Shale Gas: The Rocks Matter

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Shale Gas : The Rocks Matter

- **Economic resources**
- Exploration and development approach
- Environmental risk management

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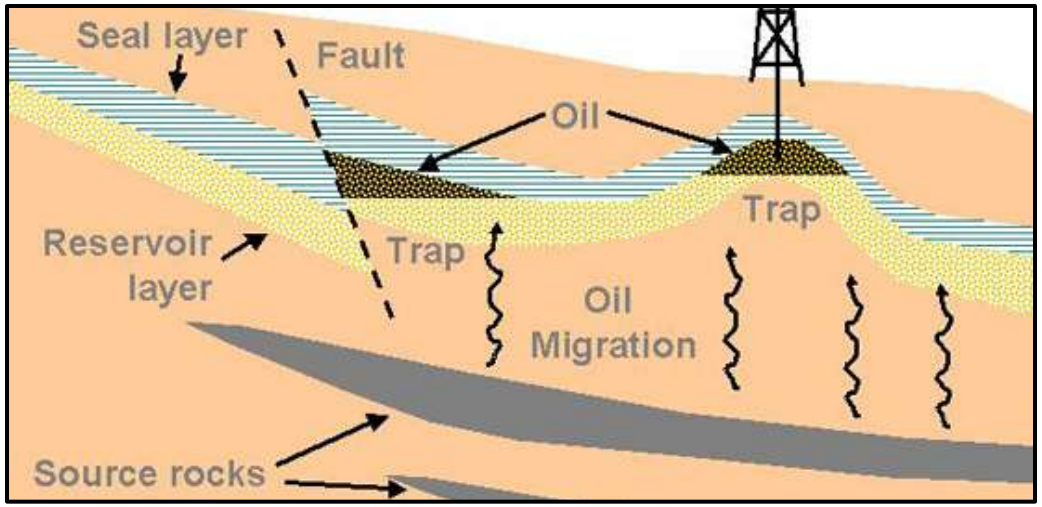
What is shale gas?

- Organic matter trapped during the deposition of fine-grained shale rocks.
- Conventional resources – Oil and gas that migrated from the shale source rock to more permeable sandstone and limestone formations.
- Unconventional resources – Oil and gas that remains trapped in the shale source rock.

- Shale gas has not been traditionally considered an attractive option due to the **low permeability** of shale rocks (0.01 - 10 μD).



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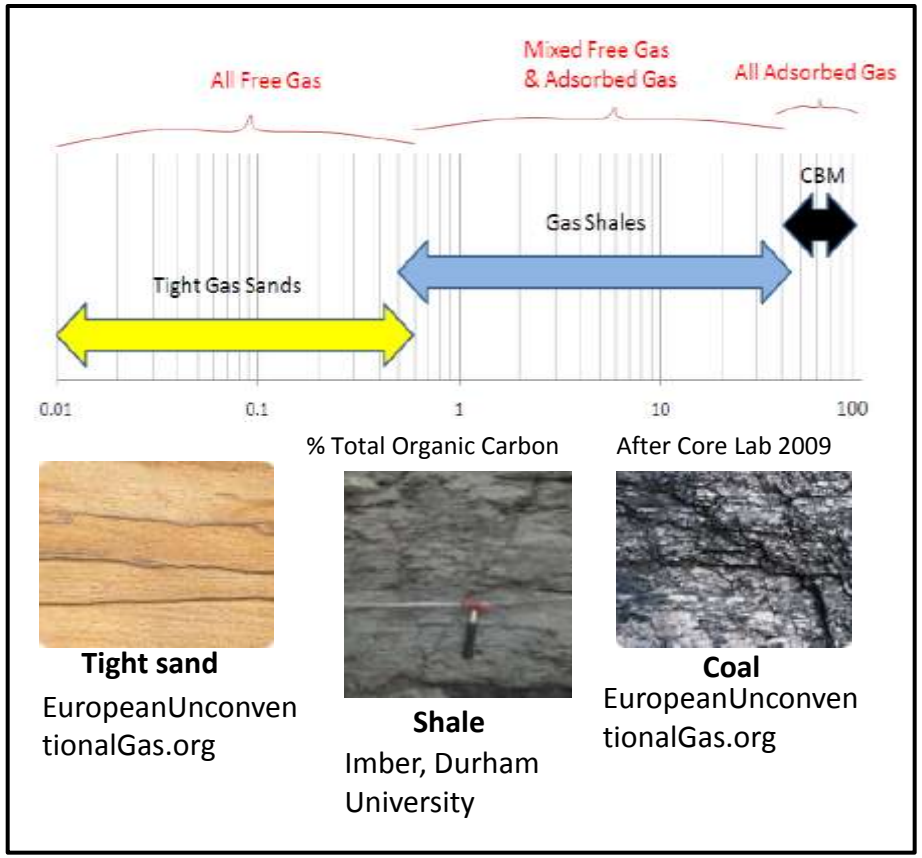
What is shale gas?

