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Unconventional gas exploitation and the environment

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Context

- Decarbonisation of the economy: renewables displacing fossil fuels?
- Industrial feedstocks: “if it can’t be mined it must be grown”

Energy is not just electricity

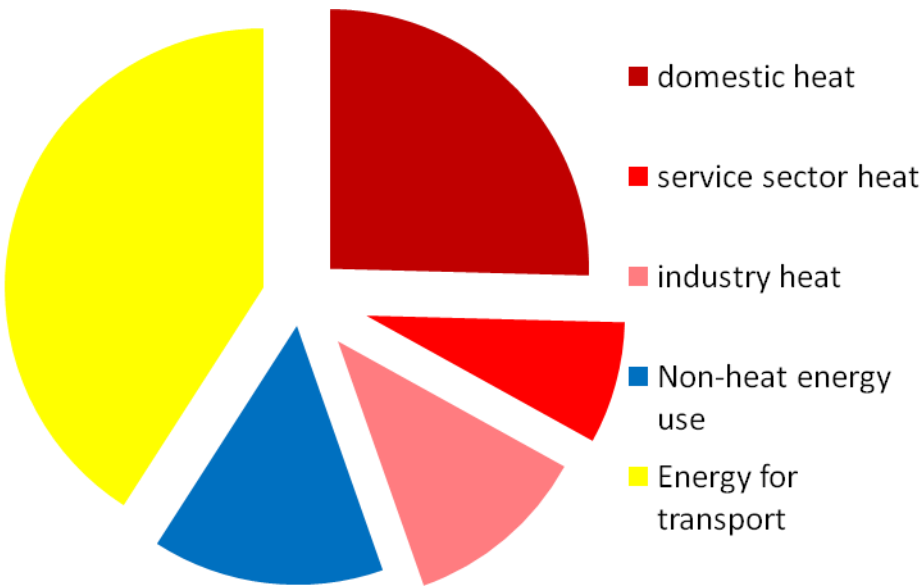
Discussion of energy policy in Scotland usually focuses on electricity. But in fact it is heat that dominates total energy use, accounting for 45% of total energy used:

- 2/3rds of gas consumption is for heat
- more than 40% of UK's CO_2 emissions arise from heat use

Must focus on heat to hit our targets on energy security and carbon emissions.

DECC estimate that percentage of UK heat from renewable sources needs to increase from around 1-2% now to 9% in 2020.

UK energy use by sector, 2011



Source: '*UK Energy Trends*', DECC, October 2011

*2.8% of heat currently used in Scotland is renewable; Scottish Government is committed to increasing this to **11%** 2020* – even that is still far less than is needed

Actual electricity production in Scotland

Actual generation of electricity by fuel type in Scotland in 2010

Fuel Type	Scotland (GWh)	Scotland % breakdown	cf Scottish total installed capacity of renewables %
Coal	14,715	29	N/A
Oil	1,213	2	N/A
Gas	8,381	17	N/A
Nuclear	16,381	33	N/A
Thermal Renewables	299	1	5.89
Hydro Natural Flow	3,266	7	33.36
Hydro Pumped Storage	1,830	4	N/A
Non-thermal renewables (mainly wind)	3,825	8	60.70
Totals	*49,908*	*100*	*100*

Current renewable installed capacity in Scotland: ~ 5 GW, or 18.5% of total

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Shrinking headroom

- The EU Large Combustion Plant Directive is forcing closer of most coal-fired power plants (farewell to 29% of electricity generation in Scotland)
- Nuclear power plants are nearing the end of their safe working lives (even with extensions) – and in Scotland new-build has been ruled out (farewell to a further 33% of electricity generation in Scotland)
- Since we still need baseload and despatchable forms of generation, which existing renewables cannot provide, these policies have between them ***created an inevitability of a further dash for gas***

Baseload v despatchable

- **Baseload**: Nuclear, gas, coal, hydro (biomass, tidal, geothermal)

- **Despatchable**:
  - *Immediate*: pumped storage, cross-boundary transfers
  - *Core*: gas, coal

NB: Wind, solar and wave are neither baseload nor despatchable; their availability depends solely on the largesse of Mother Earth

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Forthcoming electricity production in Scotland

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Actual generation of electricity by fuel type in Scotland revisited

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Within a few years, gas will account for more than 40% of power actually generated in Scotland – and likely far more later on as it replaces nuclear

It’s not just about energy …

Industrial feedstocks

- Lest we forget:
  - Hydrocarbons are not only important for power supply, domestic heating / hot water and transport fuels
  - They are also the crucial raw material for fabrication of the vast array of synthetics (especially 'plastics') with which modern society is enthralled – and for nitrogen fertilisers
  - So even if renewables began supplying baseload or even became despatchable, we would still have a large demand for fossil fuels for industry and agriculture - with no scalable alternatives as yet

A dash for gas with no new indigenous production?

- North Sea gas production is slowly declining
- (Much North Sea gas is in southern North Sea anyway, not beneath Scottish waters)
- If we rule out other forms of gas production, imports are the only way to feed the seemingly inevitable dash for gas
  - Norway is currently our main source of imports, but that won't last forever – then what?

Importing gas?

- From Russia, with love … ?
  - Western Europe is becoming increasingly dependent on Russia for natural gas
  - Ask the Georgians and Ukrainians about the joys of depending on Russia

Sources of Unconventional Gas

(or, rather, unconventional sources of gas)

Unconventional gas

- Fossil sources of unconventional gas:
  - Shale gas
  - Coalbed methane
  - Underground coal gasification

- Renewable sources of unconventional gas:
  - anaerobic digestion
  - biomass gasification
  - hydrogen from electrolysis of water

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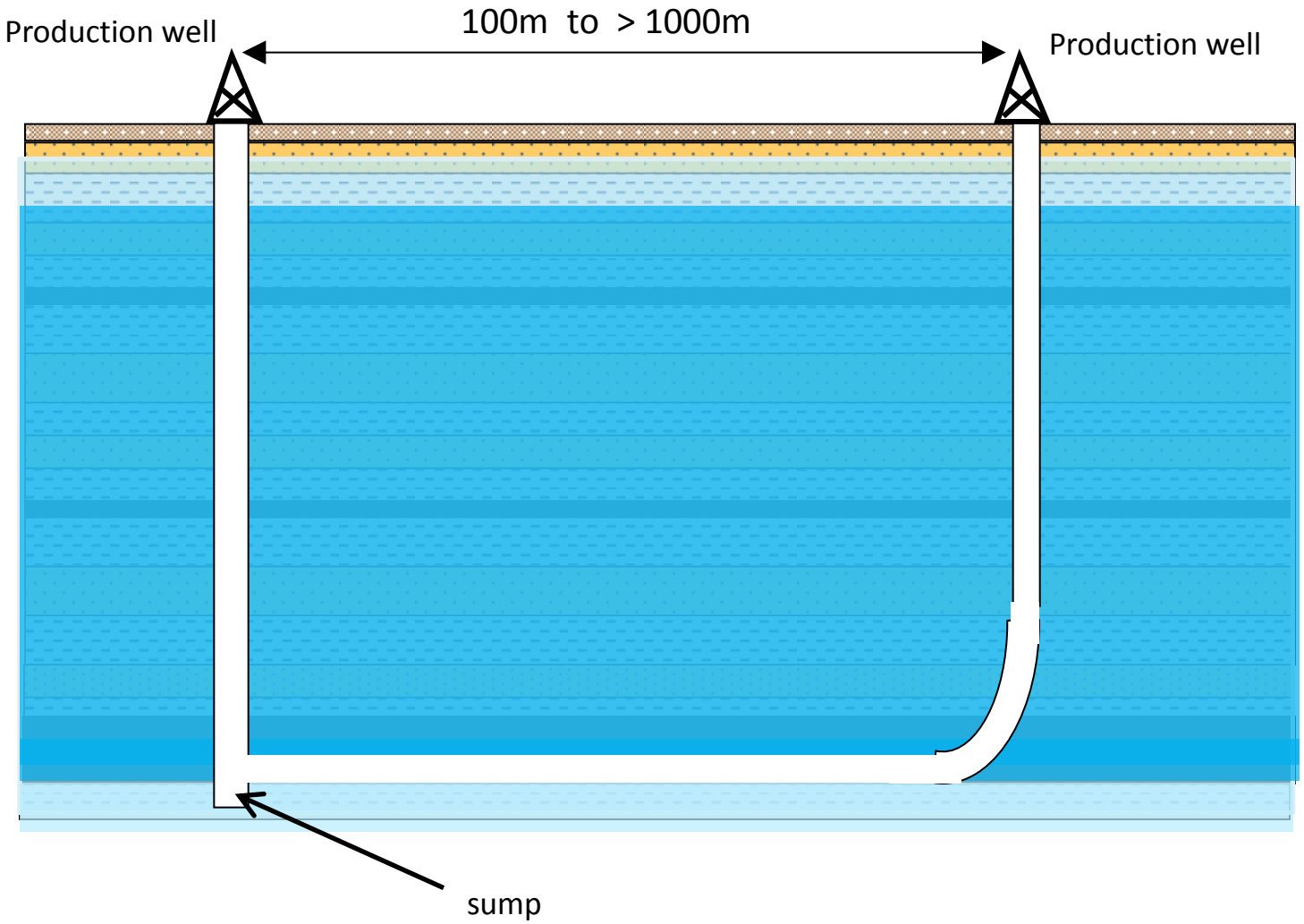
Coal Bed Methane

