

Assessing Risks of Unconventional Shale Oil and Gas Development to Groundwater Resources
 (非常规页岩油气开发对地下水资源的风险评估)

Junfeng Zhu (朱珺峰)

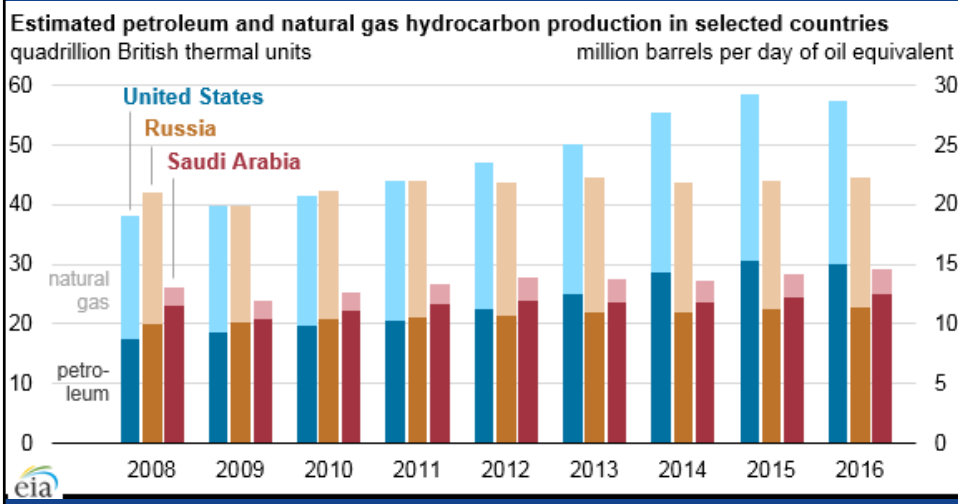
Kentucky Geological Survey
University of Kentucky
 (肯塔基大学)



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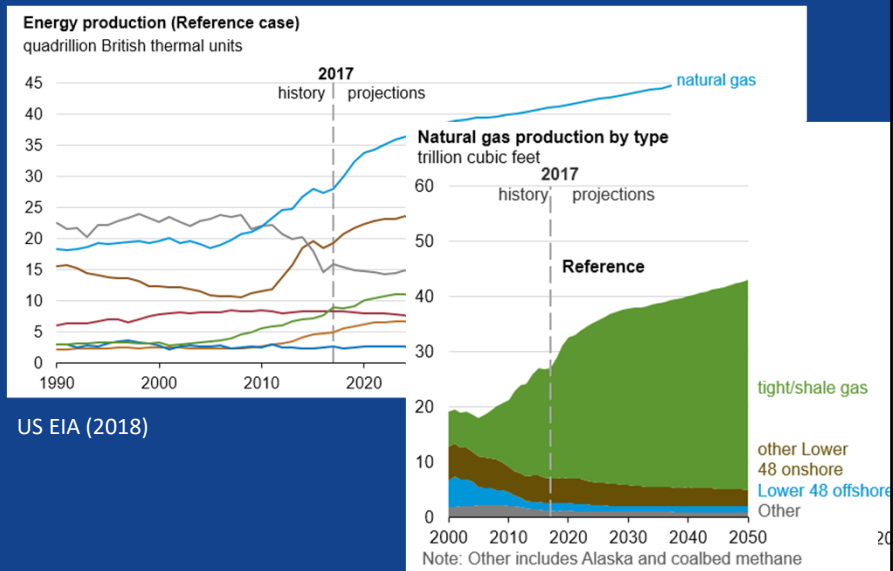
Which country is the top producer of petroleum and natural gas?
 哪个国家产油气最多?

A) Russia B) Saudi Arabia C) United States

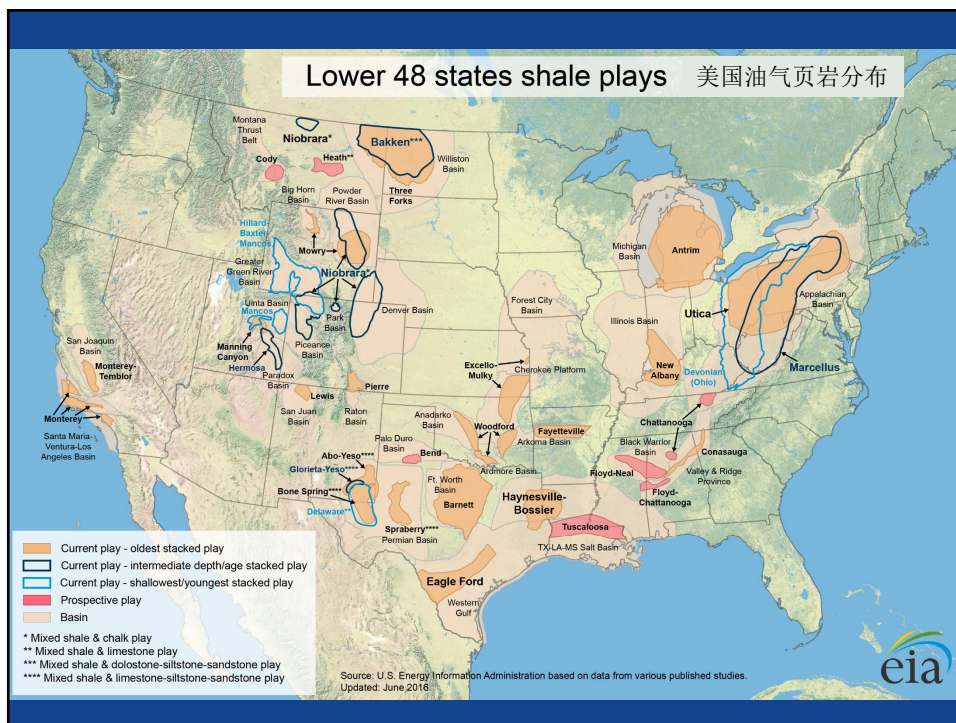


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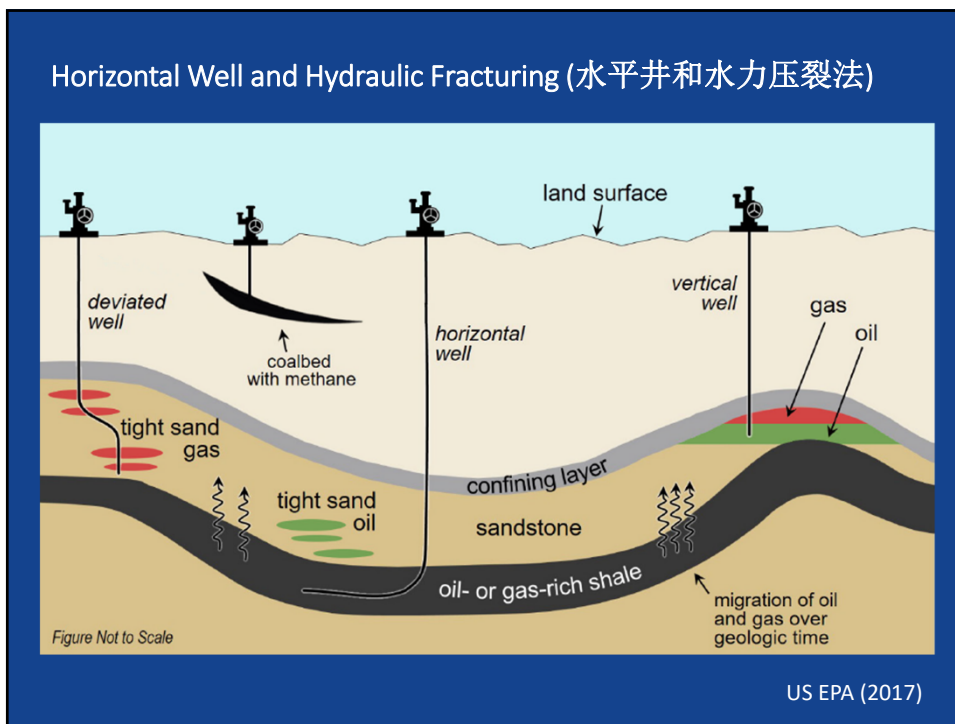
U.S. Energy Production Projection (美国能源生产预测)