- Rocks mostly formed between Cambrian to Cretaceous (spanning 500 Ma)
- Deposited in low energy marine and lake environments.
- Made up of fine grained quartz and clays.
- Gas forms from organic matter either biogenically or thermogenically.
- Shale gas rocks may be folded and/or faulted



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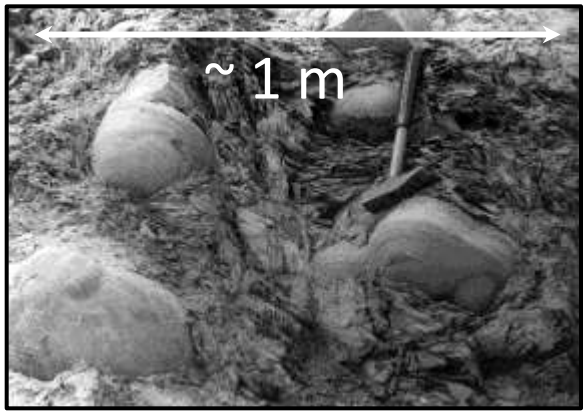
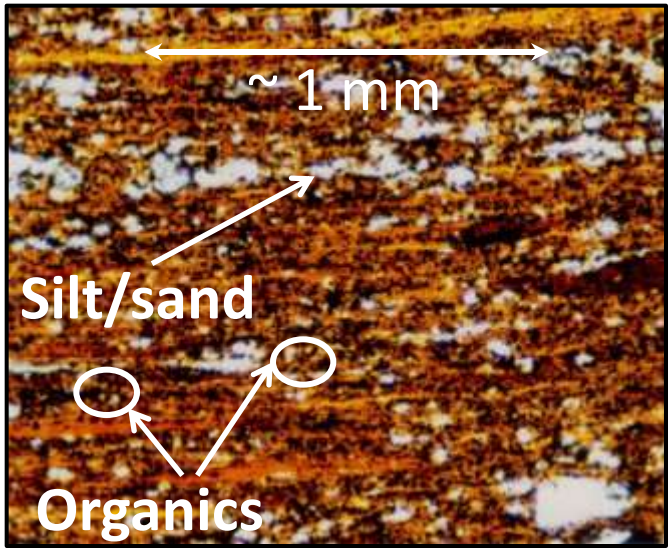
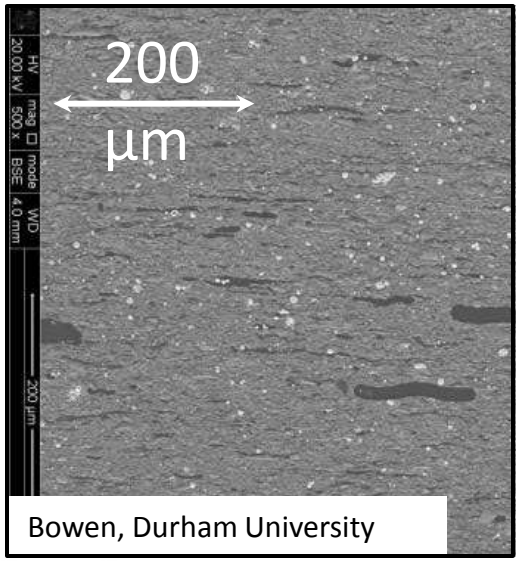
Shale at different scales







Bowen, Durham University

- Quartz
- Clays
  - Smectite
  - Illite
  - Kaolinite
  - Chlorite
- Calcite
- Pyrite
- Siderite – commonly concretions

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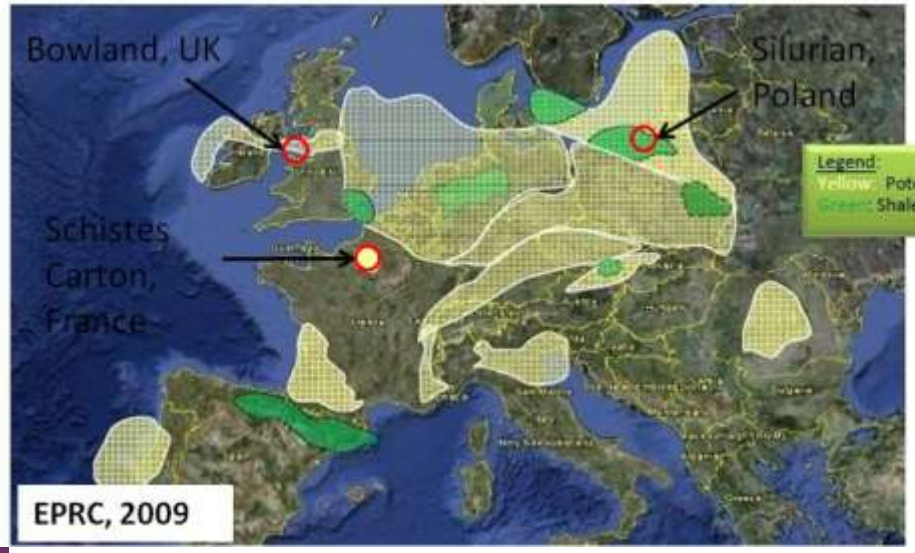
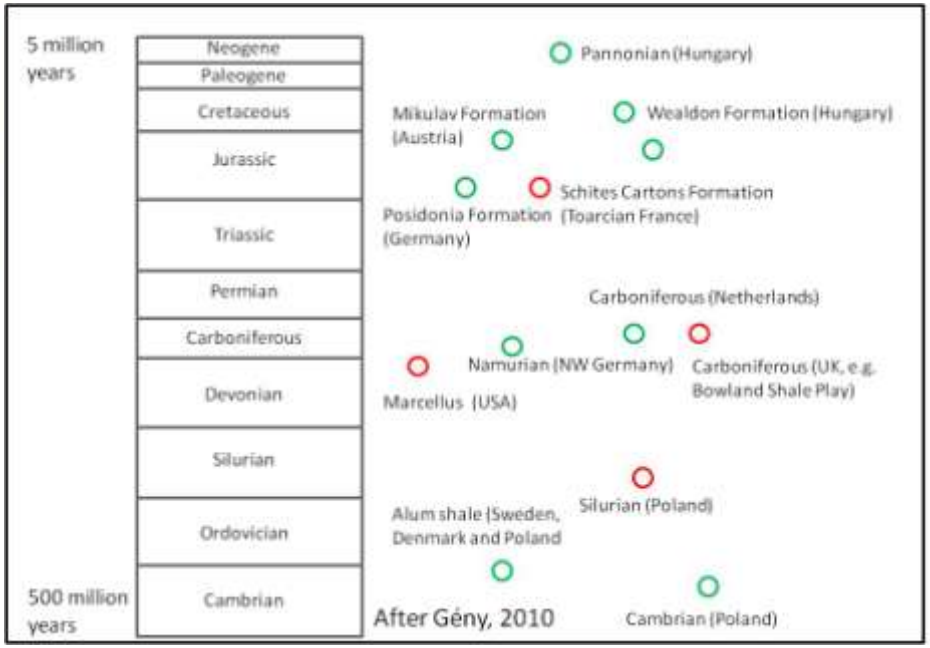
Shale gas in Europe





