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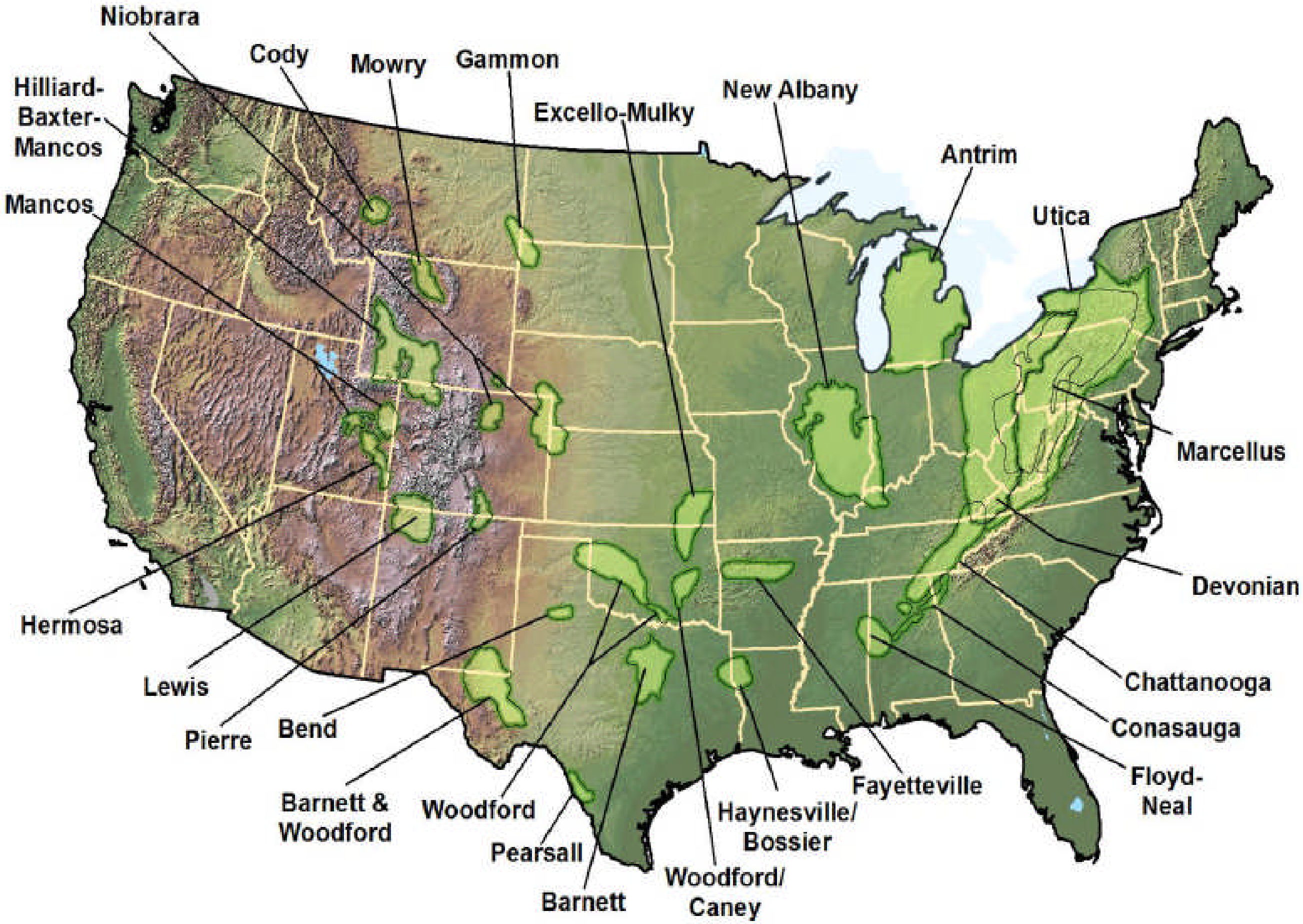

US Shale Gas What's Going On?

Phil Clarke / Stuart Fordyce
Novas Consulting Ltd

27th April 2010

US Shale Gas

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- Why is US shale gas important?
- Market context
- Geological overview
- The Magnificent Seven
  - Antrim Shale
  - Barnett Shale
- Characteristics of US shale gas basins
- Impact of Technology
- What's it worth?
- Conclusions

Why study US shale gas?

- 'Unconventionals' now provide 46% of US domestic gas production
  - Shale Gas
  - Coalbed Methane
  - Basin Centred Gas
  - Tight Gas
- Gas accounts for 22% of US energy supply
- 2008 shale gas production 2.0 TCF
  - Almost a 100% increase from 2007
  - 10% of total gas production
  - 2.1% of total US energy supply
- LNG import demand "has been destroyed by shale gas"
  - US regas capacity 15 Bcf/d
  - LNG imports 1.8 Bcf/d
- Shale gas impact
  - Bolstering domestic gas production
  - Displacing LNG in US gas market
- So
  - What has happened to trigger the sudden resurgence in US shale gas?
  - Could this happen elsewhere or is the US situation unique?
  - How will US shale gas expansion impact world gas supply?
  - What learnings can we transfer to understand European shale gas potential?

Data source: US DOE, upstreamonline.com

A brief history of US Shale Gas

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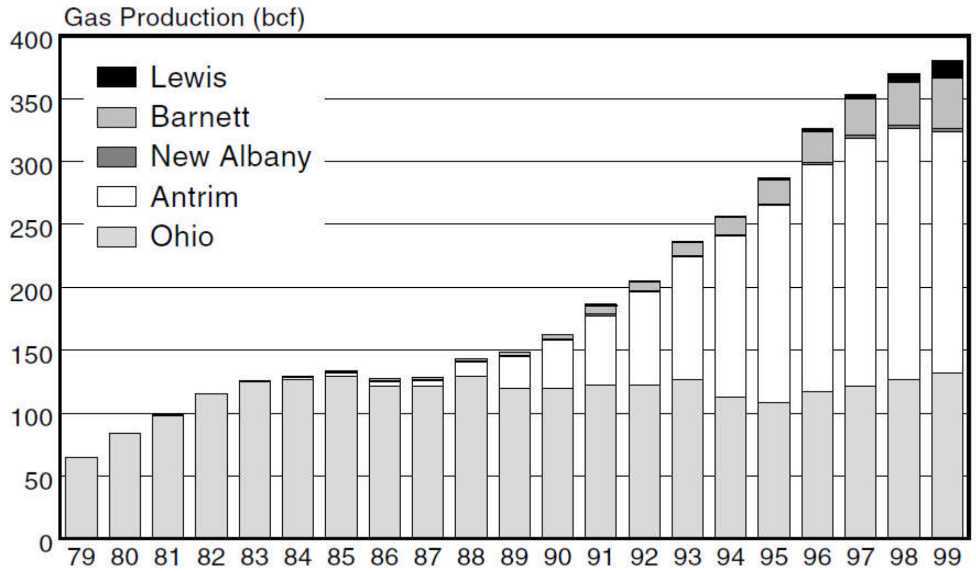
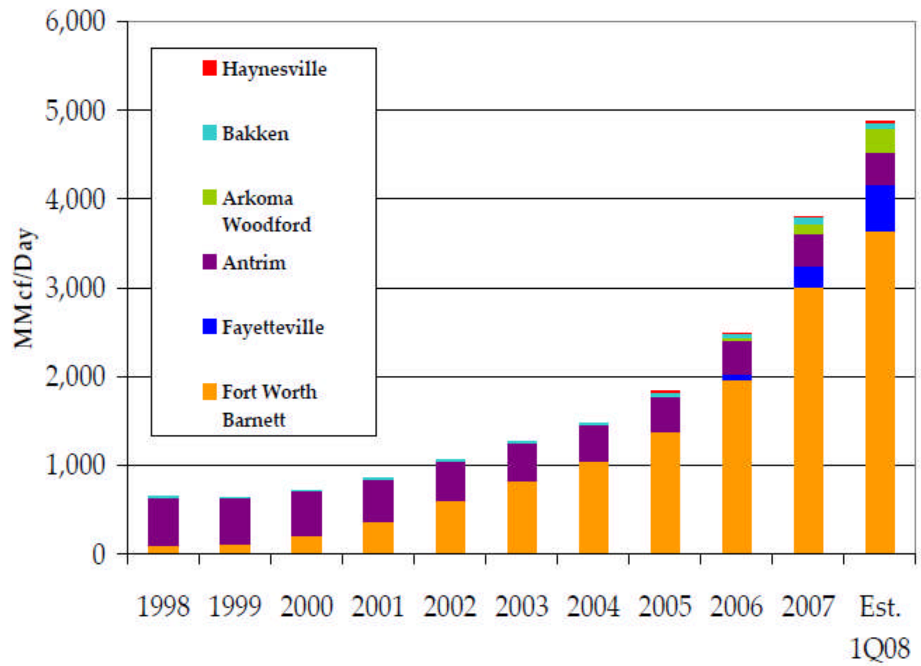
- Shale gas is not new
- Devonian shales in the NE USA have provided gas since 1821
- First industrial scale shale gas development in 1920's
  - Big Sandy field, Kentucky (Devonian Ohio Shale)
- Moderate growth in developments through subsequent decades, mainly in Ohio and Antrim shales
- Since late 1990's exponential growth in shale gas activity and production, led by Barnett Shale
- Shale gas production grew from 0.8 BCF/d in 1998 to 5.5 BCF/d in 2008
- Half of the natural gas consumed today produced from wells drilled within the last 3.5 years
- Recent feeding frenzy on US shale gas producers