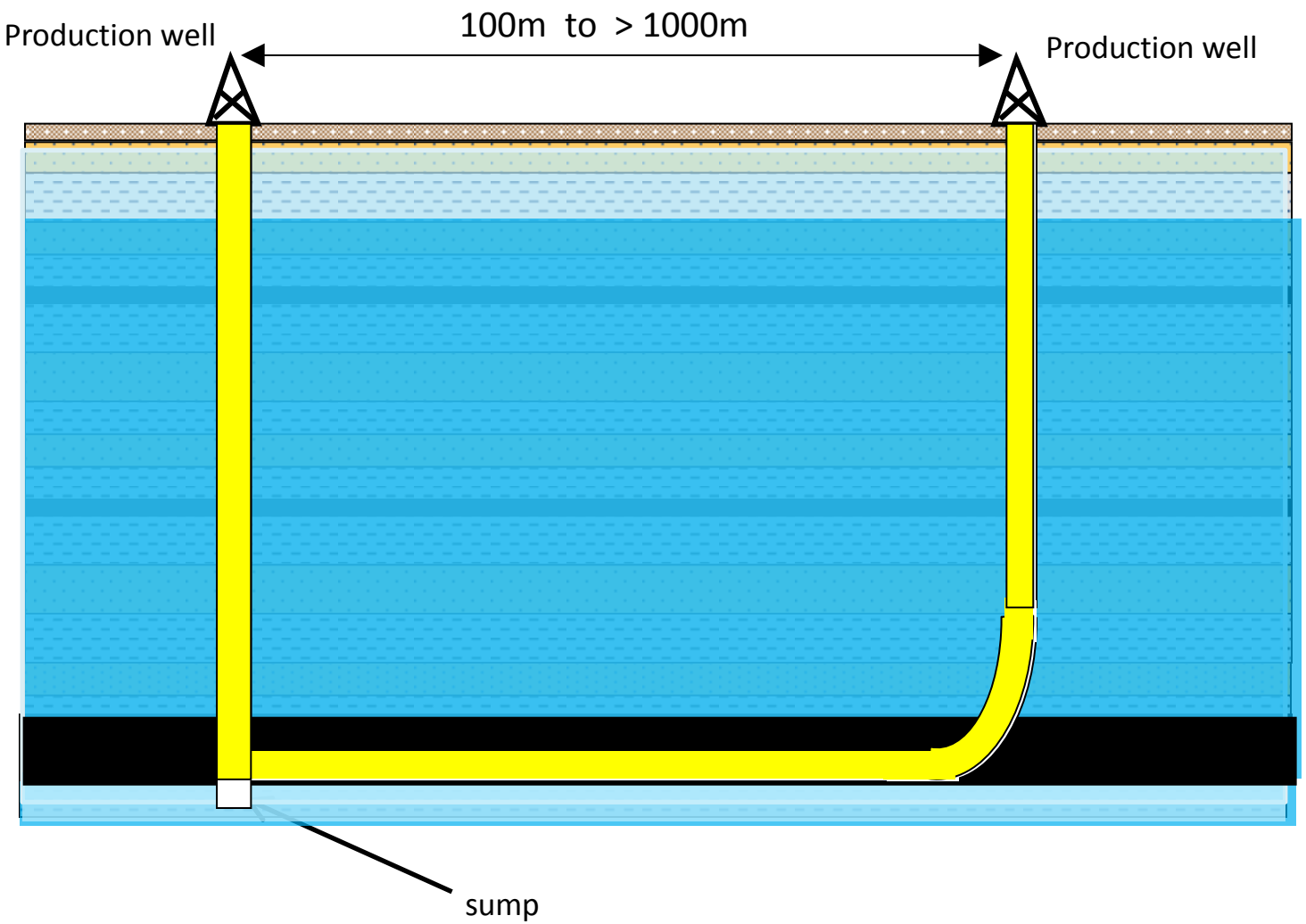
Coal Bed Methane

Composite Energy Ltd, Airth, Scotland, Aug 2007

Coal Bed Methane: process



Coal Bed Methane: process



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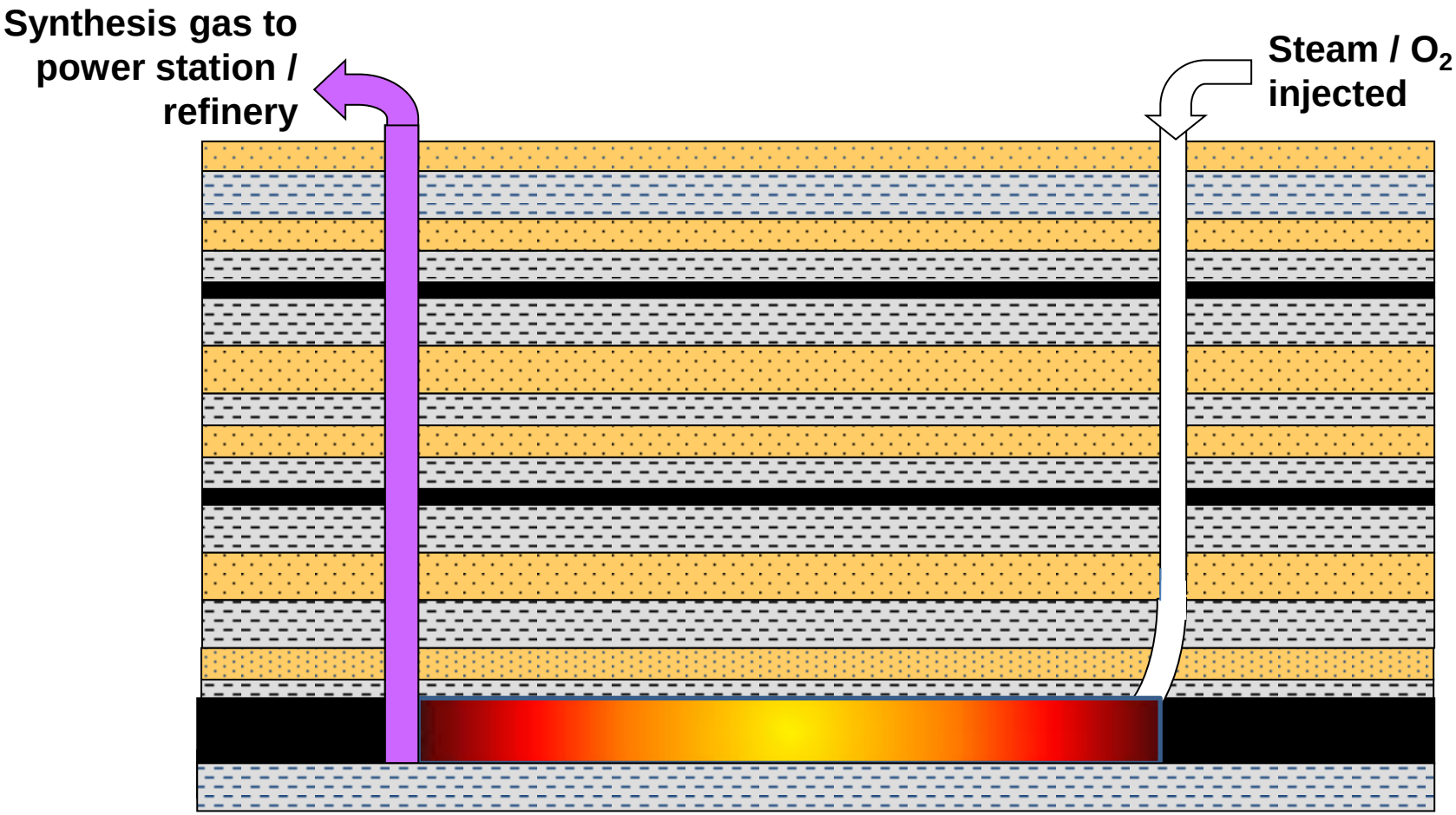
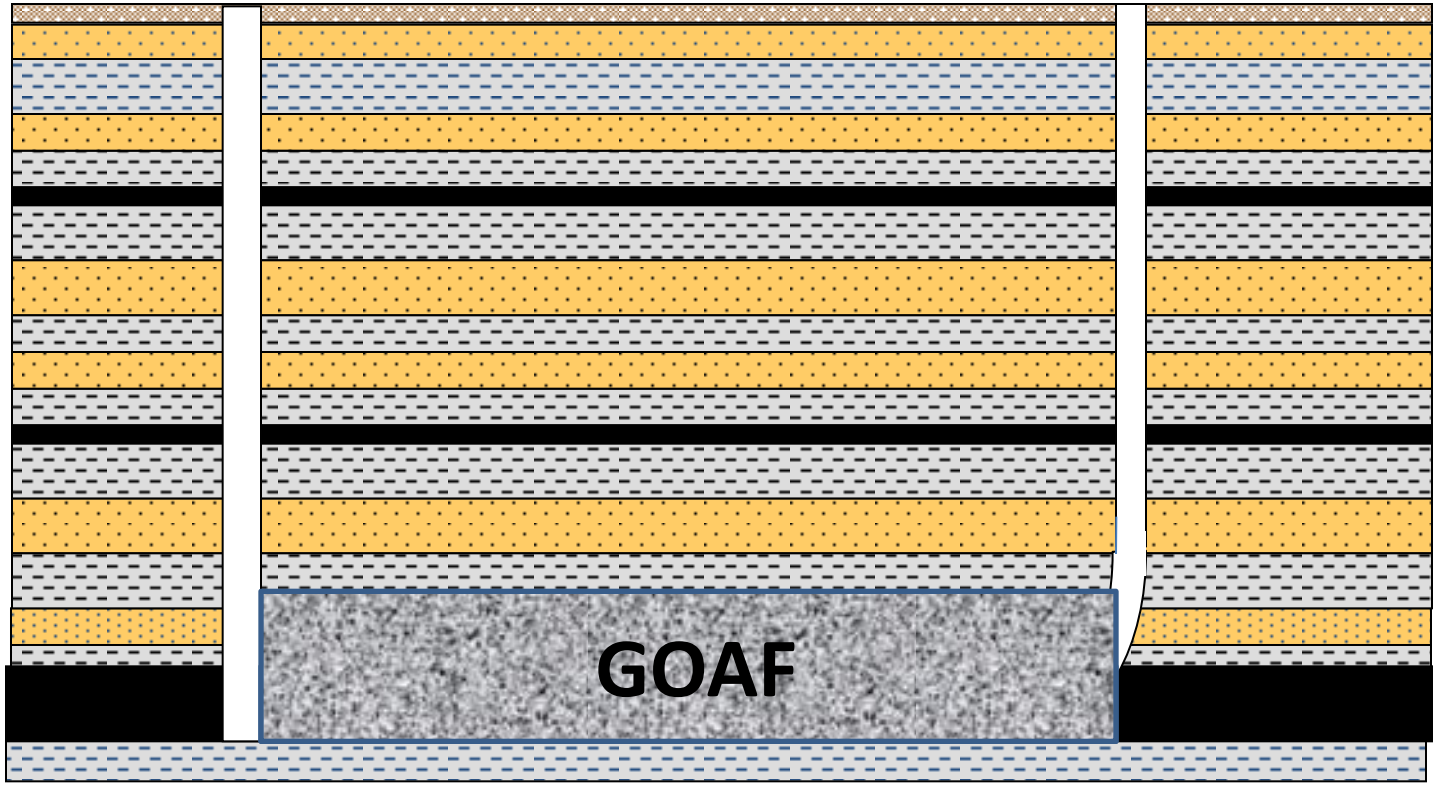
Underground Coal Gasification