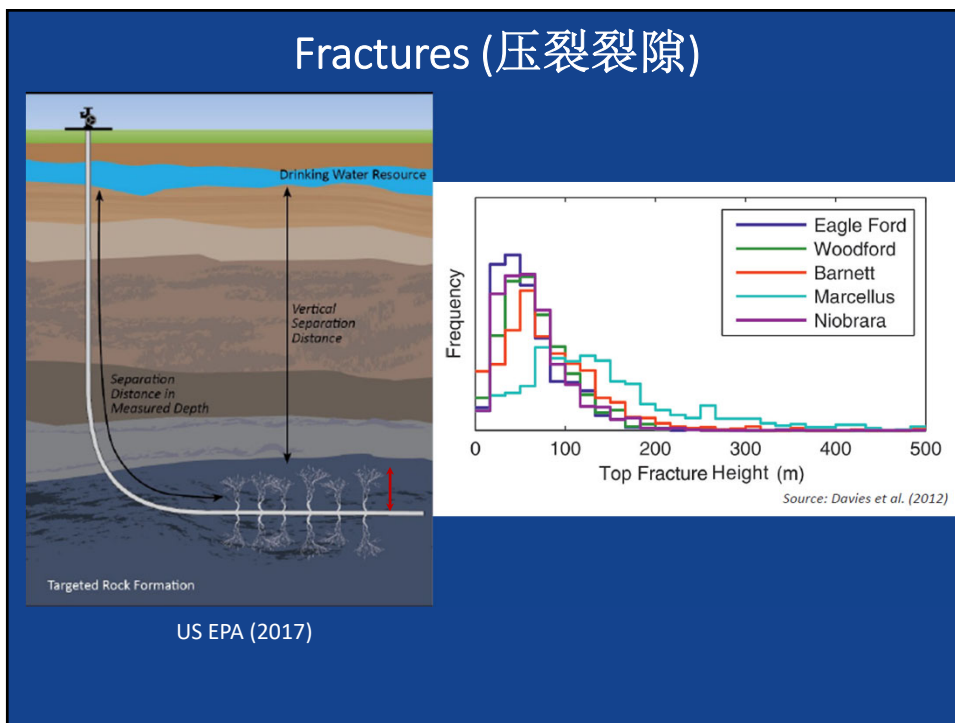
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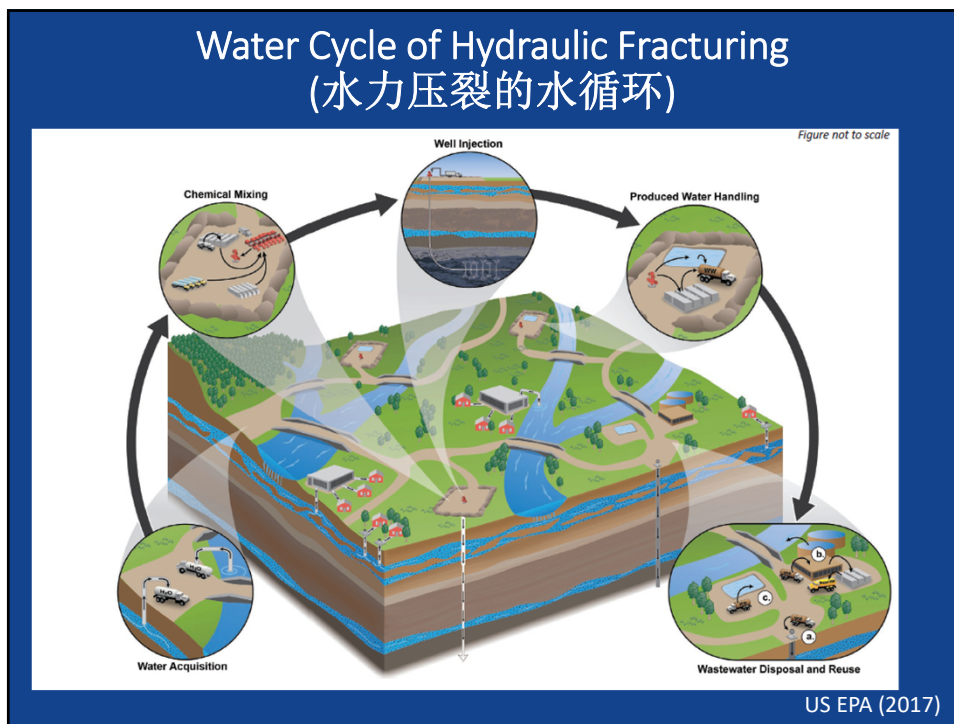
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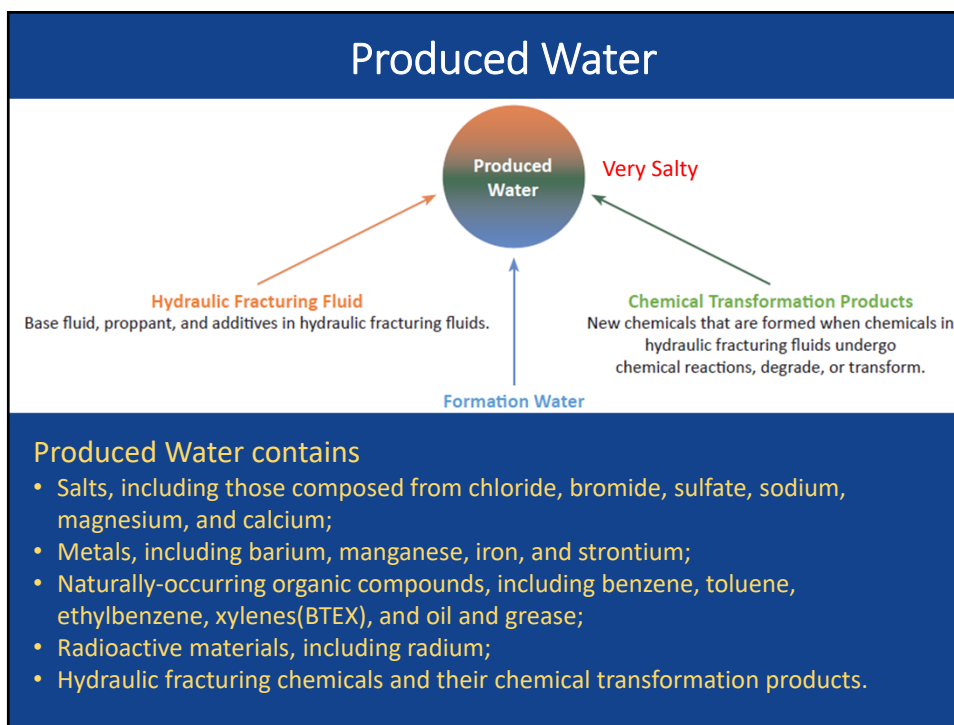
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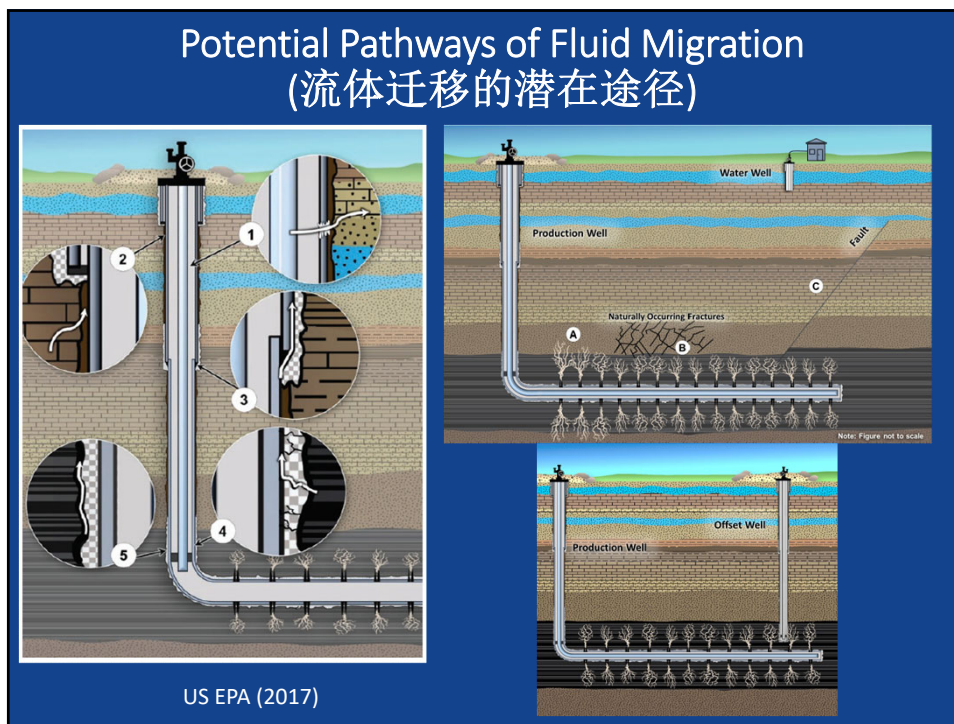
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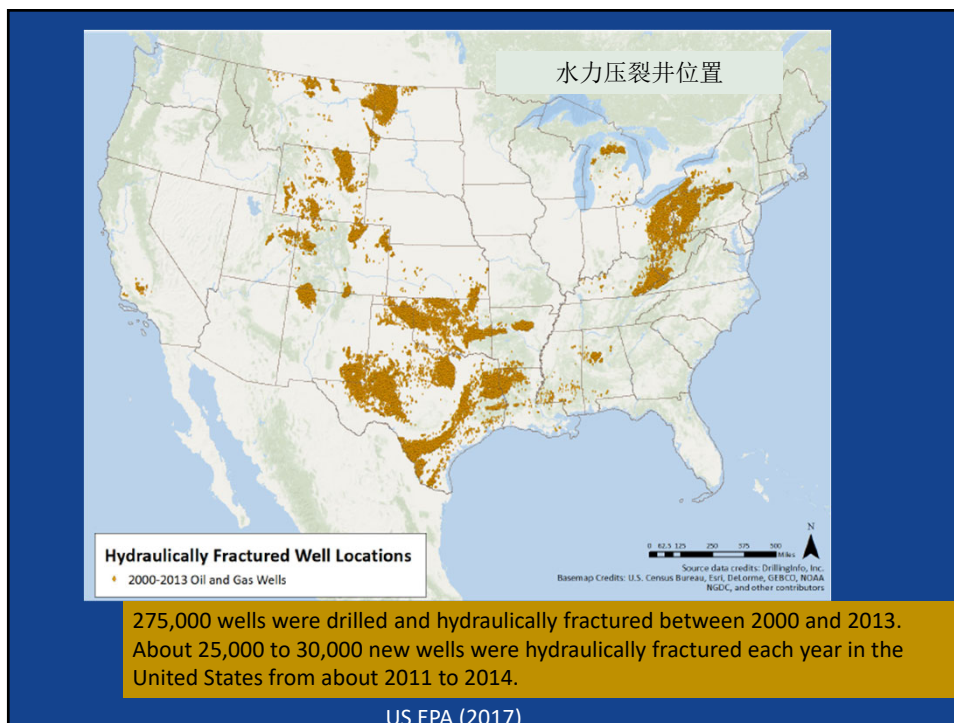
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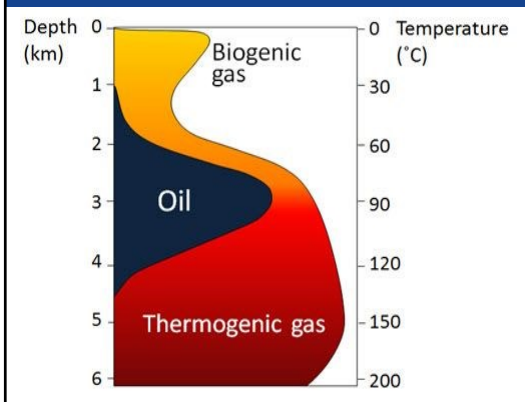


