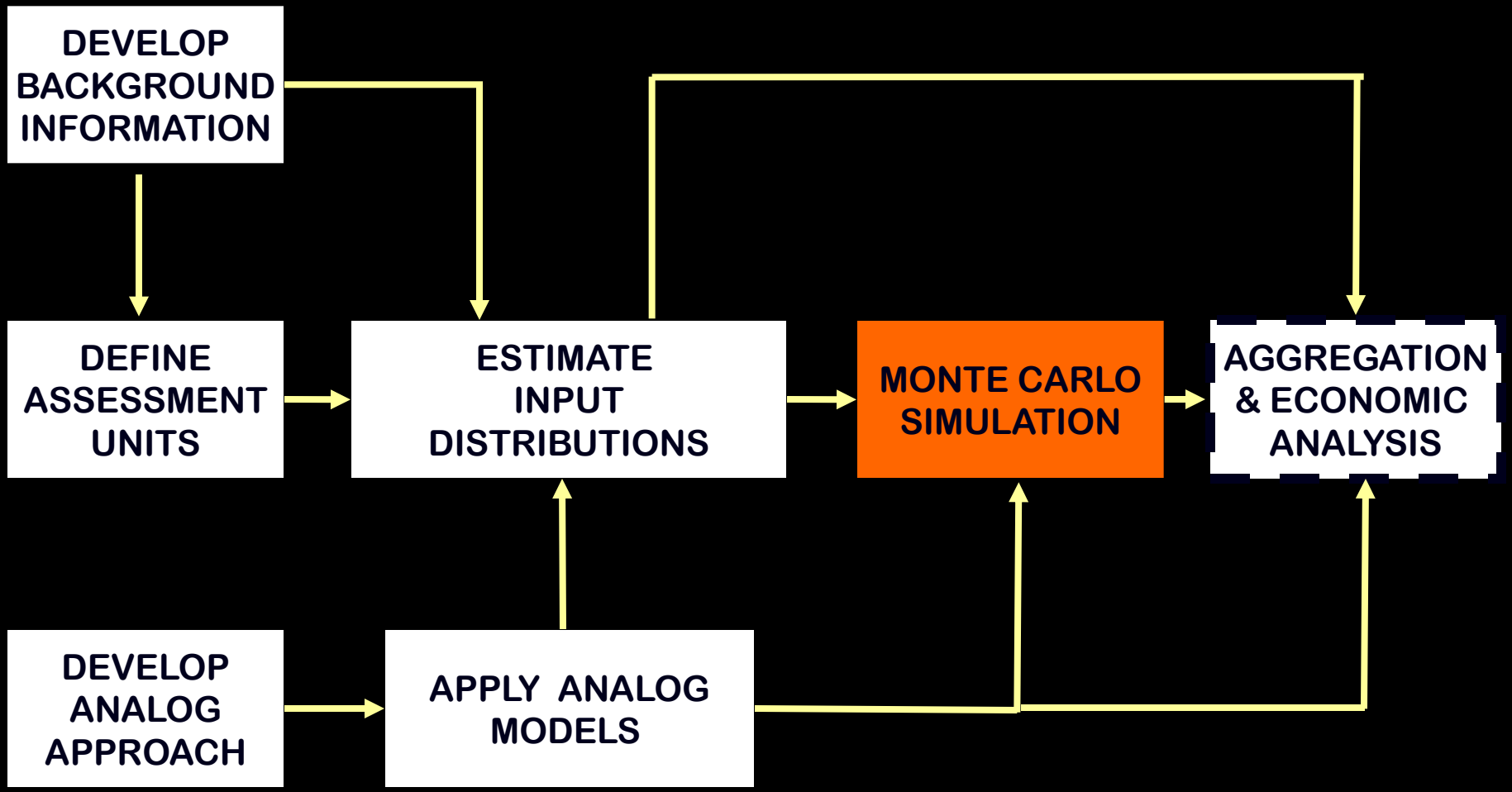
# Woodford Vertical & Horizontal Well EURs



# Some Shale Gas EURs Used by USGS



# Assessment of European Gas Shales

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# Next Steps

- Define candidate shale gas AUs in Europe
- Screen candidate AUs on geological criteria
- Organize data for assessment
- Apply NA analogs using USGS methodology
- Quantitatively assess AUs
- Aggregate results
- Appraise resource/cost functions