- Several areas of Europe have shale gas potential
- Evaluation of this potential has started

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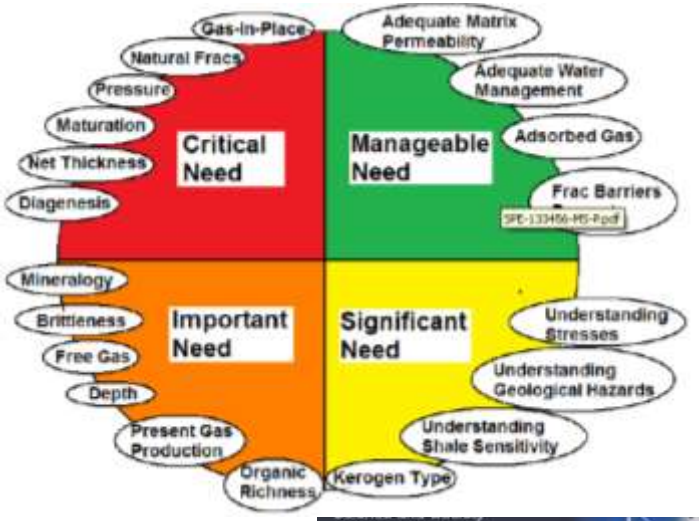
Shale reservoir characteristics

Outcrop of Silurian shale, from the Holy Cross mountains (SE Poland)

Core of Silurian shale, Poland

- The properties of the rock determine whether it will be commercially viable
- There are many characteristics that need to be assessed by drilling exploration boreholes and testing the boreholes



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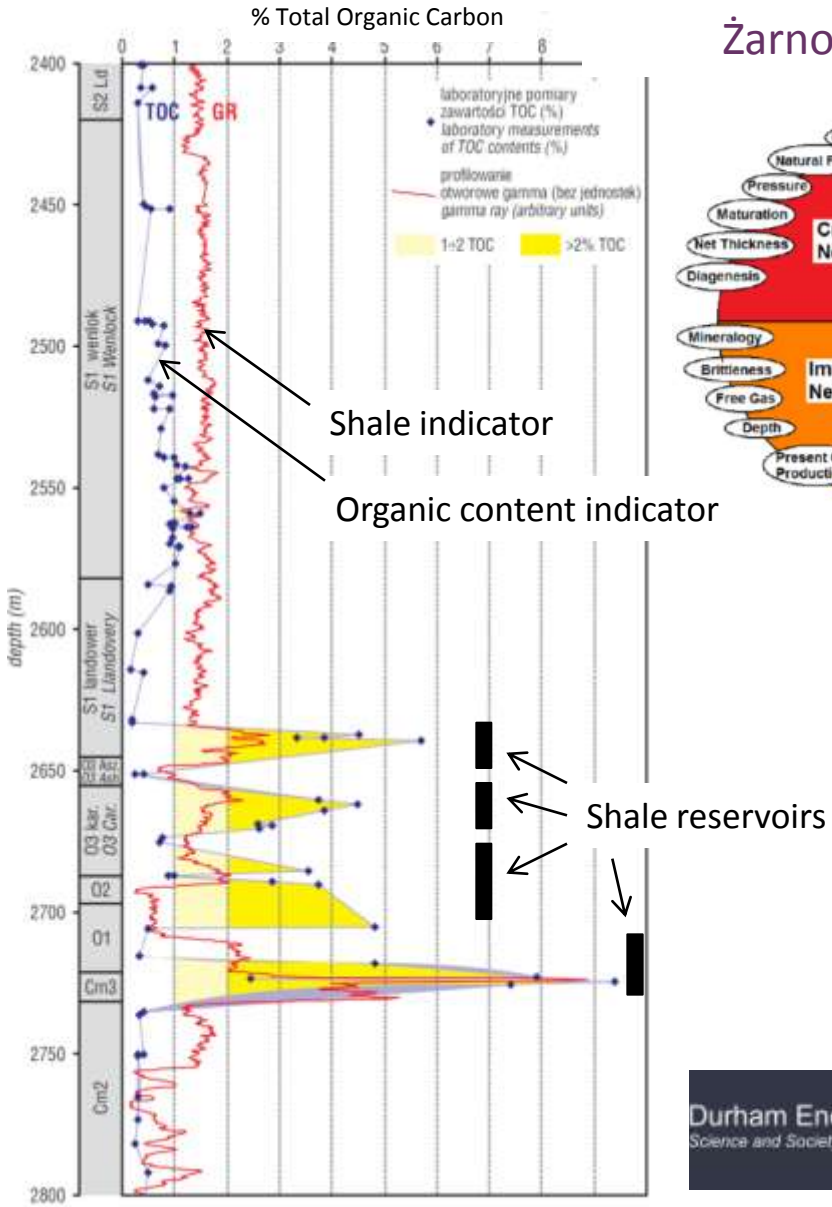
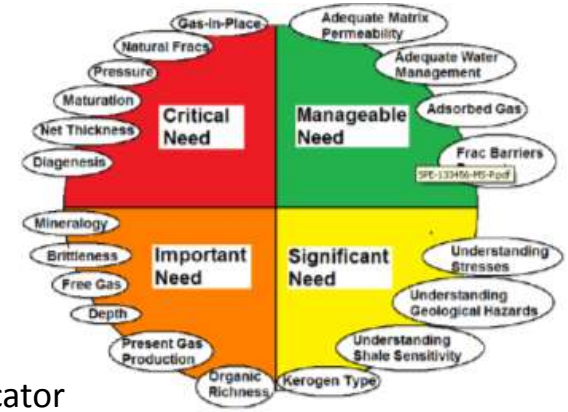