9



10

How is Methane Formed? (甲烷是如何形成的?)



www.petropedia.com

Biogenic (生物成因):

Biogenic gas is produced from bacterial activities near the earth surface (10s of meters). Biogenic gas is overwhelmingly methane ($\geq 99\%$).

Thermogenic (热成因):

Thermogenic natural gas occurs at depths exceeding 1,000 m and is generated from chemical reactions under high temperature and high pressure without the presence of micro-organisms. Thermogenic gas contains a large percentage of non-methane hydrocarbons, including ethane, propane, etc.

<https://pubs.usgs.gov/of/1996/of96-272/ch03s07.html>

11

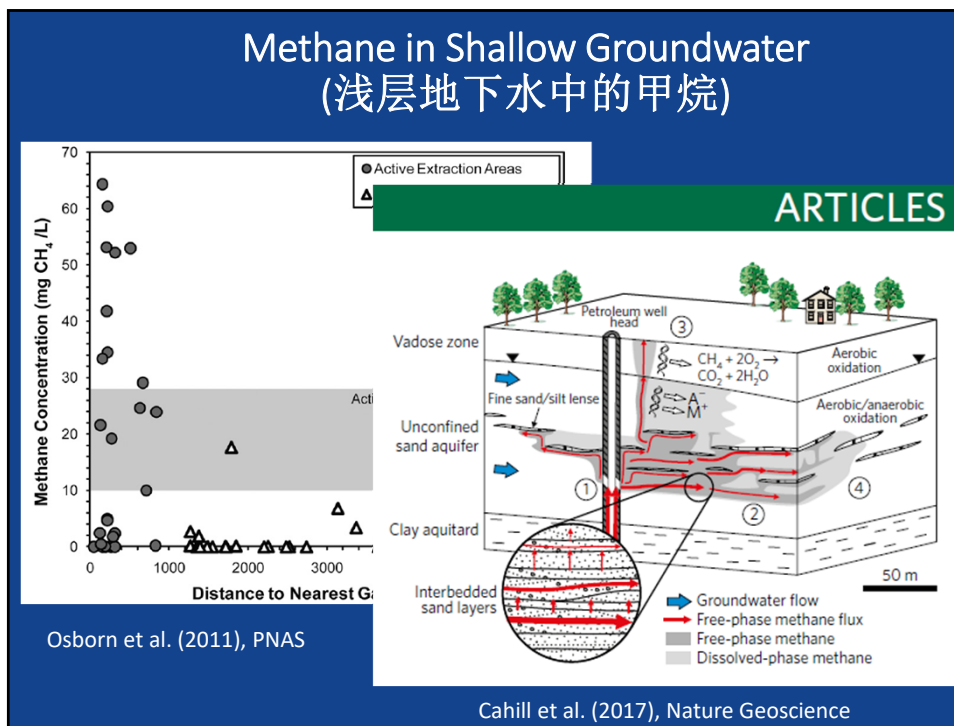
Is Methane a Contaminant? (甲烷是不是污染物?)

Action Level	Atmospheric (Percent Volume)		Dissolved in Water (mg/liter)	Soil Gas (Percent Volume)
	Occupiable Spaces (homes)	Un-Occupiable Spaces		
Immediate Action	>1.0%	>3.0%	>28 mg/L	>5.0%
Warning, Investigate	>0.5% but <1.0%	>1.0% but <3.0%	>10 mg/L but <28 mg/L	>3.0% but <5.0%
Monitor to Determine Concentration Trends	>0.25% but <0.5%			<3.0% but >1.0%
No Immediate Action	<0.25%	<1.0%	<10 mg/L	

US OSM (2001)

Methane is NOT toxic, but can cause asphyxiation and explosions when accumulated to certain level in closed environments.

12



13

Methane in Shallow Groundwater (浅层地下水中的甲烷)

SCIENCE PRODUCTS NEWS CONNECT ABOUT

Unconventional Oil and Gas Production Not Currently Affecting Drinking Water Quality

Release Date: MAY 31, 2017

Decades or longer may be needed to fully assess the effects of unconventional oil and gas production on the quality of groundwater used for drinking water in Arkansas, Louisiana, and Texas

A new U.S. Geological Survey study shows that unconventional oil and gas production in some areas of Arkansas, Louisiana, and Texas is not currently a significant source of methane or benzene to drinking water wells. These production areas include the Eagle Ford, Fayetteville, and Haynesville shale formations, which are some of the largest sources of natural gas in the country and have trillions of cubic feet of gas.

