



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Applied geoscience for our
changing Earth

Shale gas

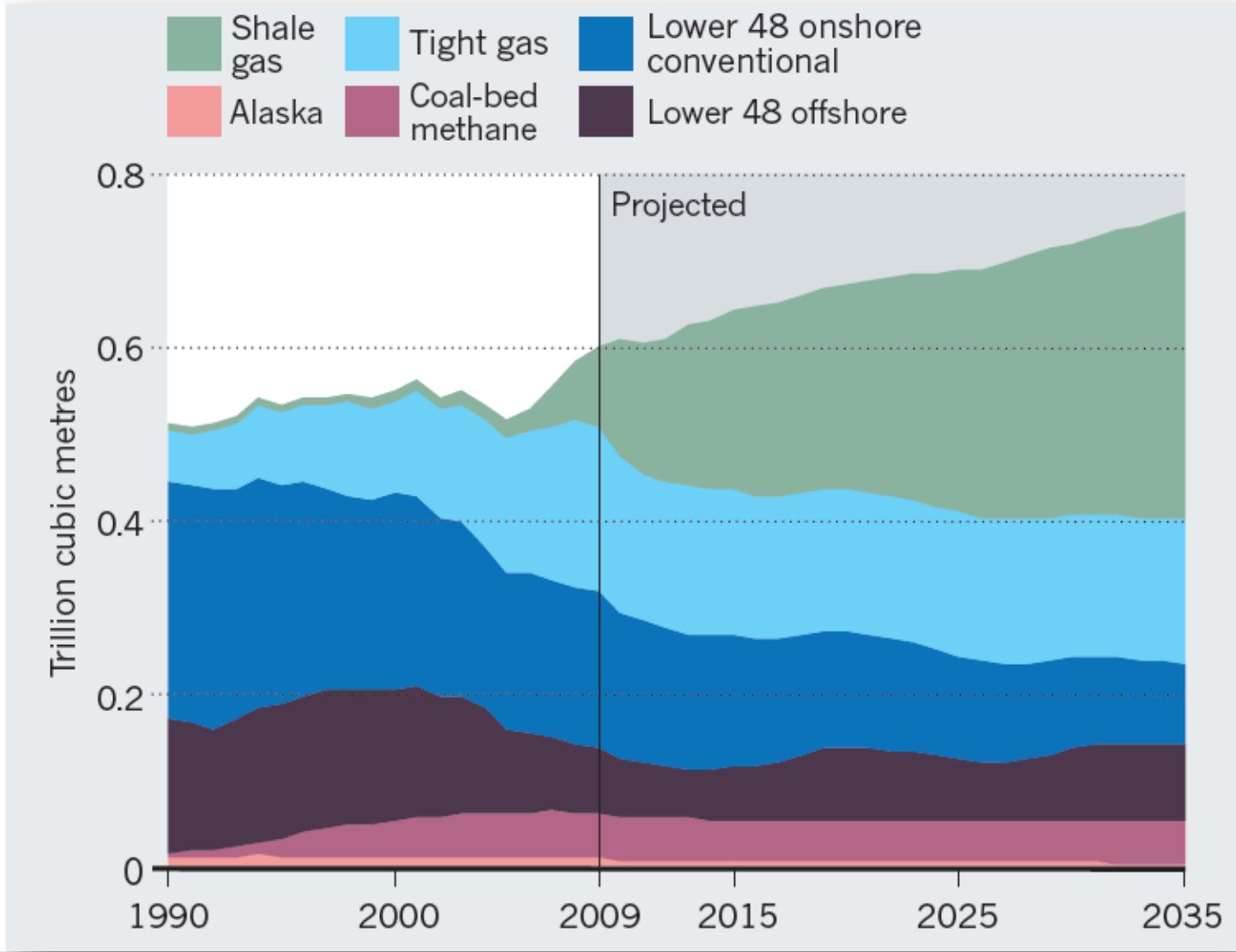
Mike Stephenson
BGS

Shale Gas Project
BRITISH GEOLOGICAL SURVEY

Contents

- Background
- What is shale gas?
- ‘Conventional and unconventional’
- Whereabouts in Britain?
- How much?
- Environmental impact