Data sources: US DOE, Curtis (2001), Navigant (2008)

Impact on US Energy Supply

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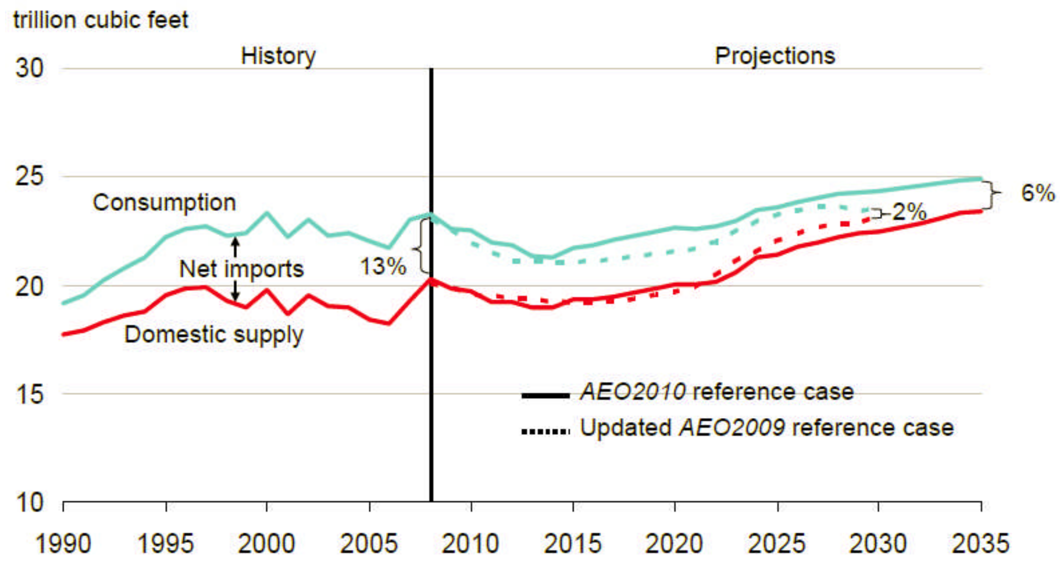
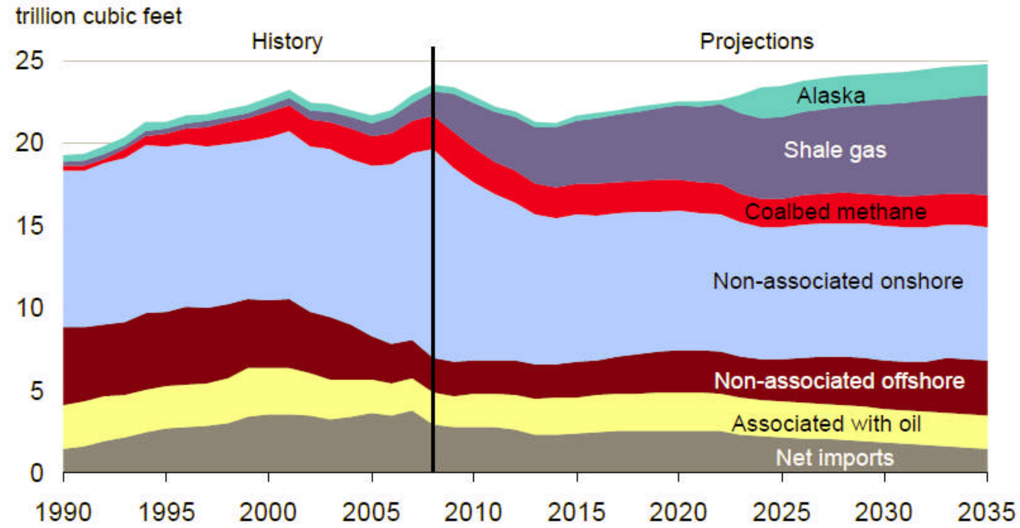
- At the start of the decade, imports of LNG were expected to play an important role in US gas supply
- LNG refining capacity end-2009 expected to be six times greater than at start of decade
- Five new LNG terminals commissioned since 2005
- LNG imports peaked at 771 bcf in 2007, but declined to 470 bcf in 2009
- LNG imports mainly from Trinidad
- 60% of US onshore recoverable reserves are of unconventional gas
- Conservative estimates of sustainable shale gas production are 27 bcf/d over next 10 years, cf. 5.5 bcf/d currently





Data source: US EIA

Impact on US Gas Reserves

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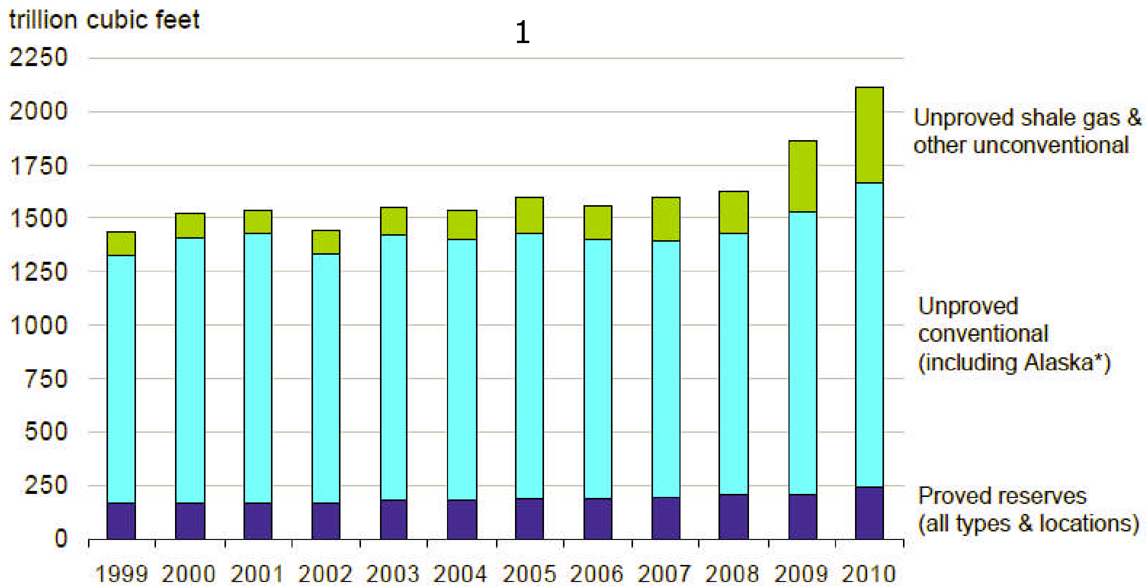


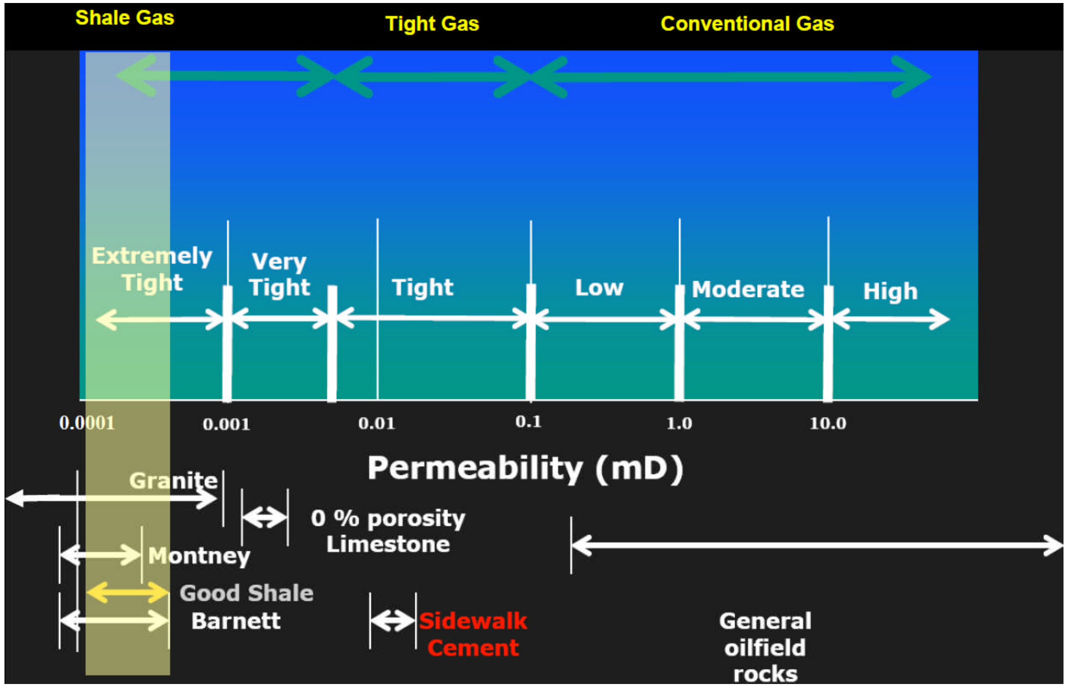
NB: Prior to 2009 Alaska gas not included in conventional reserve estimates