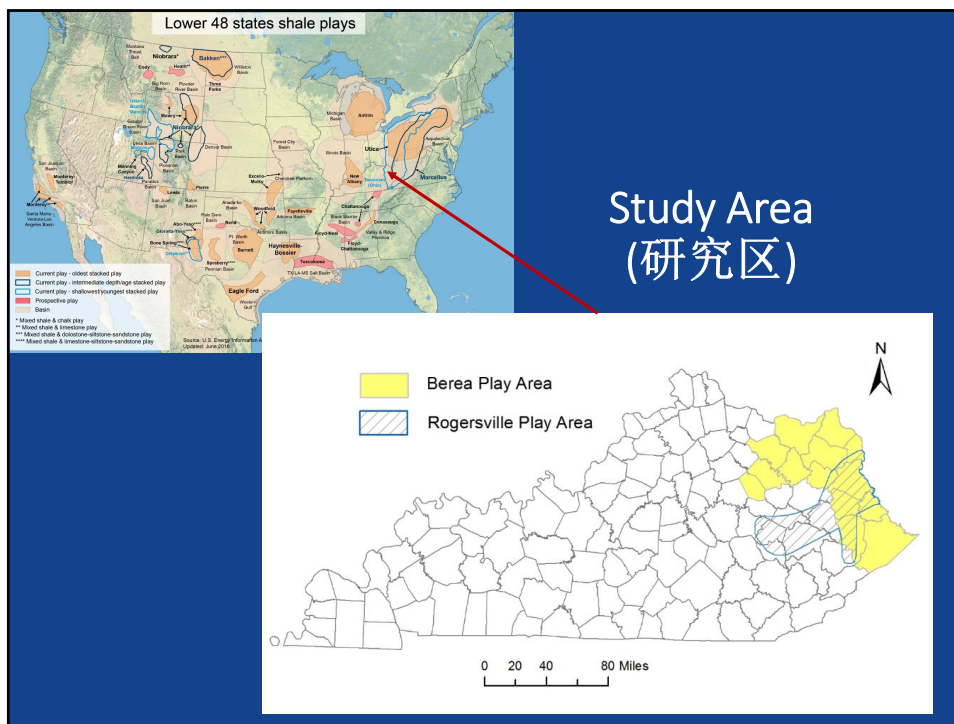
Contacts

Department of the Interior,
U.S. Geological Survey

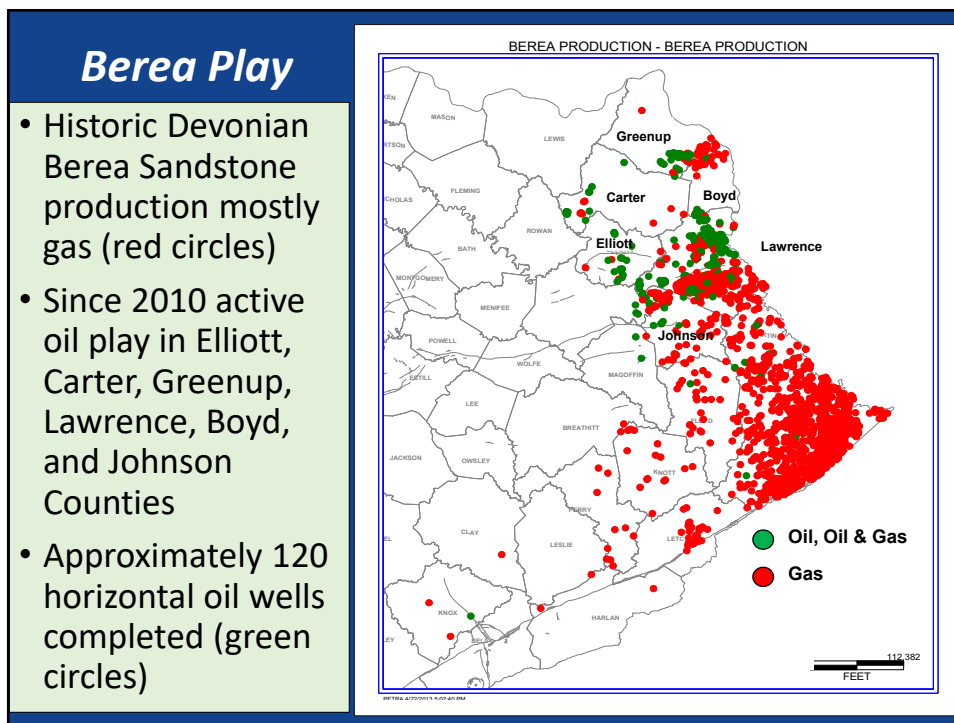
Office of Communications and Publishing
12201 Sunrise Valley Drive
Reston, VA 20192
United States

McMahon (2017), EST *"Methane concentrations were not spatially correlated with hydrocarbon well locations in any of the study areas"*

14



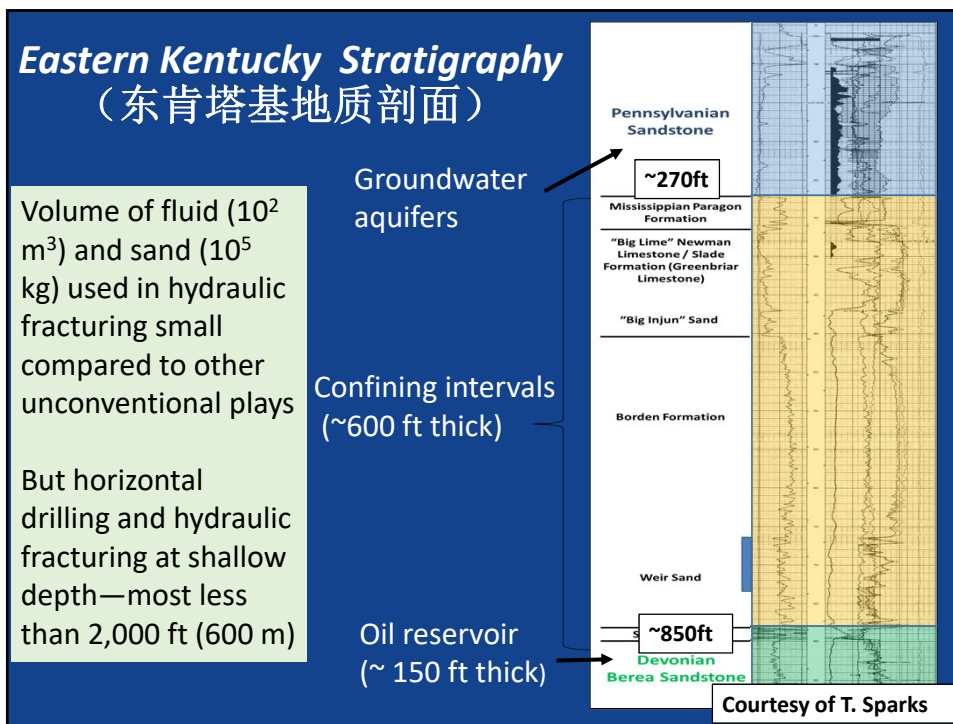
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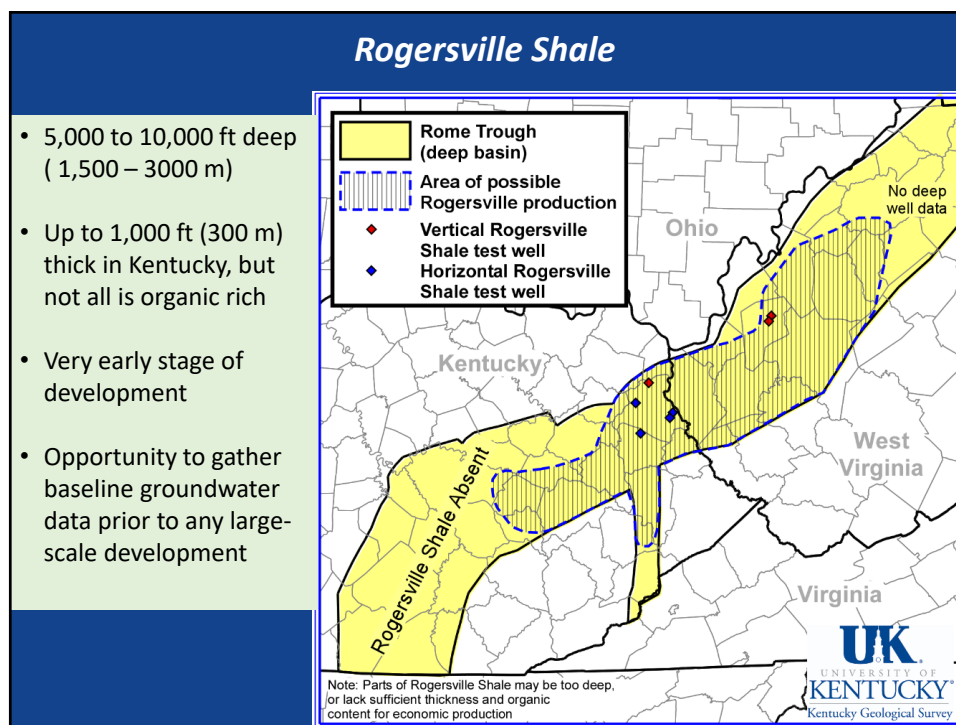
Berea Play

- Historic Devonian Bera Sandstone production mostly gas (red circles)
- Since 2010 active oil play in Elliott, Carter, Greenup, Lawrence, Boyd, and Johnson Counties
- Approximately 120 horizontal oil wells completed (green circles)

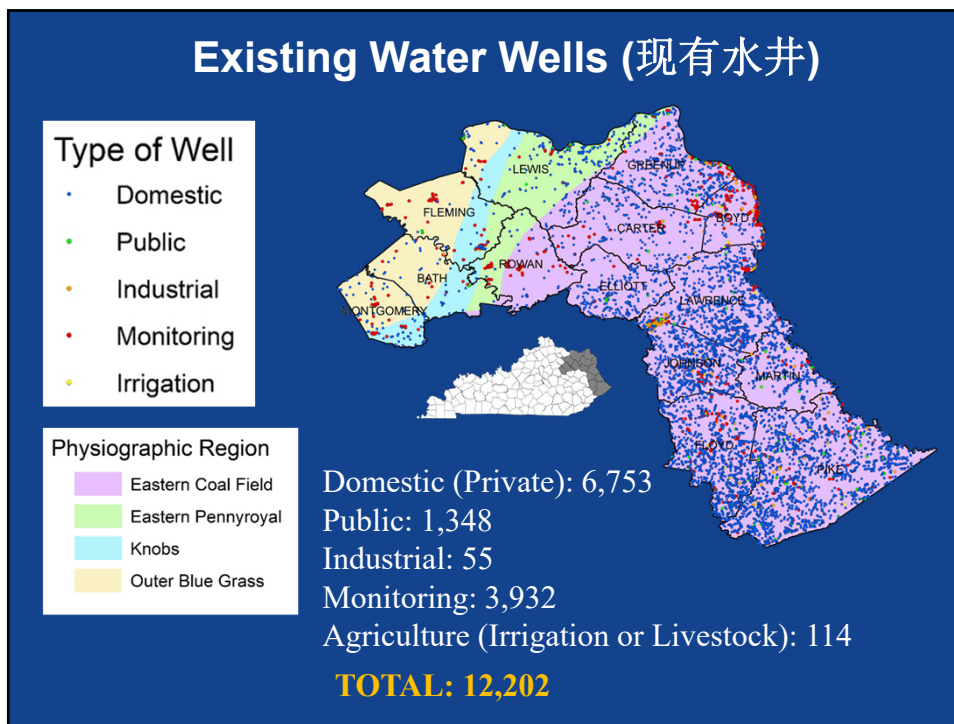
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17



