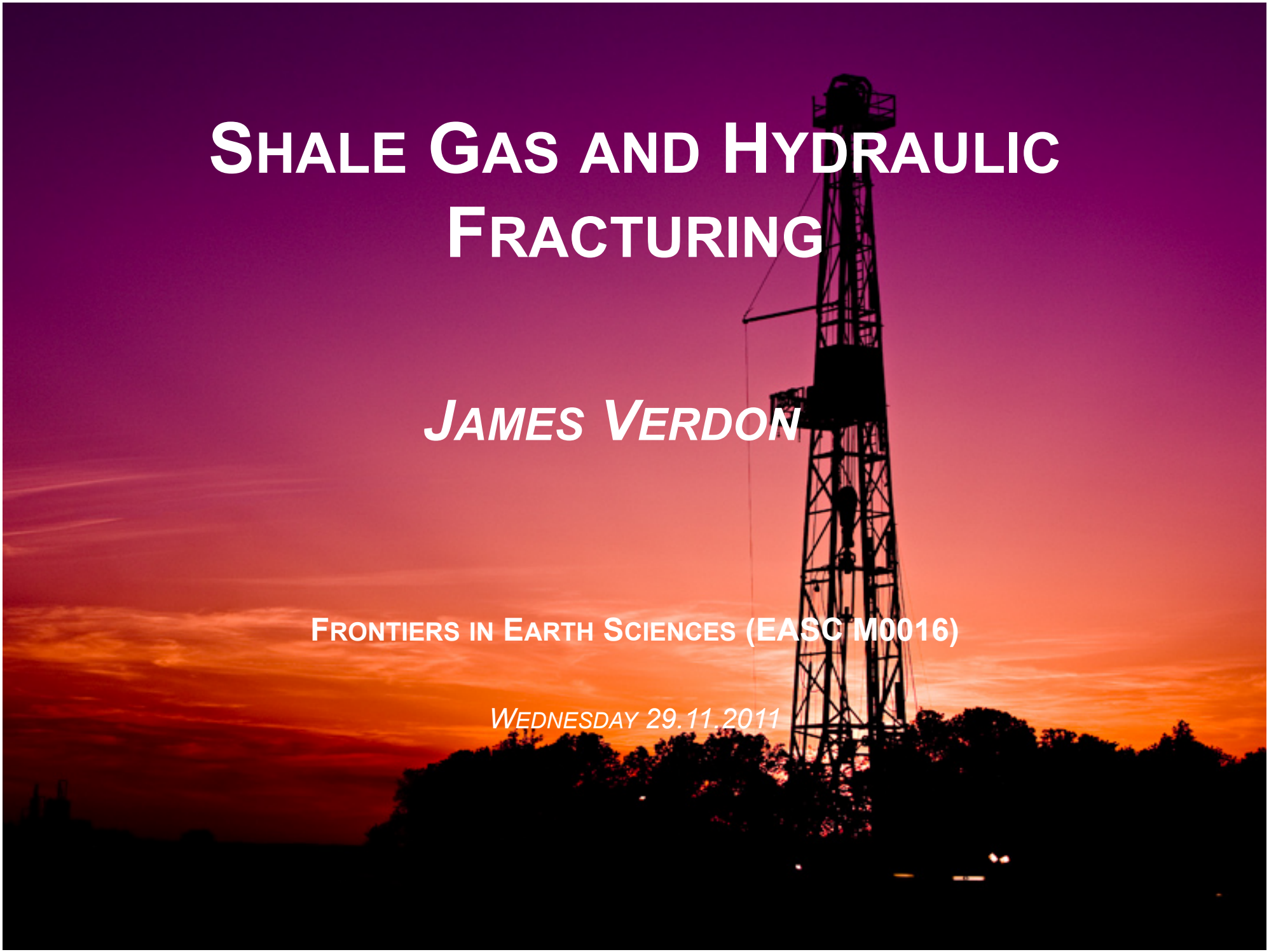


Shale Gas and Hydraulic Fracturing

James Verdon

Frontiers in Earth Sciences (EASC M0016)

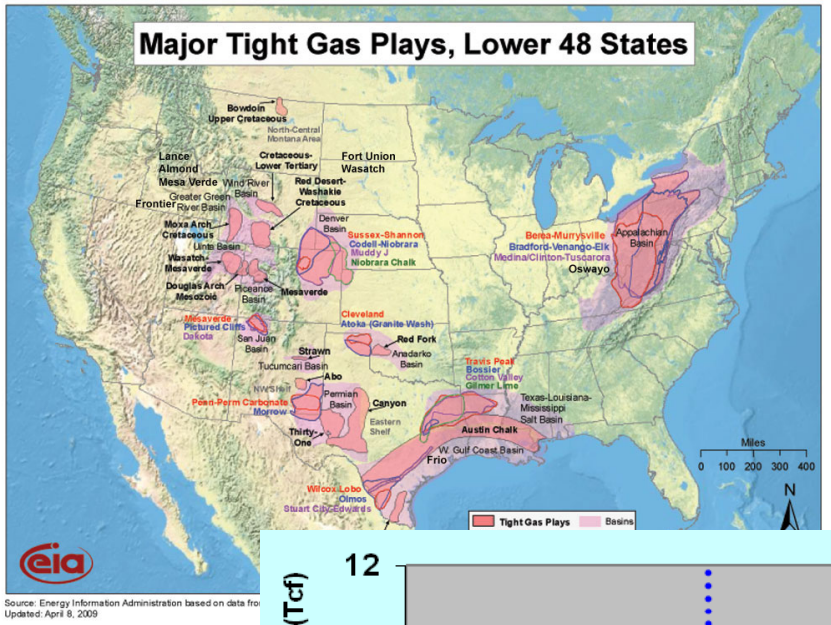
Wednesday 29.11.2011

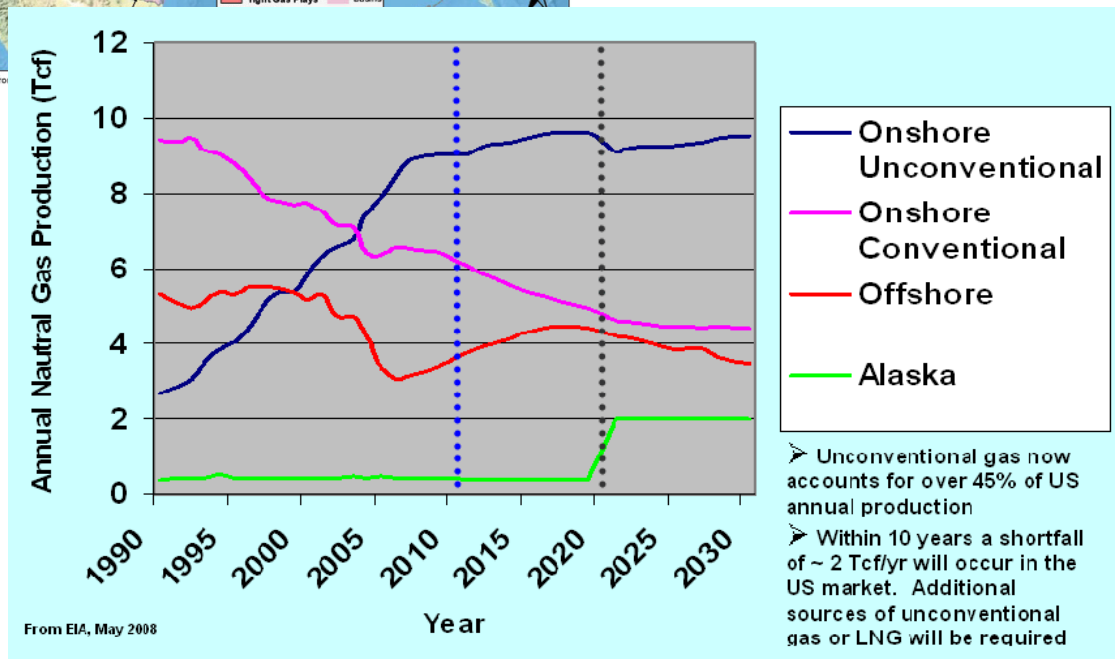
Tight gas and shale gas

- Tight gas reservoirs have permeability of 0.1mD or less – difficult to produce at economic rates.

- Current production rates rapidly increasing with rising gas prices
- Expected to contribute 65% of USA gas production by 2020 (up from 45% now).
- Estimated 2000 TcF of resources in USA.

- Gas is extracted using hydraulic fracturing.

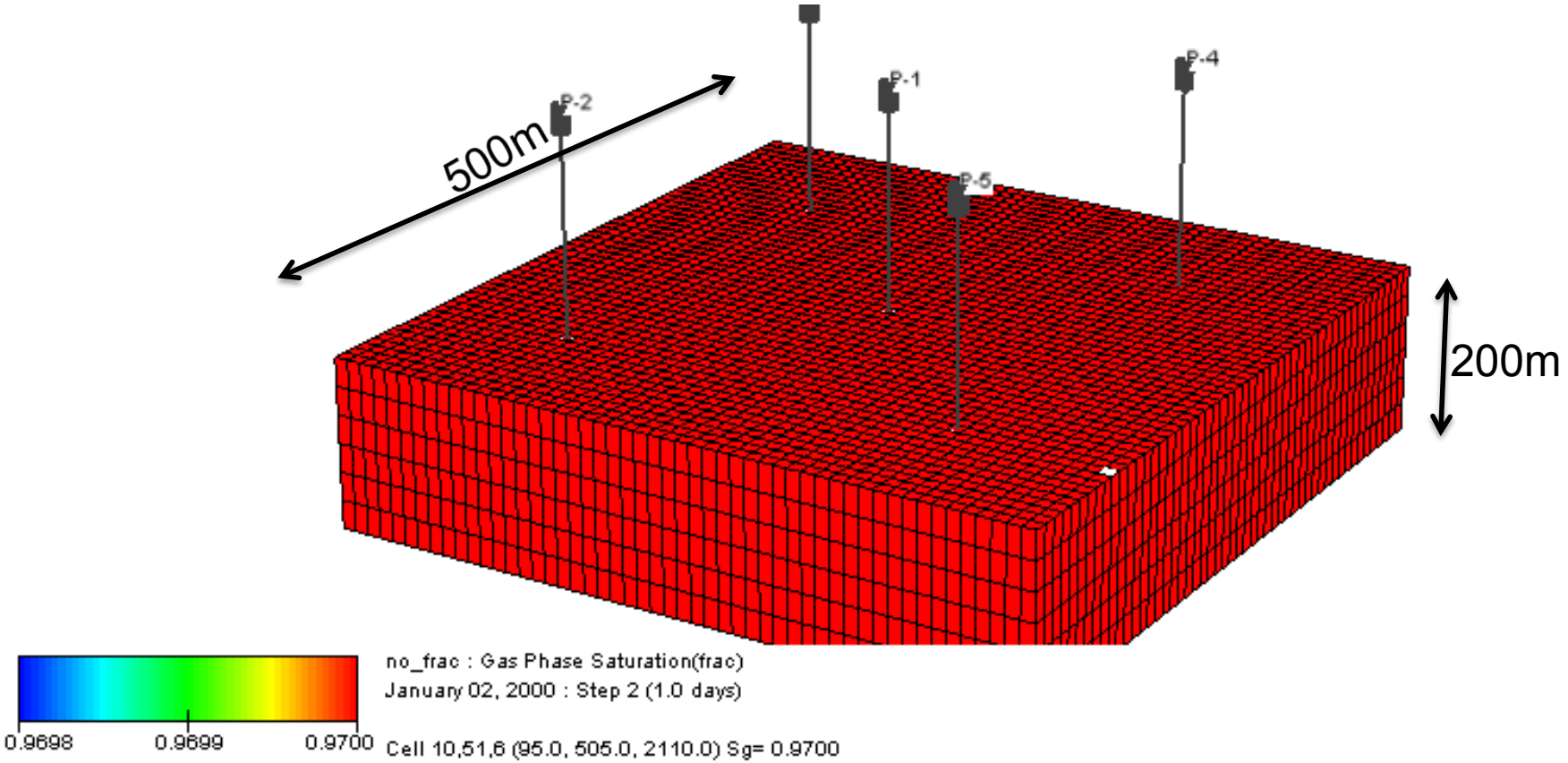




Why do we need hydraulic fracturing?