UCG

UCG process

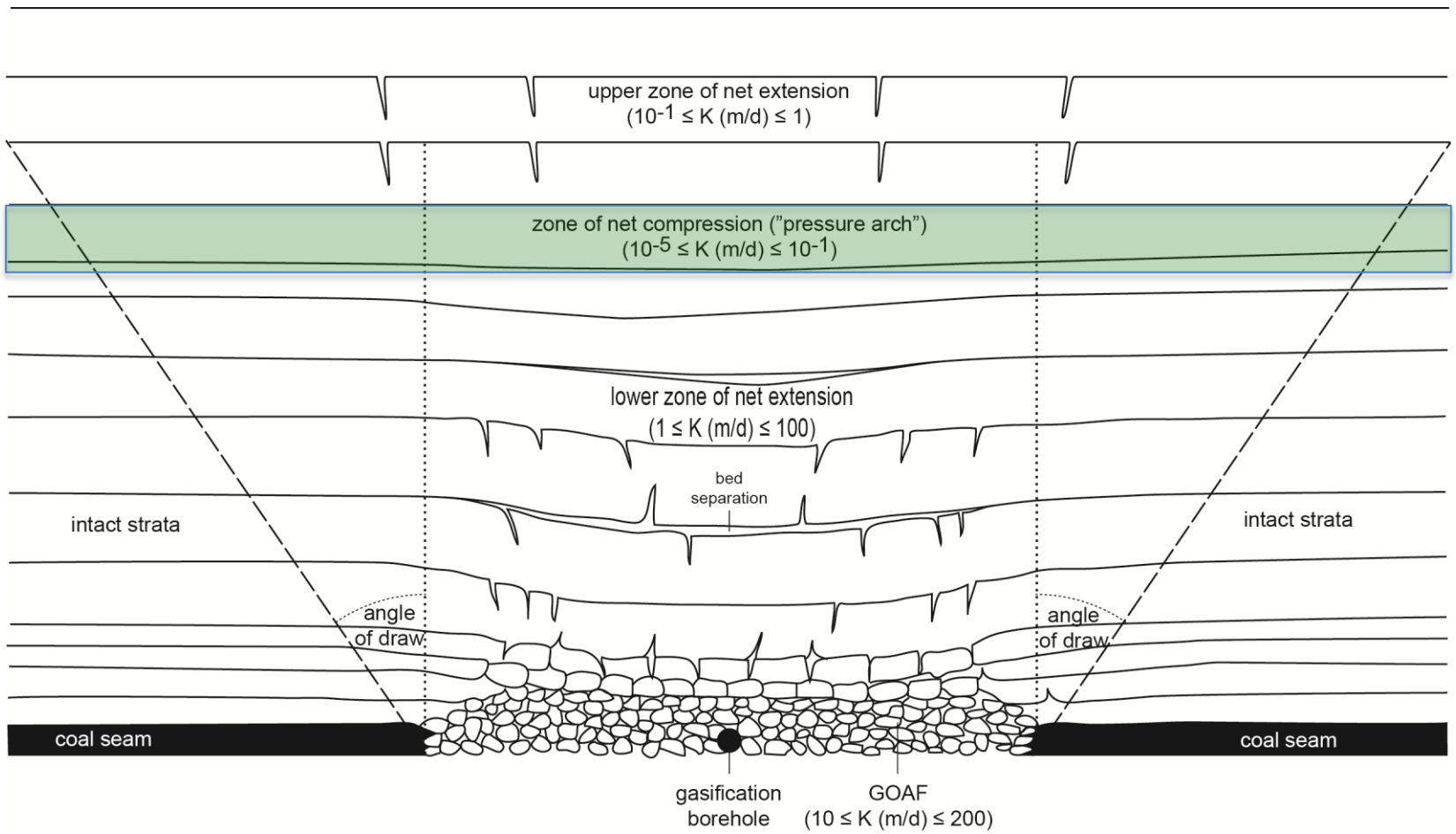


UCG process



Goaf

UCG Goaf

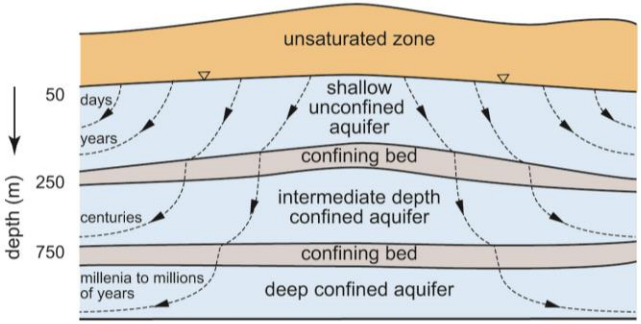

upper zone of net extension
($10^{-1} \leq K$ (m/d) ≤ 1)
zone of net compression ("pressure arch")
($10^{-5} \leq K$ (m/d) $\leq 10^{-1}$)
lower zone of net extension
($1 \leq K$ (m/d) ≤ 100)
bed separation
intact strata
intact strata
angle of draw
angle of draw
coal seam
coal seam
gasification borehole
GOAF
($10 \leq K$ (m/d) ≤ 200)

Pollution-free UCG

the triple lock mechanisms

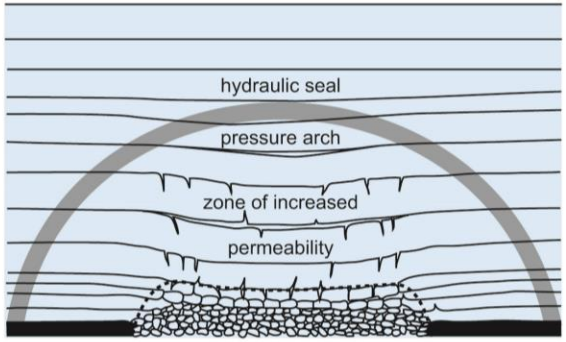
Hydrodynamic trapping

extremely slow groundwater movement at depths of hundreds of metres



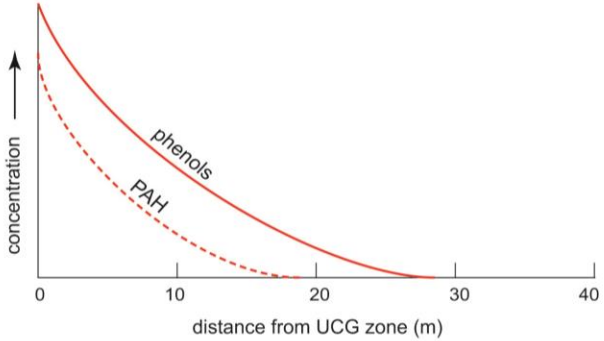
Pressure-arch trapping

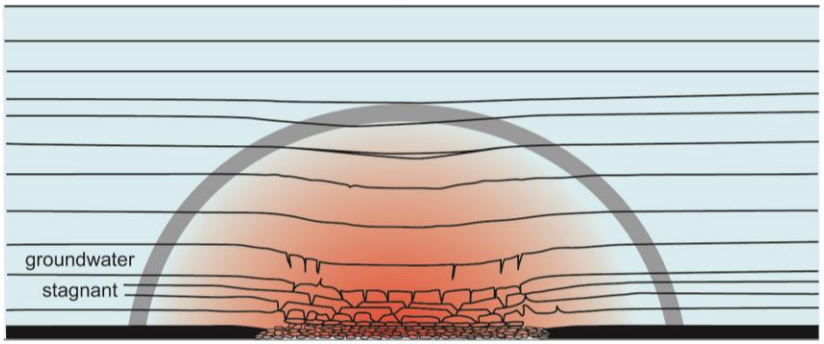
the UCG process induces development of a low-permeability zone beyond the immediate zone of stratal caving