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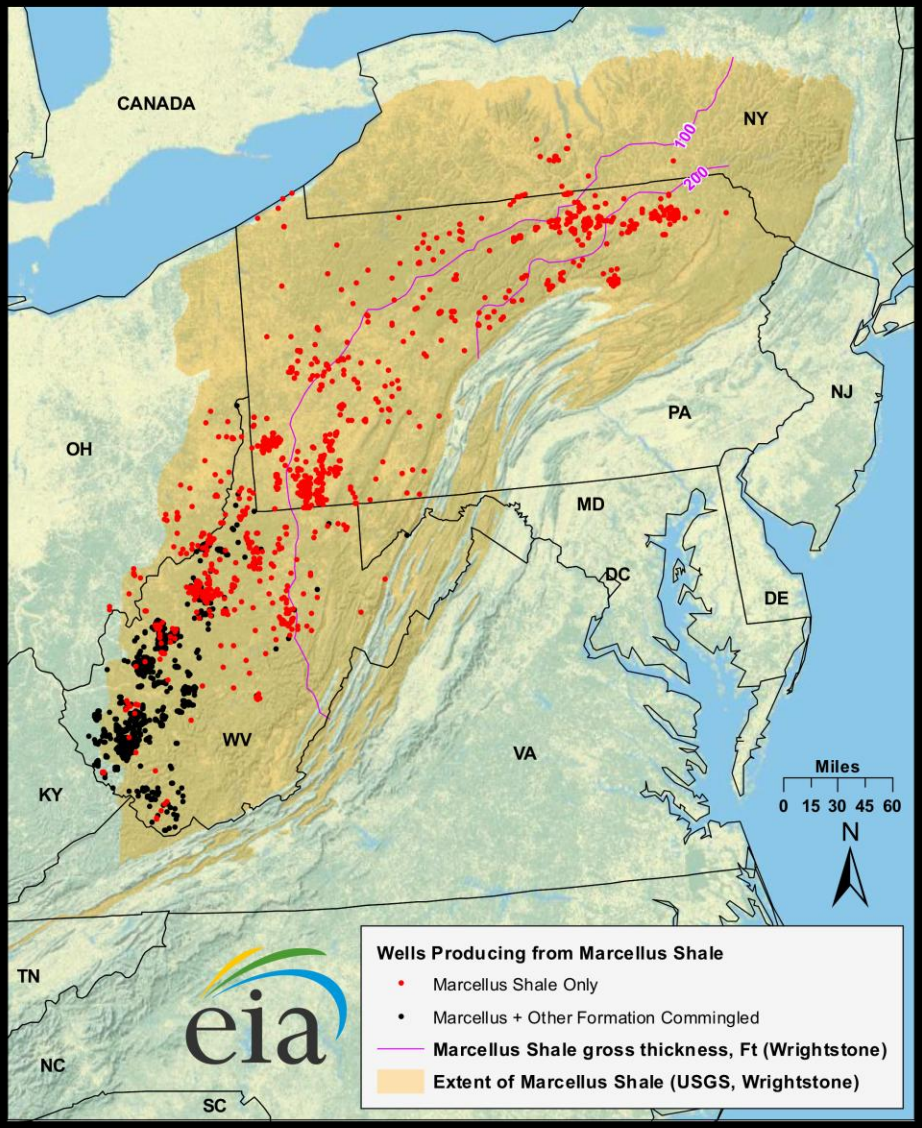
# EIA Marcellus Estimate = 410 TCF

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# 2011 USGS Estimate: 43 to 144 TCF mean = 84 TCF

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National Assessment of Oil and Gas

## Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shaleof theAppalachian Basin Province, 2011

### Introduction

Using a geology-based assessment methodology, the U.S. Geological Survey (USGS) estimated a mean undiscovered natural gas resource of 84,198 billion cubic feet and a mean undiscovered natural gas liquids resource of 3,379 million barrels in the Devonian Marcellus Shale within the Appalachian Basin Province. All this resource occurs in continuous accumulations.

In 2011, the USGS completed an assessment of the undiscovered oil and gas potential of the Devonian Marcellus Shale within the Appalachian Basin Province of the eastern United States (fig. 1). The Appalachian Basin Province includes parts of Alabama, Georgia, Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The assessment of the Marcellus Shale is based on the geologic elements of this formation's total petroleum system (TPS) as recognized in the Appalachian Basin Province. These elements incorporate the characteristics of the TPS as a petroleum source rock (source rock richness, thermal maturation, petroleum generation, and migration) as well as a reservoir rock (stratigraphic position and content and petrophysical properties).

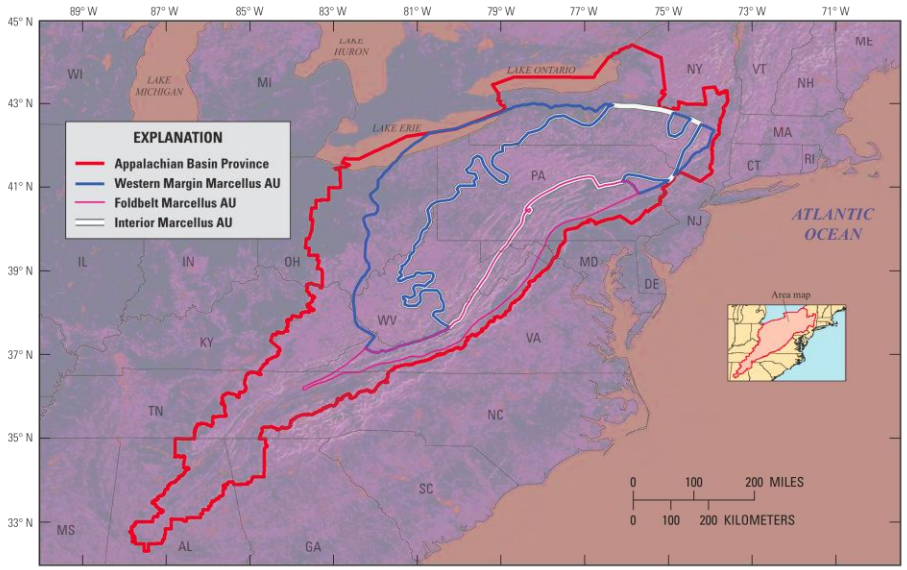


**Figure 1.** Map of the Appalachian Basin Province showing the three Marcellus Shale assessment units, which encompass the extent of the Middle Devonian from its zero isopach edge in the west to its erosional truncation within the Appalachian fold and thrust belt in the east.

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U.S. Geological Survey

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August 2011

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