- Shale gas primary source of recent growth in US recoverable gas reserves
  - 21.7 TCF proven shale reserves end 2007 (9.1% of reserves)
  - 32.8 TCF proven shale reserves end 2008 (13.4% of reserves)
- Proved conventional reserves fell by 3 TCF over the same period
- Most commentators expect further upward reserves revisions
  - Barnett Shale assessed at under 6 TCF in 2000, almost 30 TCF in 2003, and estimated 44 TCF technically recoverable in 2009!
- DOE and other independent assessors estimate that US has circa 100 years of domestic gas reserves

Data source: US EIA

What are gas shales?

- Essentially **mature source rocks**
- **Thermogenic** or **biogenic**
- **Ultra low** porosity & permeability
- Shale is both **source rock** and **reservoir**
- Large **gas in place**
- Gas stored both as **free** gas & **sorbed** gas
- Production requires **high density induced** fracture network
- **Brittle is best** – low clays, either clastic or carbonate



Data source: US DOE, courtesy TransCanada

US Shale Gas Basins

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The Magnificent Seven

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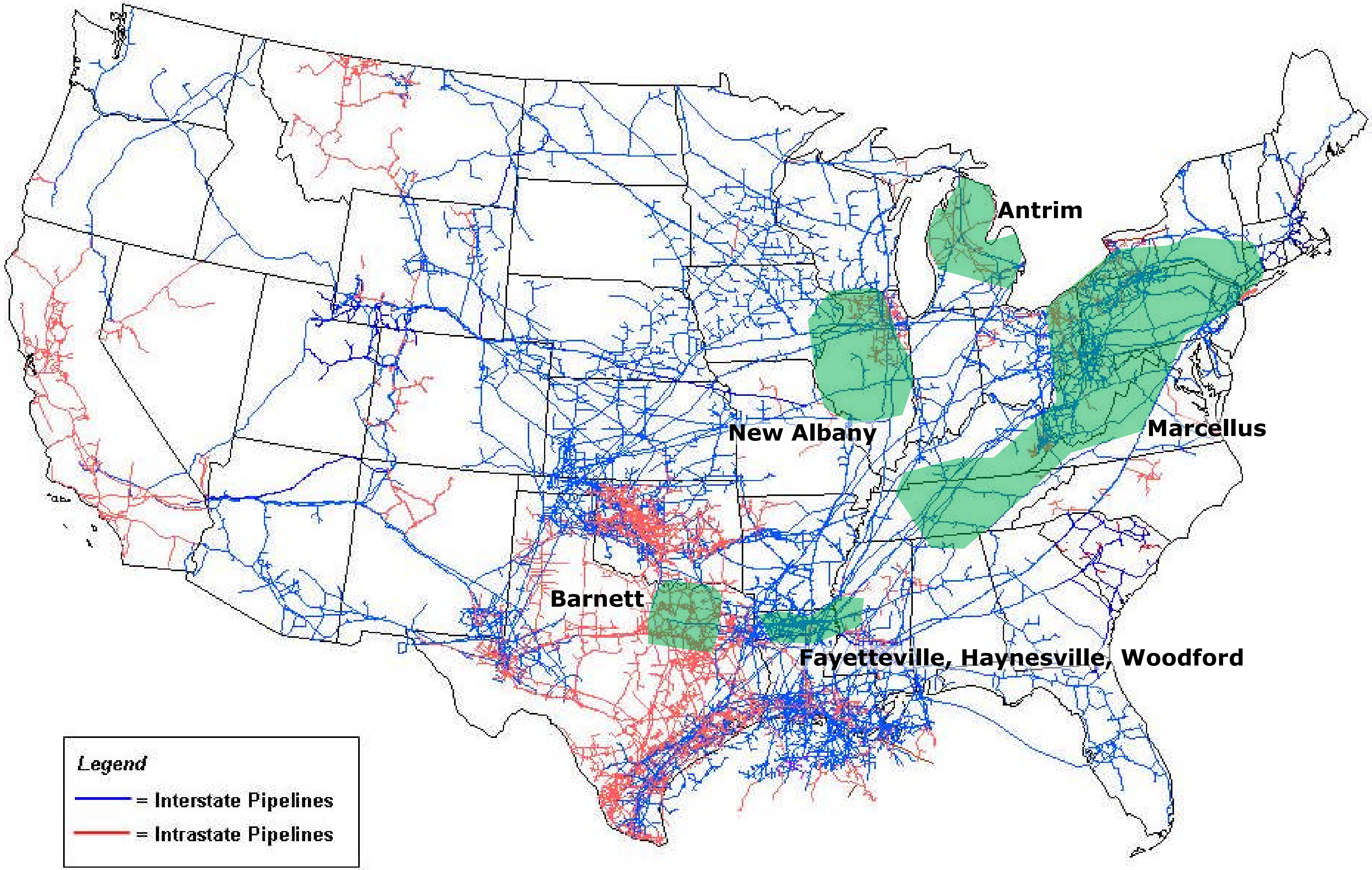
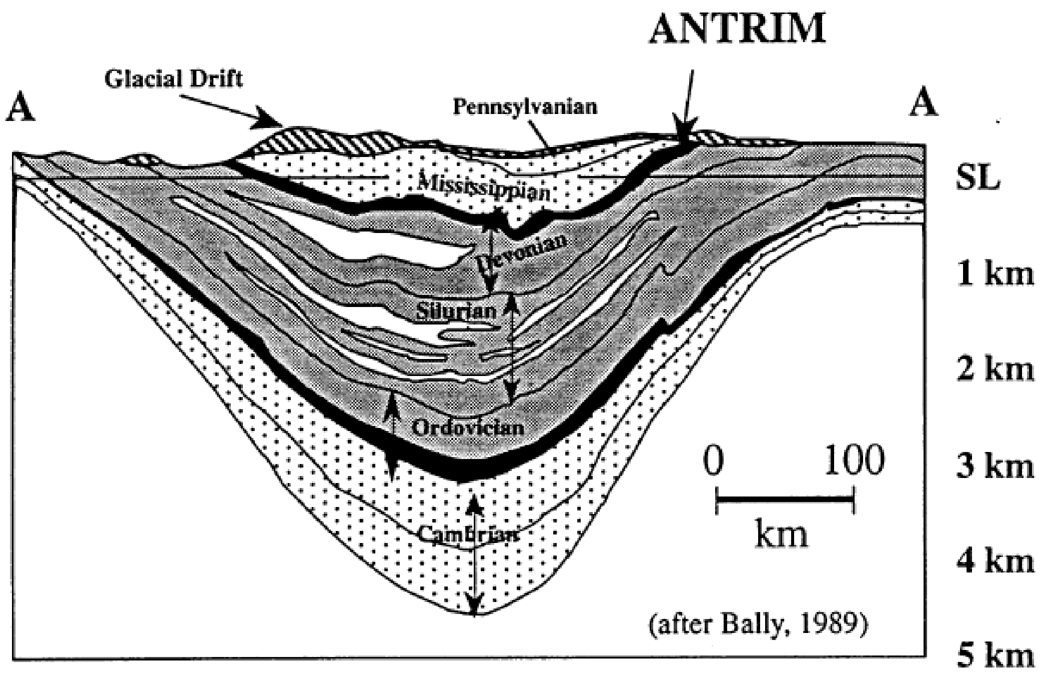


Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Antrim Shale – 20 TCF Reserves

- Late Devonian shale in cratonic sag on the margin of Canadian shield
- Inboard of forebulge to Appalachian foreland basin
- Discovered in the 1940's, with significant development beginning in the mid 1980's
- 2.6 TCF produced by end-2007
- Huge area – 11,000 square miles
- Core producing area in Northern Michigan



Data source: Martini et al (1998)