Geochemical trapping

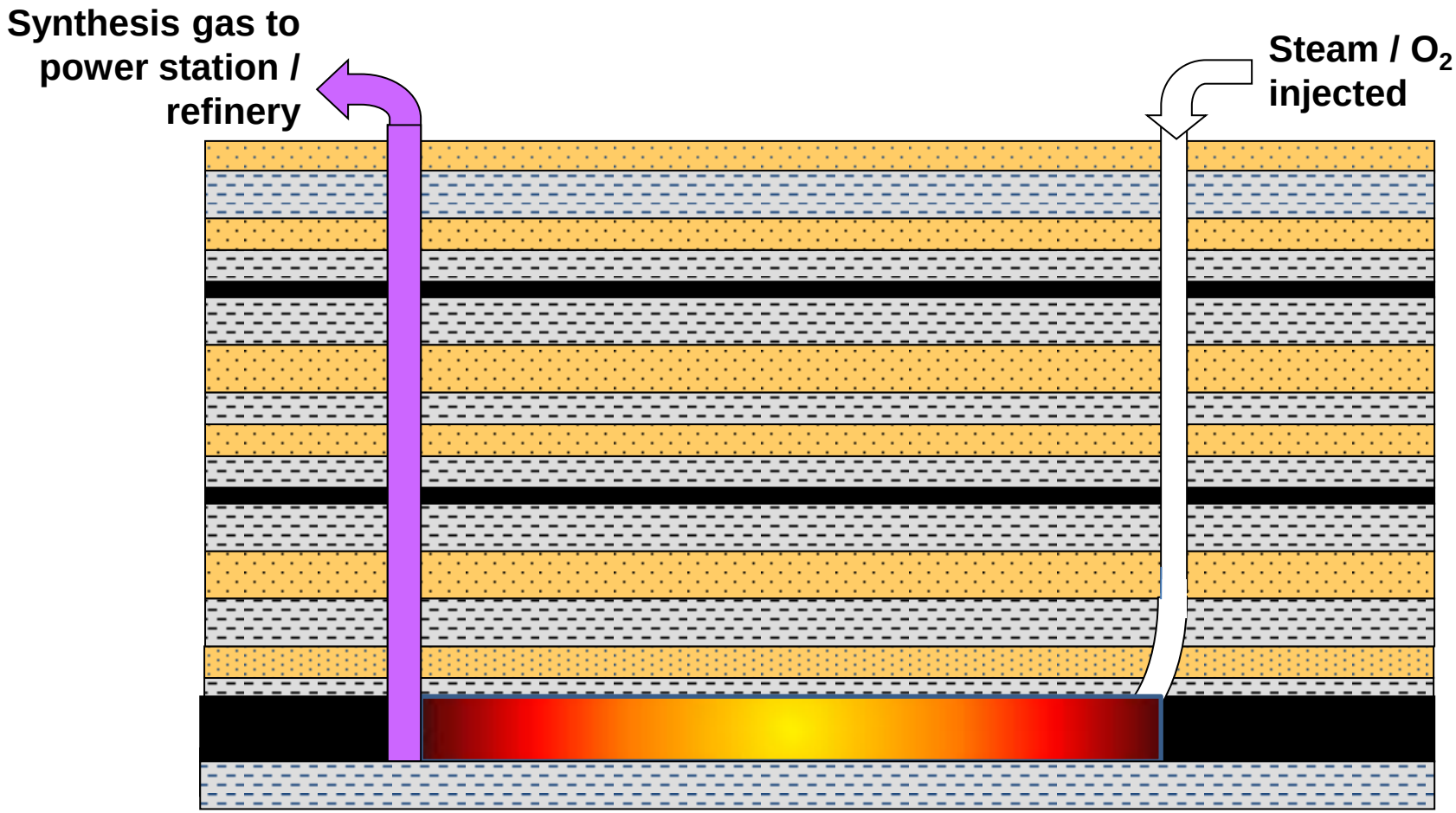
irreversible sorption, mineralisation and biotransformation limits transport of pollutants to < 30m (even if flow regime would permit this)



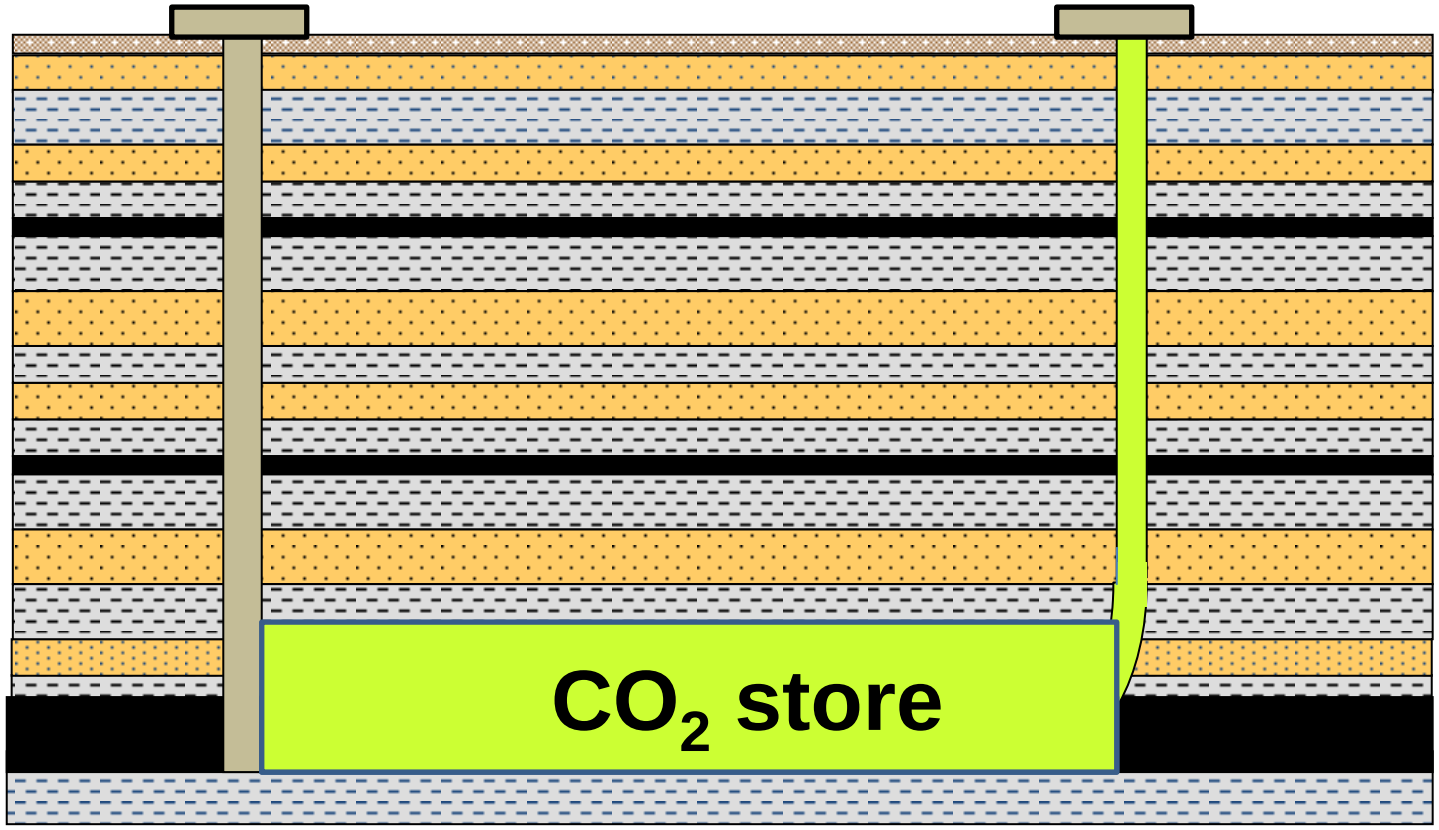


pollutants triply 'locked-in' to immediate vicinity of former UCG burn zone

From UCG …



… to CCS



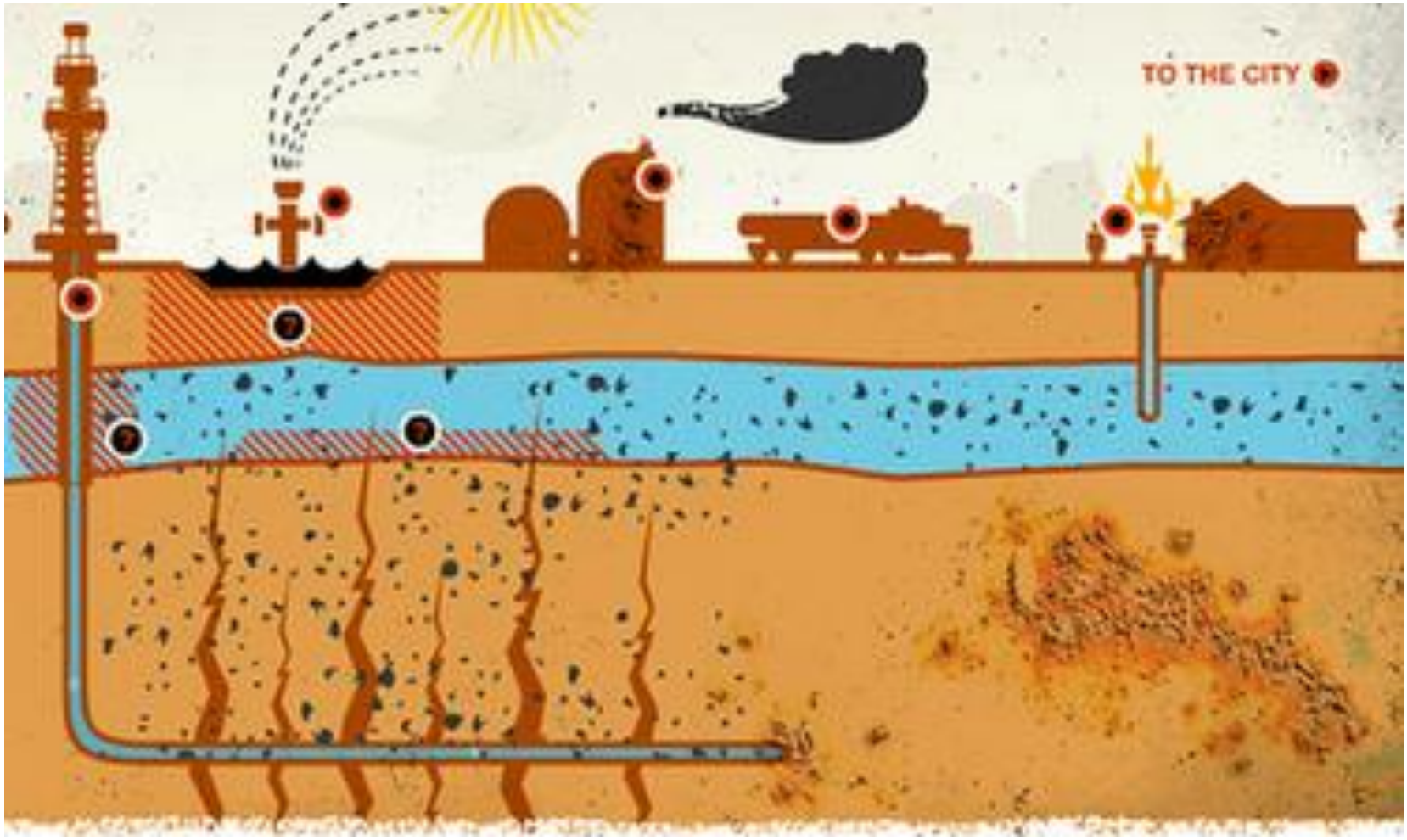
Environmental risks of unconventional gas:

concerns v. scientific insights

Frack off!