Background



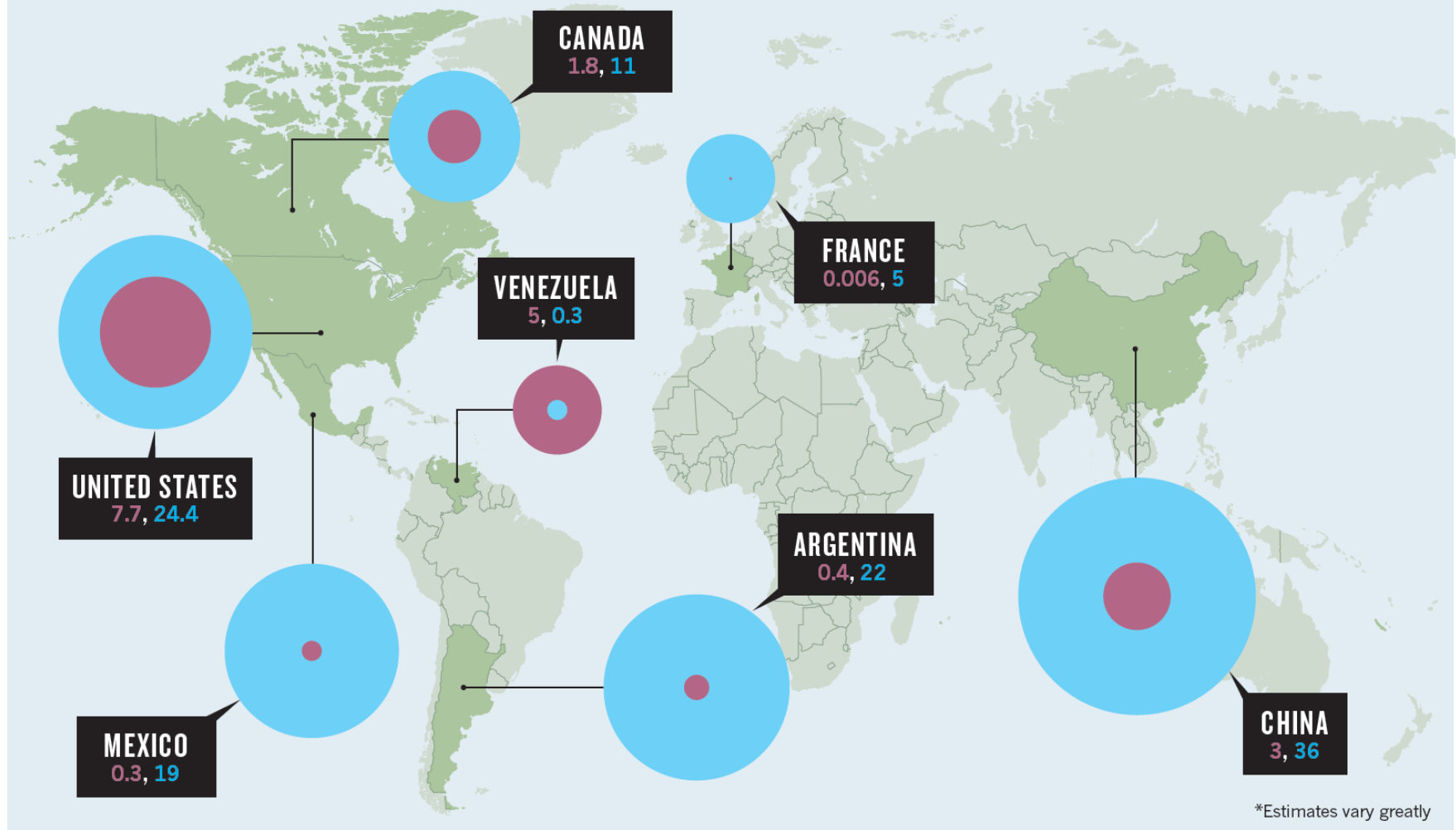
Background

GLOBAL GAS RESERVES

Using fracking to access shale gas would vastly increase gas resources in many countries. Russia and the Middle East are not included because their large reserves of easily accessible gas will render shale gas less important there.