Antrim Shale Geology

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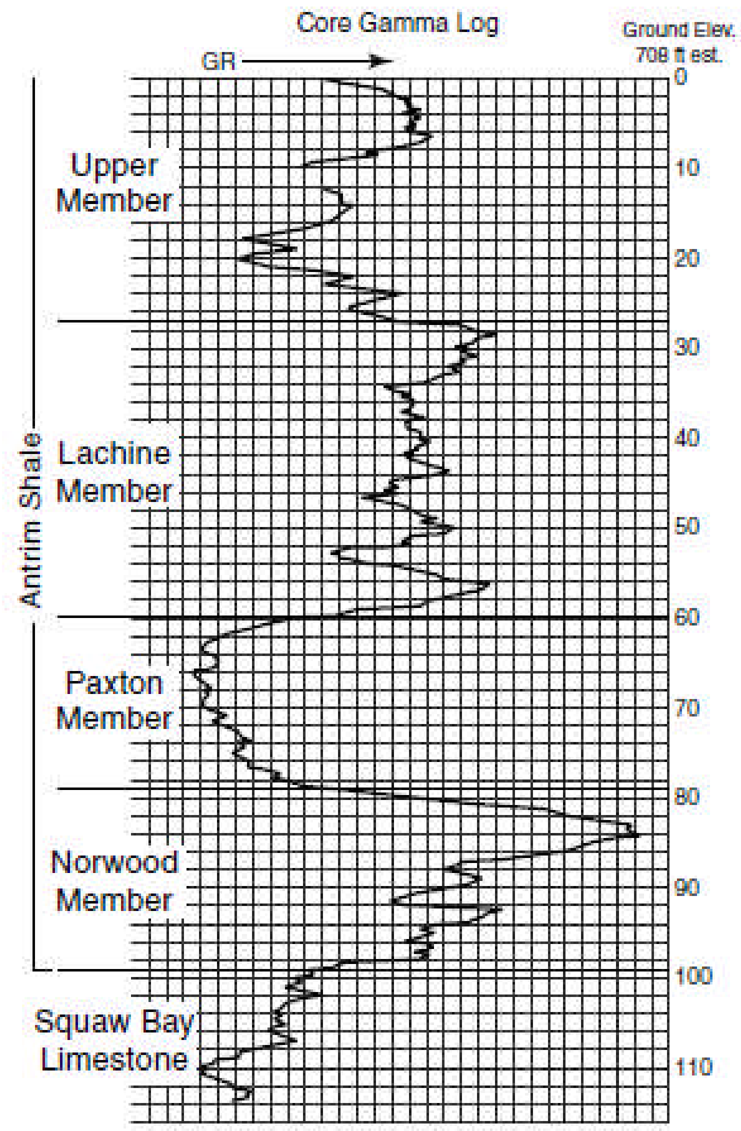
- Very shallow depth: 600 – 2,000 ft below surface
- 70 – 160 ft thick, with wells typically completed in the Lachine and Norwood members of the Lower Antrim
- TOC 1 – 20%
- Shales are silica rich (20 – 41%), with abundant carbonate in both concretions and cements
- Predominantly Type I kerogen in black shale, Type II and III kerogens in grey shale
- Large number of natural open fractures – allows use of vertical wells
  - Fracturing induced by Pleistocene glaciation
- Mixed biogenic and thermogenic contribution
  - Microbial growth prompted by the influx of meteoric water during Pleistocene
  - Active methanogenesis in progress
  - Thermogenic gas may have largely escaped
- Shallow depth means that shales are water wet, and produce CO_2



Data source: Curtis (2001)

Antrim Shale Production

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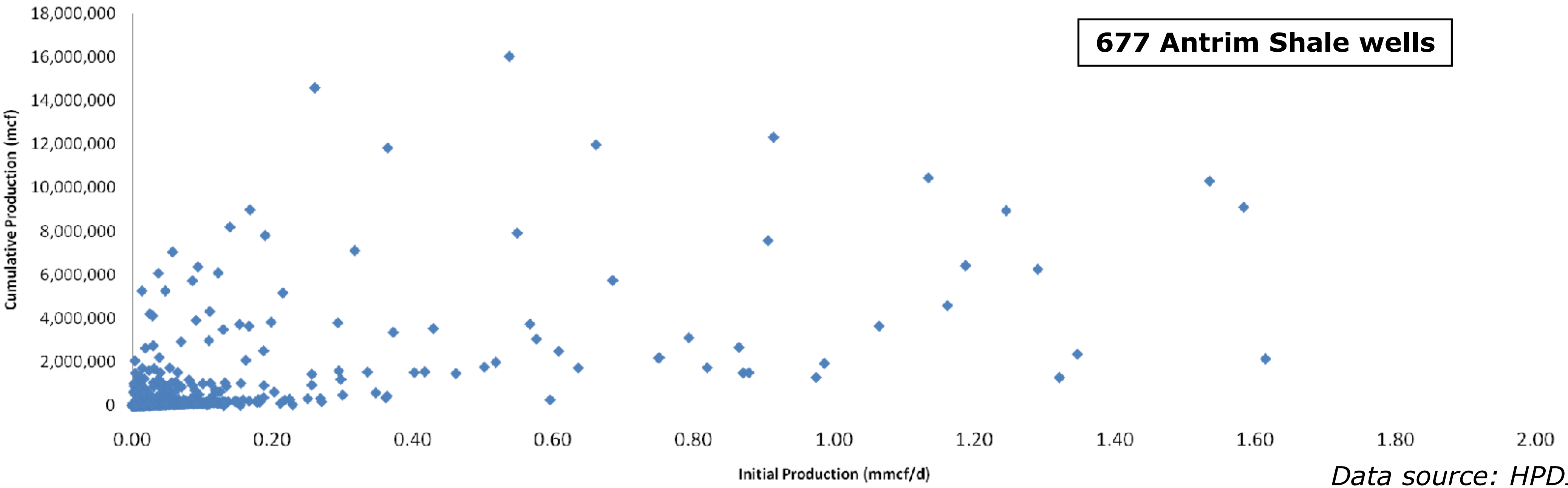
- Peak production in 1998 – 546 mmcf/d
- Produced 368 mmcf/d in 2008, from 9,382 producing wells (39 mcf/d)
- Low flow rates presumably compensated for by shallow depth, open fractures and consequently cheap production
- Average well analysed by Novas produces 0.12 mmcf/d
- Average EUR 0.69 BCF per well



Data source: HPDI

Barnett Shale – 44 TCF Reserves

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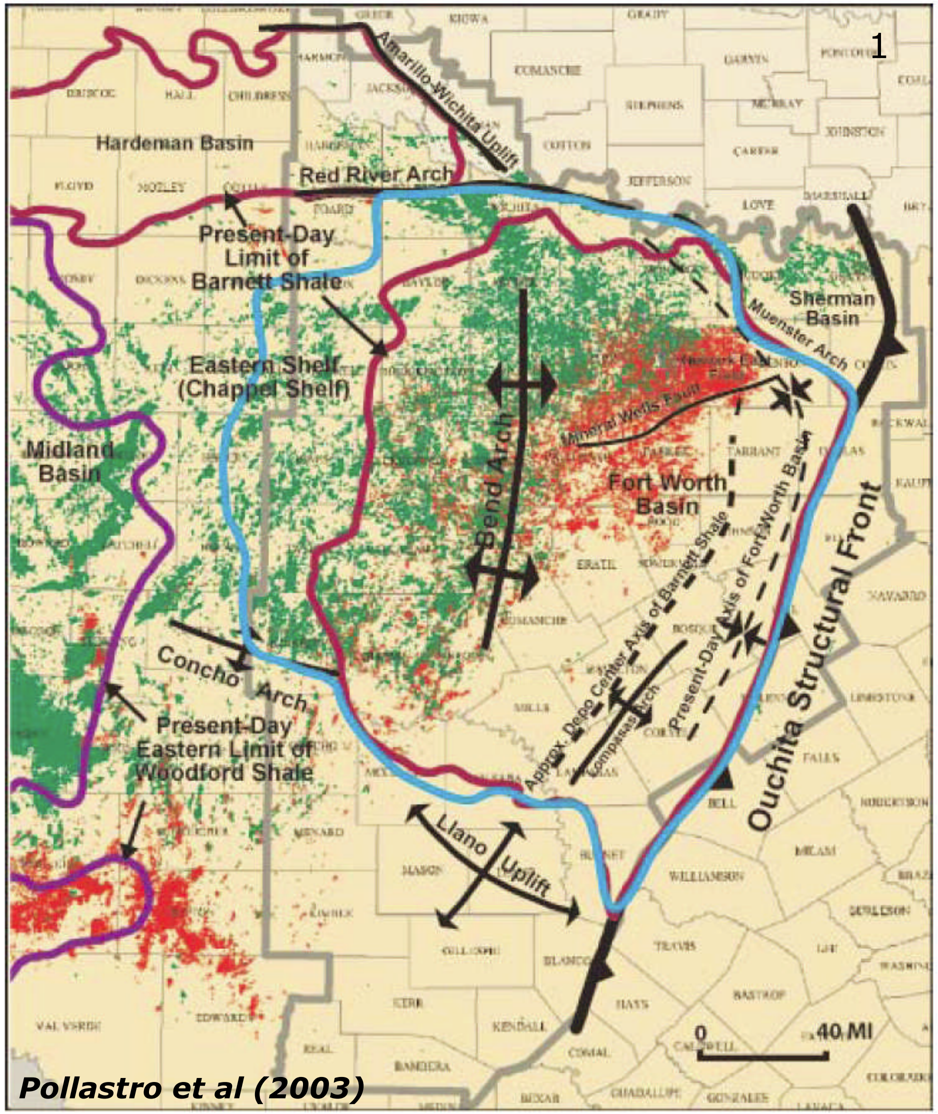

