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SHALE-DEPOSITED NATURAL GAS: A REVIEW OF POTENTIAL

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SHALE-DEPOSITED NATURAL GAS: TOPICS

- What are natural gas shale formations (gas shales);
- Technological innovations and enhanced productivity;
- Location of the gas shale formations;
- Production history and reserve potential;
- Canada's shale gas potential;
- Uncertainties in the development of shale formations.

SHALE-DEPOSITED NATURAL GAS:
WHAT ARE GAS SHALES?

- **Geologic characteristics of shale:**
  - **sedimentary rock formation;**
  - **consolidated clay and silt-sized particles;**
  - **organic-rich.**

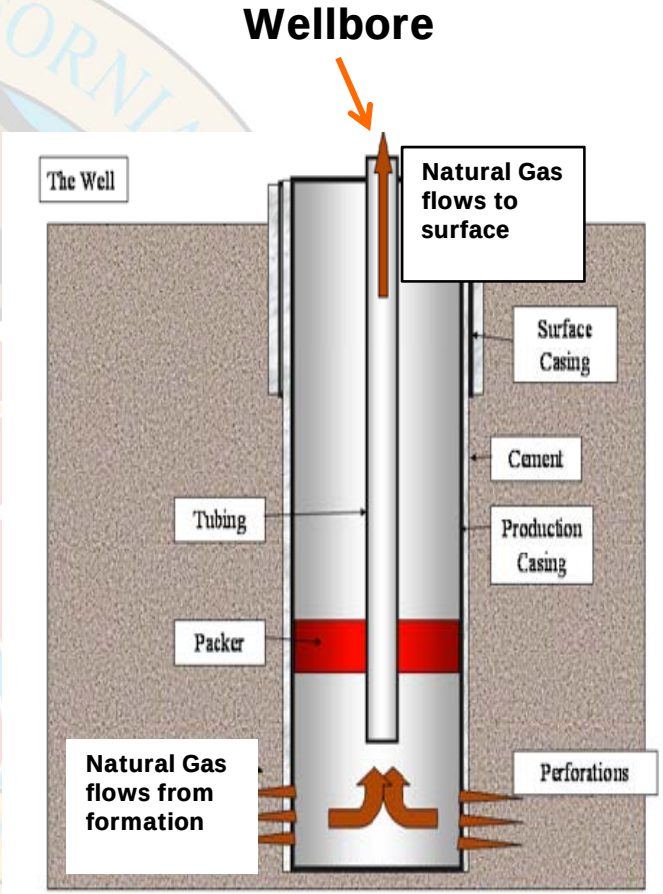
- **Primary function of shale:**
  - **trap and seal deposits in natural gas-bearing sandstone and carbonate reservoirs (pools).**

Shale-Deposited Natural Gas:
What are Gas Shales? (cont'd)

- **Three storage mechanisms:**
  - **Free natural gas within natural micro-fractures;**
  - **Free natural gas within minute rock pores;**
  - **Adsorbed gas**
    - **methane molecules attached to organic material contained within solid matter;**
    - **20 to 85 percent of total natural gas.**

Shale-Deposited Natural Gas: Requirements for Economic Production

- **Producing from a rock formation (reservoir):**
  - **Significant deposit;**
  - **Sufficient porosity;**
  - **Sufficient effective permeability.**
- **All three requirements *must* be present.**
- **Little or no natural permeability in gas shales.**