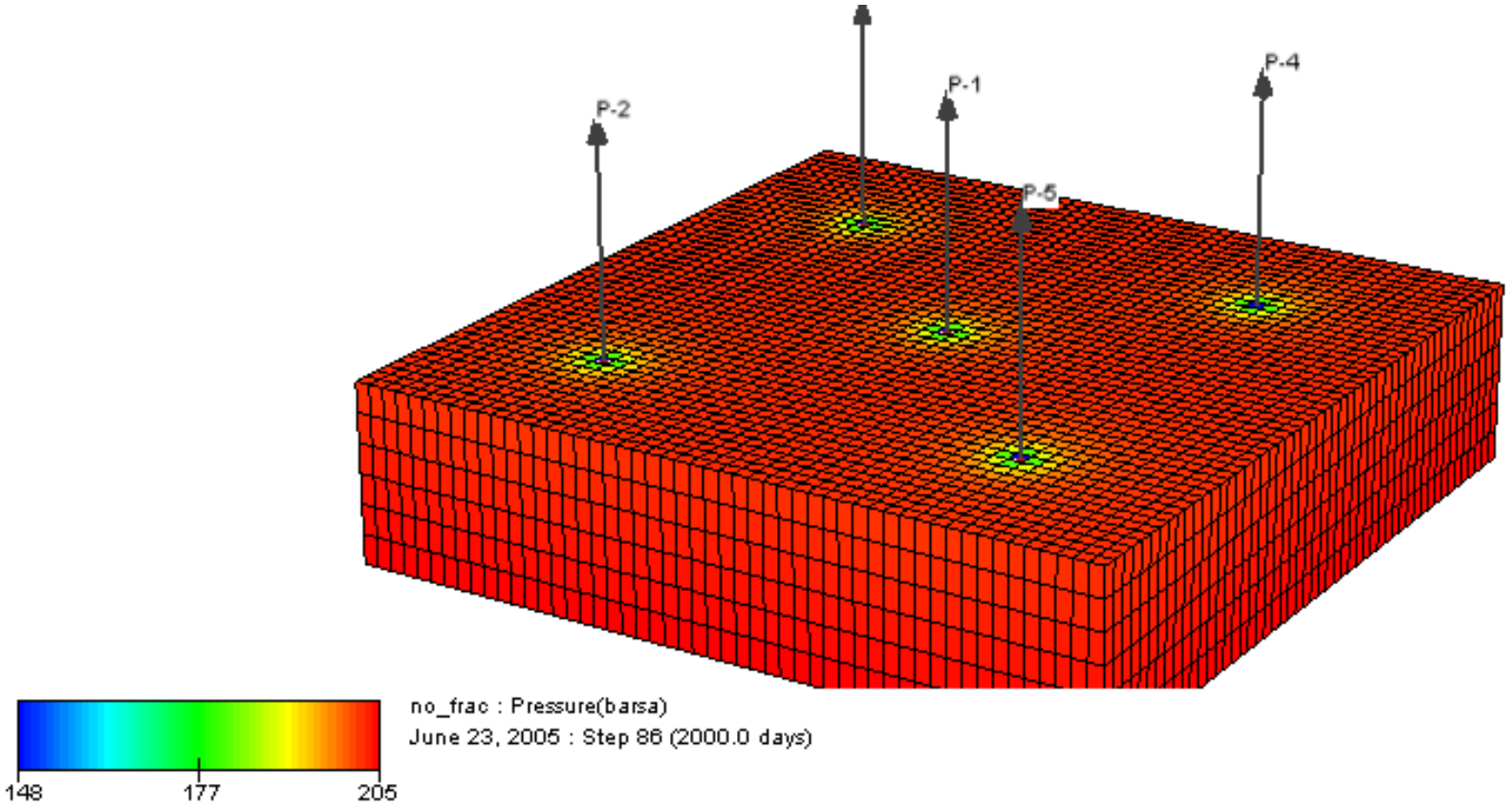
Production from a tight reservoir

- Example – reservoir simulation of a tight gas reservoir.
- Porosity = 5%, permeability = 0.01mD
- 5-spot well pattern drilled



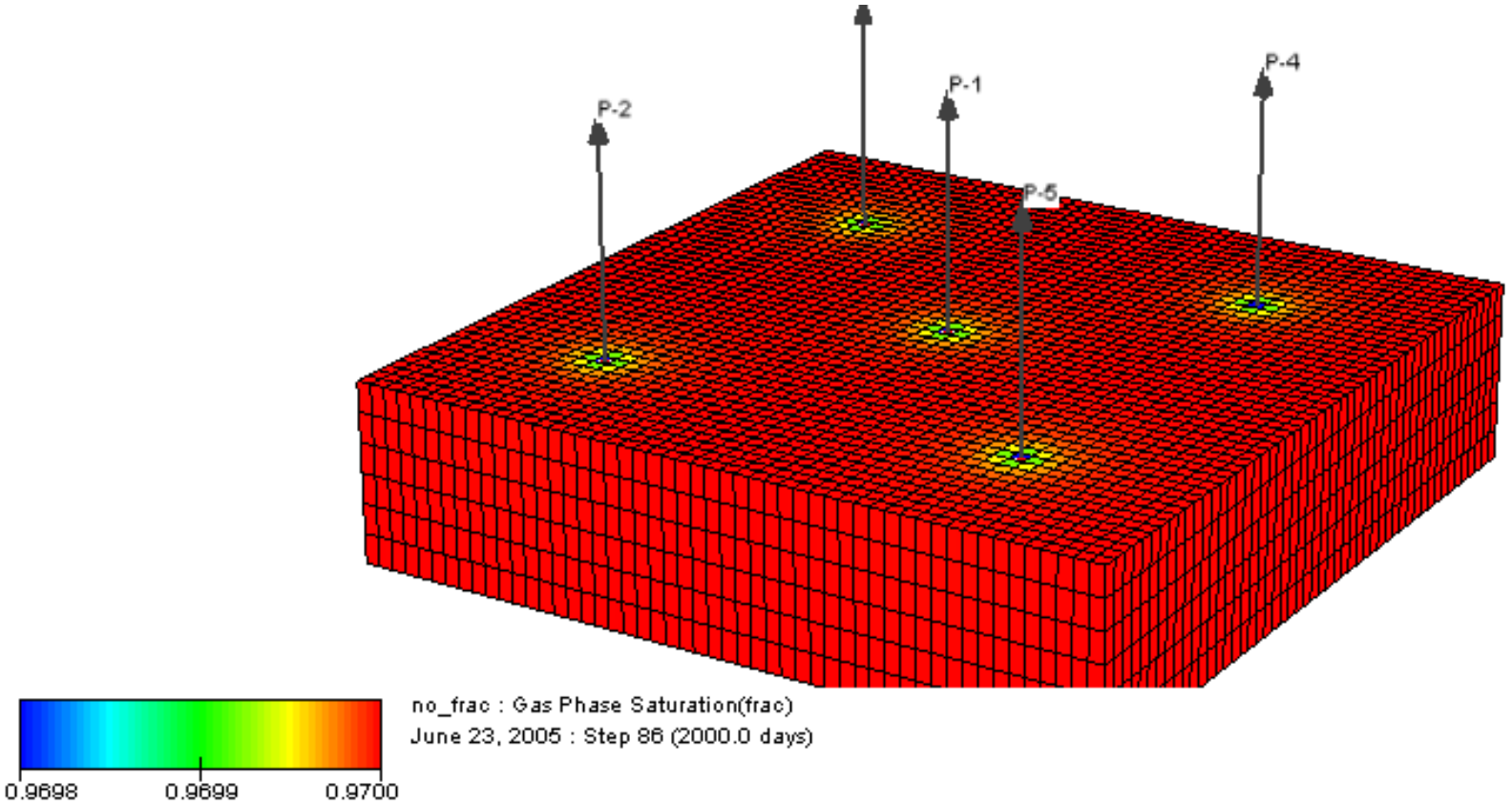
Production from a tight reservoir

- Fluid pressure after production:



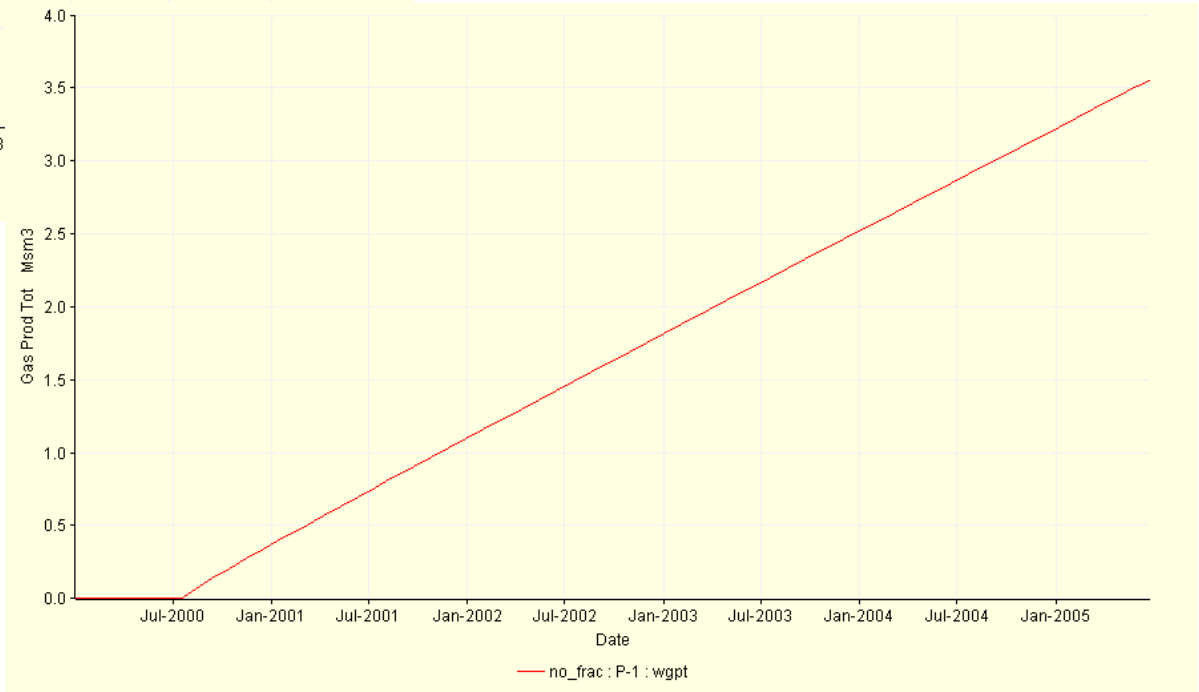
Production from a tight reservoir

- Gas saturation after after production:



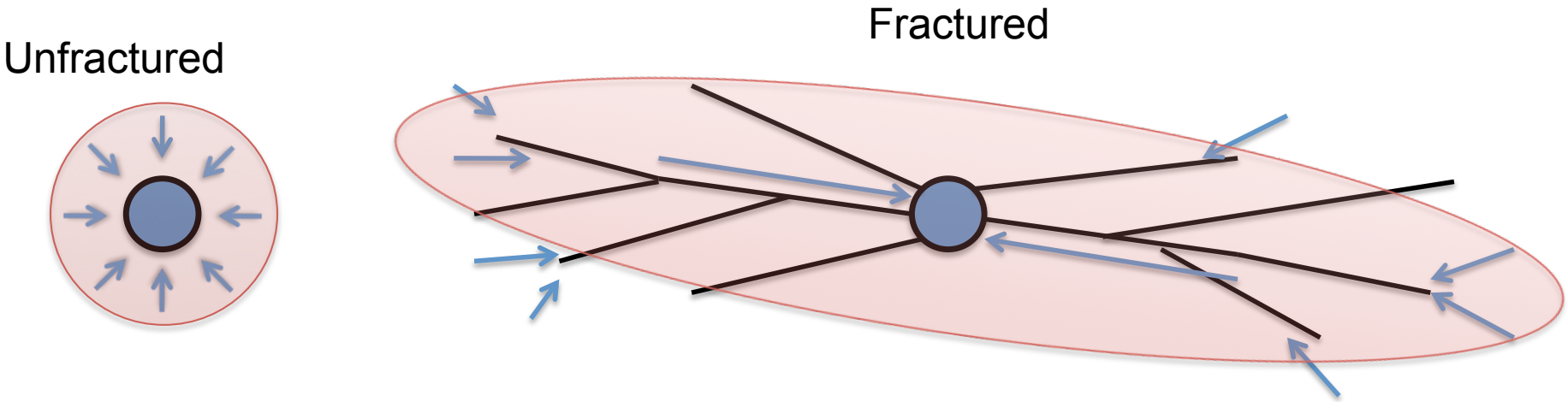
Production from a tight reservoir

- Rate and total gas production



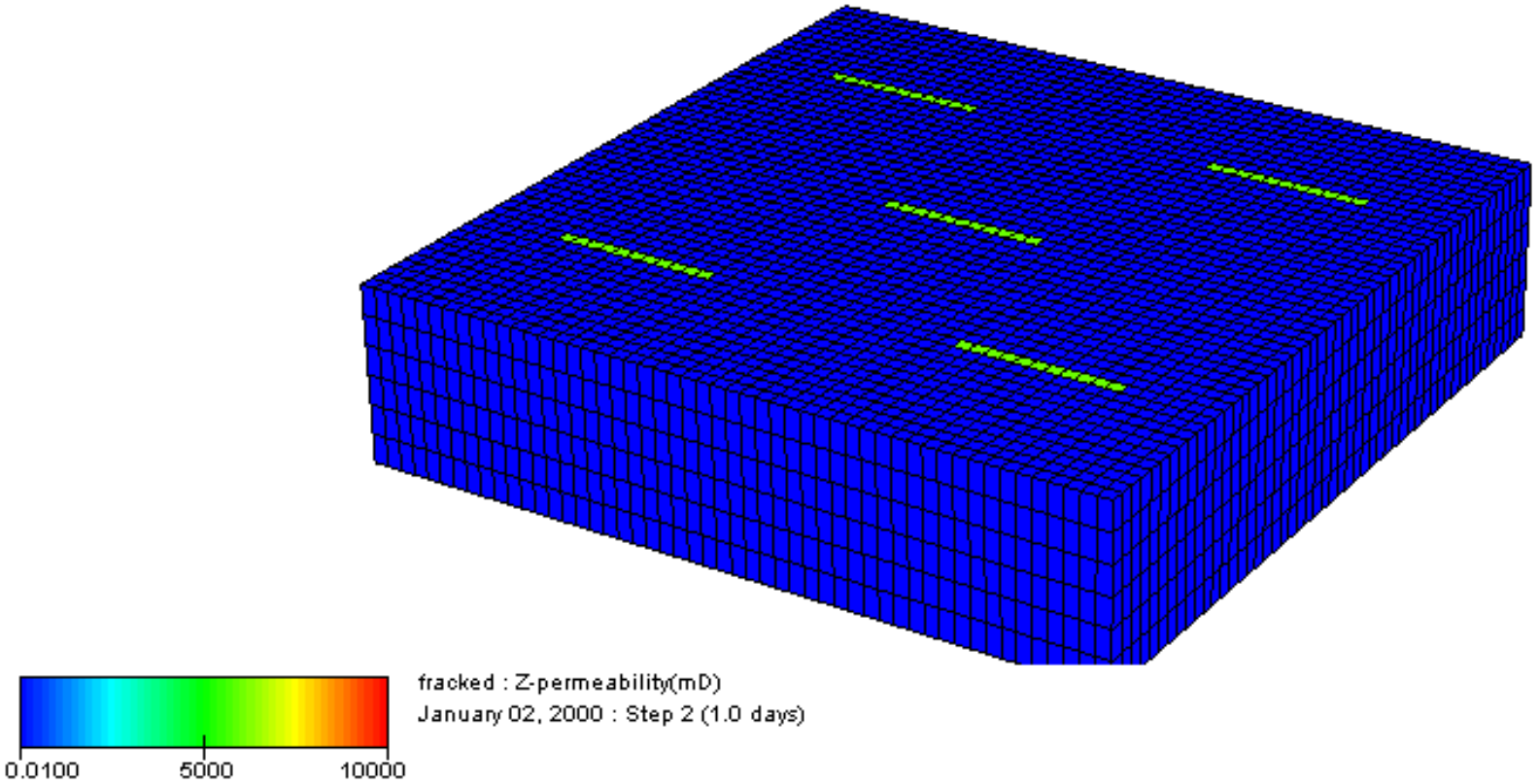
Hydraulic fracturing

- Hydraulically induced fractures help to connect the reservoir to the wells.



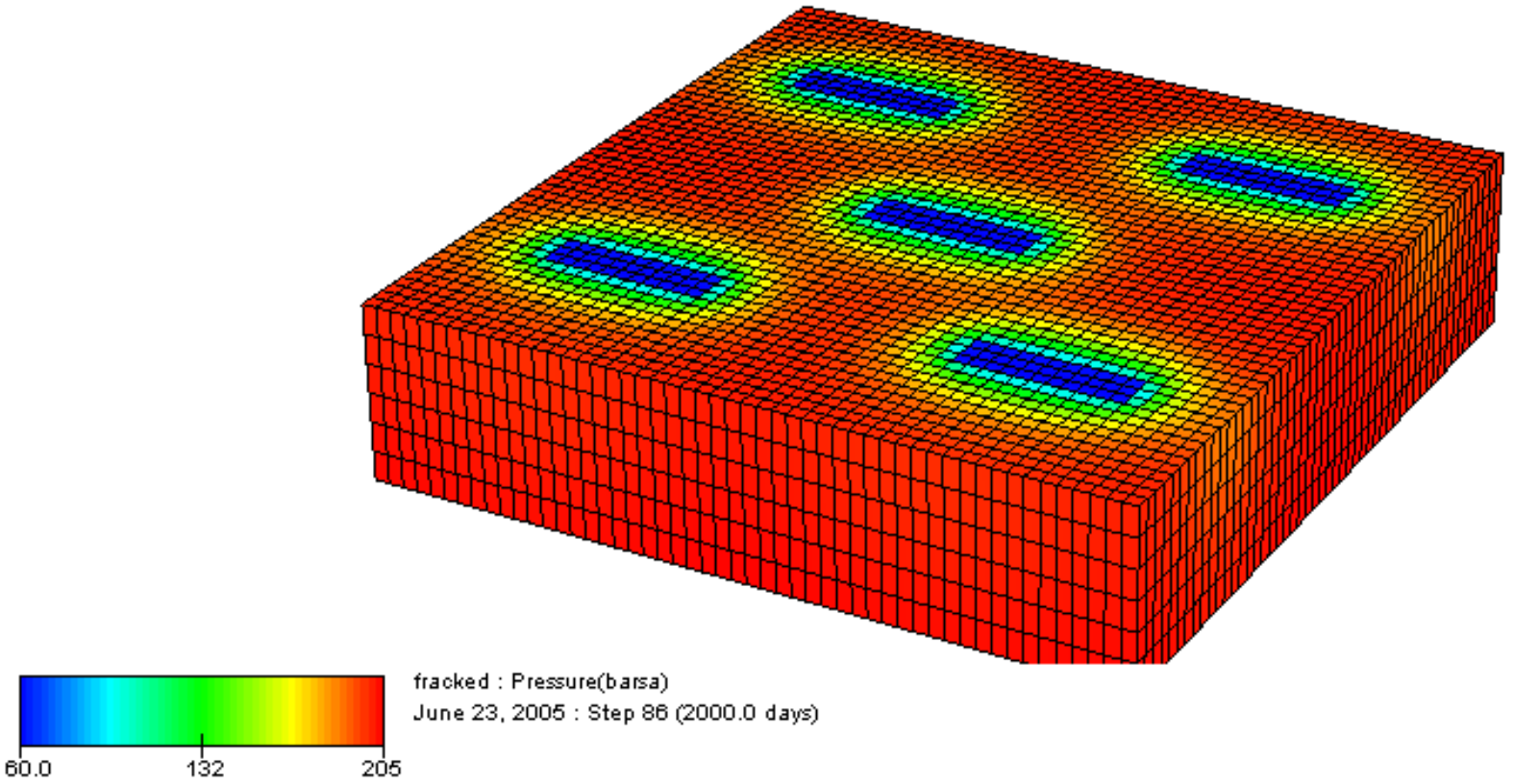
Hydraulic fracturing

- Hydraulic fracture stimulation – induce 100m long linear fractures from the wells. Fracture permeability = 10000mD



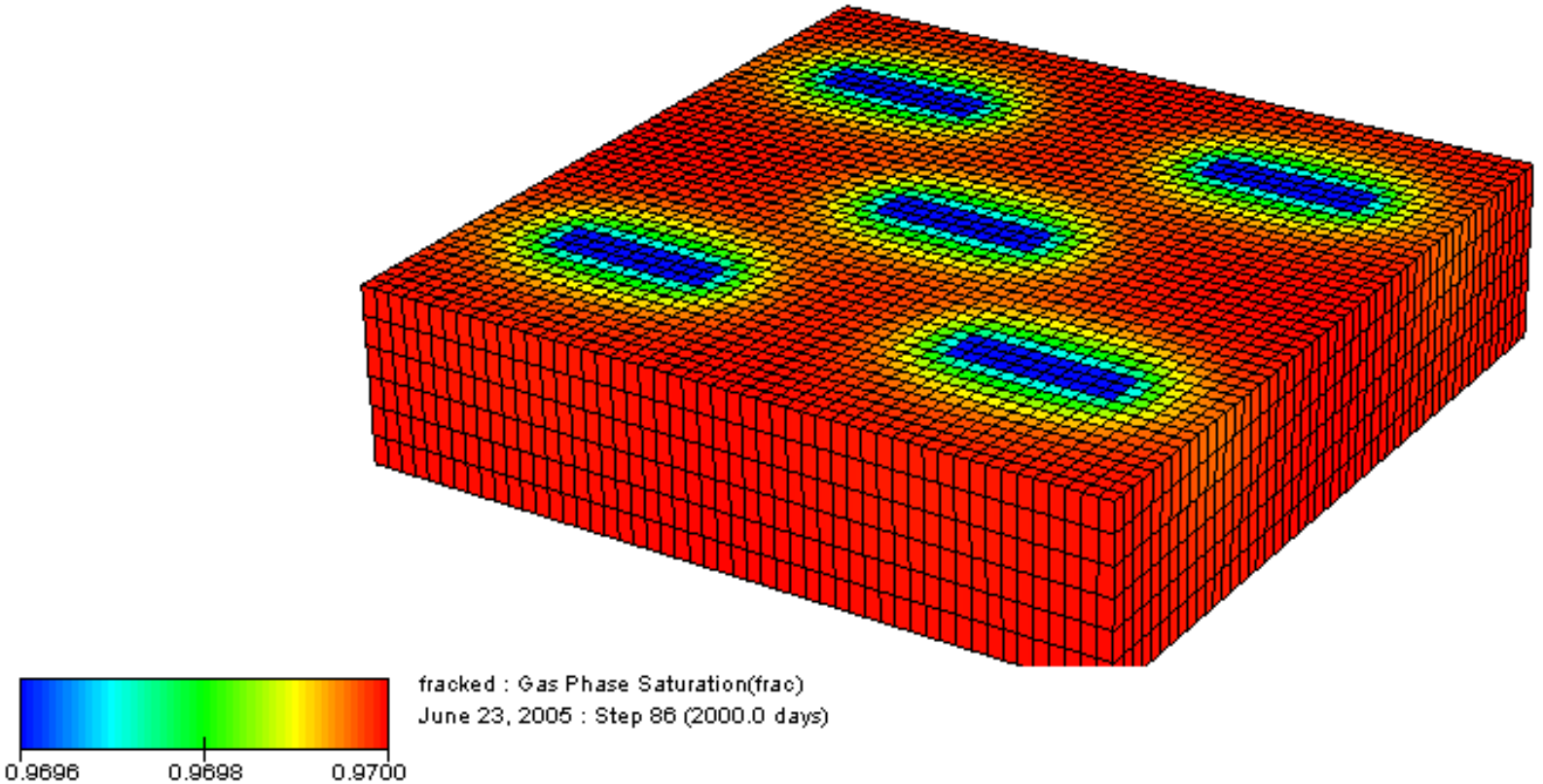
Hydraulic fracturing

- Pressure after production:



Hydraulic fracturing

- Gas saturation after production



Hydraulic fracturing

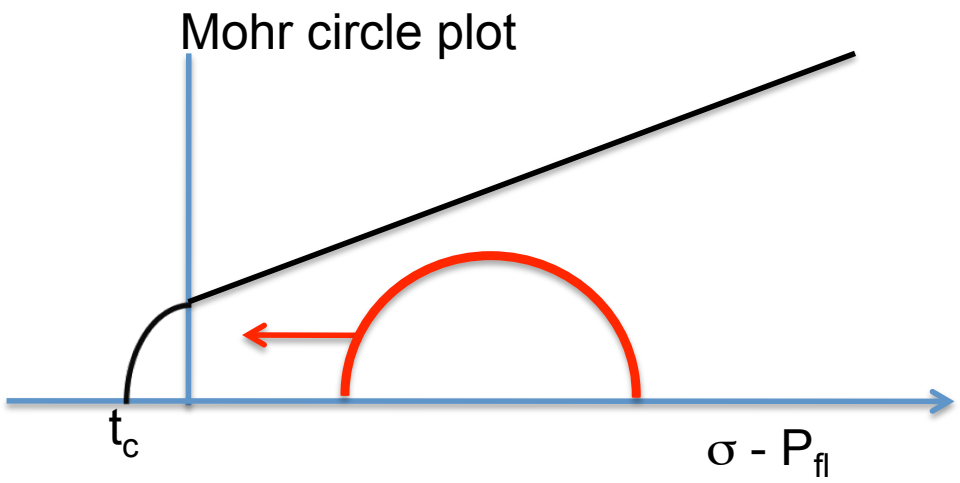
- Gas production rate and total

How do we frack?