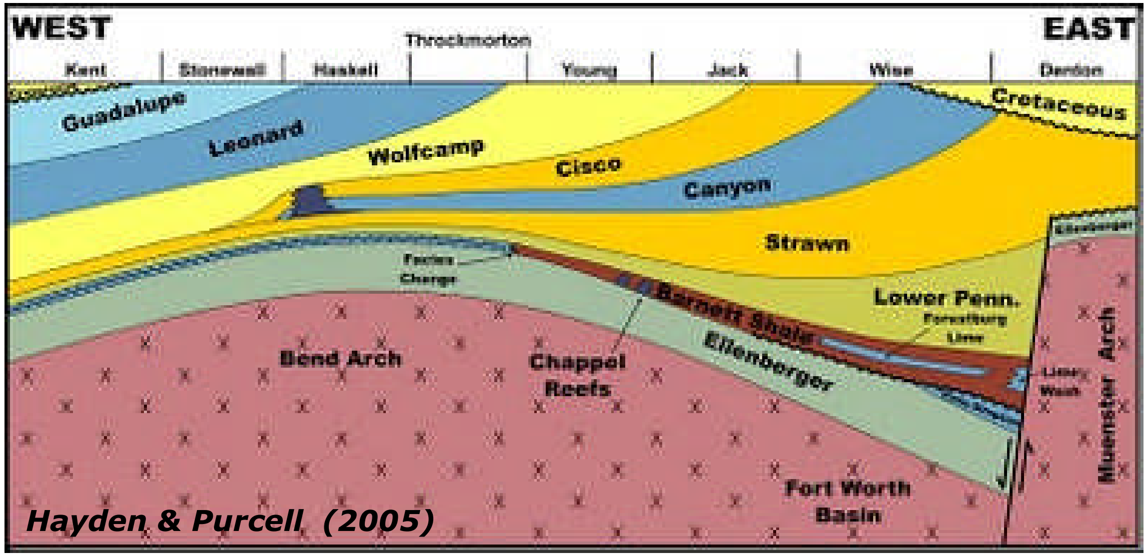

- Mississippian shale in Ouachita foreland
- Gas mainly in front of Ouachita thrust
- Depths of 6,500 to 8,500 ft
- Average Barnett thickness 350 ft
- Large area – 5,000 square miles
- Vitrinite reflectance profiles and basin modelling indicate several thousand feet of upper Palaeozoic and Mesozoic sediments eroded since time of maximum burial

Barnett Shale Depositional Environment

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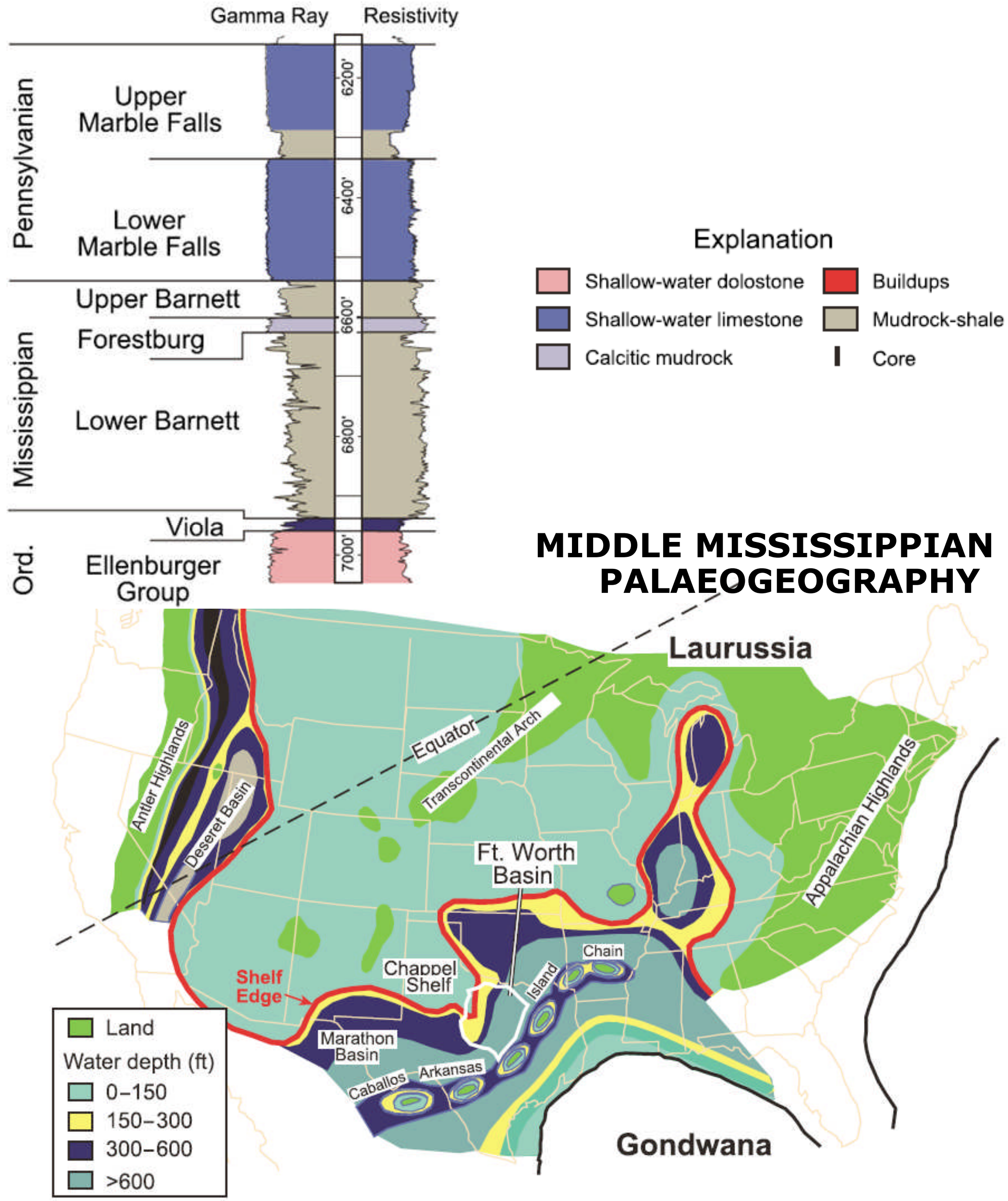
- Narrow inland seaway between converging continents of Laurussia and Gondwana
- Deepwater deposition – 120 to 215 m (400 to 700 ft)
- Poor circulation with open ocean led to anoxia
- Three principal lithotypes
  - laminated siliceous mudstones
  - laminated argillaceous lime mudstones
  - skeletal argillaceous lime packstone
- Barnett composed of debris transported from shelf or upper slope by hemipelagic mud plumes, dilute turbidites and density/debris flows
- Both carbonate and clastic sources
- Divided by Forestburg limestone, an interval of carbonate rich sediments



Data source: Loucks & Ruppel (2007)

Mineralogy & Geochemistry

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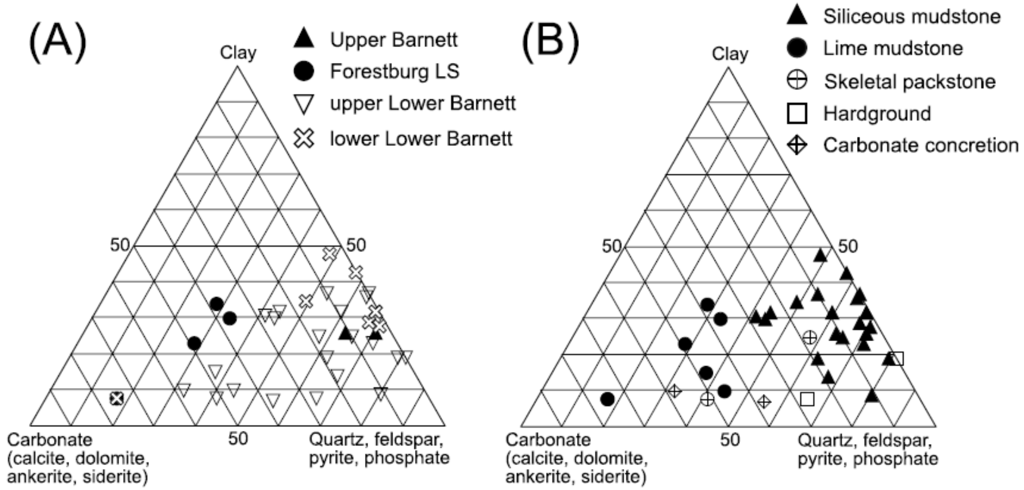
- Barnett less than 1/3rd clay minerals
  - Predominantly illite, minor smectite
- Silica dominant (clay to silt size crystalline quartz)
- Carbonate common in form of silt-sized peloids and fine skeletal calcite/dolomite
- Strong gamma ray response
- Mean TOC of 4.5%