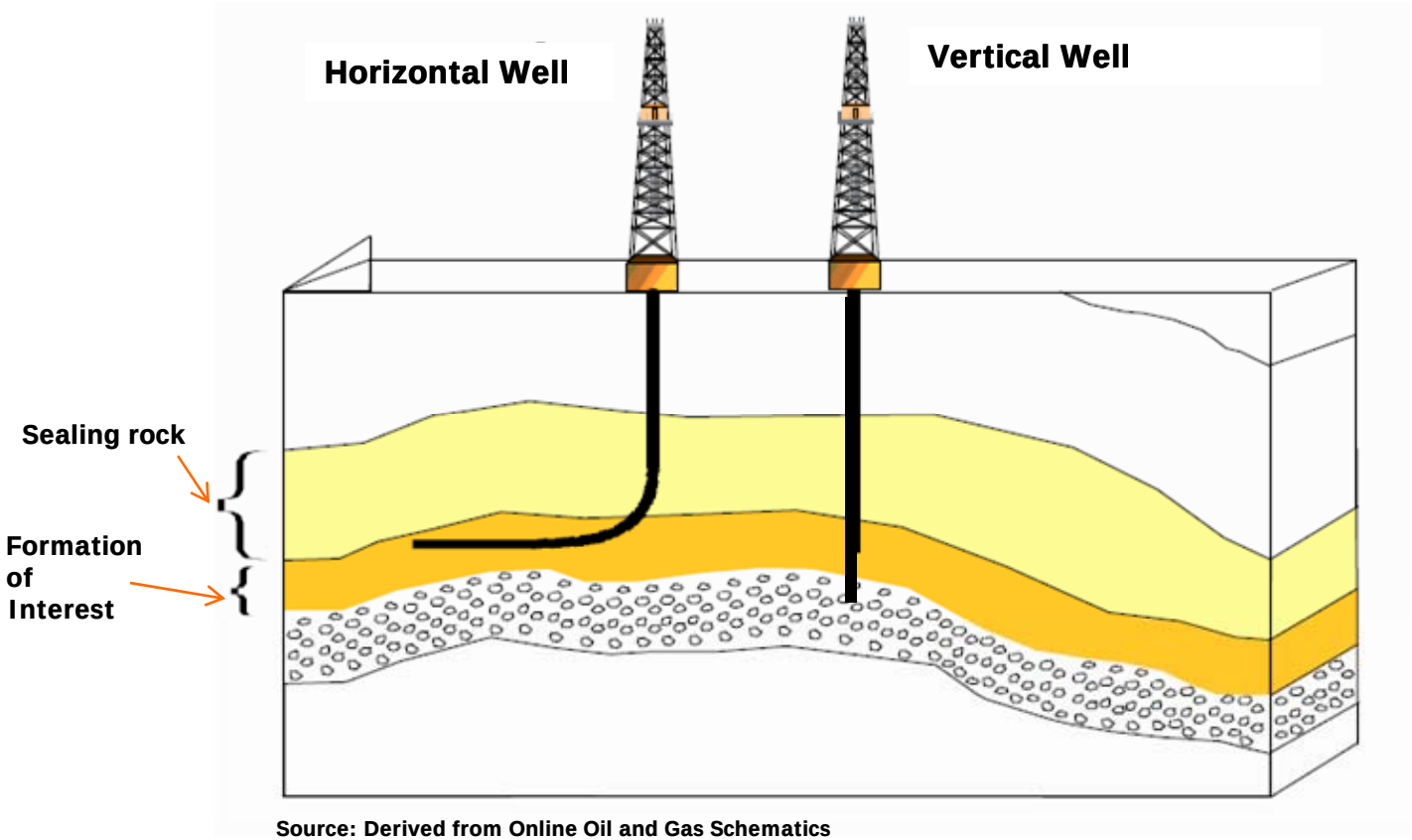
Source: Derived from Oil & Gas Journal and Natural Gas Supply Association

SHALE-DEPOSITED NATURAL GAS: WHAT ARE THE TECHNOLOGICAL INNOVATIONS?