 **Proven gas reserves**
(trillion cubic metres)

 **Technically recoverable shale gas resources***
(trillion cubic metres)



*Estimates vary greatly

Source: Nature Sept 2011



Background



GASLAND
THEMOVIE.COM



Background

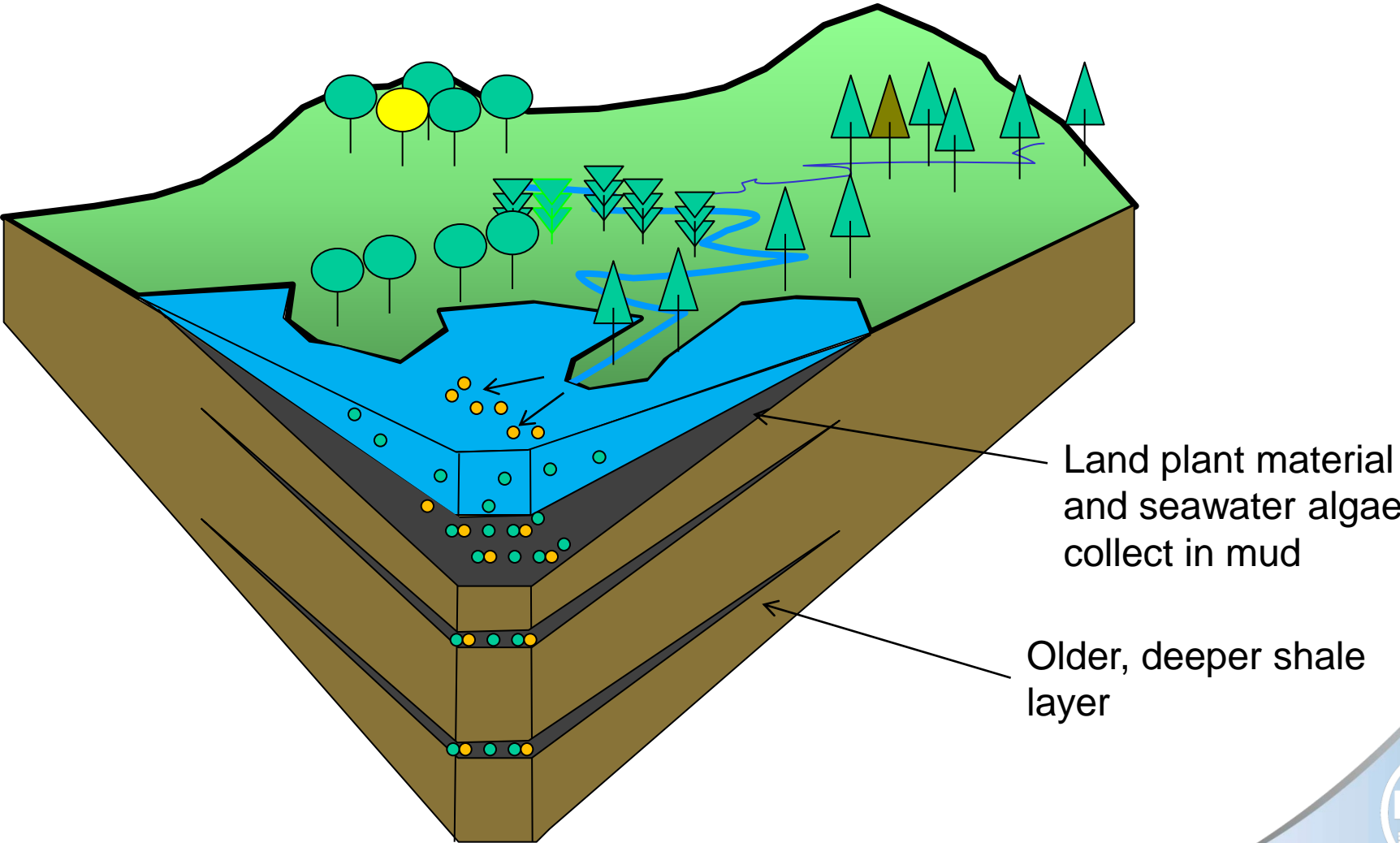


Shale basics

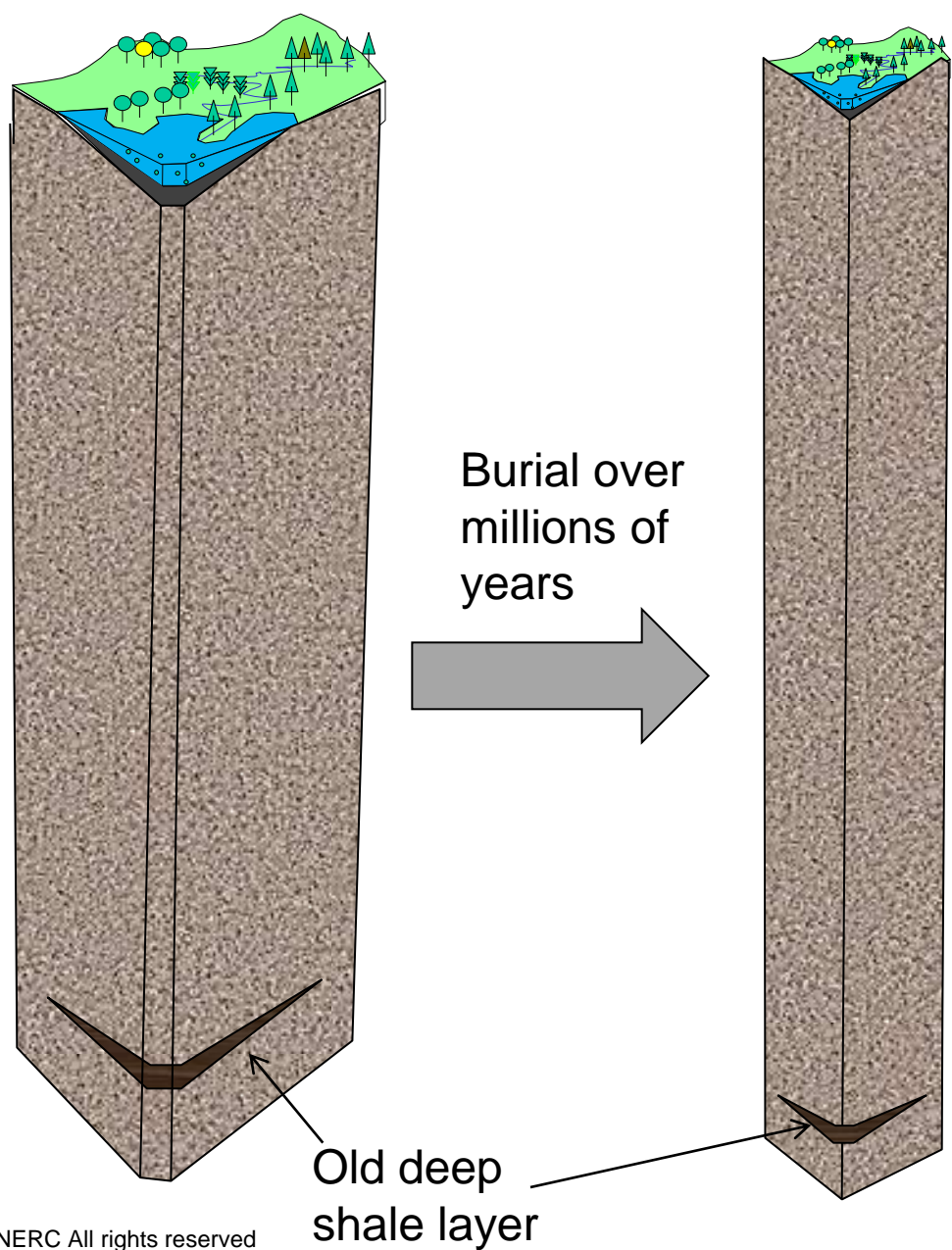


- Grey or black, soft
- Fine grained