Frack off!

Protestors concerns



Root cause of concerns

- Under the Bush Government in the USA, Vice-President Dick Cheney had amendments to law passed (flagrantly in conflict of interest as a senior executive of a major oilfield services company):
  - In the USA 2005 Energy Act, hydraulic fracturing was exempted from being considered an 'underground injection' under the Safe Drinking Water Act
  - Compliance with various federal requirements to prevent water contamination was no longer necessary for shale gas operations
  - Fracturing wastes are exempt from disposal restrictions under the Resource Conservation and Recovery Act
  - Operators are exempt from certain liabilities and reporting requirements relating to waste disposal under the Comprehensive Environmental Responsibility, Compensation, and Liability Act
  - Exemption from the Emergency Planning and Community Right to Know Act means the type and quantity of chemicals to be used in fracturing do not need to be disclosed to the EPA.
- The result: a "bonanza" situation with every cowboy driller in the country rushing to drill and frack at depths far shallower than would normally be contemplated

Protestors' concerns

- Induced seismicity
- Groundwater pollution
- Fugitive gas emissions:
  - Risk of explosion
  - Contribution to climate change

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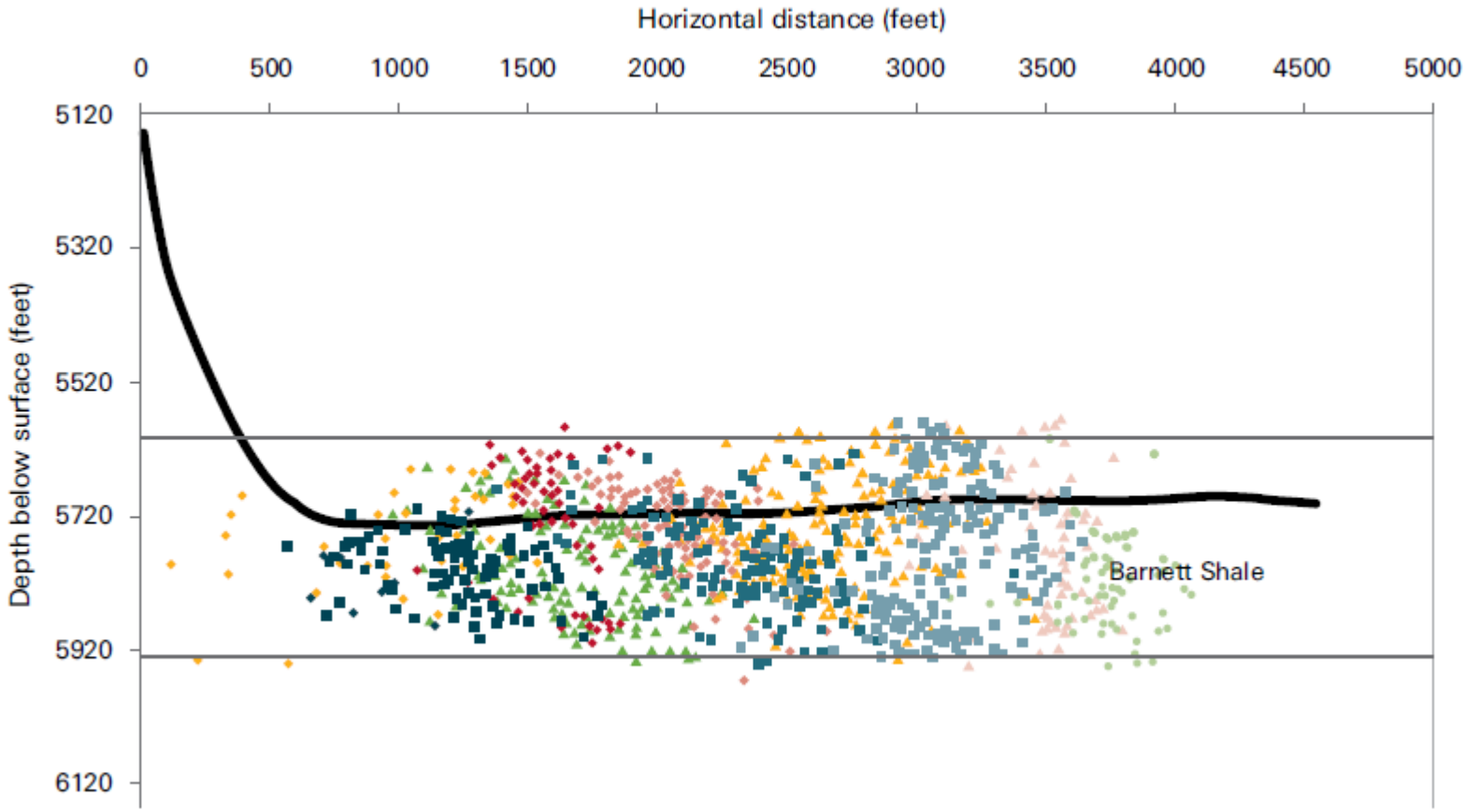
Induced seismicity

Induced seismicity is inherent to hydraulic fracturing



Seismicity: a matter of degree

- Seismicity is a fact of life: it is a widespread and unstoppable consequence of plate tectonics
- Fortunately the vast majority of seismic events are harmless – including many that are powerful enough to be felt at surface
  - Many such events cause no more vibration than a bus going past or a tube train passing below us
- Many human processes induce seismicity:
  - Mining and tunnelling
  - Reservoir filling / draining
  - Military activities

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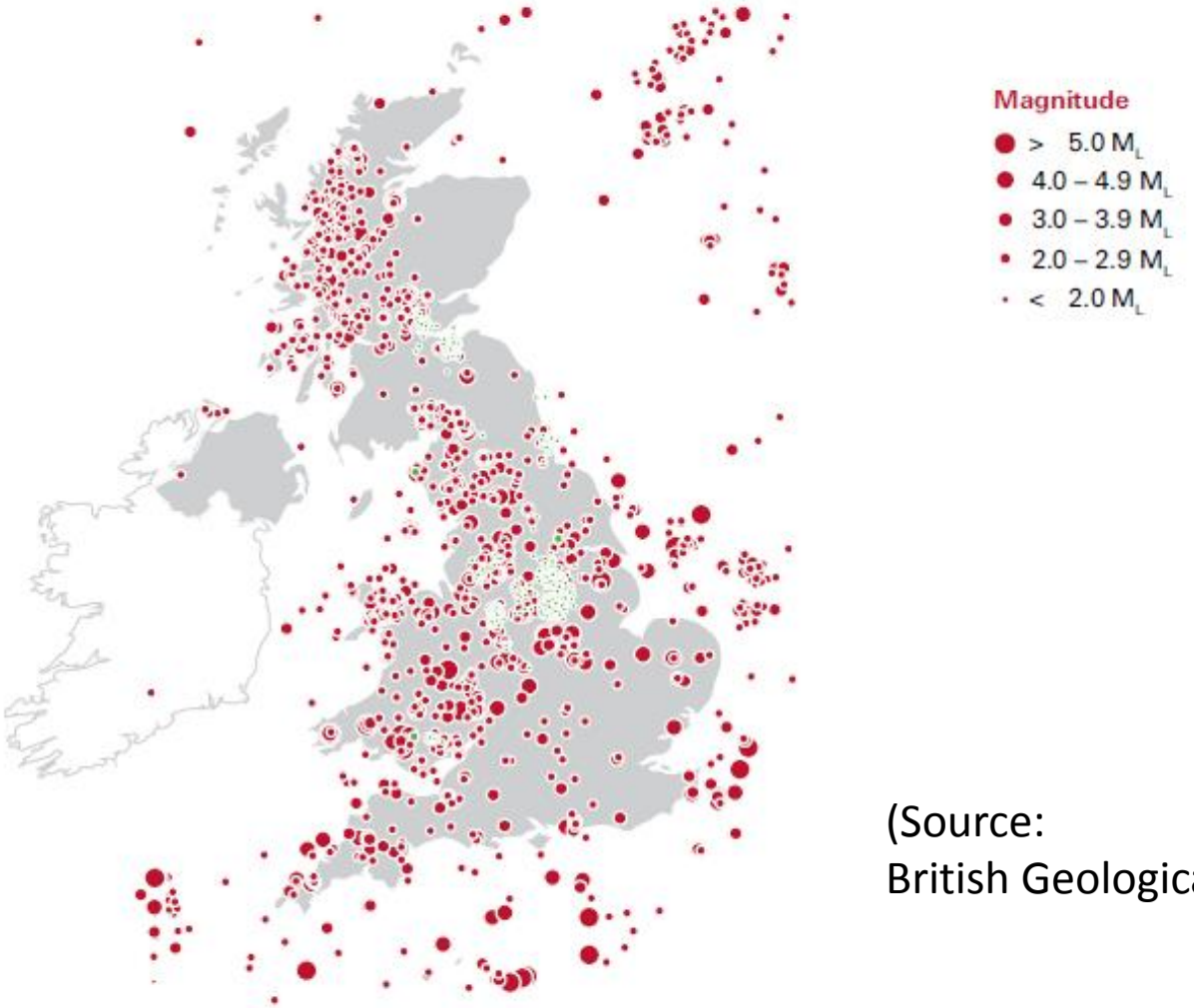
Natural seismicity (red) and coal mining-induced seismicity (green) in the UK from 1382 to 2012



(Source:
British Geological Survey)

THE ROYAL SOCIETY

ROYAL ACADEMY OF ENGINEERING

Preese Hall seismic events

- On 1st April 2011, the Blackpool area experienced a seismic event of magnitude 2.3 M_L shortly after Cuadrilla's Preese Hall well in the Bowland Shale was hydraulically fractured
- Another seismic event of magnitude 1.5 M_L occurred on 27th May 2011 following renewed hydraulic fracturing of the same well.
- These events were detected by the BGS national seismic network; some local residents subsequently claimed to have felt them. As would be expected, neither event caused any reported damage
- Natural events in this area in the past have ranged up to 4.4 M_L (at Lancaster in 1835)

Preese Hall: seismic mechanisms

- Analysis of the seismic data suggests that the two Preese Hall events were too large to be due to hydraulic fracturing *per se*
- Rather, they were due to unintended reactivation of a previously-unknown pre-stressed fault near to the well
- From existing data it is not possible to determine whether the fault was directly intersected, or whether hydraulic fracturing led to pressure changes that induced a distant fault to slip

Cause for alarm?