How are fractures created

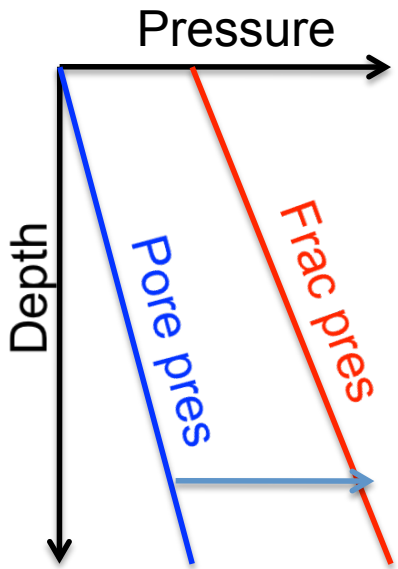
- To frack, we inject fluid at high pressure to induce fractures

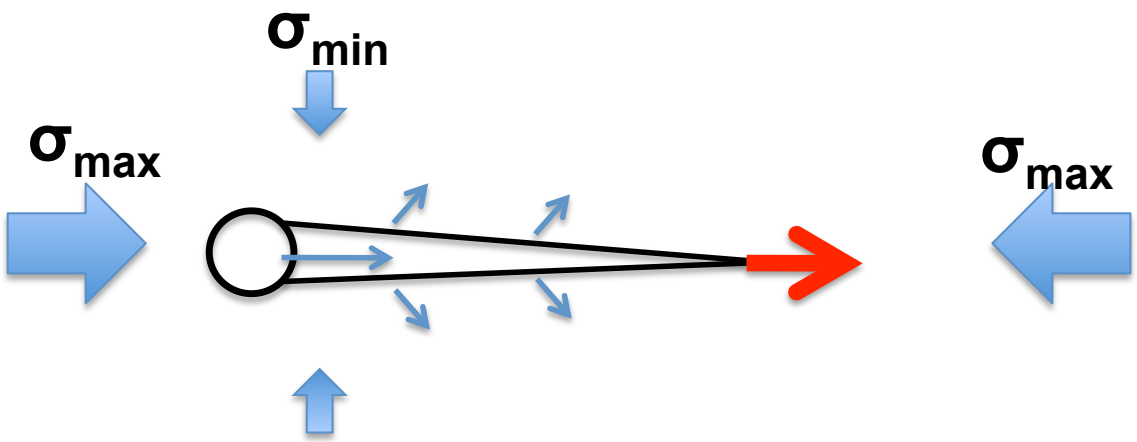
- Increasing pore pressure reduces effective stress until the tensile failure limit is reached.



How are fractures created

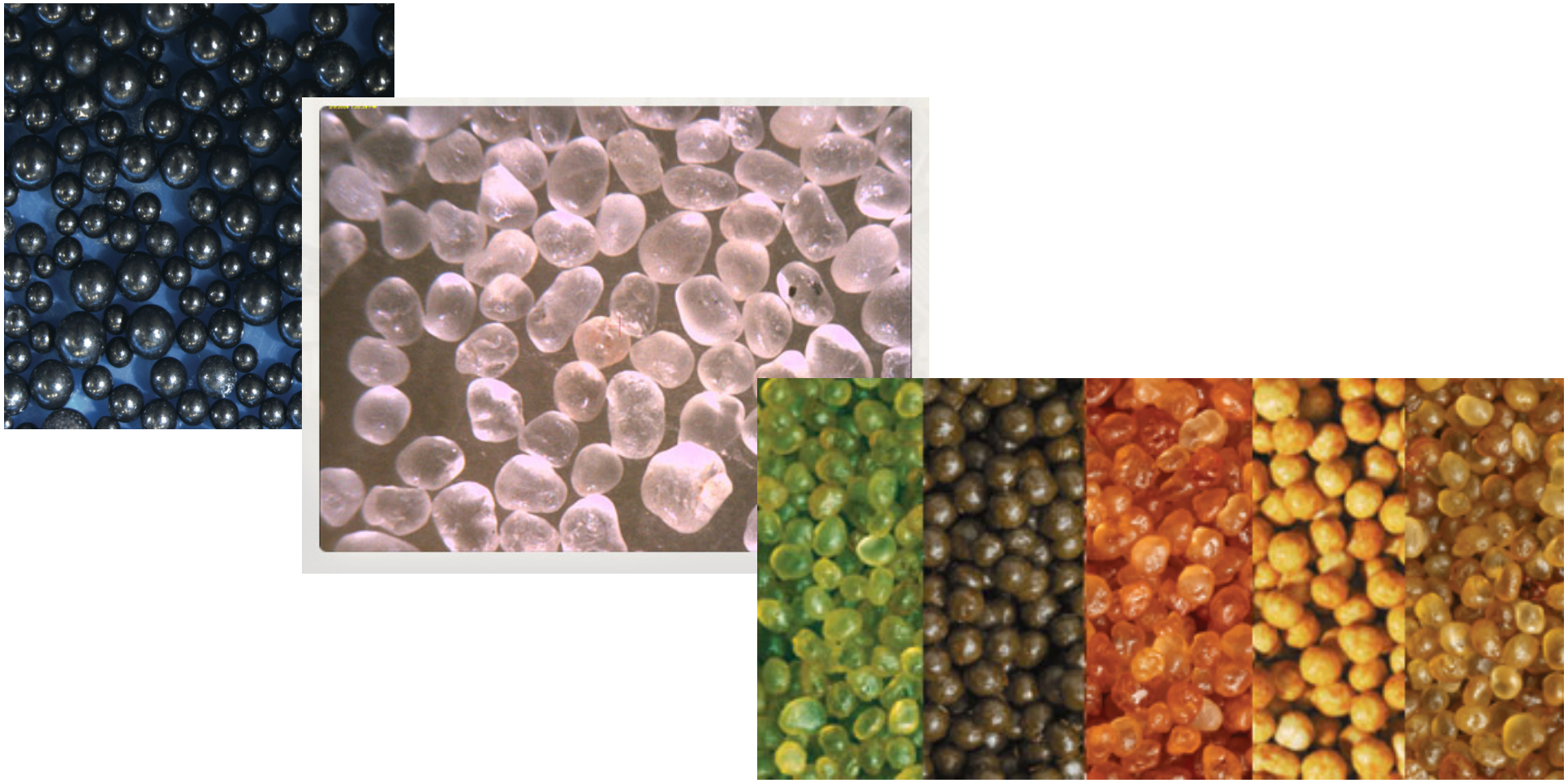
- The pressure needed to hit the tensile failure point is described by the fracture pressure.
- Once failure occurs, fractures propagate from the injection well perpendicular to the minimum stress direction.





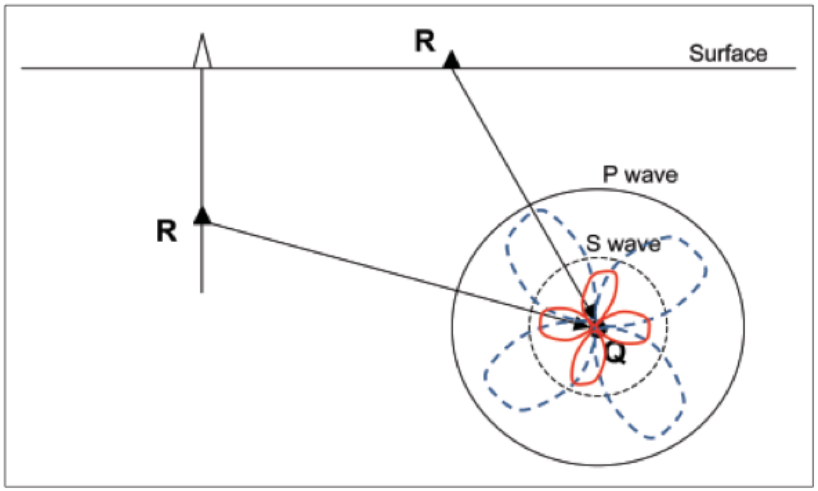
How are fractures created

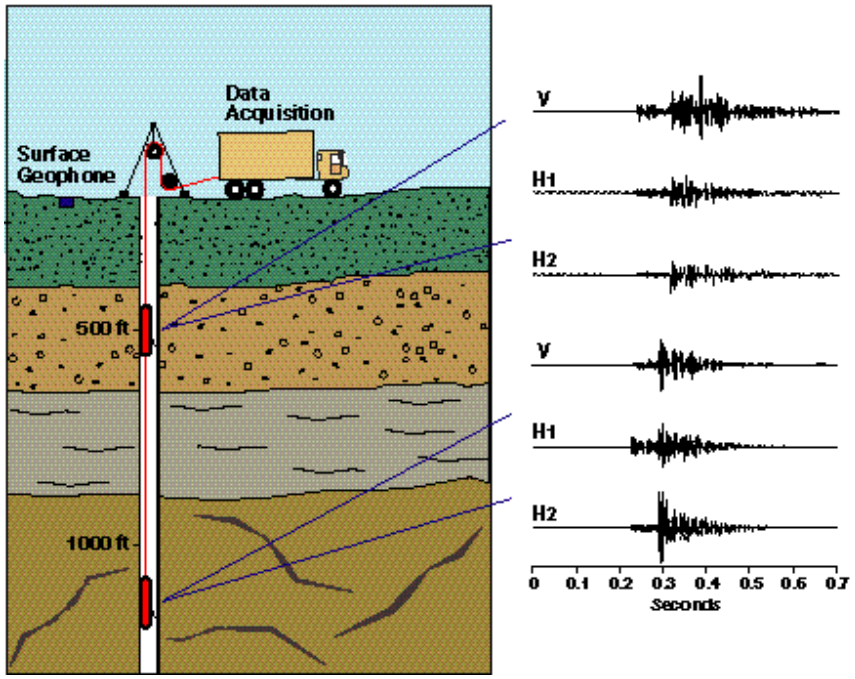
- Once the fractures have been created, proppant is injected to ‘prop’ the fractures open.
- Otherwise, the stress would force the fractures closed again.
- Proppant can be sand grains or specially manufactured ceramic balls

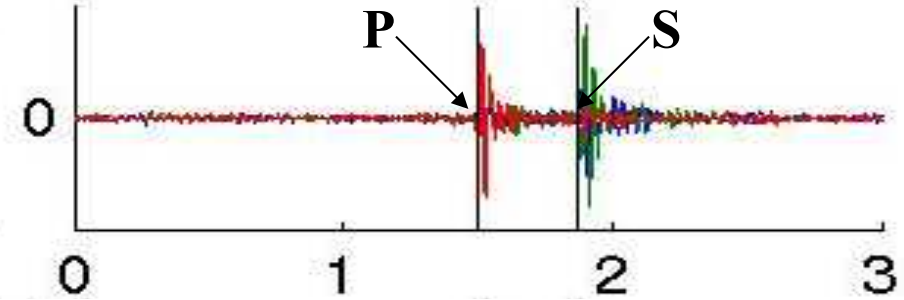


Monitoring fracturing

- Fracture formation can be tracked by monitoring the ‘microearthquakes’ created.
- A Bristol speciality: http://www1.gly.bris.ac.uk/BUMPS/



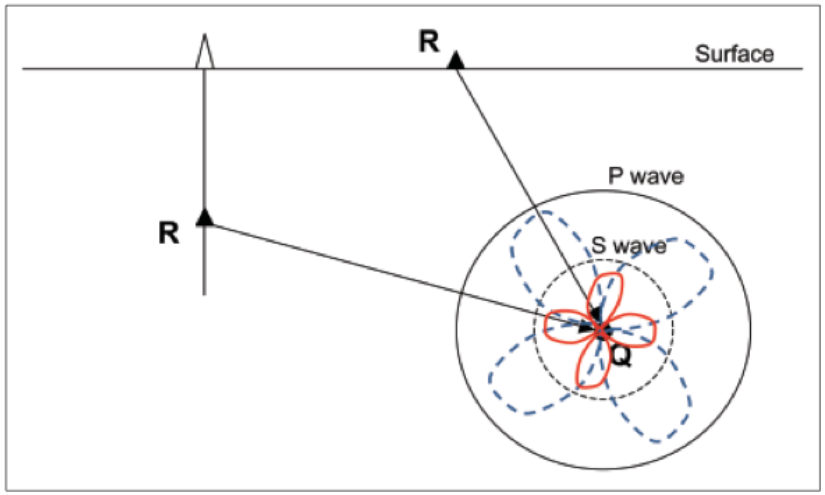




WHAT IS A MICROSEISMIC EVENT?

MICROSEISMIC EVENTS are analogous to earthquakes – slip on a pre-existing joint or fracture

P and S wave energy is released.