- 70% of the world's surface rocks are sedimentary; 50% of those are shale.
- Contain ~95 % of the organic matter in sedimentary rocks

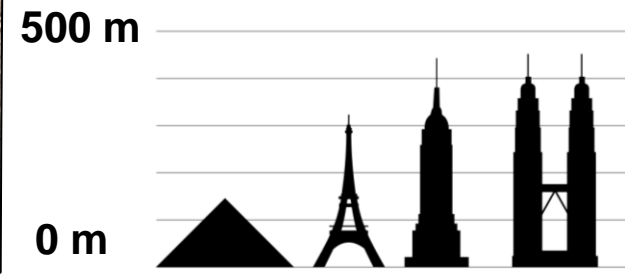
Where does the organic material come from?



What is shale gas?



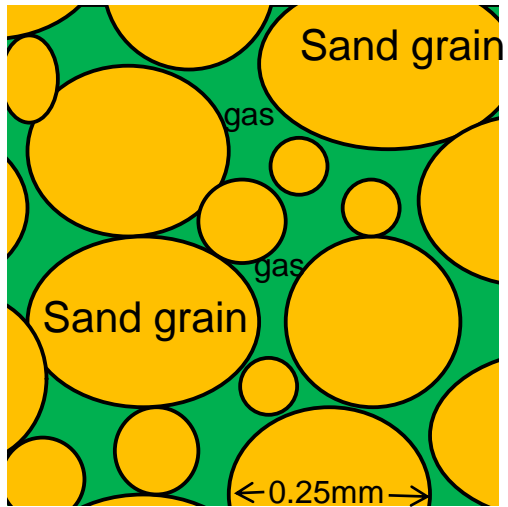
- Shale buried
- Biological decay – biogenic methane
- Organic matter ‘cooked’ – thermogenic methane