Żarnowiec IG-1 well



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Middle Carboniferous UK

- No two shales are the same
- Need to be drilled to understand their characteristics
- Early days in Europe – full potential is not yet understood
- Development of the reservoirs will depend upon a series of geological factors

Bowland Shale, Middle Carboniferous, UK

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Shale reservoir characteristics

	Marcellus (U.S.)	Lublin (Poland)	Bowland (UK)
Age	Devonian (350 - 410Ma)	Silurian (410 - 435Ma)	Carboniferous (300 - 360Ma)
Extent	<246000km^2 covering 5 U.S. and 1 Canadian states	<23000km^2 covering the Lublin region of South-East Poland	<17500km^2 covering West Lancashire
Thickness	Up to 270m (900ft) thick	Up to 150m (490ft) thick	Up to 790m (2600ft) thick
Composition	Sandstone, siltstone, black (organic) shale and grey shale	Organic rich black shale	Organic rich black shale, grey shale, sandstones and limestones
Total organic carbon	<20%	4 – 20%	0.7 – 15%
Gas in place (estimated)	360Tcf (trillion cubic feet)	222Tcf	200Tcf (?)

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The Rocks Matter

- Economic resources
- **Exploration and development approach**
- Environmental risk management

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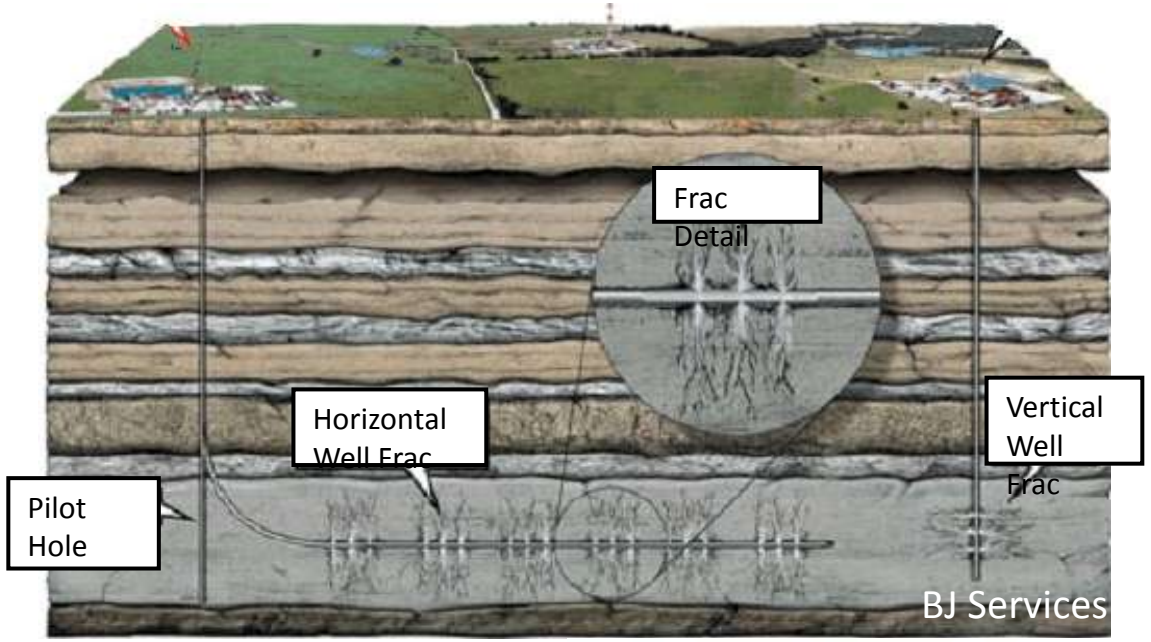
Hydraulically fracture the reservoir