TYPICAL MAGNITUDES: M_W = -3 to 0 (cf. earthquakes >3)

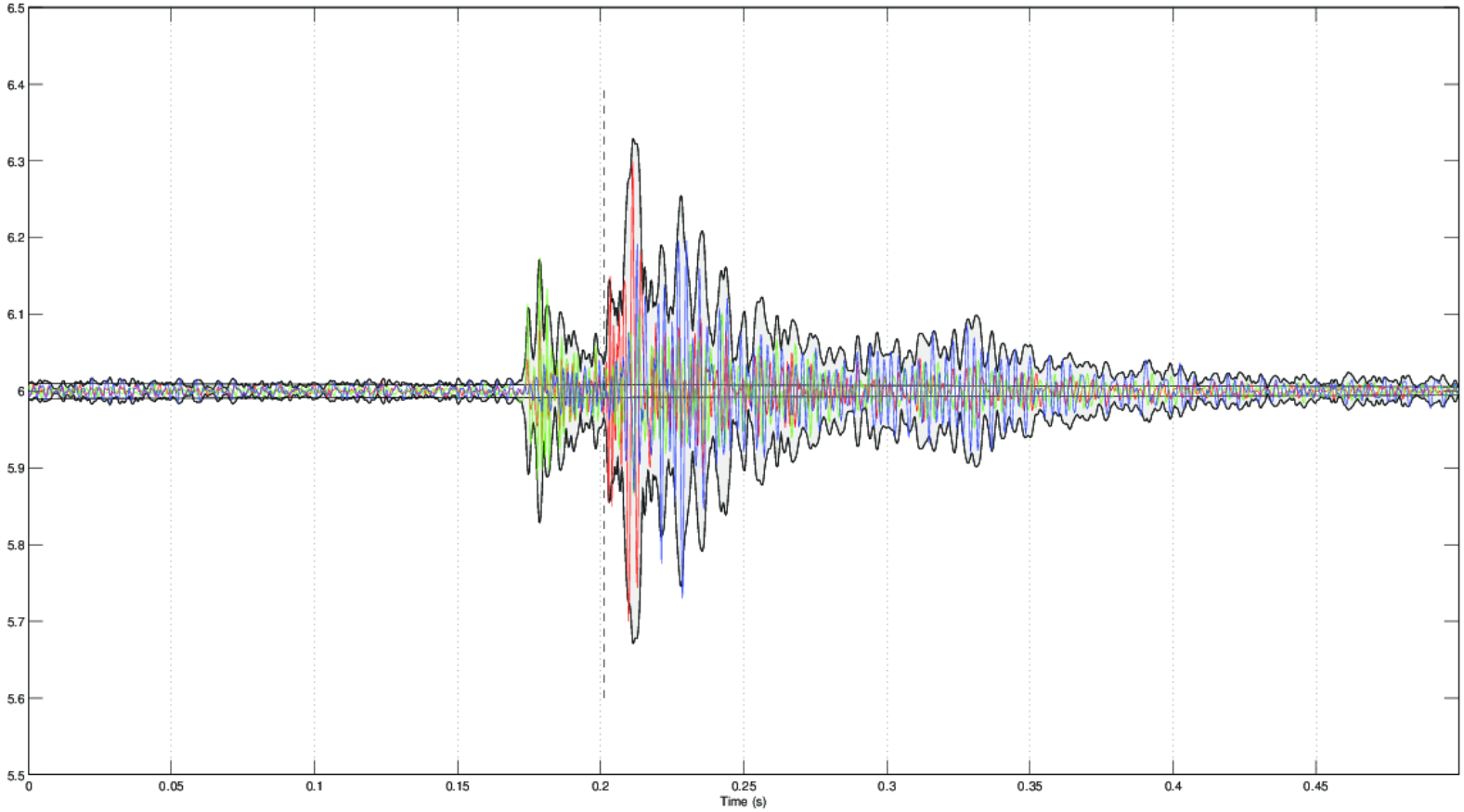
$$\left(M_w = \frac{2}{3}\log_{10} M_0 - 10.7\right)$$

M_0 = 10^{11} to 10^{16} D (cf. 10^{20})

$$M_0 = \mu A D, \quad D \approx A/100$$

TYPICAL RUPTURE: A = 0.001m^2 – 0.5m^2 (cf. 100m^2)

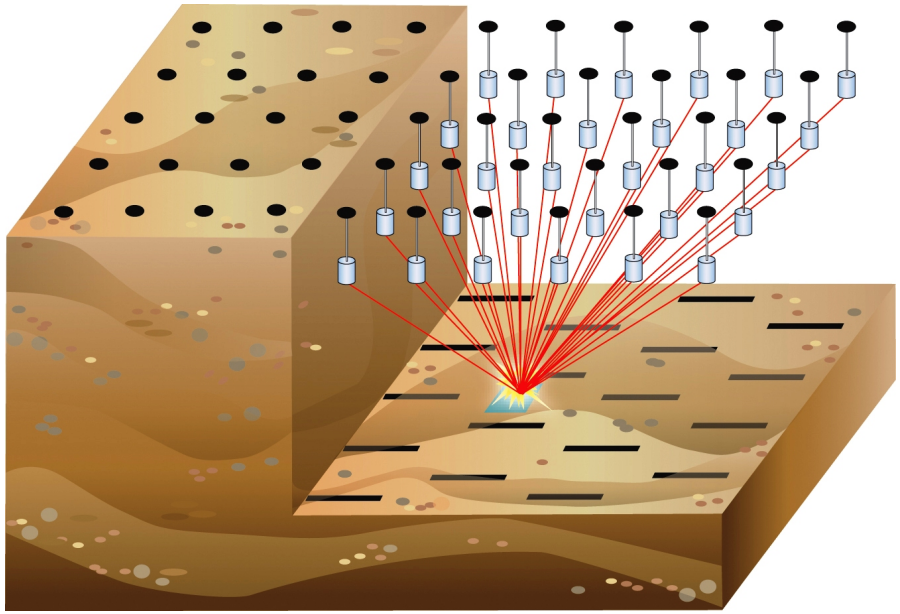
What is a Microseismic Event?

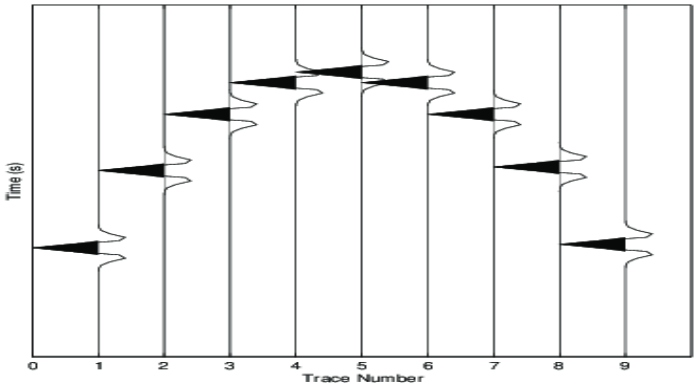


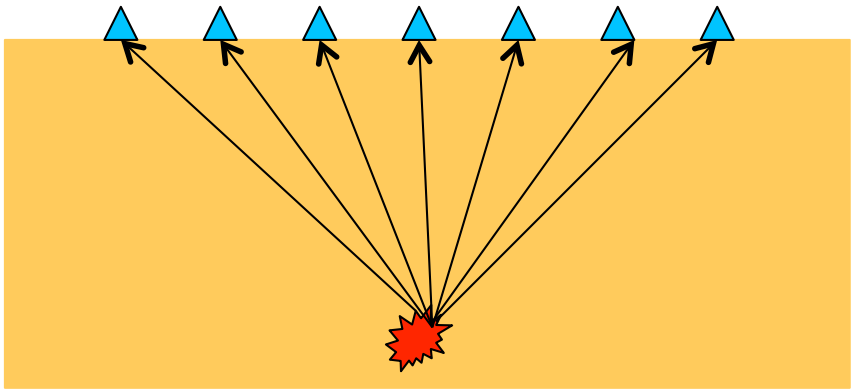
MICROSEISMIC MONITORING METHODS

SURFACE ARRAYS: A dense array of 1000s of 1C geophones placed on the ground surface.

Larger events detected directly, smaller events located with migration algorithms.







MICROSEISMIC MONITORING METHODS

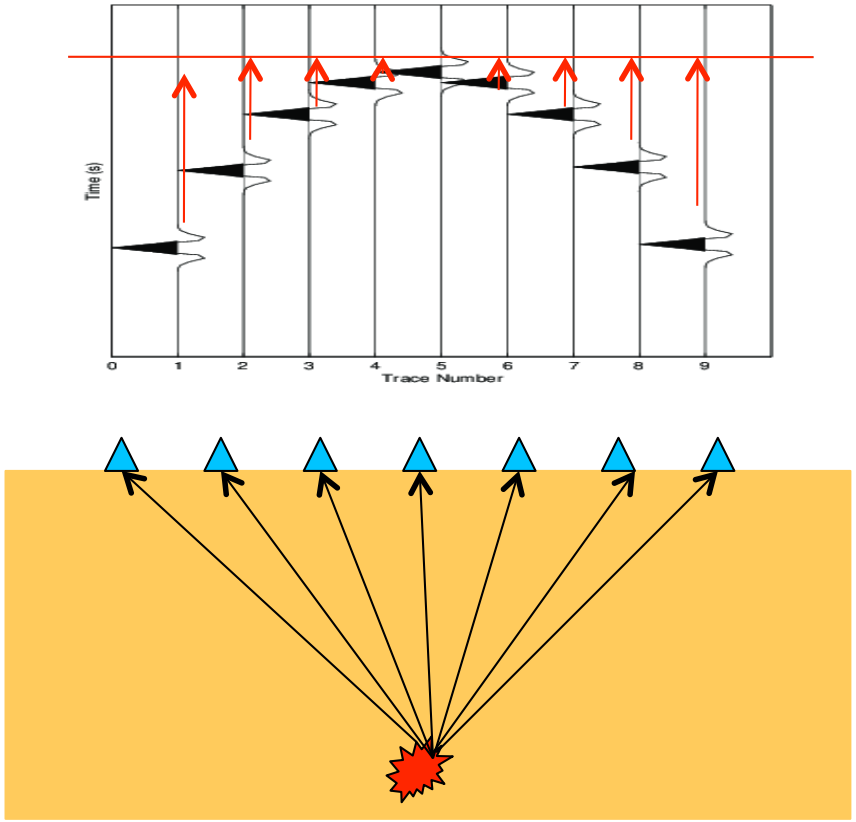
SURFACE ARRAYS:

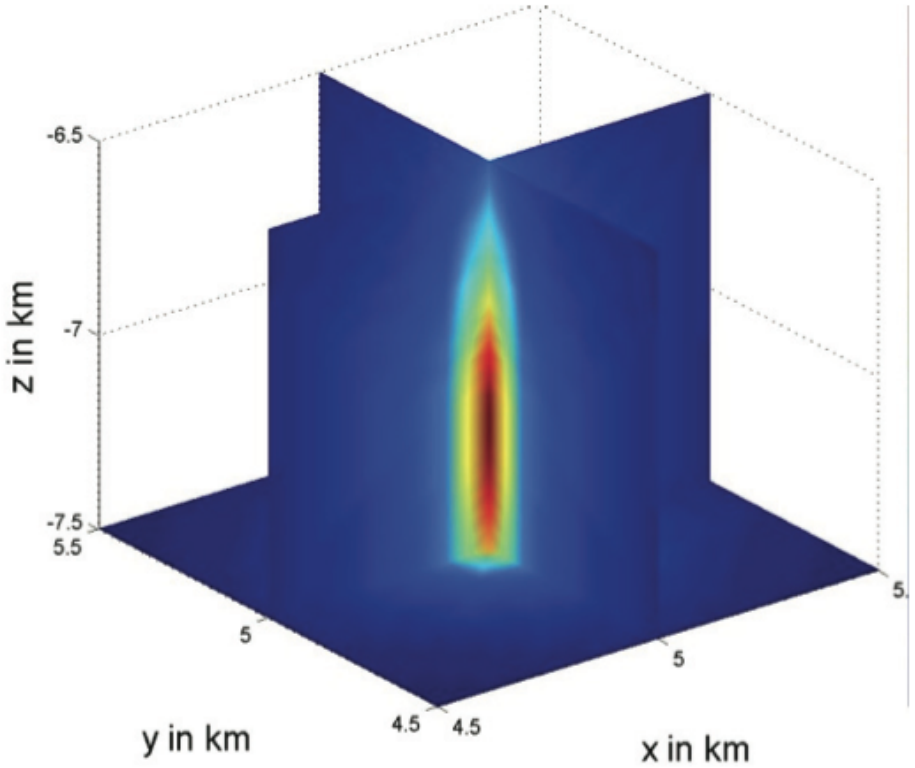
Good lateral extent of coverage.

Well constrained X-Y location.

Limited detectability.

Poor depth locations.