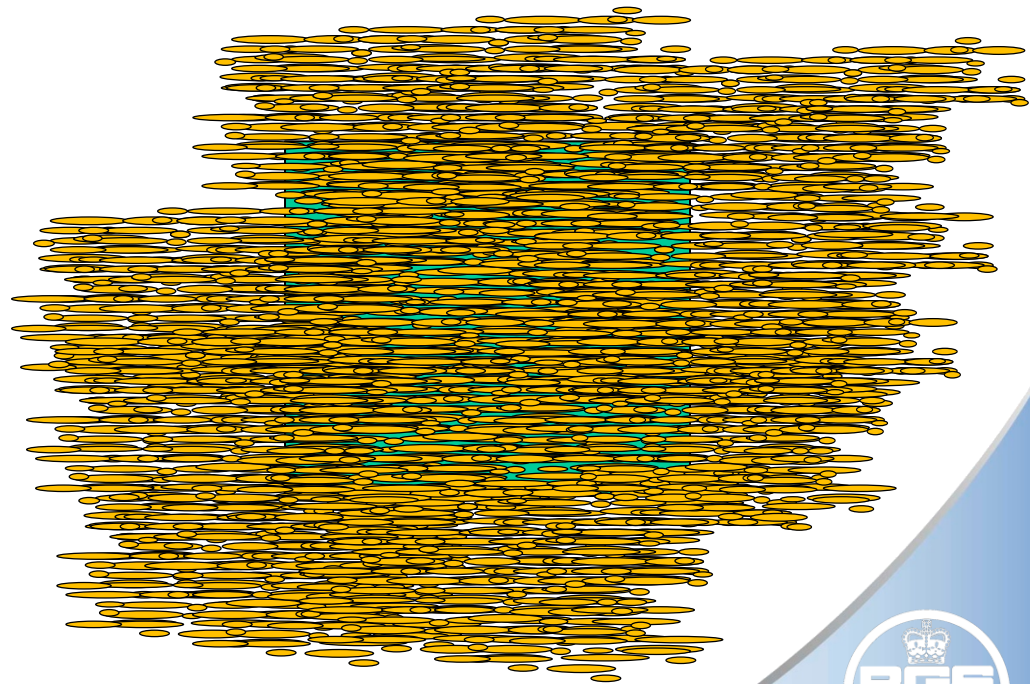
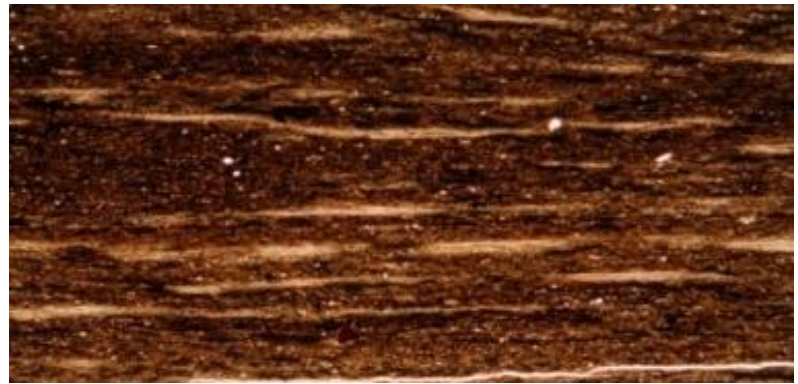
Conventional and unconventional