- Thermally immature Barnett contains Type II, oil prone kerogen
- Maturity increases to north and east, reflecting burial and multiple heating events from late Pennsylvanian to Permo-Triassic
- Gas derived from primary cracking of bitumen and secondary cracking of oil
- Pre-Cretaceous and younger uplifts have raised Barnett to economically exploitable depths
- Natural fractures abundant in Barnett, nearly always healed with cement, commonly calcite, due to strong hydrothermal overprint close to Ouachita thrust front

Data sources: Loucks & Ruppel (2007), Pollastro et al (2007)

Barnett Shale Production

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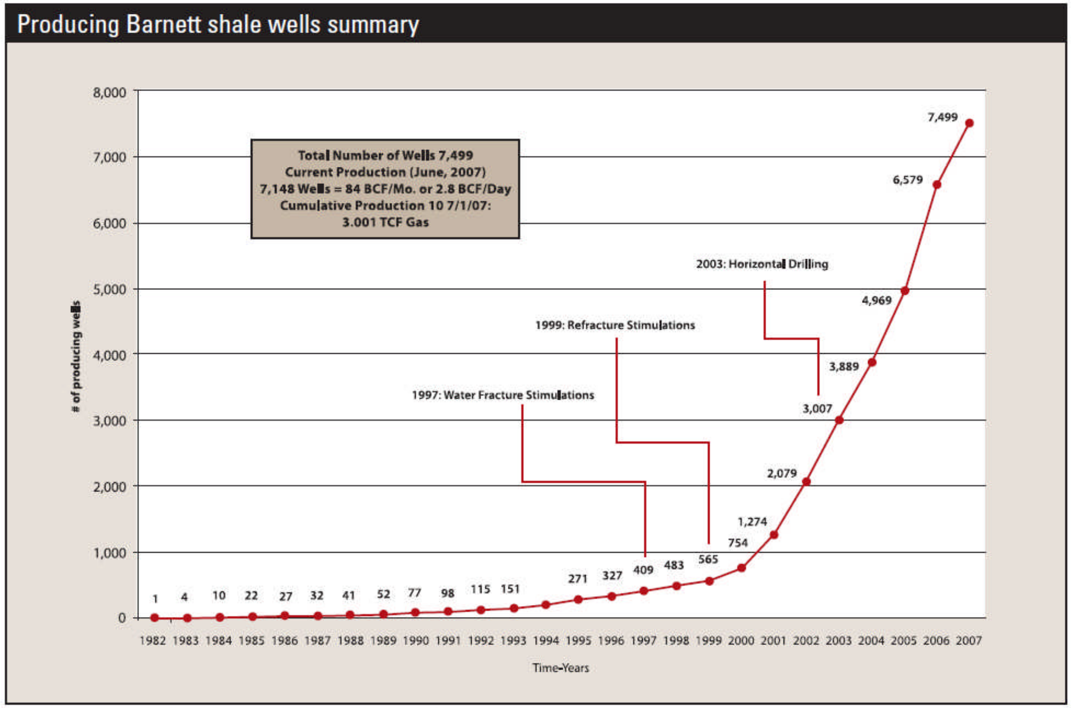
- Development driven by Mitchell Energy, subsequently purchased by Devon Energy
- Currently producing 651,000 boepd
- USDOE (2009) estimates:
  - 327 TCF initially in place.
  - 44 TCF ultimately recoverable based on current technologies
- Well spacing ranges from 60 to 160 acres per well
- Jarvie et al (2007) estimate 2.5 – 3.5 BCF per well from a horizontal well
- Novas’ analysis of production data from 7,190 wells supports this
- Schlumberger estimate only 25 – 30% of perforations actually produce gas
- Acreage is graded – not all areas of the Barnett are created equal!
- Initial production figures can be extremely misleading – as yet no reporting standard



Number of producing Barnett shale wells over time as of July 1, 2007. (Graph courtesy of: *Barnett Shale News*)

Data source: DrillingInfo, Oil & Gas Investor (Jan 08)

Example Production Analysis

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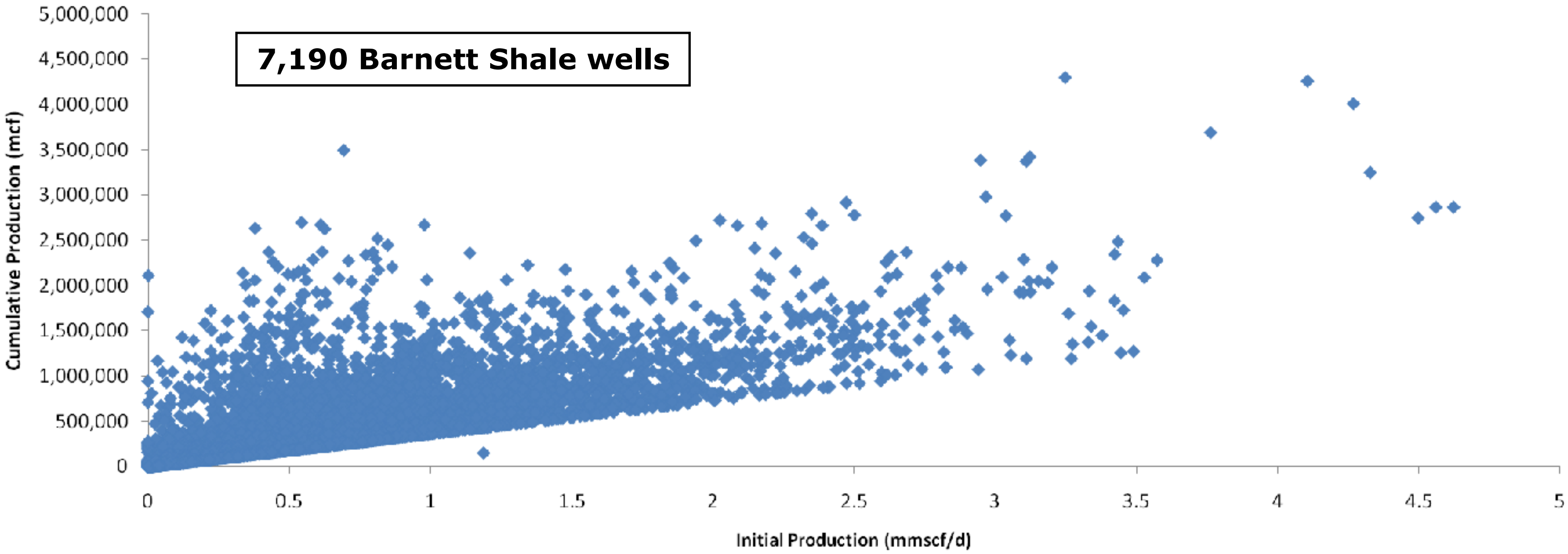