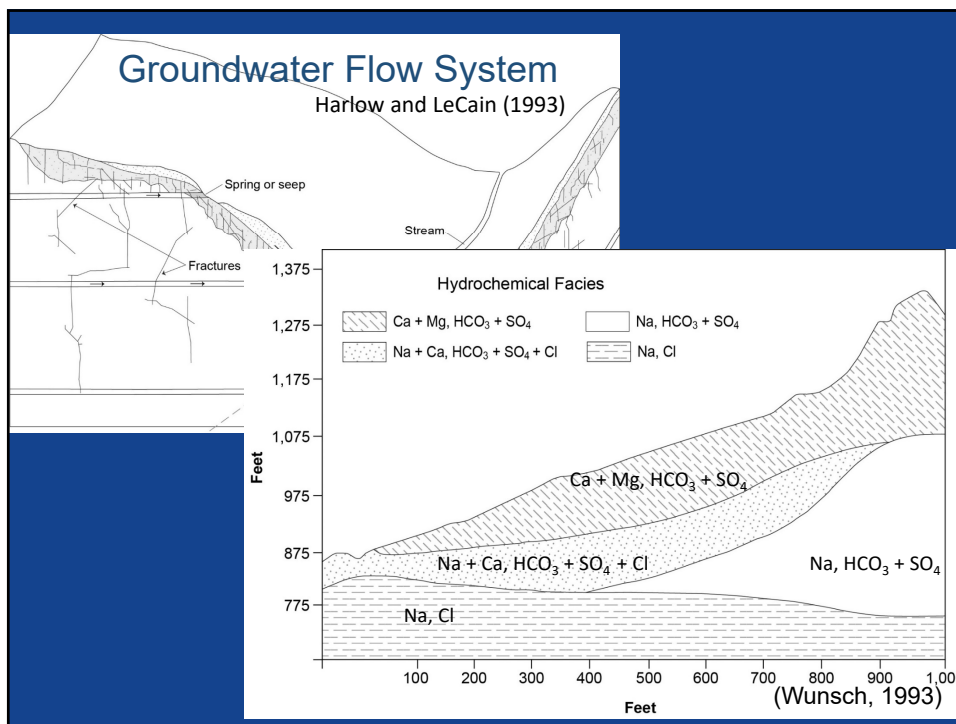
18



19



20



21

Possible Methane Contamination of Drinking Water Wells in Kentucky

Posted by [Erin Savage](#) | August 11, 2011 at 3:18 pm

"In all my 20 years of working on water quality problems, I have never seen a drinking water well catch on fire and burn continuously for days on end," Donna Lisenby said in reaction to [news reports](#) of a well fire in Pike County, Kentucky.



Kentuckians for the Commonwealth Steering Committee member Ted Withrow contacted Appalachian Voices for assistance with heavy metal sampling for 4 Kentucky families whose wells may be contaminated with methane. One well has flames that shoot more than a foot high out of the top of their well. Families in the area report that the water sometimes runs orange or black, and causes their skin to burn upon contact. Some individuals suspect nearby Excel Number 2 mine to be the source of the contamination. The families reported the

"In all my 20 years of working on water quality problems, I have never seen a drinking water well catch on fire and burn continuously for days on end"

(<http://appvoices.org/2011/08/11/methane-well-contamination-kentucky/>)

22

Advanced Analytical Methods (先进的分析方法)

RPSEA 11122-45



- 3-Year project in 2 phases (currently in Phase II)
- \$3.5M from DOE/RPSEA, \$900k in cost share

RESEARCH FOCUS ON THREE KEY ENVIRONMENTAL ISSUES:



Baseline Sampling and Stray Gas Investigation



Advanced Analytics for Air Emissions



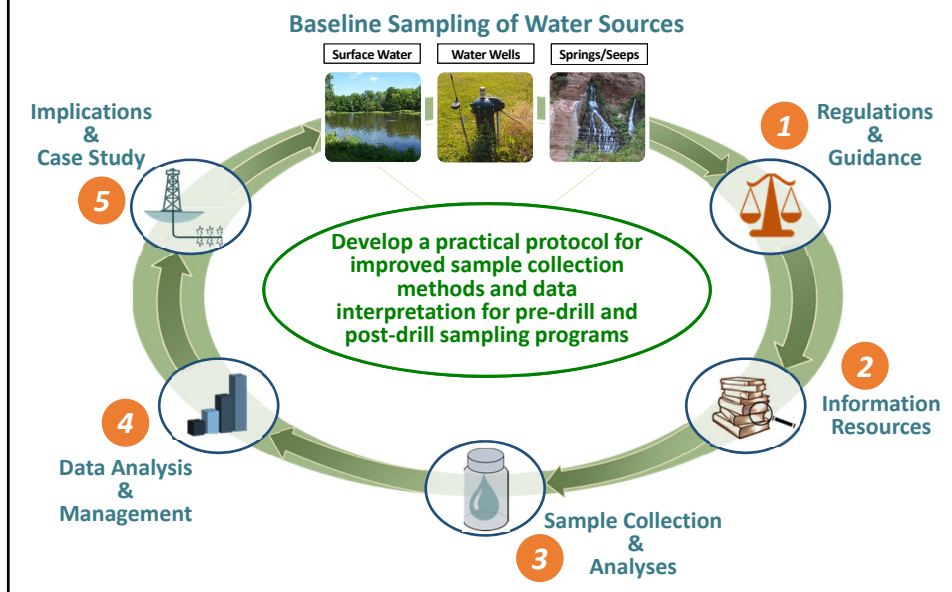
Produced Water Characterization



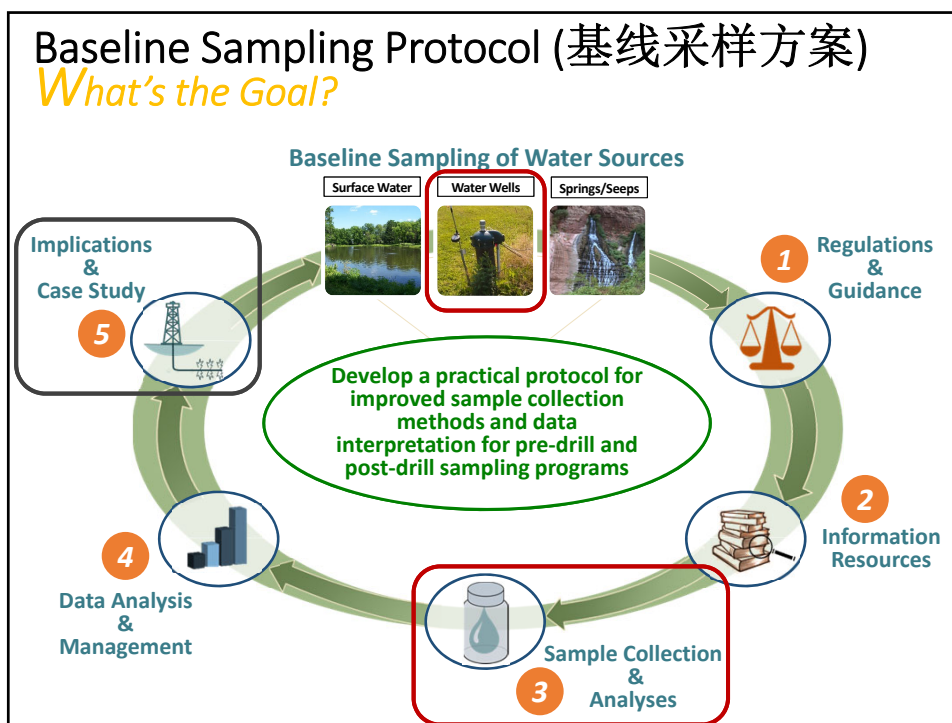
23

Baseline Sampling Protocol (基线采样方案)

What's the Goal?



24



25

Scope of Work (项目方案)

- 1** Select up to 50 water wells in the study area, including Greenup, Carter, Boyd, Lawrence, and Johnson Counties.
- 2** Follow the Baseline Sampling Protocol to collect water samples, which are analyzed for:
 - Dissolved gases
 - Major cations, anions, and metals
 - Carbon and hydrogen Isotopes (samples with $\text{CH}_4 > 1 \text{ mg/L}$)
 - BTEX/TPH
- 3** Analyze the resulting dataset for:
 - Spatial variability in dissolved gases
 - Relationship between water quality parameters and methane occurrence
 - Origins of methane

26

Locating Water Wells (寻找取样水井)

With help from UK Agricultural Cooperative Extension Office, contact well owners to get permission to sample



<https://extension.ca.uky.edu/county>

27

Field Sample (现场取样)