- Low permeability rocks do not produce gas at enough rates
- This is partially mitigated by using horizontal wells, which increase well-face area.
- Hydraulic fracturing enables permeability to be artificially enhanced
- Natural fractures may help



Natural fractures in the Devonian of USA

Engelder *et al.*, 2009, AAPG Bulletin

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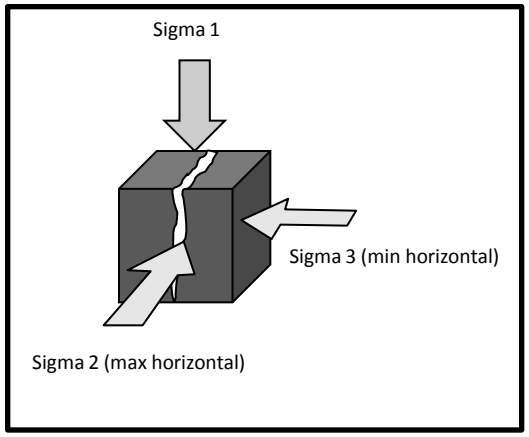
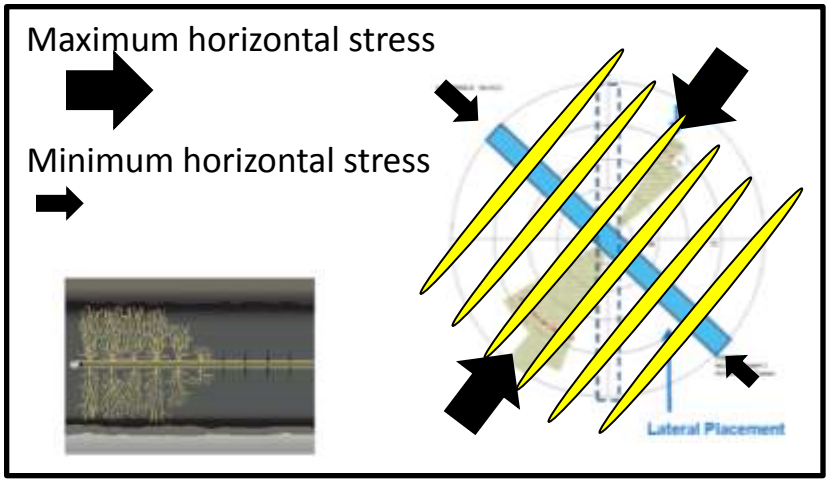
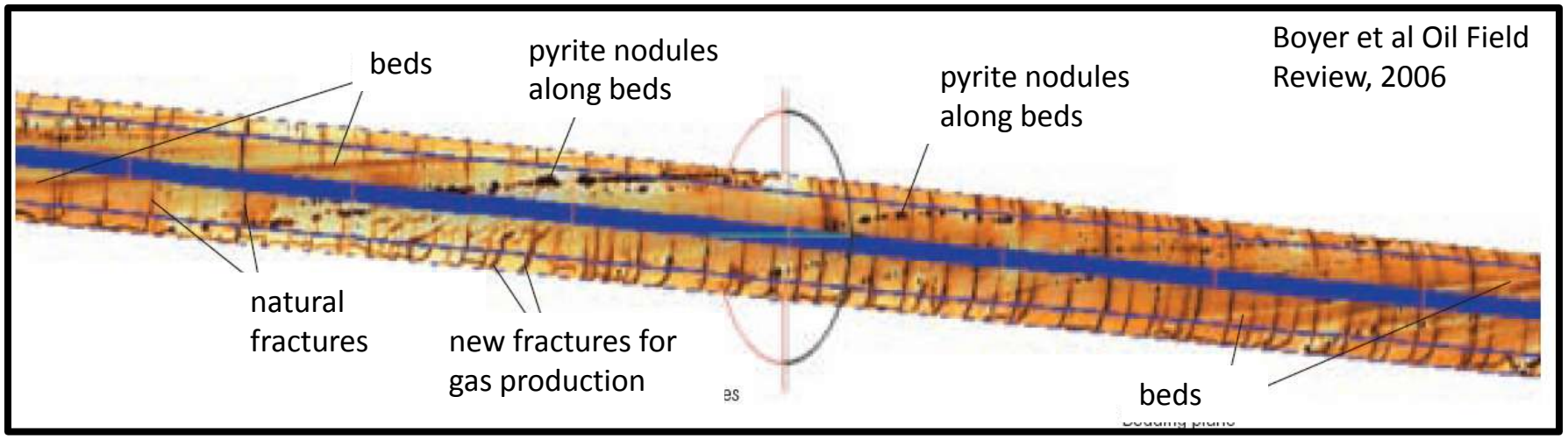
Hydraulic fractures are created and held open





Maximise stimulated rock volume (SRV)