- **Technological innovations in *exploration:***
  - **Development of 3-D and 4-D seismic;**
  - **Enhanced capability to delineate the limits of the deposits.**

- **Technological innovations in *drilling:***
  - **Horizontal drilling increased wellbore exposure by a factor of five to twenty times.**

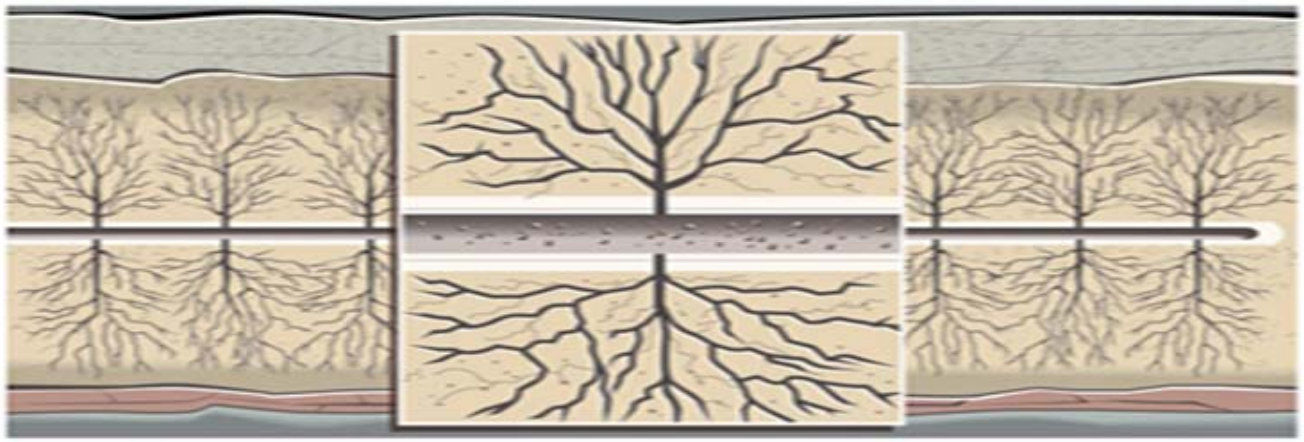
Shale-Deposited Natural Gas:
Schematic of Wells (Horizontal vs Vertical)



Source: Derived from Online Oil and Gas Schematics

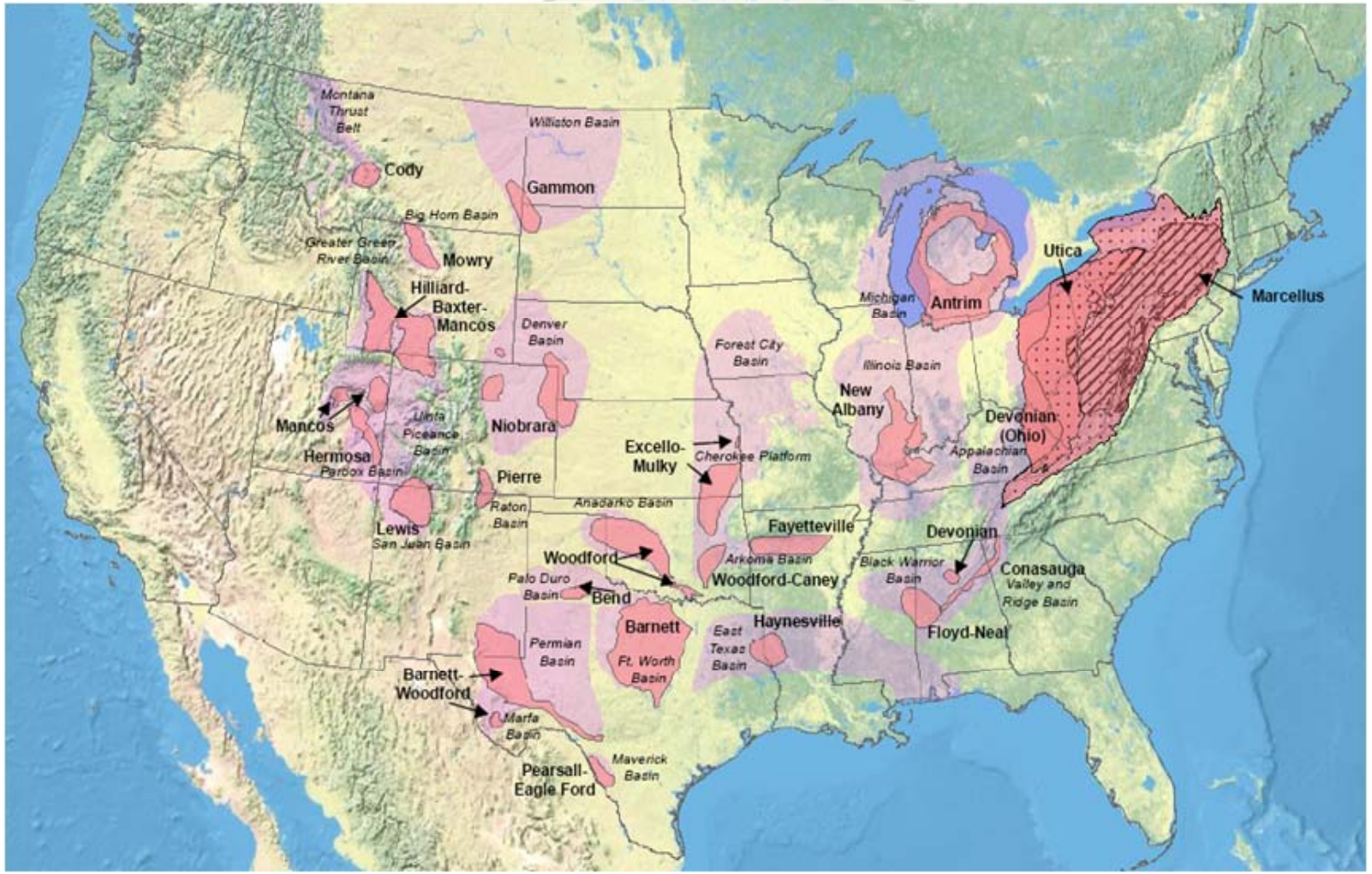
Shale-Deposited Natural Gas: What are the technological innovations?