- Is *any* induced seismicity, however harmless, an outrage requiring prohibition?
- In the coalfields, induced seismicity has frequently approached 4 M_L (cf. usual natural maxima in UK of 5 M_L) but was never considered sufficiently problematic to warrant the prohibition of mining
- If non-damaging vibration from fracking is intolerable, why should we tolerate similar vibrations from buses and trains?

Does induced seismicity not create pathways for pollutants?

- If non-damaging induced seismicity is not a problem *per se*, is it not of concern that such seismic events might compromise borehole integrity, create permeable paths to overlying freshwater aquifers, or even to surface allowing gas leakage to occur?
- This speculation is the root of the protestors' concern over possible groundwater pollution and fugitive gas emissions

Protestors' concerns

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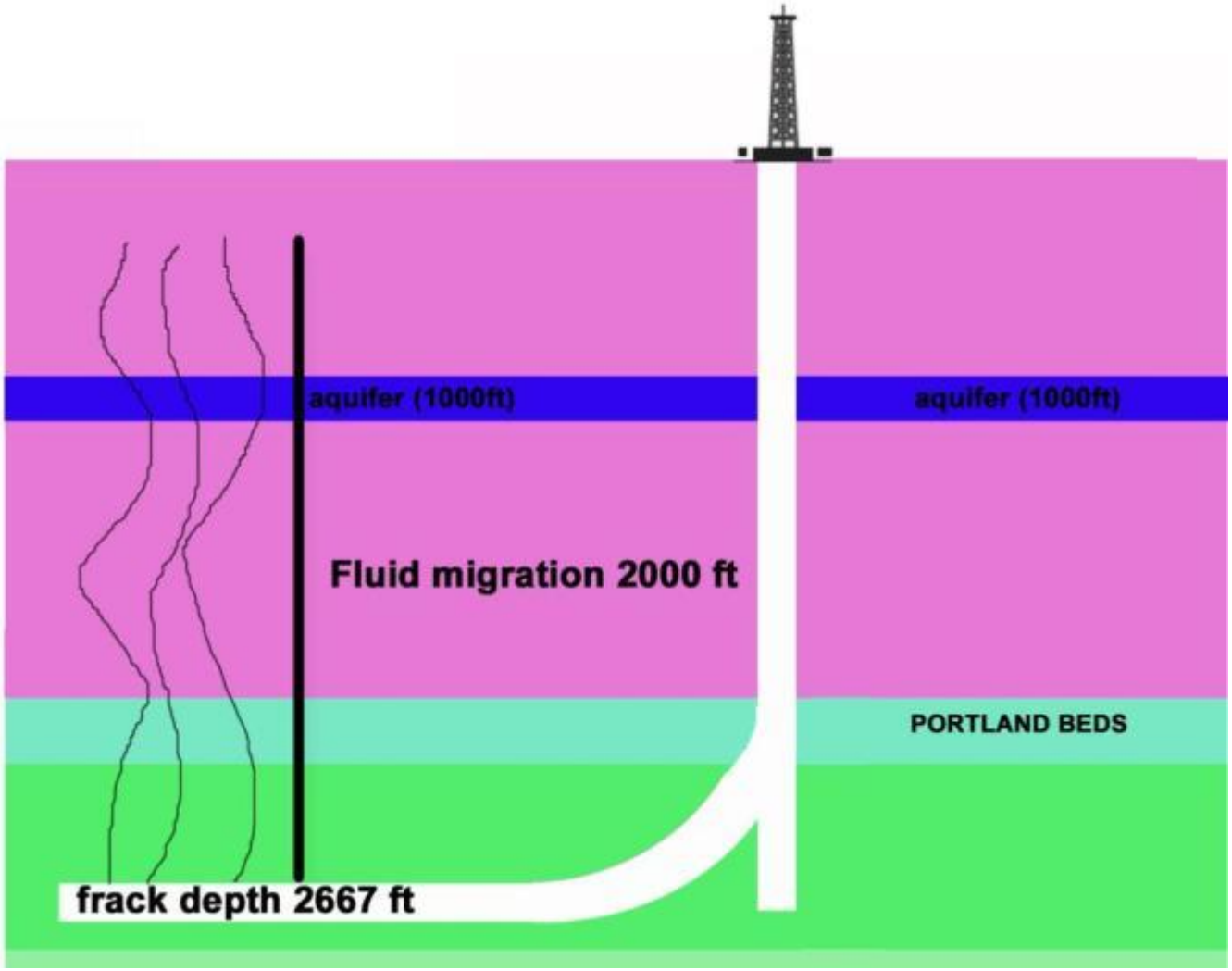
- Groundwater pollution
- Fugitive gas emissions:
  - Risk of explosion
  - Contribution to climate change

Groundwater pollution risk: the protestors' hypothesis



What controls groundwater pollution risk?

- Permeability
- Head gradient
- Presence of mobile pollutants in fracked zone

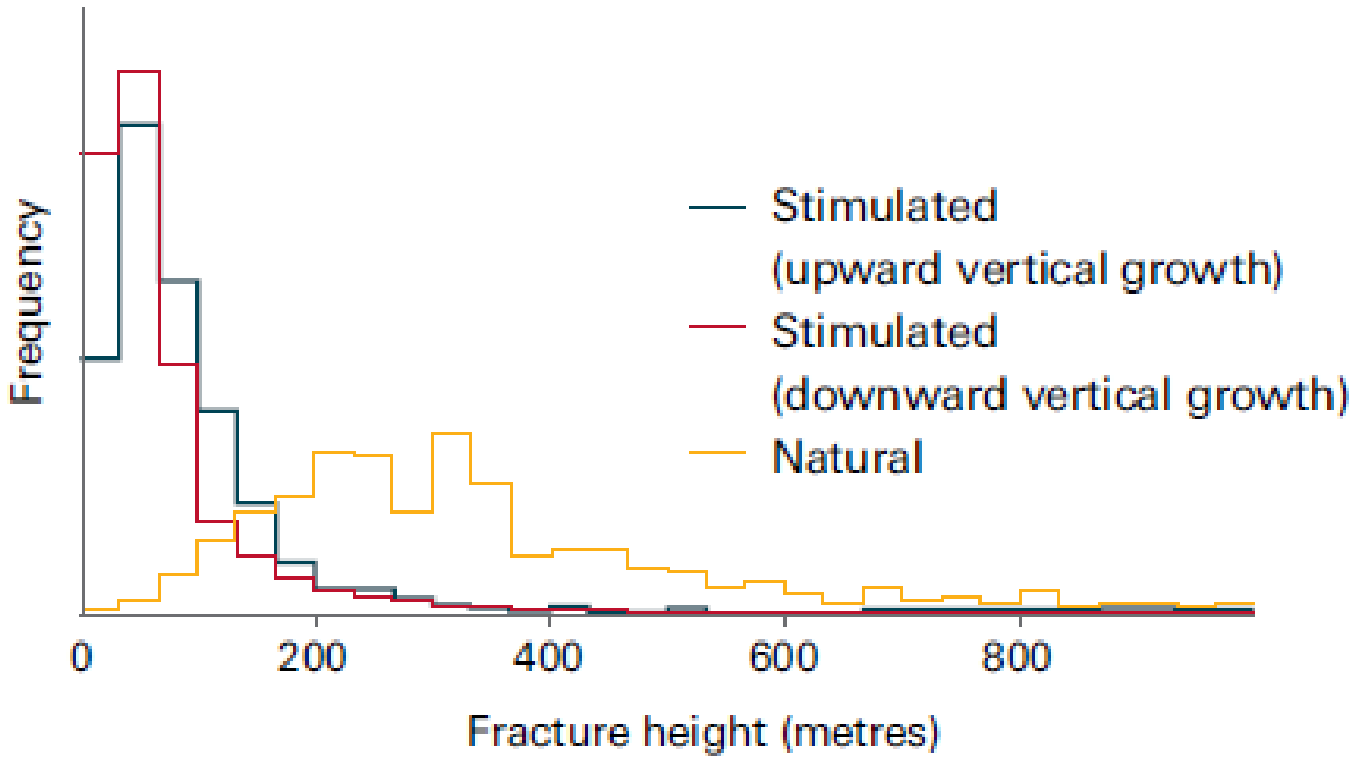
Permeability

- Even fracked mudstones have very low permeabilities by hydrogeological standards (typically < 1 mD)
- They are typically several orders of magnitude lower than those of freshwater aquifers (typically > 1000 mD)
- Surrounding, un-fracked mudstones are less permeable still (e.g. 10^{-1} – 10^{-3} mD)
- It is hard to get concerned about permeability

Head gradient

- Because the production zones of shale gas typically lie at great depths, and they are purposely de-pressurised by pumping, if anything the head gradient will be *downwards from shallow aquifers towards the shale gas zones, not upwards to the aquifers*
- Vast experience of mining beneath the seabed and aquifers shows that anything more than about 100m of low-permeability strata will be enough to rule out downward or upward flow