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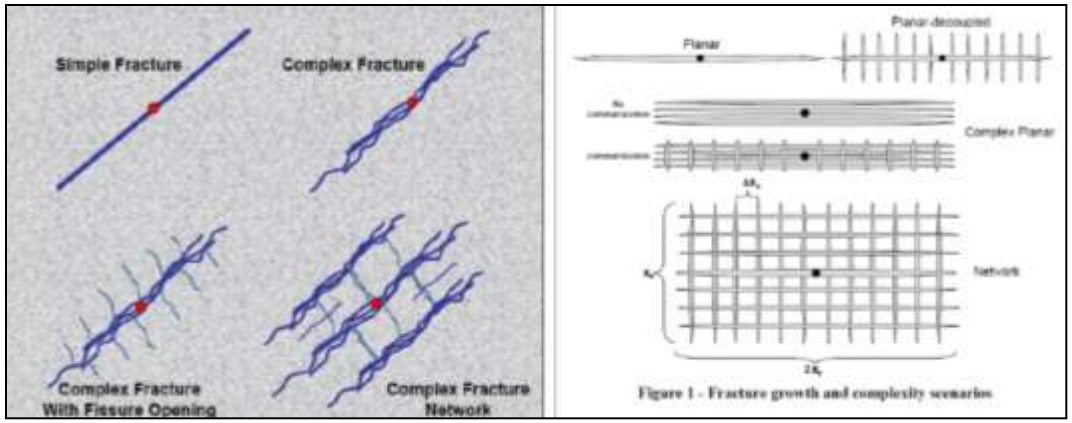
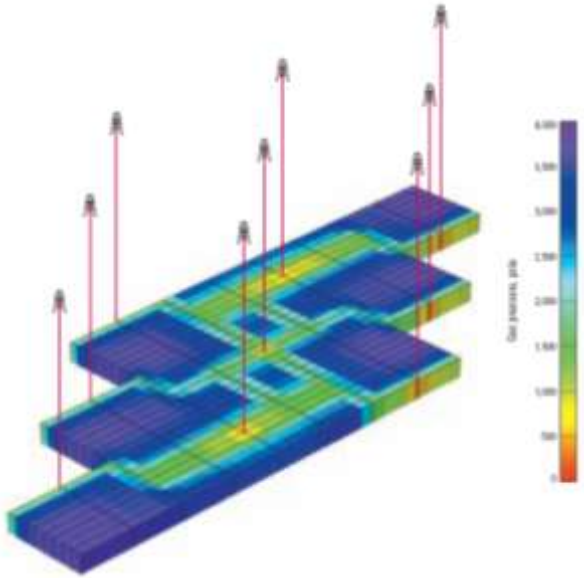
3D network of fractures



- Gas flows through fractures
- Produce through a grid of boreholes



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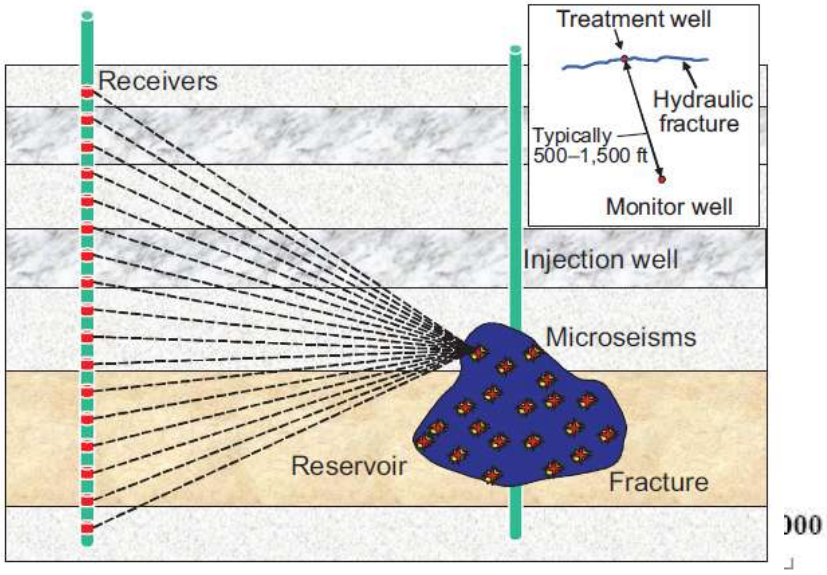
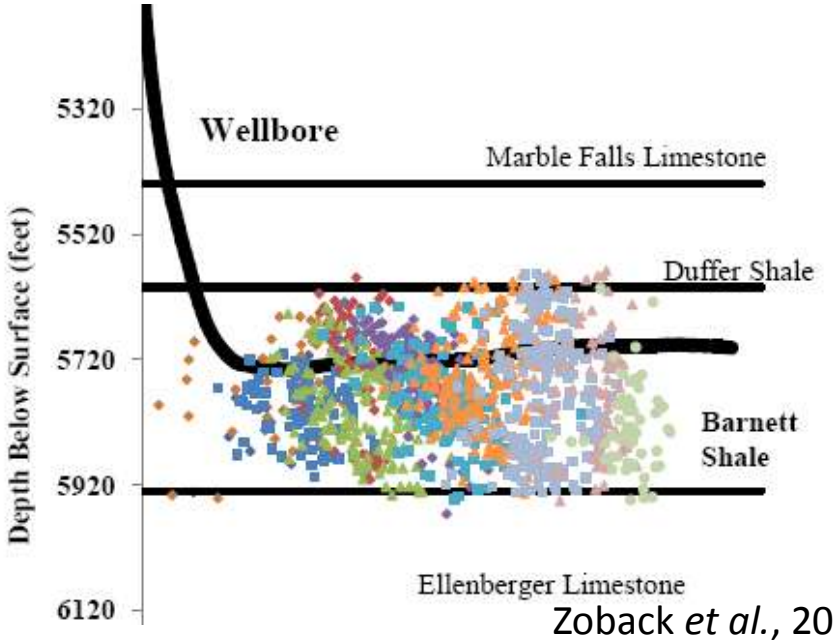
Monitoring hydraulic fractures with micro-seismic