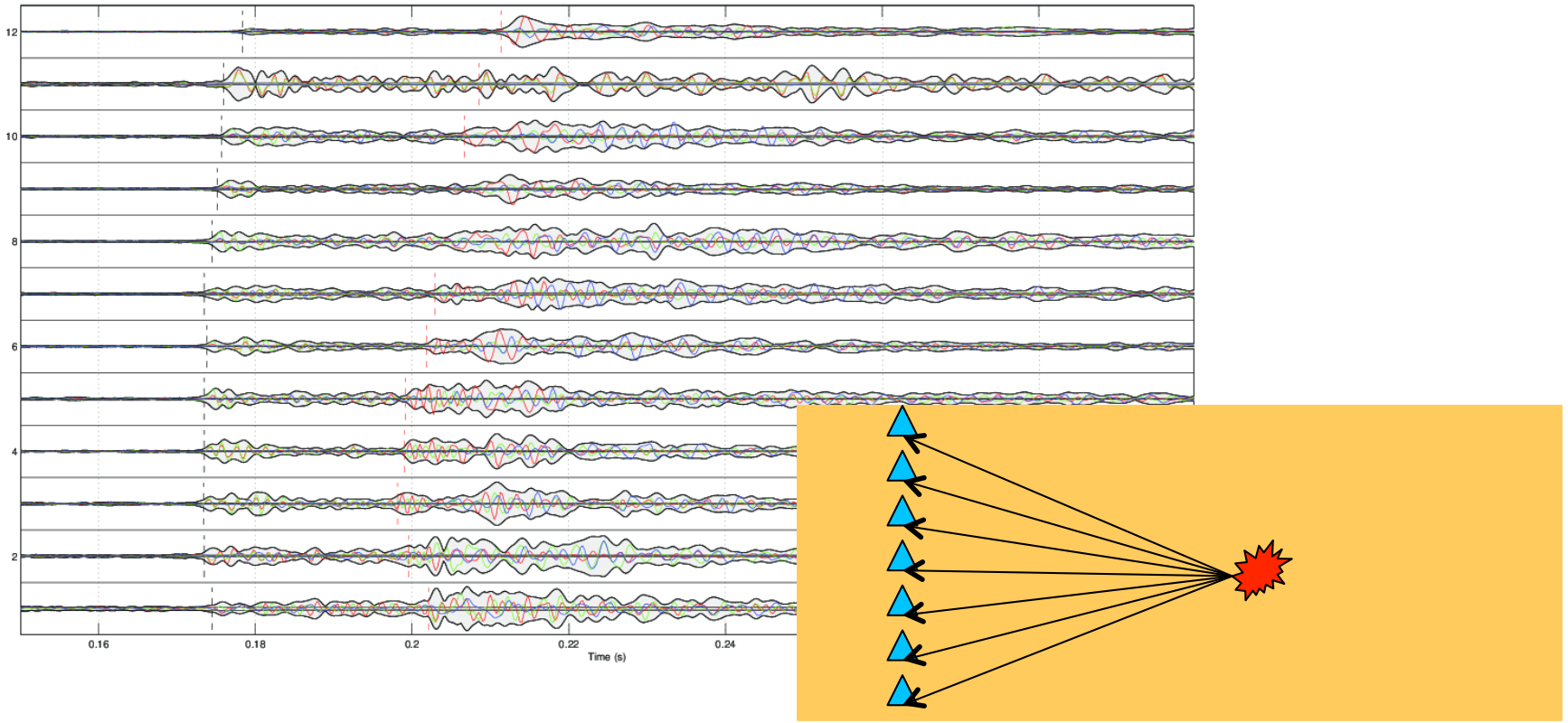




MICROSEISMIC MONITORING METHODS

DOWNHOLE ARRAYS: A string of 6 – 20 3C geophones is installed in a borehole near to the injection site.

Differential P-S arrival times, and P wave particle motions, are used to locate the events.



MICROSEISMIC MONITORING METHODS

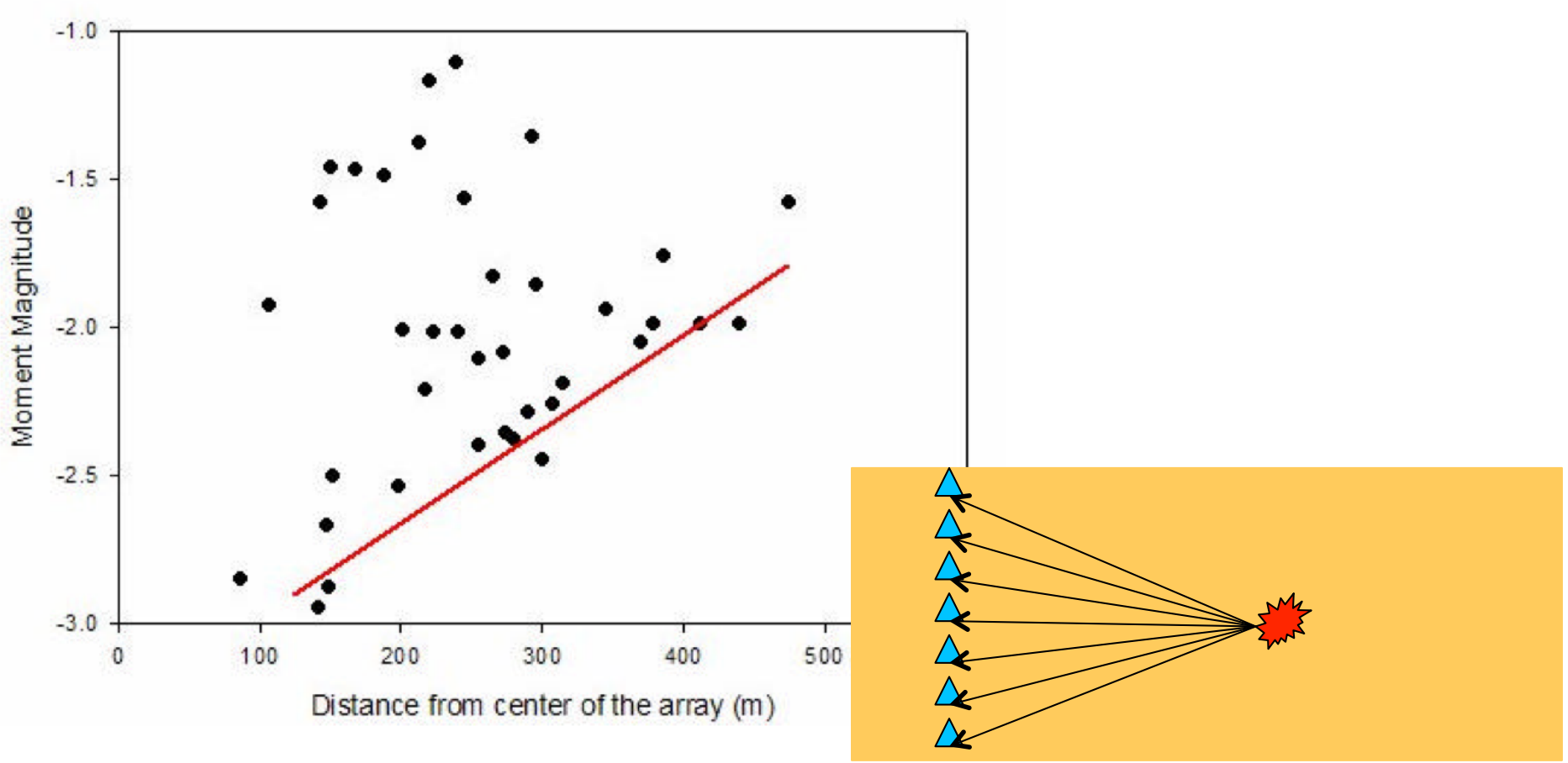
DOWNHOLE ARRAYS:

Accurate depth location.

Good detectability.

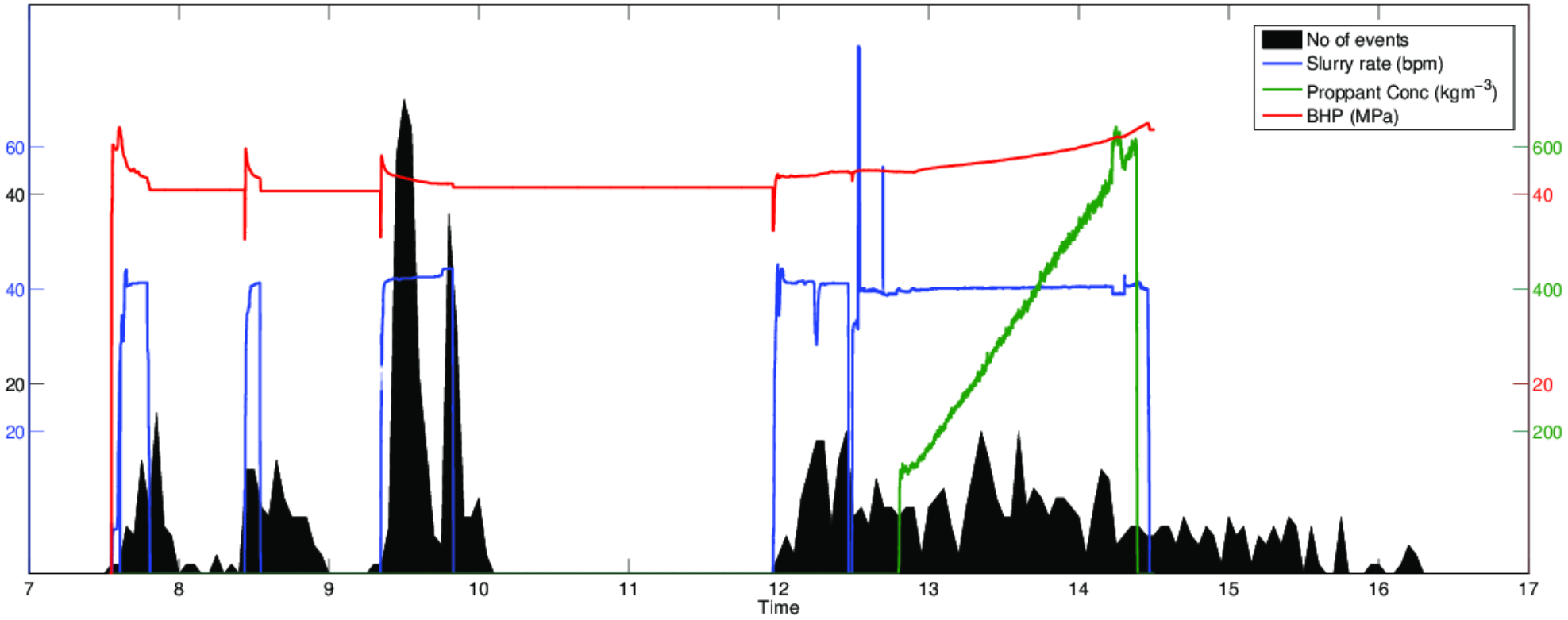
Limited lateral extent.

Poorer X-Y locations.



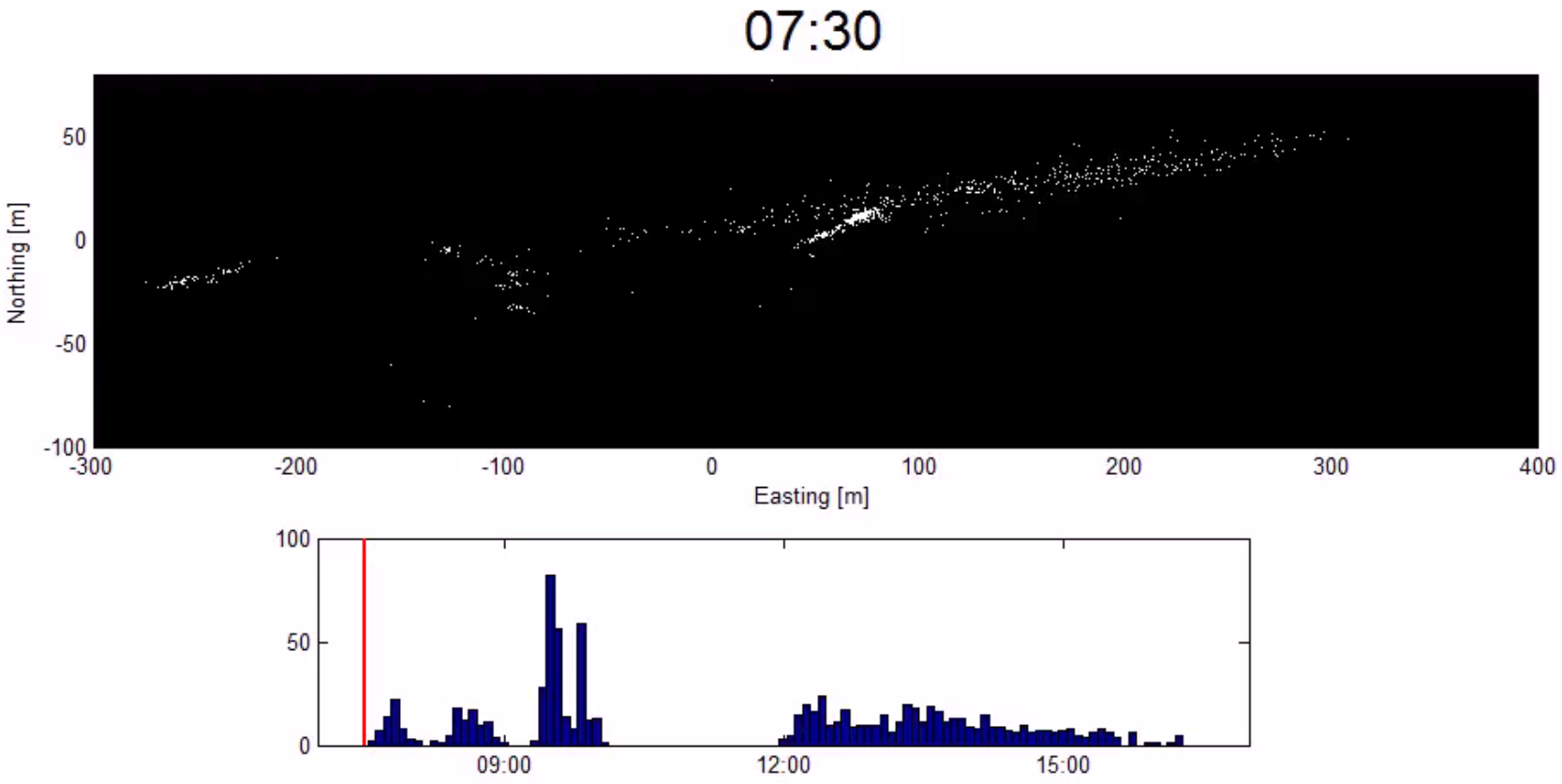
A Classic Frac

- Hydraulic fracture stimulation at Cotton Valley, East Texas, 1997.
- 3 initial phases of injection to fracture, and a final phase with proppant