- **Technological innovations in *well completions:***
  - **Hydraulic fracturing increased effective permeability;**
  - **Multiple-stage stimulations now possible;**
  - **Network of artificial fractures raises effective permeability.**
  - **Techniques boosted recovery rates.**



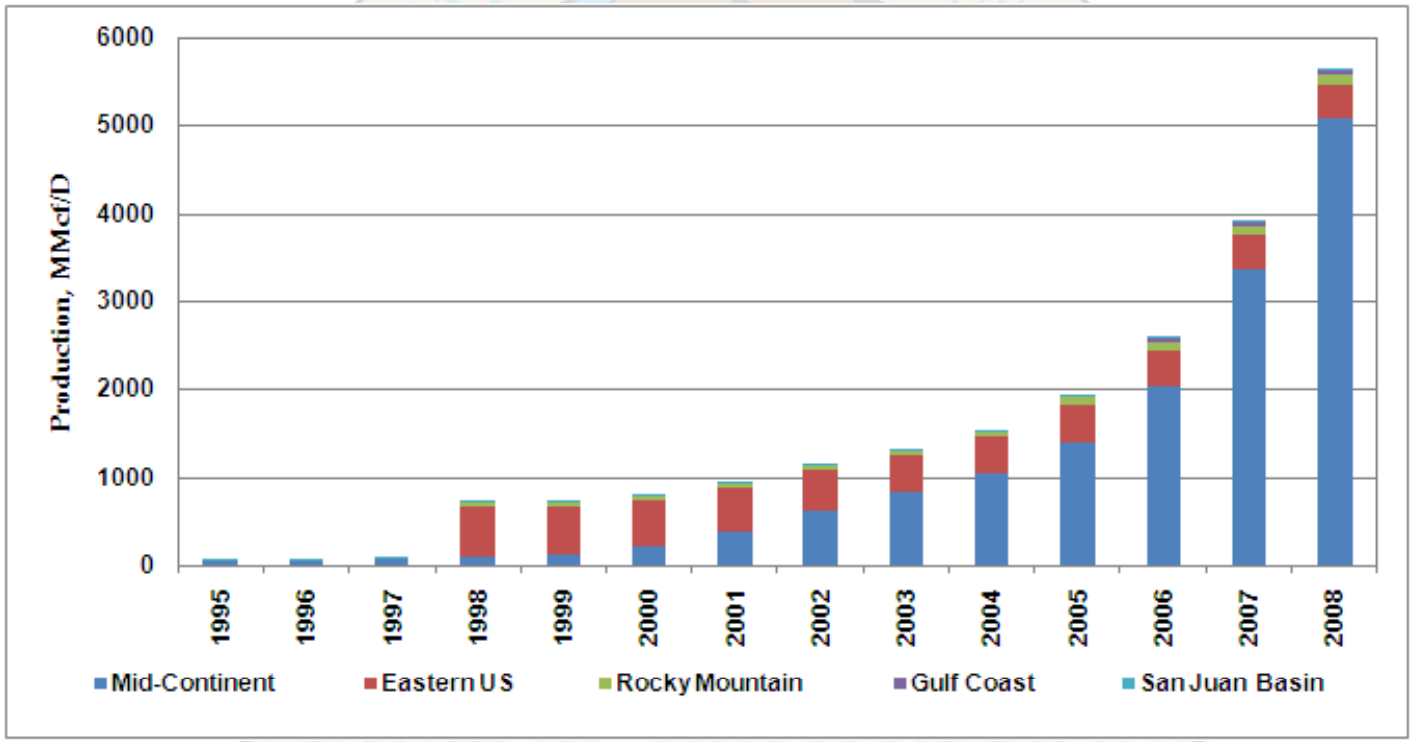
Source: Natural Gas Supply Association

Shale-Deposited Natural Gas: Where are the Lower 48 shale formations?



Source: Energy Information Administration

Shale-Deposited Natural Gas:
History of L48 Shale Natural Gas Production



Source: Lippman Consulting, Inc.

SHALE-DEPOSITED NATURAL GAS:
GAS SHALES IN CANADA

- **Identified shale formations:**
  - Horton Bluff, Utica, and Lorraine in Eastern Canada
  - Muskwa shale of the Horn River Basin in northeast British Columbia
  - Montney shale in the Western Canadian Sedimentary Basin (British Columbia)
- **Eastern Canada**
  - Producers are testing the Horton Bluff Shale, the Utica Shale, and Lorraine
  - Discovery well in the Utica Shale flowed 1000 Mcf/d.
- **Western Canadian Sedimentary Basin**
  - Producers are testing the Montney Gas Shale
  - Initial tests from three wells flowed: 8800 Mcf/d, 6100 Mcf/d, and 5300 Mcf/d.