- As hydraulic fractures propagate, swarms of micro-earthquakes (harmless) are generated locally.
- The 3D map of induced micro-seismic events can then be used to infer the spatial extent and location of the fracture network zone.





Warpinski, 2009

Zoback *et al.*, 2010

The Rocks Matter

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- **Environmental risk management**

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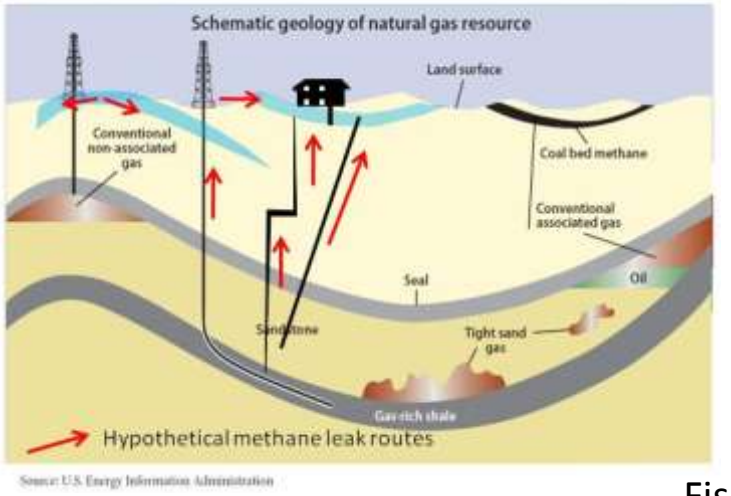
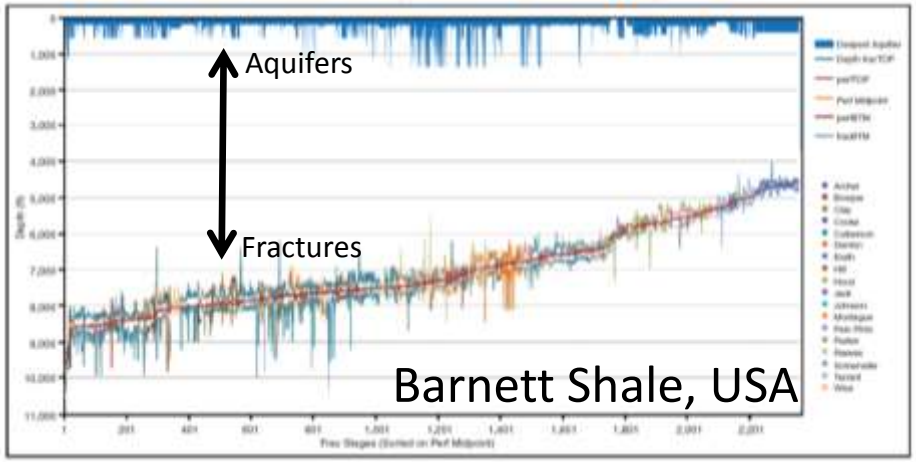
Drinking water in aquifers

- Are there shallow aquifers used for drinking water?
- Depth and extent?
- Need to be separate from methane production
- Issues:
  - ?Methane leak up faults or fractures
  - ?Leak behind well casing
- Good seismic imaging allows aquifers to be mapped
- Extent of fractures monitored
- Sound casing



Fisher, 2010



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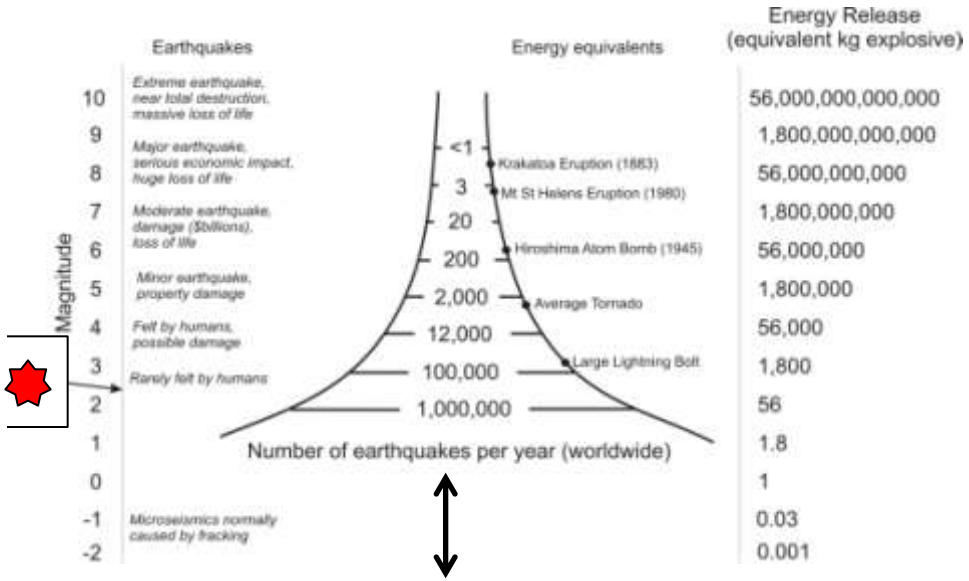
Energy released due to microseismicity