Collect well information

Purge



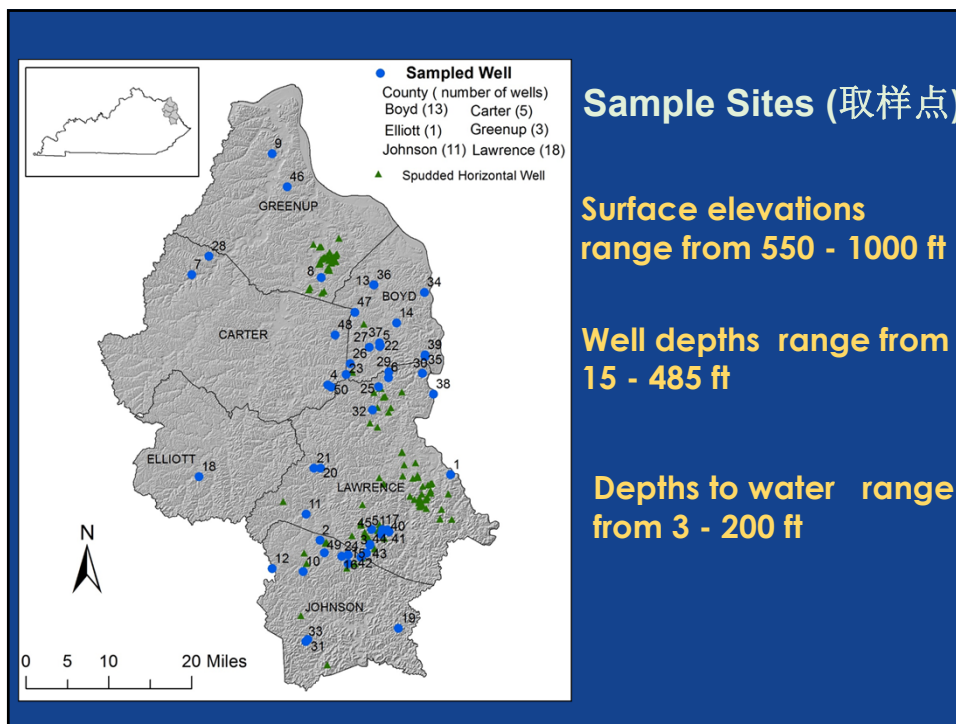
51 wells sampled in March-April 2016

Collect water samples

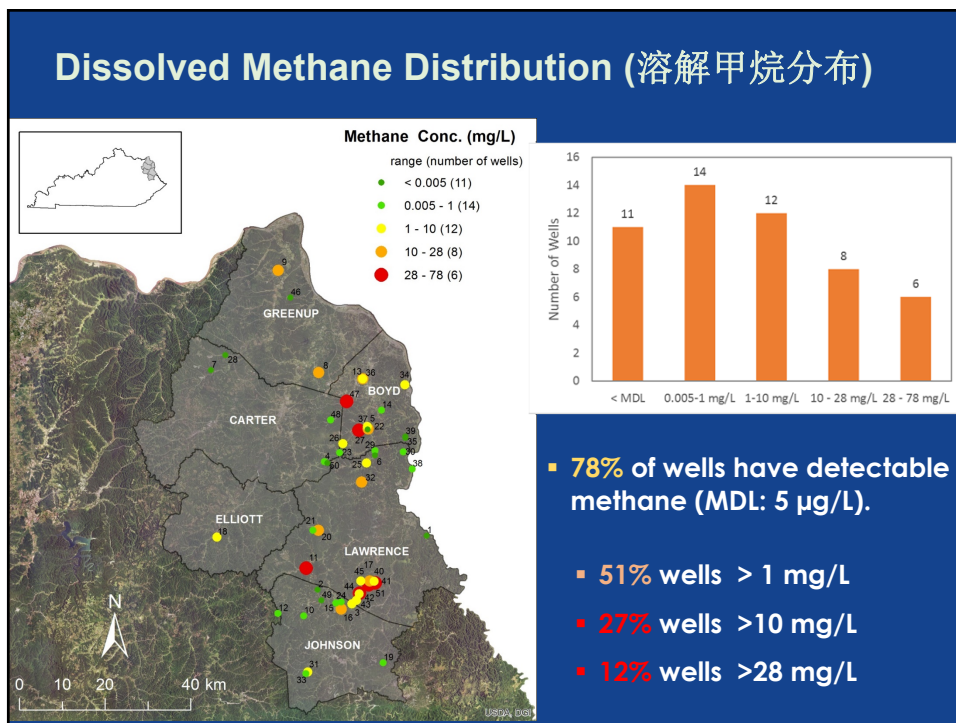
Deliver water samples



28

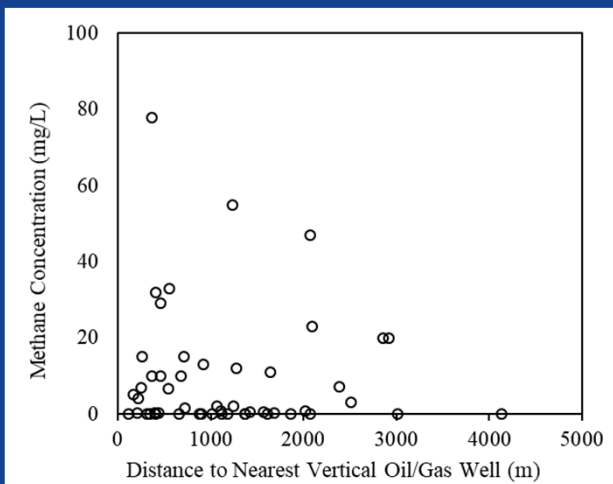


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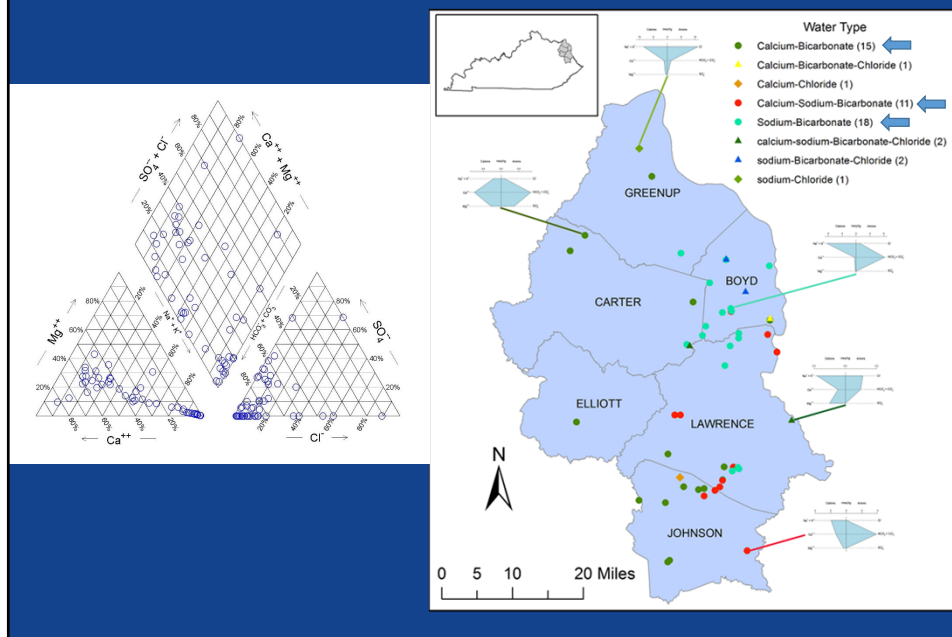
Distances to Oil/Gas wells (甲烷浓度与油气井距离)



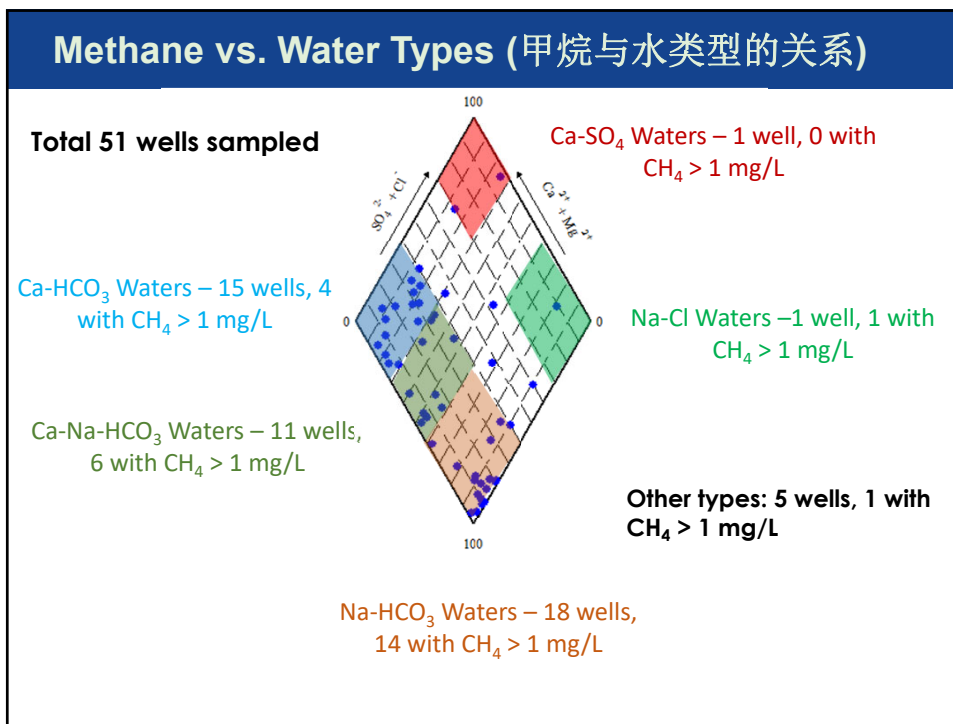
A Kendall's τ analysis ($\tau = -0.03$, $p=0.73$)