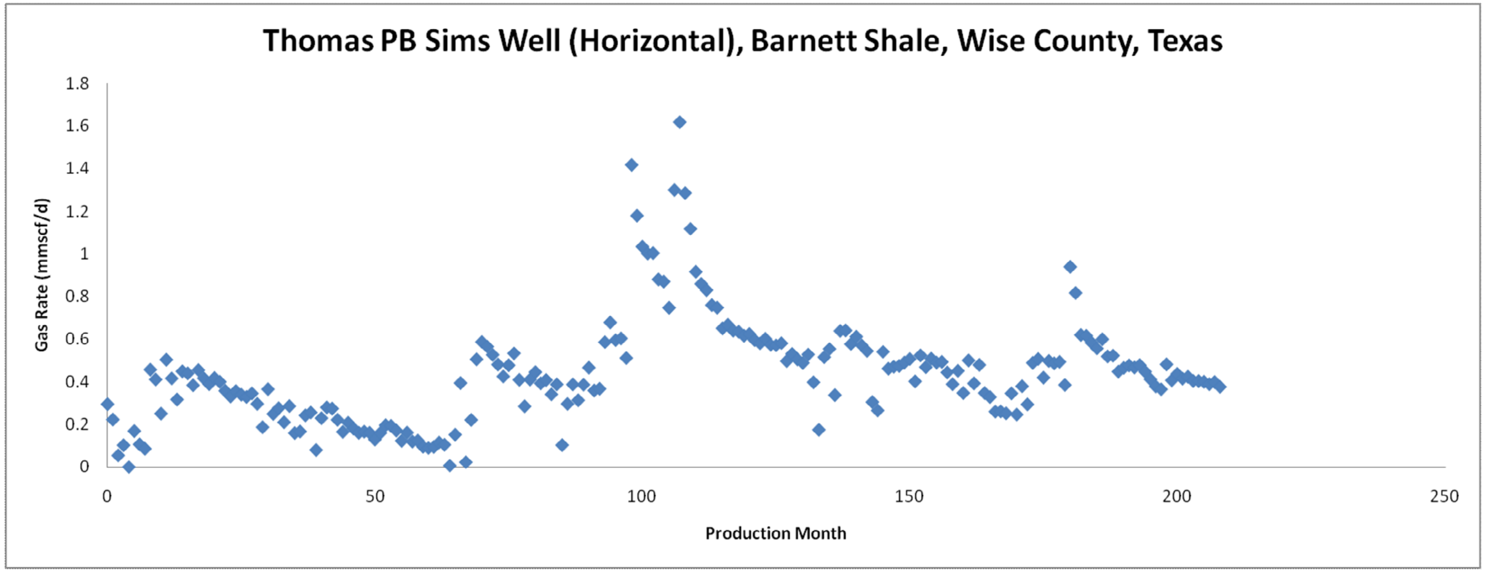

Data source: HPDI

Characteristics of key US shale gas basins

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- Large scale
- Consistent geological setting
  - Foreland basins dominate
- Simple geological history
  - Long steady burial
  - Subsequent uplift
- High operational levels of activity
  - Intense rig activity
  - Considerable support infrastructure
- Beneficial impact of drilling and completions technology
  - Horizontal wells
  - Multiple staged hydraulic fraccing
- Transformation in well production rates
  - Order of magnitude

Famous Five... or is it Fore?

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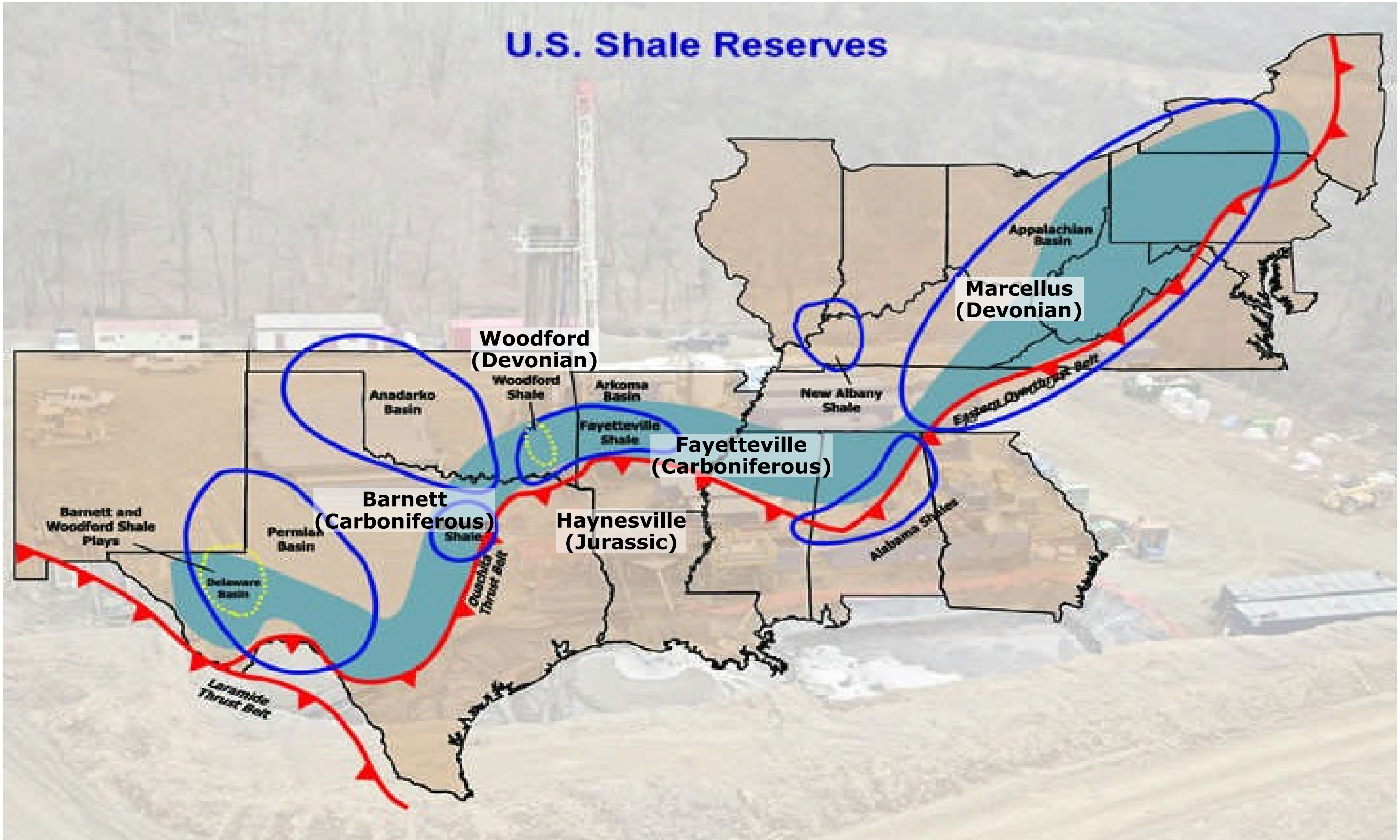

Data source: http://blumtexas.blogspot.com

Technology driven success

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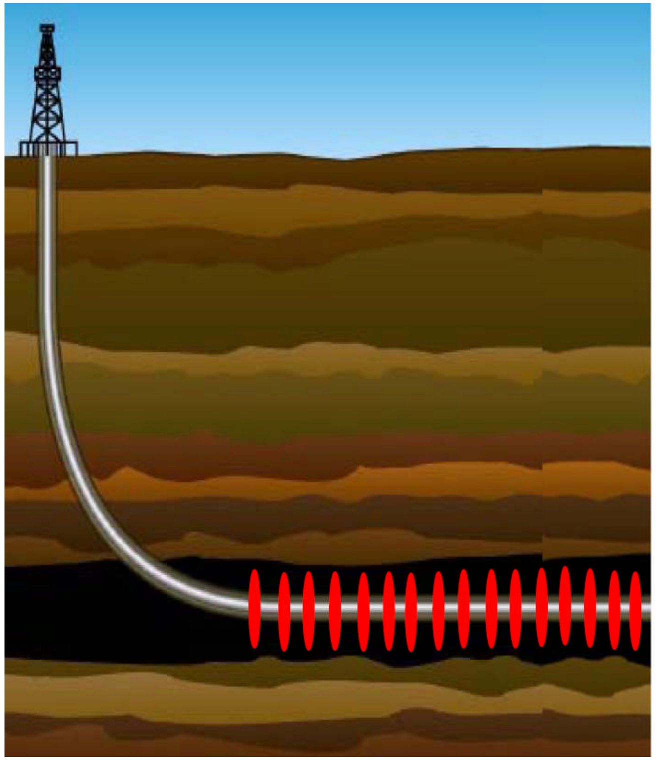
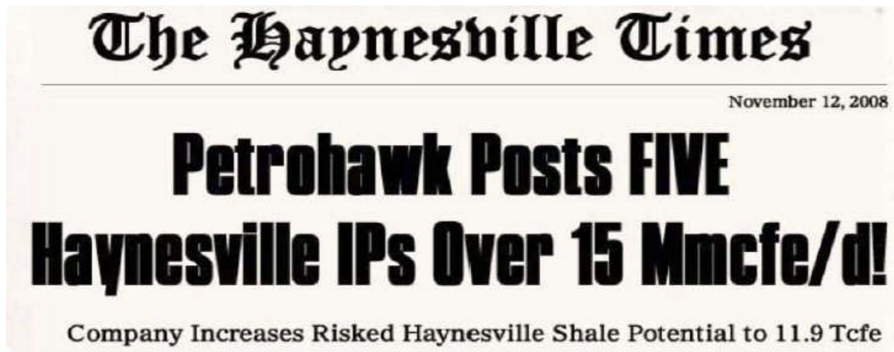
- Shale gas production success is attributable to a combination of horizontal drilling and developments in hydraulic fracturing
- In late 1990’s only 6% of US onshore rigs had horizontal capability
- By May 2008, the proportion had ballooned to 28%
- Barnett average lateral length 2 – 4,000 ft, with 4-8 frac stages
- DOE estimate $2.5 mm for fracced horizontal, $0.8 mm for vertical



Horizontal drilling with laterals exceeding a mile in length in combinations with massive multi-stage hydraulic fraccing (20 stages) has revolutionized the gas industry.