- Microseismicity is extremely low energy and not felt
- Well known that hydrocarbon extraction can cause small earthquakes (1-3 magnitude) because of subsidence. No damage recorded. Coal mine subsidence also does this.
- Blackpool, UK - small earthquakes (max 2.3) in April-May 2011, rare occurrence. Also examples from Fort Worth, Texas (USA).



Largest Blackpool (UK) Induced Earthquake

microseismic events due to hydraulic fracturing

earthquakes due to oil and gas field depletion

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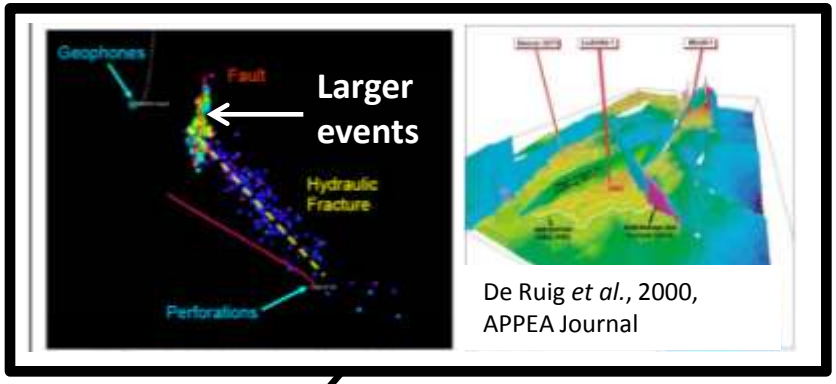
What is potential an environmental incident?

Based upon US examples: spillage of fluid or leak of methane behind casing can occur.

Spillage or leak behind casing

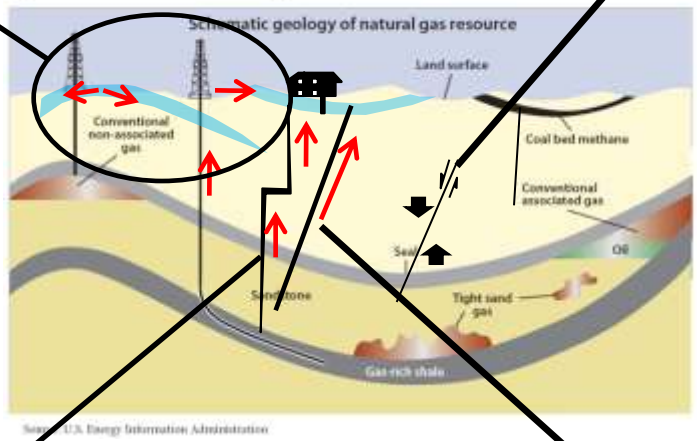


De Ruig *et al.*, 2000, APPEA Journal

Fault Reactivation and Earthquakes

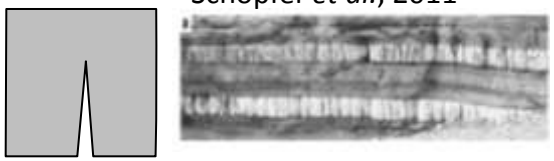
Possible – Blackpool 2011 is first recorded example due to fracturing process itself since 2005 (1000s of wells have been drilled since 2005)

Methane leak routes



$$Q = \frac{kA}{\mu L}(P_H - P_L)$$ Darcies Law

Schöpfer *et al.*, 2011

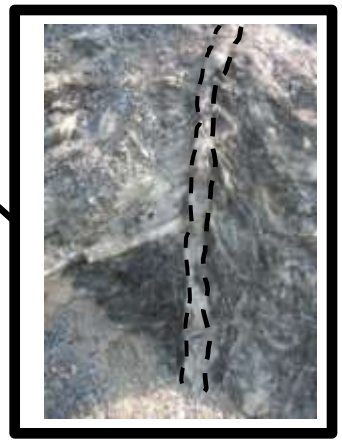


Stress dissipation at other fractures of mechanically different rocks

Very unlikely, fractures tend to not propagate far

Leak Through Fractures or Through Rock

Methane leak-up faults causing contamination



Very unlikely unless reservoir close to aquifer

The Rocks Matter

- Economic resources
  - ➢ Rock characteristics determine whether its economic
  - ➢ All shales are different
  - ➢Need to be drilled to verify whether development should go ahead

- Exploration and development approach

➢ Because of low permeability shale needs to be fractured

➢Number of wells, design of fracturing process depends on the rock characteristics

- Environmental risk management

➢ Issues to consider aquifer contamination and seismicity

➢ Both can be mitigated

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