31

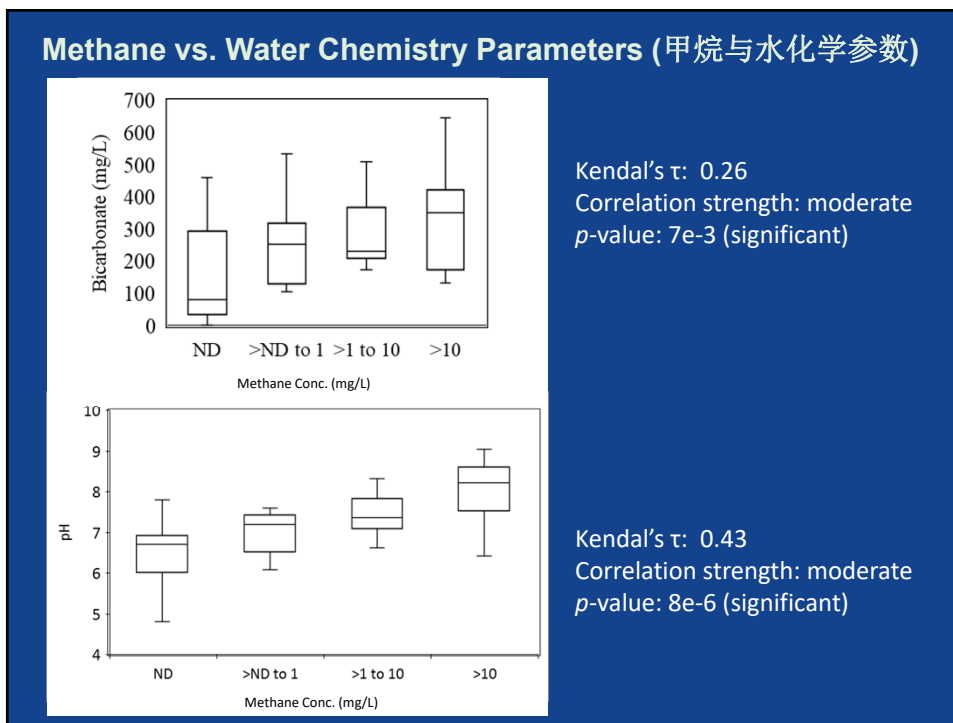
Methane vs. Water Types (甲烷与水类型的关系)



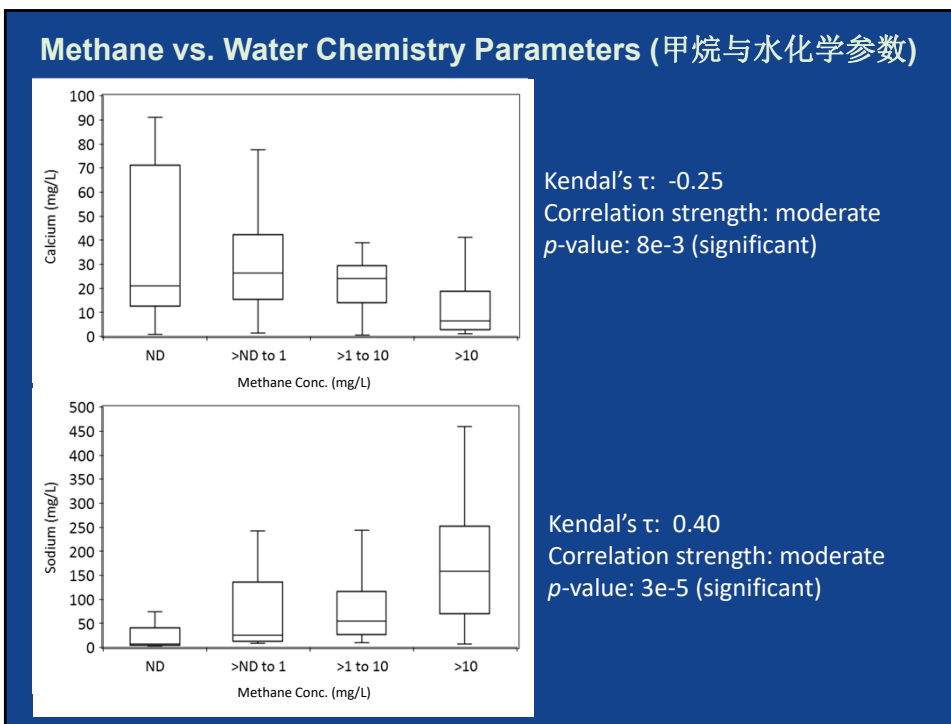
32



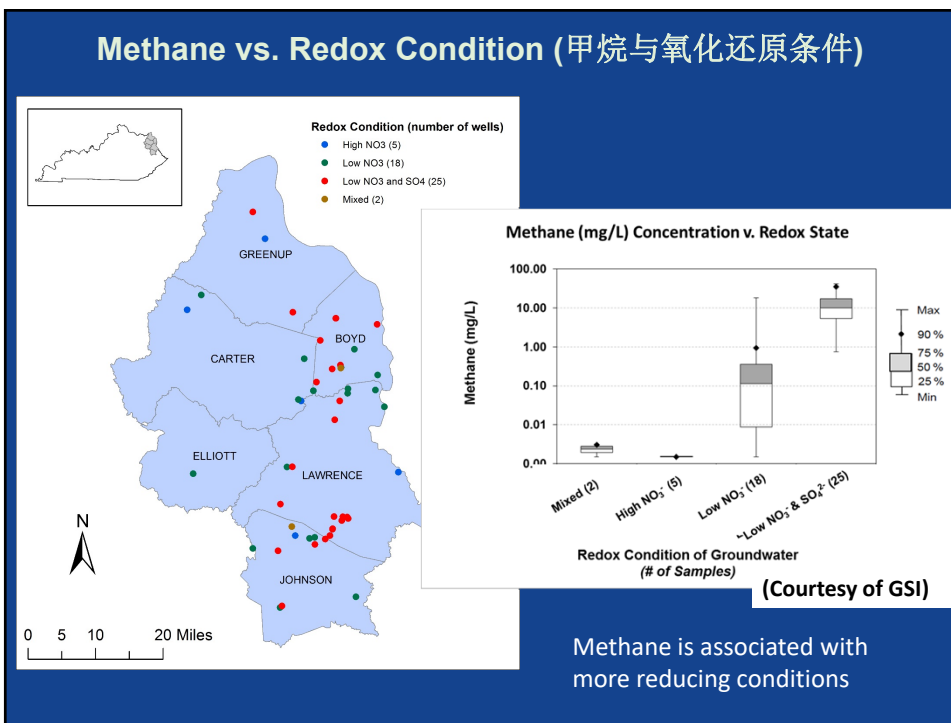
33



34



35



36

Methane(CH₄) Isotopes (δ²H and δ¹³C) 甲烷同位素

$$\delta^2\text{H}(\text{‰}) = \left[\frac{(^2\text{H}/^1\text{H})_{\text{sample}}}{(^2\text{H}/^1\text{H})_{\text{standard}}} - 1 \right] \times 1000$$

$$\delta^{13}\text{C}(\text{‰}) = \left[\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}}}{(^{13}\text{C}/^{12}\text{C})_{\text{standard}}} - 1 \right] \times 1000$$

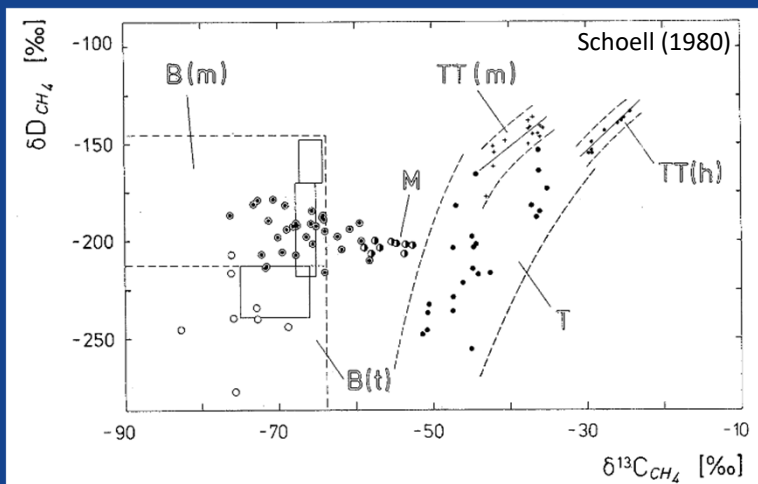
Standard:

Hydrogen isotopes: standard mean ocean water (SMOW)

Carbon isotopes: Vienna Pee Dee Belemnite (VPDB)