The Haynesville Times

November 12, 2008

Petrohawk Posts FIVE Haynesville IPs Over 15 Mmcfe/d!

Company Increases Risked Haynesville Shale Potential to 11.9 Tcfe

Courtesy: TransCanada

Now that's what I call a frac job…

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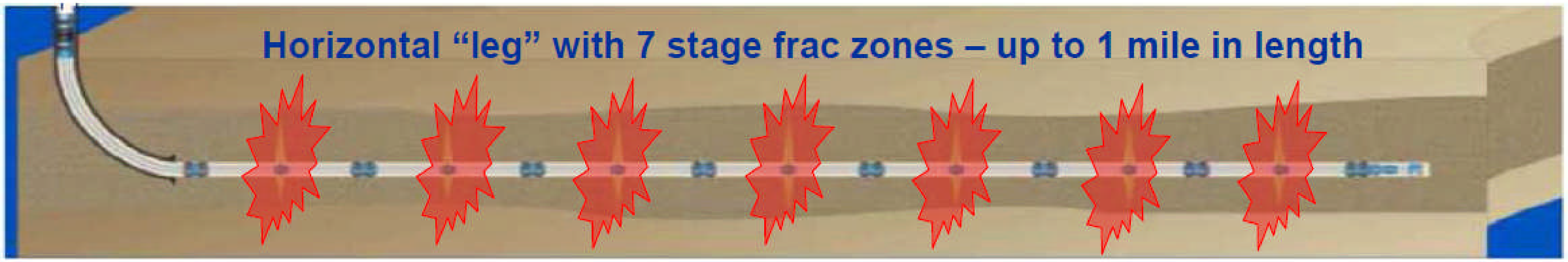

Requires 4 - 8 million gals. of water & 2,000 – 3,000 tonnes of sand

TransCanada

Shale Gas Deals

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- US shale gas historically operated by local players
- Key initial moves made by US intermediates
  - e.g. Devon purchase of Mitchell Energy in 2001
- In 2008-09, multinationals moved in
- Bandwagon or party time?
- Recent deals value shale gas on a par with oil

Year	Target	Bidder	Assets	Reserves (boe/tcf)	Deal Value ($ bn)	Unit Value ($/boe)	Unit Value ($/Mcf)
2001	Mitchell Energy	Devon Energy	Barnett	1.4 TCF + 187 mmbbl	$3.5 bn	$8.17/boe	$1.41/Mcf
2009	Chesapeake	Statoil Hydro	Marcellus	2.5 – 3.0 billion boe	$3.375 bn	$1.23/boe	$0.21/Mcf
2009	Chesapeake	Total	Barnett	3 TCF	$2.25 bn	$4.35/boe	$0.75/Mcf
2009	XTO Energy	ExxonMobil	Shale Gas, Shale Oil, Tight Gas and CBM	45 TCF equivalent	$40 bn	$5.16/boe	$0.89/Mcf

Data source: Principally upstreamonline.com

Conclusions

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- Shale gas, long viewed as a quiet backwater of the industry, has seen phenomenal growth in the US
- Growth driven initially by gas price increases but was sustained and accelerated through technological advances
- Step changes in productivity offer opportunity for more robust commercial viability
- Current frenzy in activity demonstrates that the industry is more market competitive and can displace conventional supplies
- The US is undoubtedly blessed with considerable shale gas resource thanks to a coincidence of geological and operational factors
- Despite this, commercial viability remains patchy
- Learnings from the US industry can be directly applied to Europe
- European geology is more complex and will require a ‘smarter’ approach to identify and exploit commercial shale gas resources

Multi-Client Report Available

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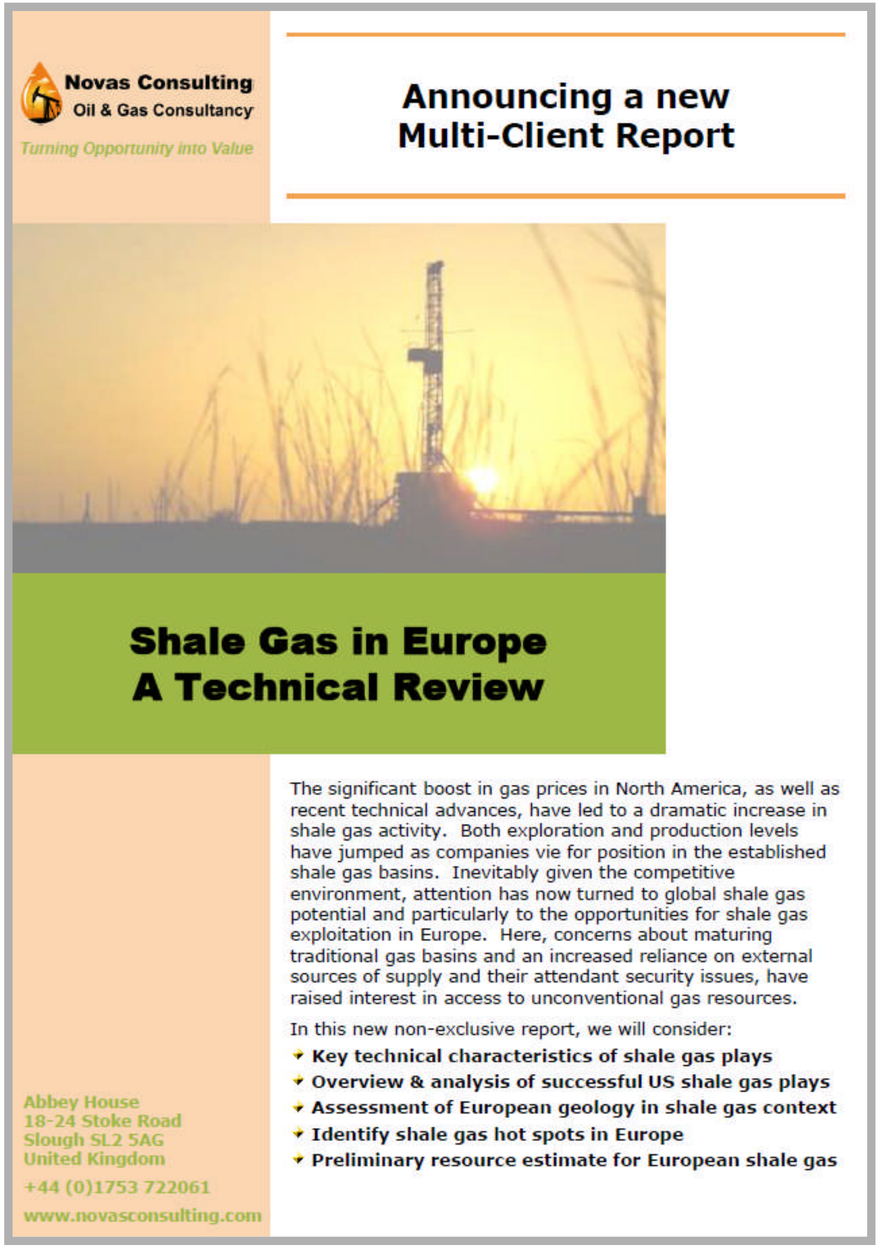
- Report Contents:
  - **Shale Gas Plays**
  - **Shale Gas in North America**
  - **Assessment of Principal US Shale Gas Plays**
    - Magnificent Seven
  - **Introduction to Shale Gas in Europe**
  - **European geology in the Shale Gas context**
    - Potential shale gas source rocks in Europe
    - Review of shale gas potential by terrane/basin
    - Integration of results by country
  - **Conclusions**
    - Scale of the Shale Gas opportunity in Europe
    - Preliminary view of risk and resource potential
    - Hot spots and first movers
- Publication end-2Q 2010
- £4k cover price, £3k for pre-subscribers


Novas Consulting
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Turning Opportunity into Value

Announcing a new Multi-Client Report

Shale Gas in Europe
A Technical Review

The significant boost in gas prices in North America, as well as recent technical advances, have led to a dramatic increase in shale gas activity. Both exploration and production levels have jumped as companies vie for position in the established shale gas basins. Inevitably given the competitive environment, attention has now turned to global shale gas potential and particularly to the opportunities for shale gas exploitation in Europe. Here, concerns about maturing traditional gas basins and an increased reliance on external sources of supply and their attendant security issues, have raised interest in access to unconventional gas resources.

In this new non-exclusive report, we will consider:

- **Key technical characteristics of shale gas plays**
- **Overview & analysis of successful US shale gas plays**
- **Assessment of European geology in shale gas context**
- **Identify shale gas hot spots in Europe**
- **Preliminary resource estimate for European shale gas**

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