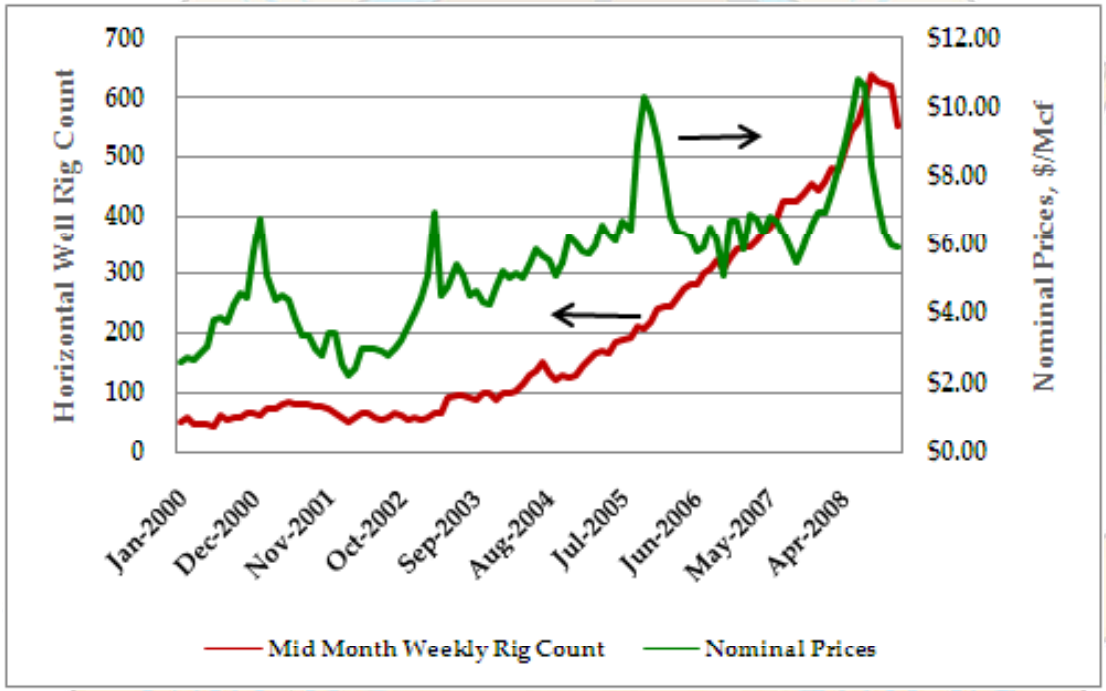
Shale-Deposited Natural Gas: Uncertainty ~ Recoverable Reserve Potential

- **Estimates of Original Gas-In-Place (OGIP) for shale formations exceed 3,000 Tcf;**
- **Assessments of recovery (extraction) rates produce a wide range of values;**
- **Estimates of recoverable reserves range from 267 Tcf to 842 Tcf;**
- **Major differences arise from reserve estimates of two shale formations: The Marcellus and the Haynesville;**
- **Number in table reflects a composite of current and "best available "estimates.**

Natural Gas Shale Formations in the Lower 48		
Shale Formation	Approximate Vertical Depth, feet	Approximate Recoverable Reserves, Tcf
Barnett	6500 - 8500	44.0
Wordford	6000 - 11000	11.4
Fayetteville	1000 - 7000	41.6
Antrim	600 - 2200	20.0
Huron	1000 - 7000	N/A
Marcellus	4000 - 8500	392.0
New Albany	500 - 2000	19.2
Bakken	>10000	N/A
Baxter	>11000	N/A
Pierre	2500 - 5000	N/A
Mancos	>13000	N/A
Haynesville/Bossier	>11000	251.0
Pearsall-Eagleford	>11500	N/A
Lewis/Mancos	3000 - 6000	20.0
Total		799.2

Source: Various, including EIA, Navigant Consulting and others

SHALE-DEPOSITED NATURAL GAS:
UNCERTAINTY ~ ECONOMICS OF DEVELOPMENT



Source: California Energy Commission (Derived from Baker Hughes and NYMEX)

Shale-Deposited Natural Gas: Uncertainty ~ Environmental Impacts

- **General environmental concerns:**
  - **Surface disturbance**
  - **Greenhouse gas emissions**
  - **Potential leakage into the groundwater.**

Shale-Deposited Natural Gas: Issues

- **Will future production of natural gas from shale formations meet expectations of the natural gas industry?**
- **What factors affect the reliability of recoverable reserve estimates?**
- **How will the current pricing environment affect drilling programs scheduled for natural gas shale formations?**
- **Will the potential environmental impacts affect future drilling and production?**
- **Will natural gas from shale formations displace the importation of liquefied natural gas (LNG) in the United States and Canada?**
- **Will natural gas from shale formations continue to capture demand-side market share?**
- **Is natural gas from shale formations a viable long-term source of natural gas?**

SHALE-DEPOSITED NATURAL GAS: A REVIEW OF POTENTIAL

- **QUESTIONS?**
- **COMMENTS?**