37

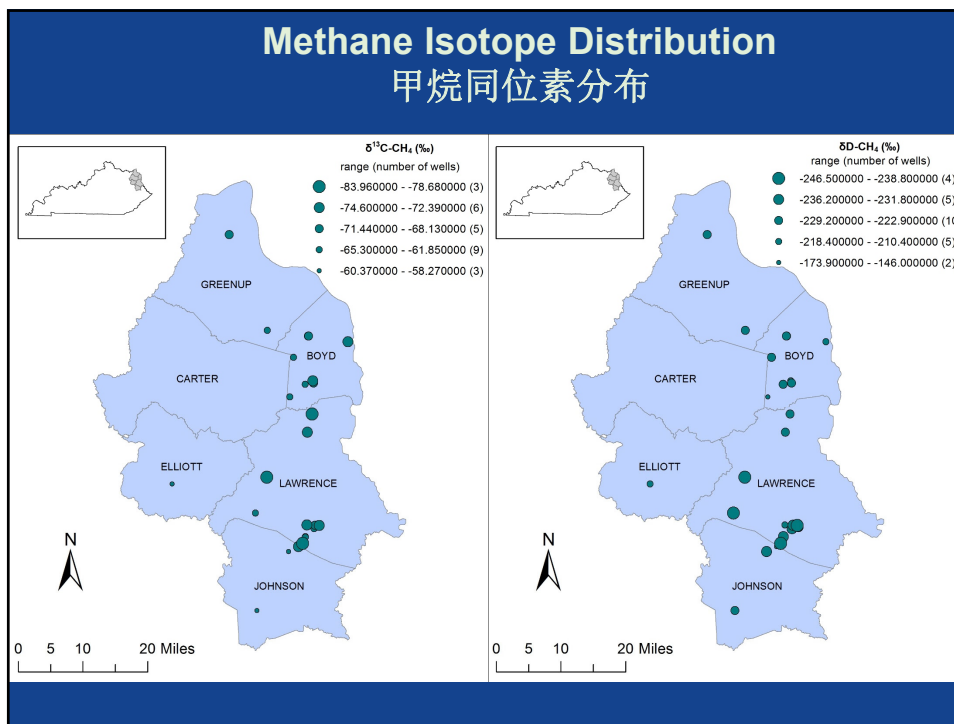
Methane(CH₄) Isotopes (δ²H and δ¹³C) 甲烷同位素



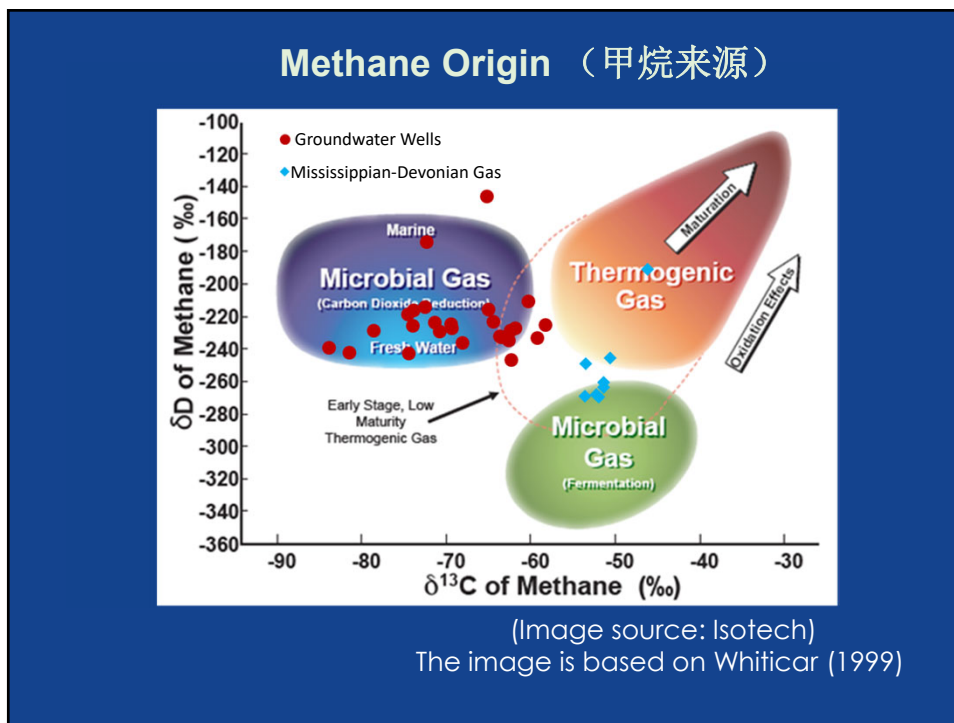
B(m): biogenic marine
B(t): biogenic terrestrial
M: mixed gas

TT(m): thermogenic marine-sapropelic
TT(h): thermogenic humic terrestrial
T: wet gas (C₂₊ > 5%)

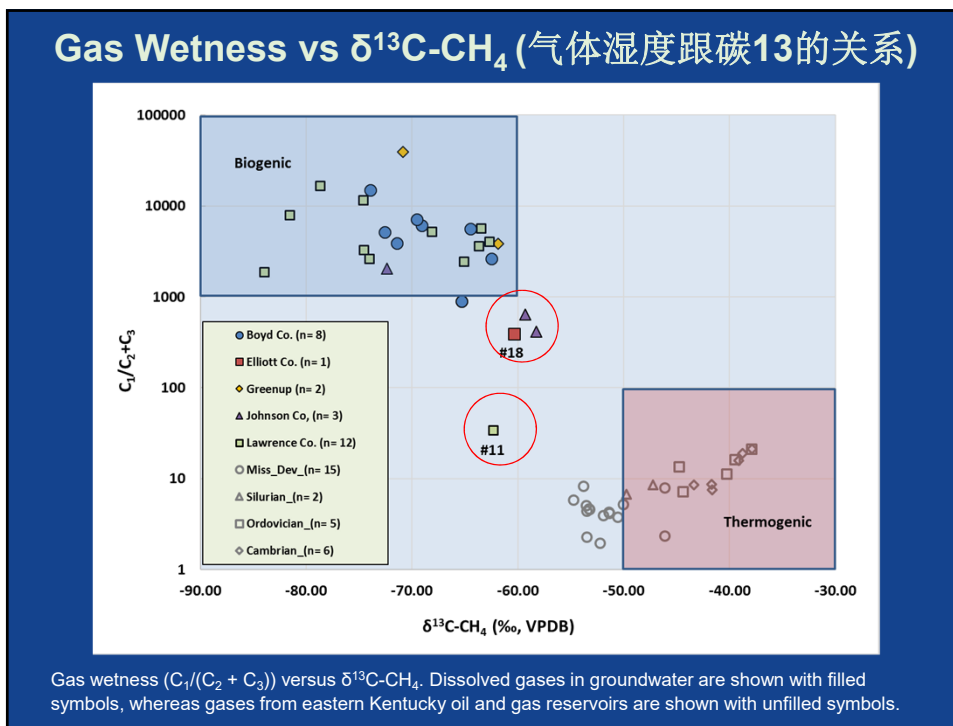
38



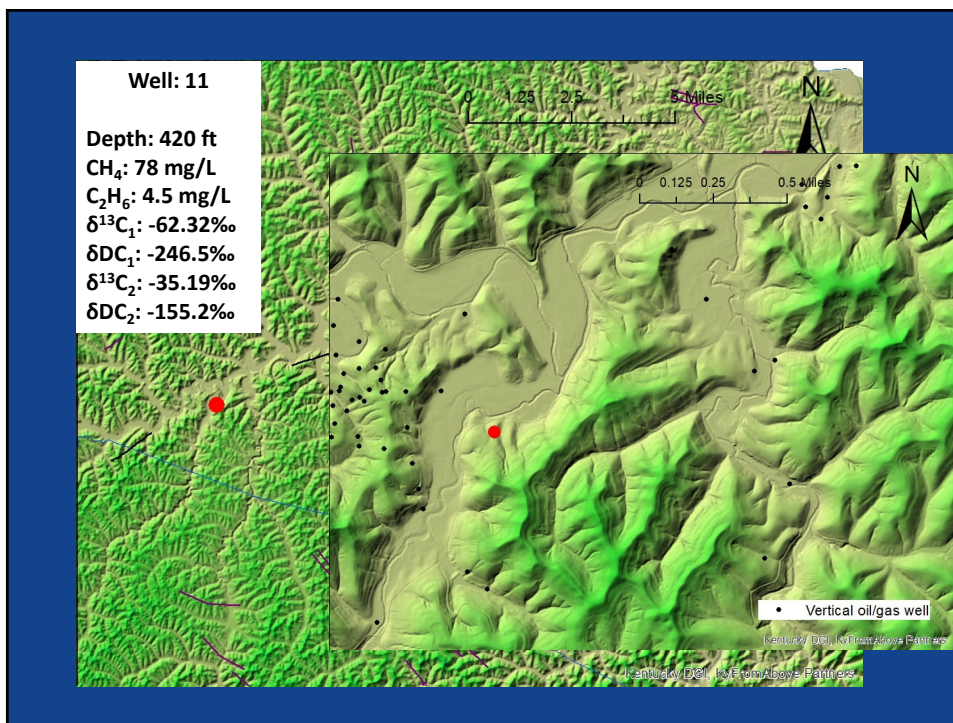
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41



42

Conclusions (结论)

- Methane is a relatively common occurrence in shallow groundwater in Berea and Rogersville play areas of eastern Kentucky.
- Methane in groundwater is primarily generated from microbial sources.
- Methane is associated with hydro-geochemical conditions. Elevated methane concentrations were found more common in sodium-rich water and reducing redox conditions.

43

Acknowledgements

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44



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Questions?

junfeng.zhu@uky.edu