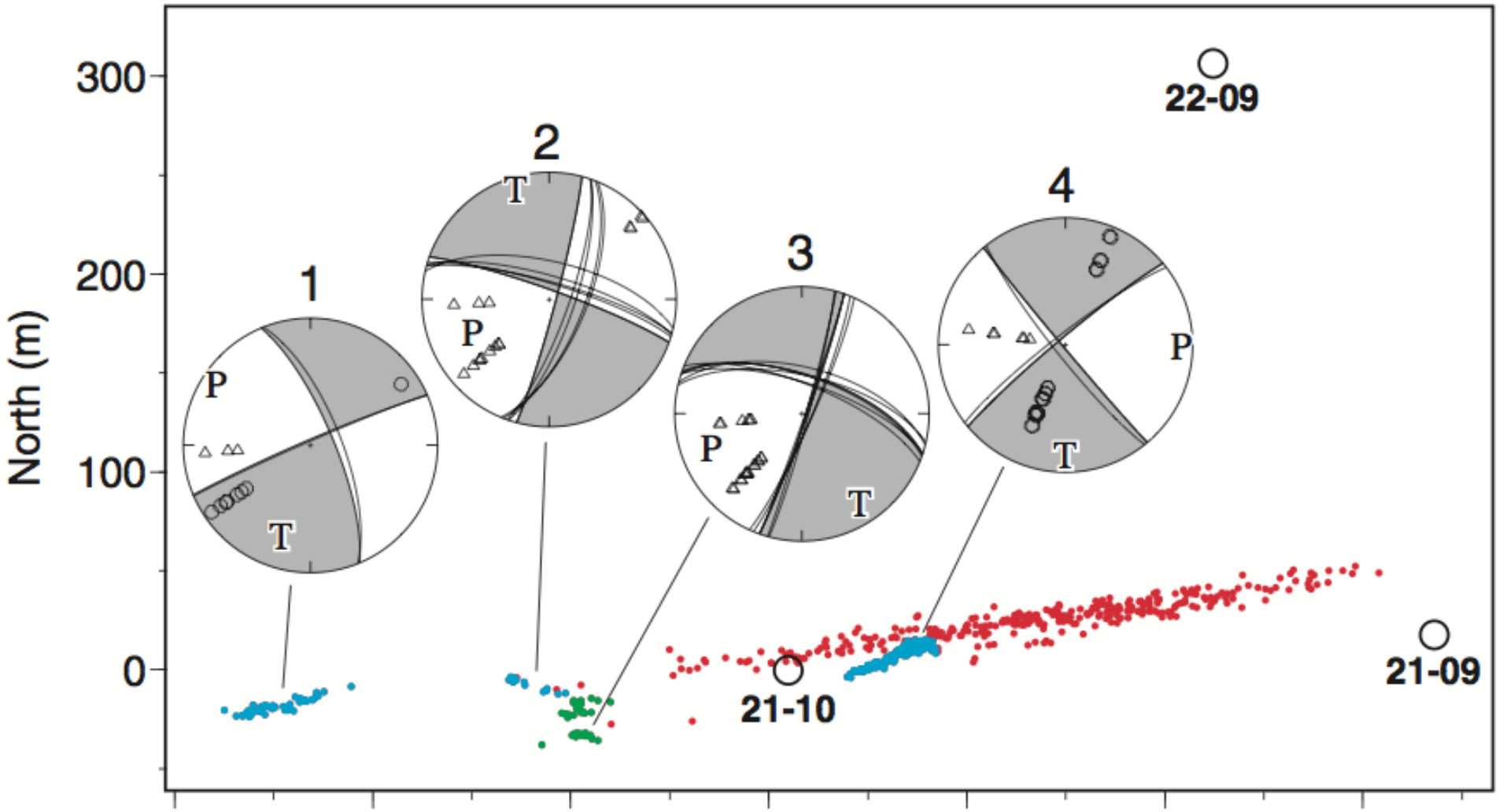
A Classic Frac

- Microseismic events track the formation of fractures



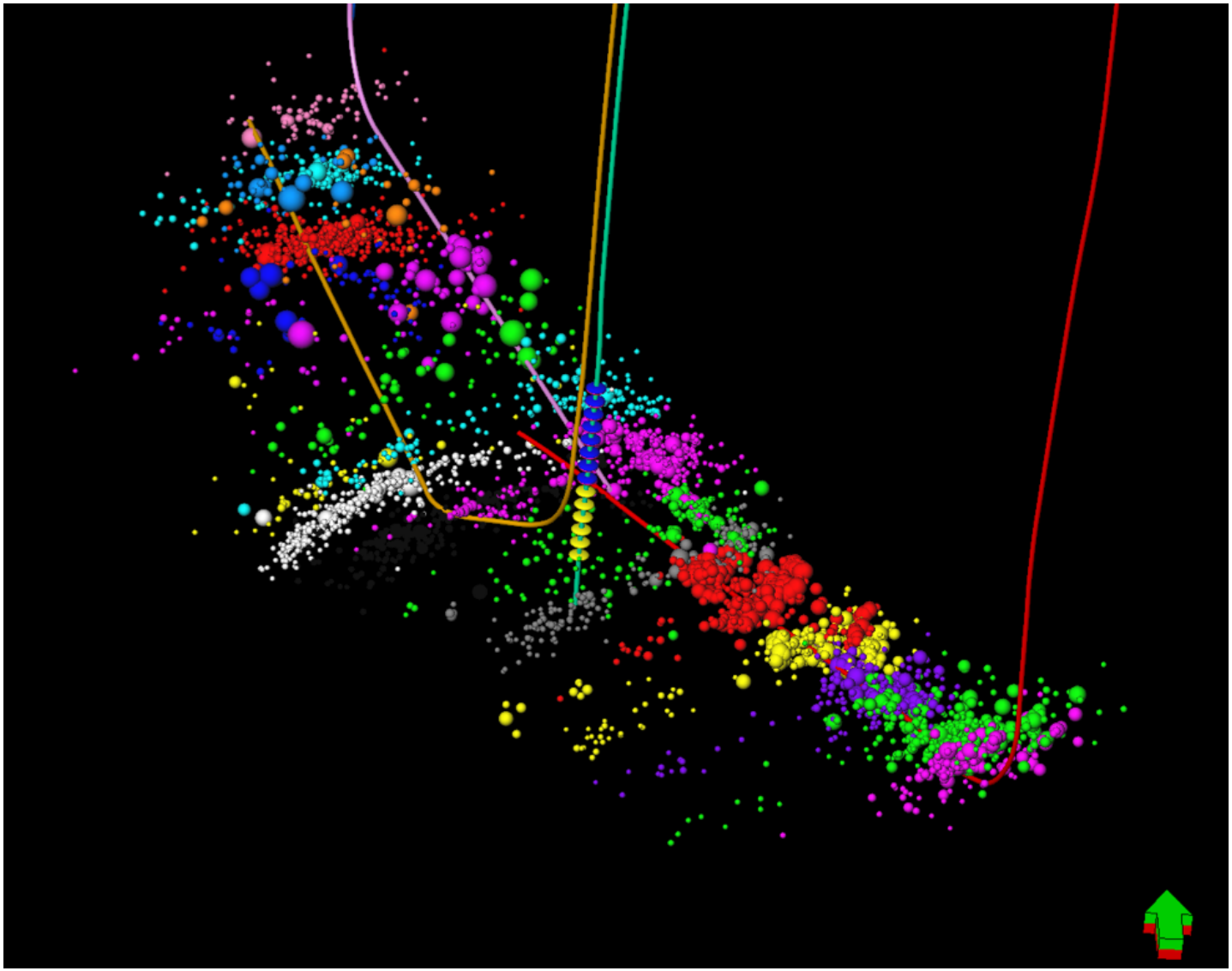
A Classic Frac

- Focal mechanism analysis have been used to learn more about the fractures (just like we do with conventional earthquakes).

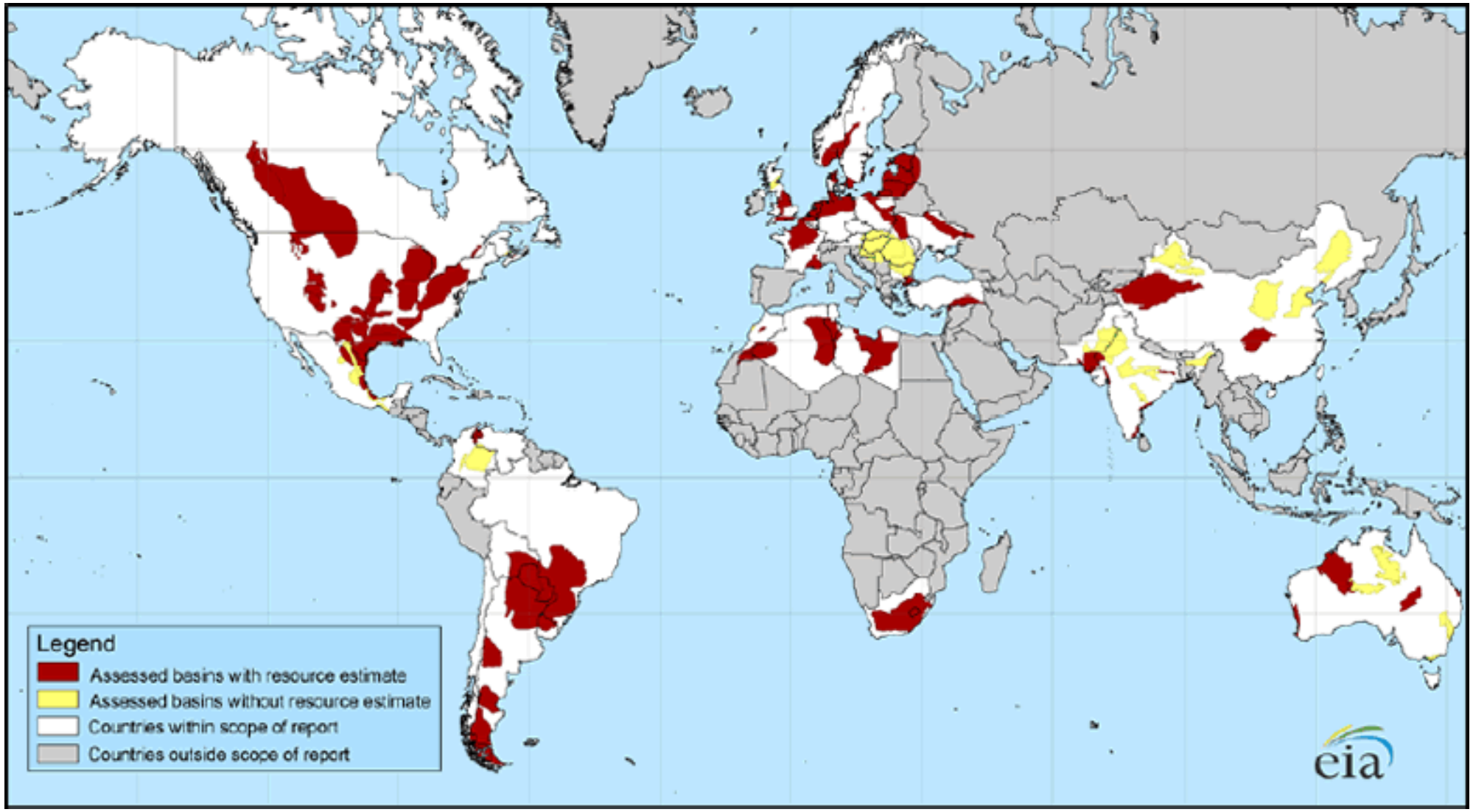


Horizontal well fracking

- Typically, horizontal wells are drilled, with numerous stages of fracking along the well.