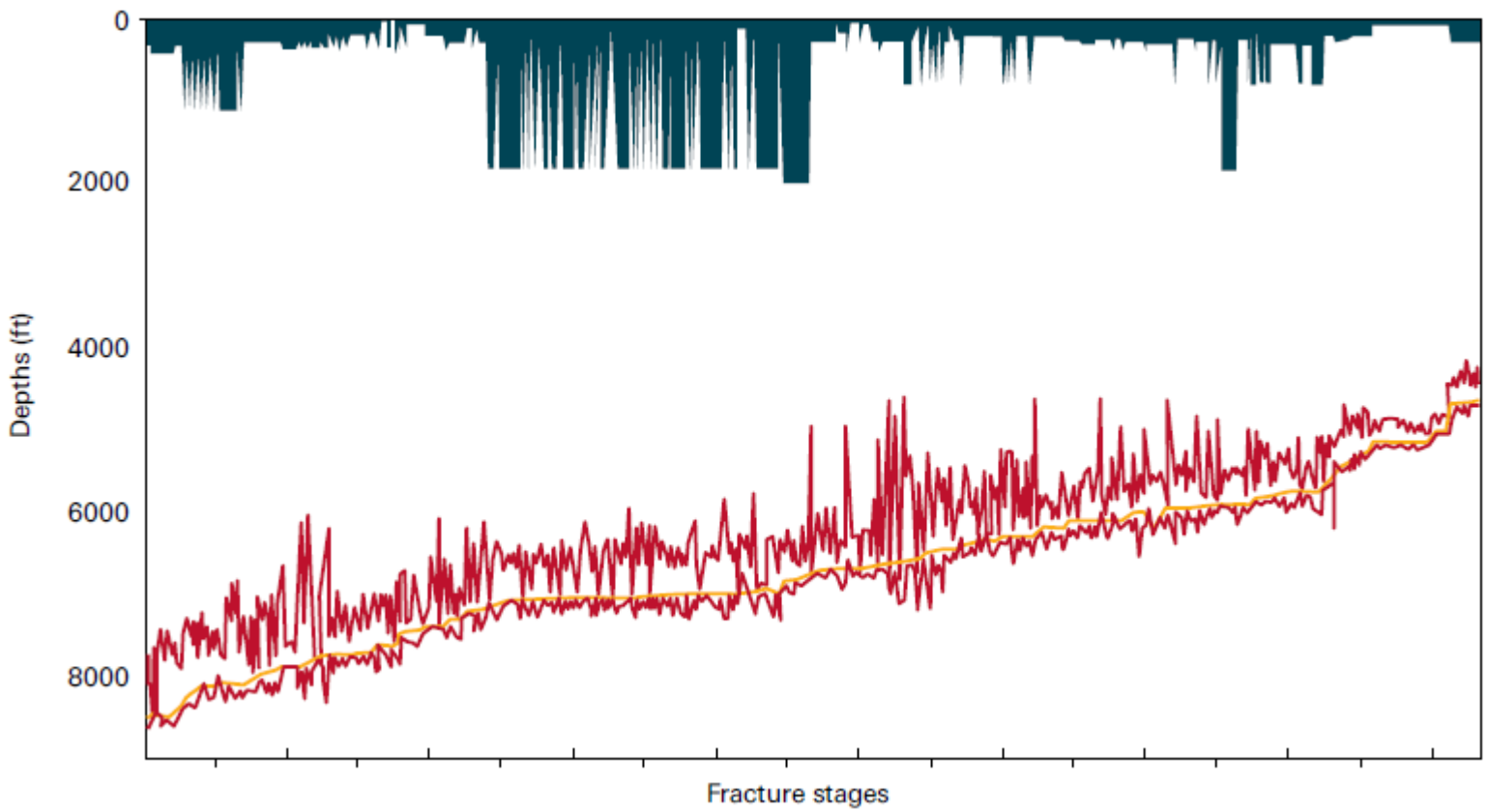
Maximum extent of hydraulic fractures



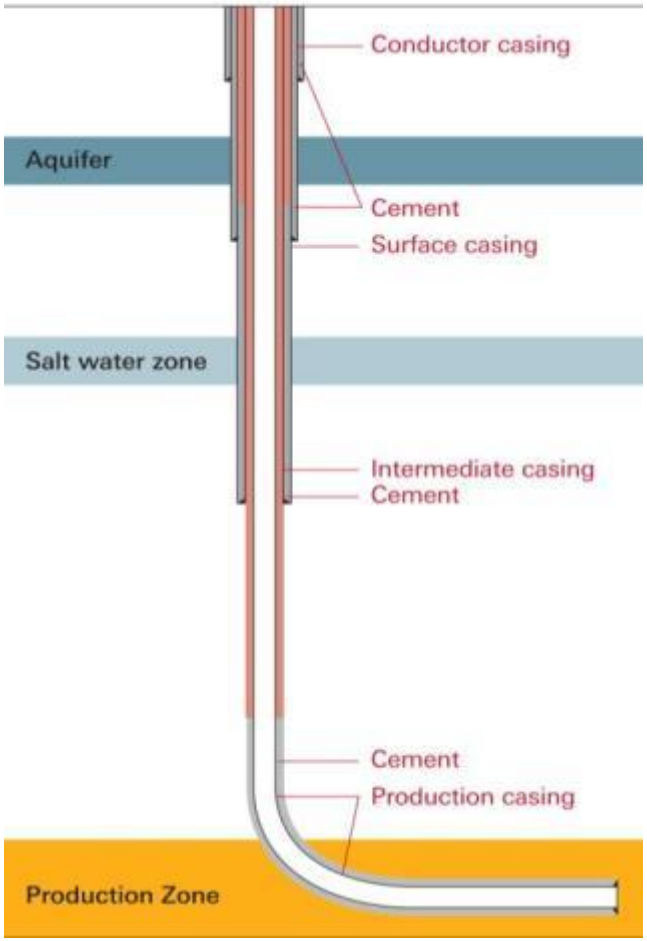
Source: Davies *et al* (2012) ***Hydraulic fractures: how far can they go?***. Marine and Petroleum Geology (in press). http://www.dur.ac.uk/resources/dei/JMPG_1575.pdf

Fracking and proximity to freshwater resources

Data from Marcellus Shale, USA



Ensuring well integrity



- Academies' review recommended improving the UK's existing well examination scheme:

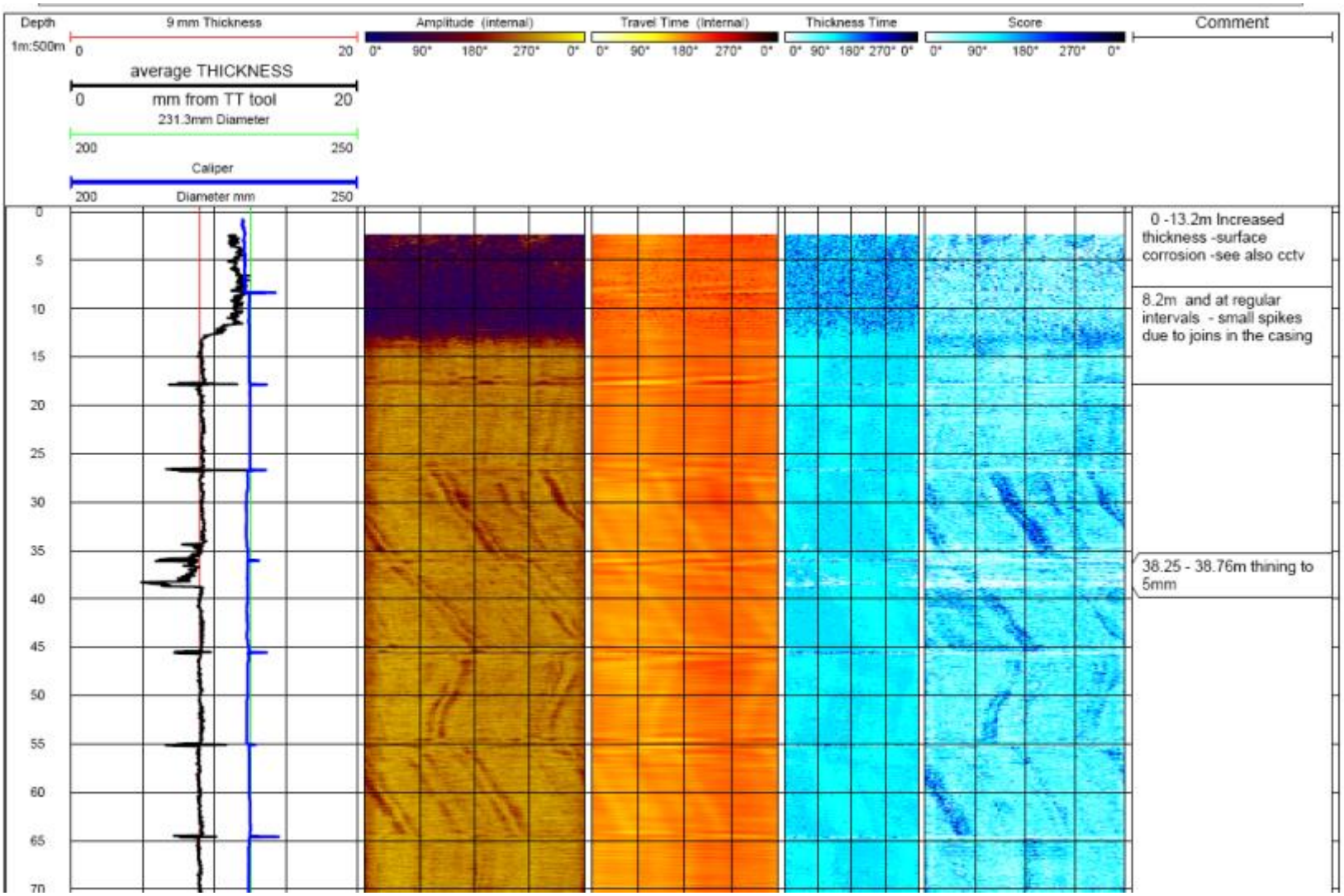
1) Clarify guidelines to ensure independence of reviews