Shale Gas worldwide

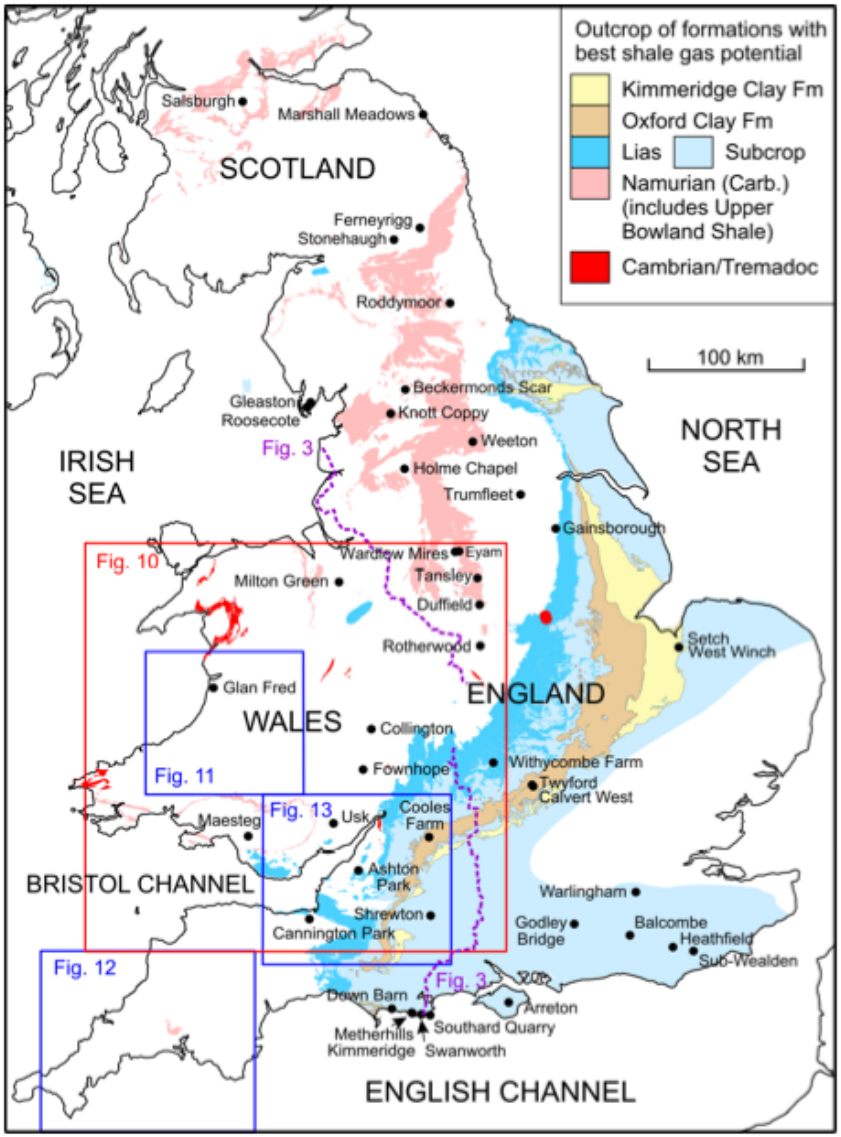


Shale Gas in the UK

Estimated reserves = 150 billion cubic meters.

This is worth ~£50 billion.

Test wells have been drilled near Blackpool into the Bowland shale.



CUADRILLA RESOURCES

Fracking – A controversial technology

- **INDUCED SEISMICITY**
- **WATER CONTAMINATION**

Shale Gas and Environmental Concerns

INDUCED SEISMICITY:

During and after stimulation at Cuadrilla's Blackpool site, two earthquakes occurred, a magnitude 2.3 (1st April) and a magnitude 1.5 (27th May).

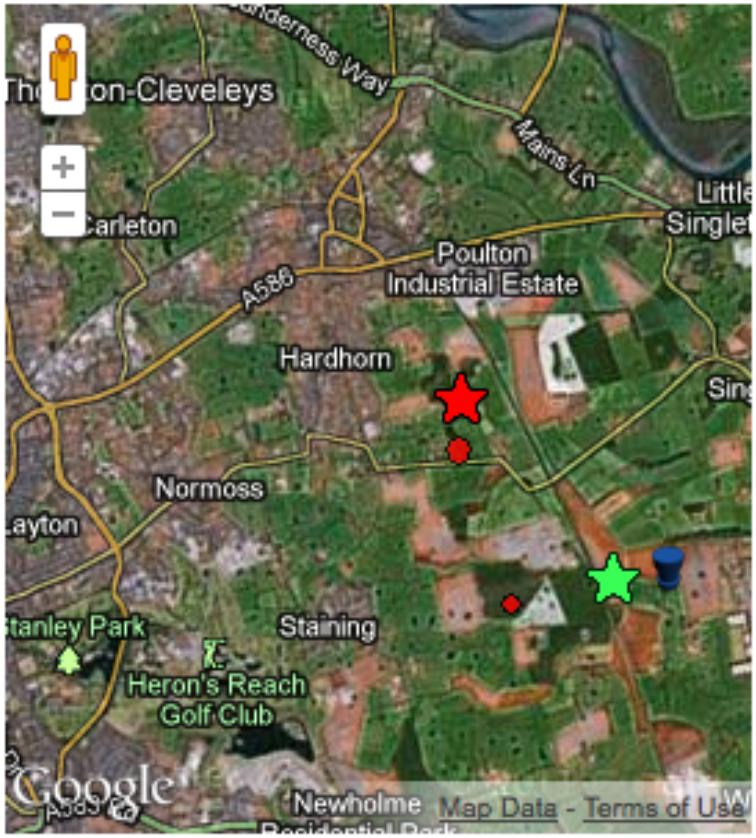
These quakes have now officially been attributed to fracking operations.

Typically, microearthquakes do not exceed magnitude 0.

How much seismicity is too much seismicity?

Cuadrilla have implemented a 'traffic-light' system:

- Magnitude smaller than M_W=0: regular operation
- Magnitude between M_W=0 and M_W=1.7: continue monitoring after the treatment for at least 2 days until the seismicity rate falls below one event per day.
- Magnitude > M_W=1.7: stop pumping and bleed off the well, while continuing monitoring.



Shale Gas and Environmental Concerns

WATER CONTAMINATION:

As well as the frack fluid and proppant, small amounts of chemicals are often injected – e.g., surfactants to reduce friction.

When the water flows back, it can bring with it heavy metals leached from the formation.

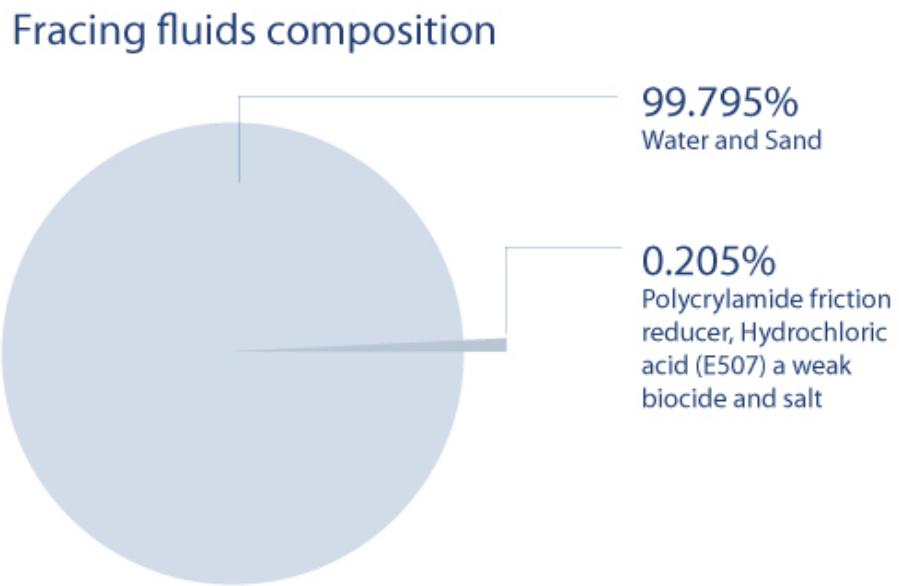
It has been claimed that these chemicals have contaminated water supplies and caused health problems.

If chemicals have got into the water supply, the key question is how they got there?

- Through the fractures and back to the surface?
- From flow-back water and/or poorly maintained tailings ponds?

Chemicals Used in the Hydraulic Fracturing Process in Pennsylvania
Prepared by the Department of Environmental Protection
Bureau of Oil and Gas Management
Compiled from Material Safety Data Sheets (MSDS) obtained from Industry

Chemical	Product Name
2,2-Dibromo-3-Nitrilopropionamide	Bio Clear 1000/Bio Clear 2000/ Bio-Clear 200/ BioRid20L/ EC6116A
2-methyl-4-isothiazolin-3-one	X-Cide 207
5-chloro-2-methyl-4-isothiazolin-3-one	X-Cide 207
Acetic Acid	Fe-1A Acidizing Composition/ Packer Inhibitor
Acetic Anhydride	Fe-1A Acidizing Composition
Acetylene	GT&S Inc./ Airco
Alcohol Ethoxylated C12-16	NE-200
Alkyl benzene sulfonic acid	Tetrolite AW0007/ FR-46
Ammonia (aqueous)	FAW-5



Shale Gas and the media

- Shale gas has been hailed as our economic saviour….

Shale gas could solve the energy shortage

Is shale gas about to become a global panacea for the world's energy shortage? A bullish reading of a new report by the US Energy Information Agency (EIA) implies that it could.

Shell's shale gas exploration site in Haynesville, Louisiana. Photo: NEIL JOHNSON

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Business › Oil and gas companies

Energy firm Cuadrilla discovers huge gas reserves under Lancashire

As Cuadrilla's drill sites multiply in and around Blackpool, locals' concerns are growing

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Fiona Harvey in Singleton
The Guardian, Saturday 24 September 2011
Article history

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Our coal industry is in tatters and the gas is running out. Is there an alternative? Incredibly, there really is

By DAVID ROSE

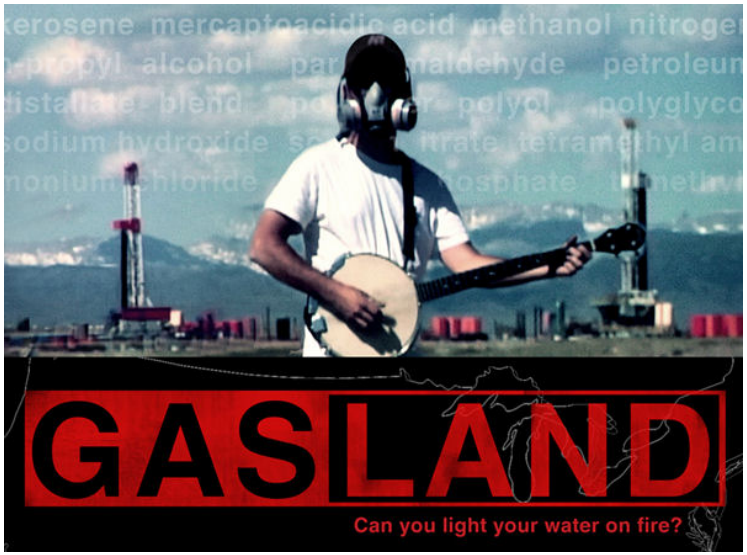
Last updated at 10:32 PM on 5th November 2011

Comments (146) | Share +1 1 Tweet 29 Like 126

Beneath swathes of the UK lie billions of pounds worth of shale gas. And now we can get to it. David Rose reports on how the recession (and wind turbines) may soon be just a bad memory

Shale Gas and the media

- … and the harbinger of our final doom….



Environment › Shale gas and fracking

Fracking protesters storm shale gas exploration site

Frack Off group brings work at Merseyside rig to halt as activists in separate protest attempt to disrupt industry summit in London

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James Meikle and Shiv Malik
guardian.co.uk, Wednesday 2 November 2011 09.37 GMT
Article history

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Protesters scale a shale gas rig at Banks, Merseyside, as an inquiry says it was 'probable' that fracking caused two small quakes in Lancashire. Photograph: Peter Byrne/PA

Protesters have brought work at a gas exploration site on Merseyside to a halt as they stepped up demonstrations against the controversial methods

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Shale gas and fracking
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Protest

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More on this story

Fracking 'probable' cause of Lancashire quakes

Shale Gas and the media

- GASLAND Trailer

  http://www.youtube.com/watch?v=dZe1AeH0Qz8

Bristol CO_2 Group

BCOG

http://www1.gly.bris.ac.uk/~JamesVerdon/

http://www1.gly.bris.ac.uk/BCOG/

Bristol University Microseismicity ProjectS

BUMPS

http://www1.gly.bris.ac.uk/BUMPS/