2) Review well designs from H&S <u>and</u> environmental perspective

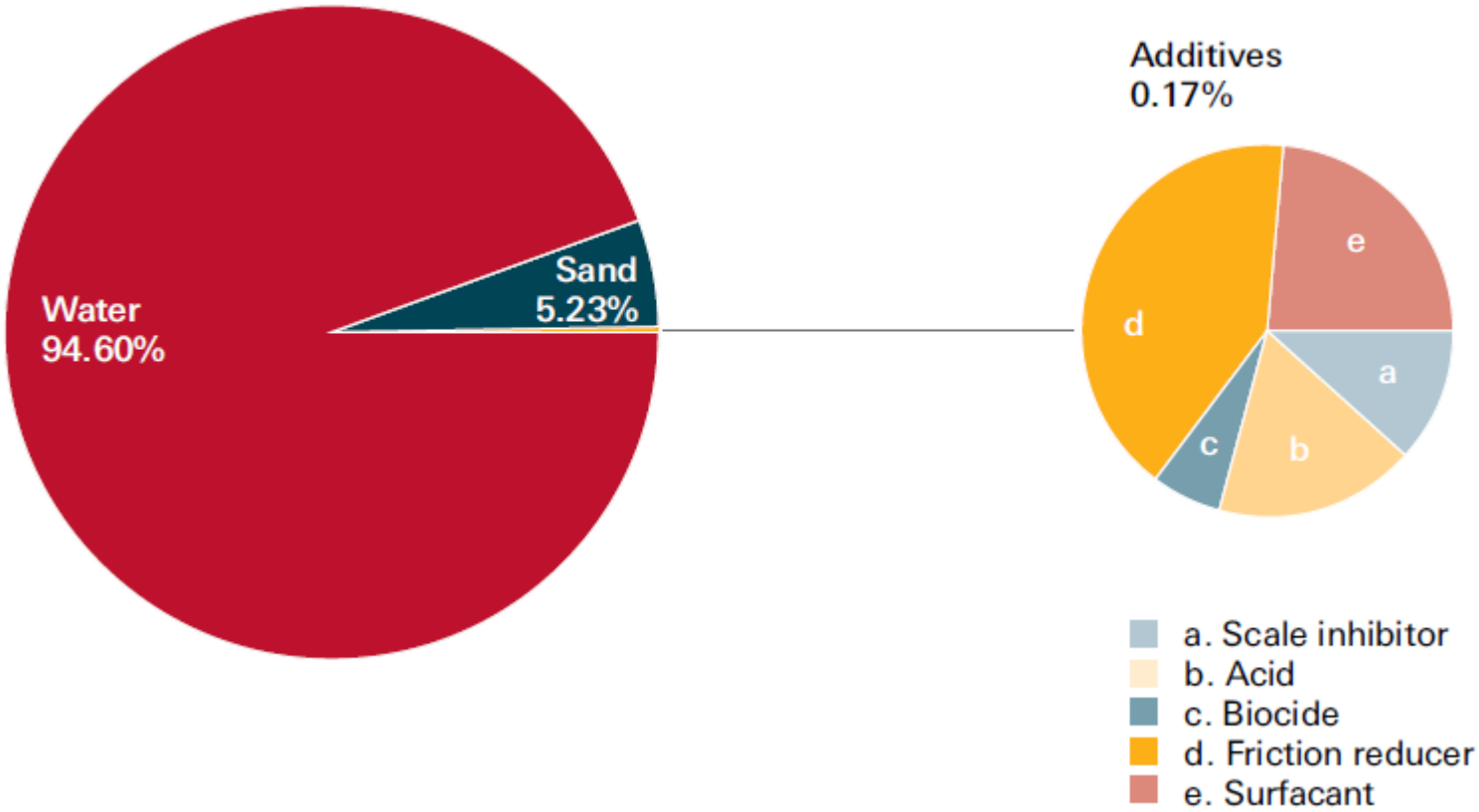
3) Onsite inspections as appropriate

4) Submit results of well tests and reports of well examinations to DECC

Geophysical testing of casing integrity and cement bond quality



Are fracking fluids toxic?



Water pollution: surface site management

- There is more of an objective risk of water pollution from failure to follow best practices in management of injection / produced water at surface – so enforce best practices!
- Some produced water may contain small quantities of NORMs
- Standard Scottish wastewater regulation is more than capable of coping with any potential issues

Transferable know-how

We know lots about prevention of pollution from subsurface mineral exploitation in Scotland – having learned the hard way since the advent of large-scale coal and oil shale mining in the 19th Century

Much transferable knowledge has been acquired in recent decades

Evaluating the potential impact of opencast coal mining on water quality (Groundwater Regulations 1998)

An assessment framework for Scotland

March 2004

Prepared for the Scottish Environment Protection Agency (SEPA)

by

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[a]University of Newcastle Upon Tyne
[b]NuWater Ltd, Newcastle Upon Tyne, UK

NuWater Ltd

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SEPA Scottish Environment Protection Agency

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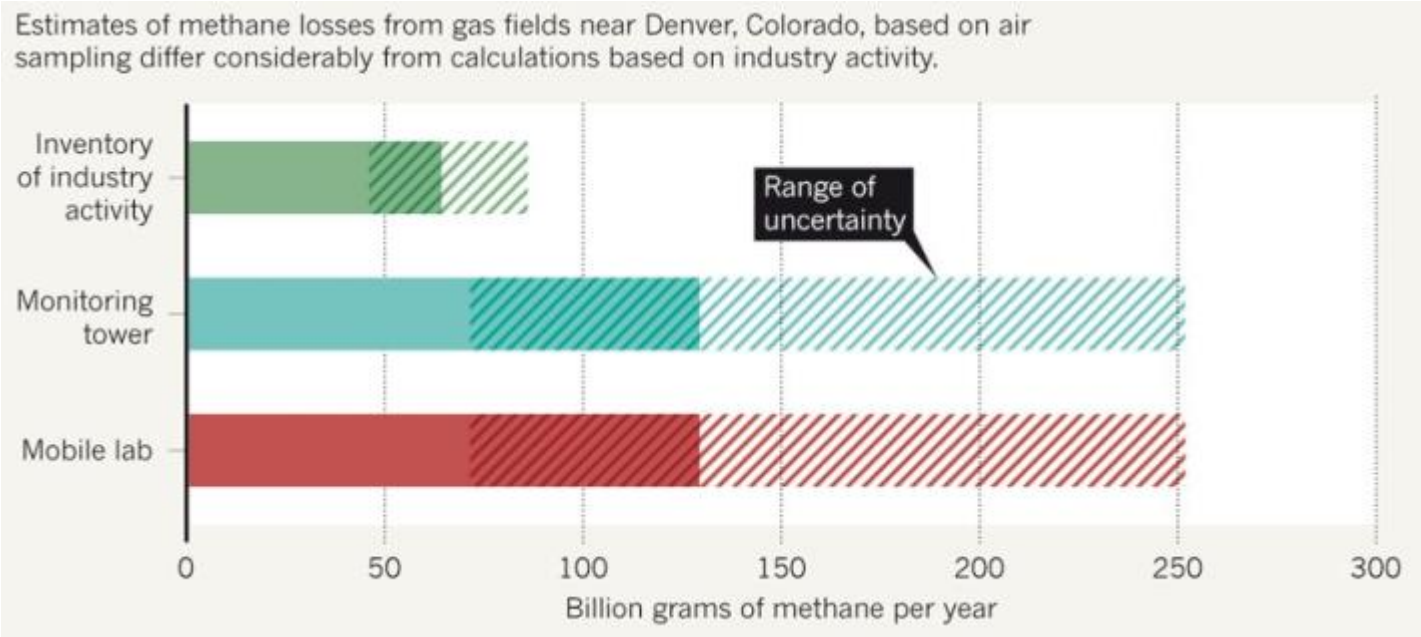
Fugitive gas emissions

Fugitive gas emissions

- Scale of fugitive emissions (i.e. not captured and flared)



- Howarth et al. (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change 106 DOI 10.1007/s10584-011-0061-5
- O'Sullivan and Paltsev (2012) Shale gas production: potential versus actual greenhouse gas emissions. Environ. Res. Lett. 7 044030 doi:10.1088/1748-9326/7/4/044030
- Petron et al. (2012) Hydrocarbon emissions characterization in the Colorado Front Range- a pilot study, Jour. Geophys. Res., doi:10.1029/2011JD016360.

Operators are not idiots

- Well operators have a vested interest in minimising fugitive gas emissions, as these represent:
  - Safety risks to their workforce, and
  - Lost revenue
- For this reason huge precautions are taken to attain, test and verify casing and cement integrity in wells, to use blow-out-preventers during drilling, and to use gas-proof wellheads after completion
- In the case of shale gas, the problem is getting gas from the rock at all, not stopping it shooting out unaided – hence the usual "conventional well" precautions are largely overkill in shale gas operations anyway

Shale gas and climate change

- Direct emissions of CH_4 from sites is to be avoided, given potency of CH_4 as a greenhouse gas
- Shale gas is certainly a better bet than oil or coal as a fuel, though likely has a higher carbon footprint than conventional gas
- If used in plants with CCS, shale gas can provide valuable baseload and despatchable power generation without greatly exacerbating greenhouse gas emissions

Public acceptability

- Transparency is key
- Respectfully address legitimate public concerns
- Respond to ridiculous scare stories calmly, with the facts

'We could be sitting on a Mendip volcano' says Somerset expert

trusted source

Wells Journal Follow Saturday, December 03, 2011

Does a great and terrible fate await us if drilling starts below the Mendip hills to extract gas?

A Mendip hills expert says it might. Nigel Taylor, caver, wildlife and nature campaigner, explosives expert and Mendip district councillor, has carried out a study of the Mendip Hills and has discovered that there is a volcanic plug that could be holding back a river of lava ready to erupt if disturbed.

A volcano erupts in Ecuador

"It may sound ridiculous," said Mr Taylor, "but it is no more ridiculous than drilling deep into the earth's crust and setting off explosions to release trapped gas without knowing all of the potential consequences.

"We could be sitting on a Mendip volcano."

http://www.thisissomerset.co.uk/sitting-Mendip-volcano-says-Somerset-expert/story-14010082-detail/story.html#axzz2SbMDo8gX

But will Scotland see a shale gas boom in any case?

- Not very likely, given:
  - limited on-shore resource base, and this mainly in densely populated areas where *any* drilling is awkward
  - separation of surface ownership rights from oil and gas licensing rights (unlike USA): surface owners can say no
  - Scottish planning regime (far stricter than USA)
  - No relaxation of environmental regulations for this industry (SEPA would not do this, and EU rules would preclude it anyway)

- Same applies to Coalbed methane

- However, it is possible that a new offshore industry in underground coal gasification (with CCS) could arise, securing the future of Grangemouth (*inter alia*)

Thank you

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