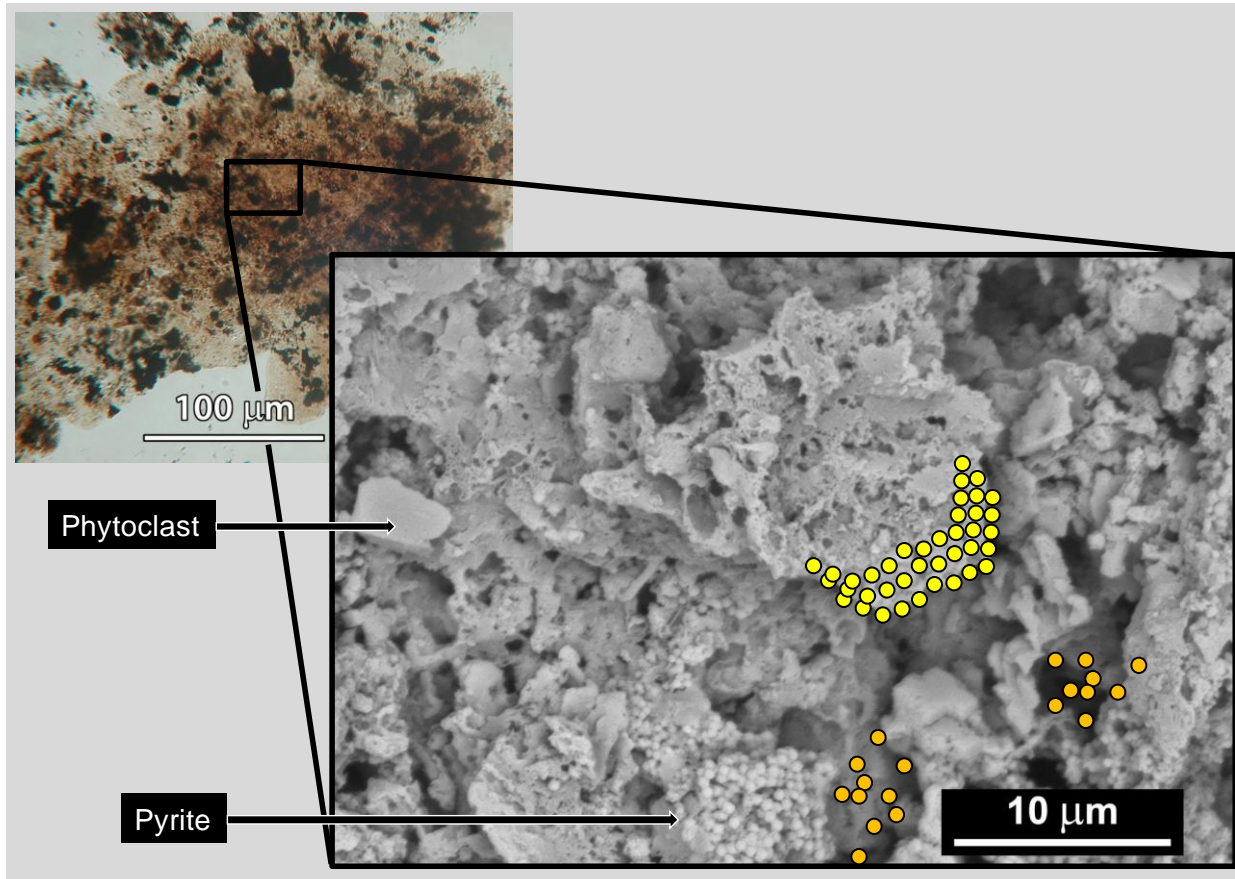
sandstone



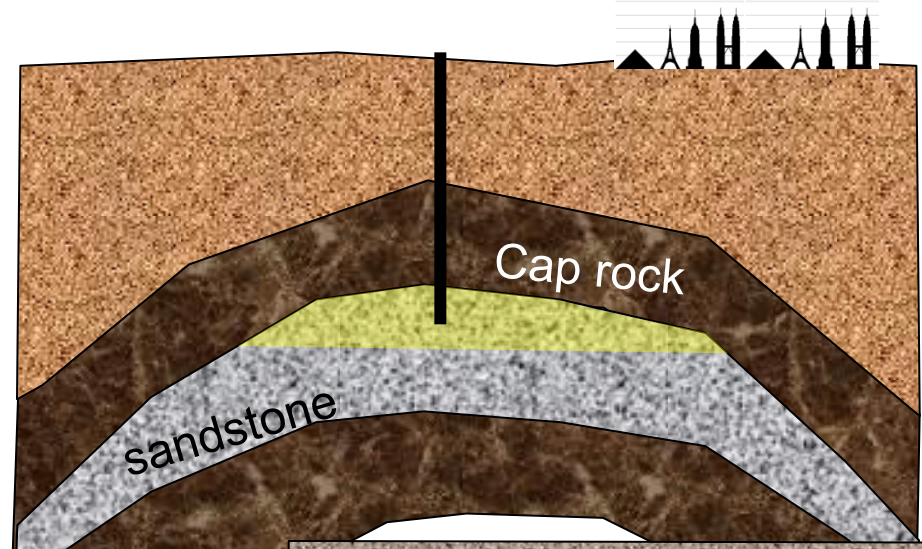
shale



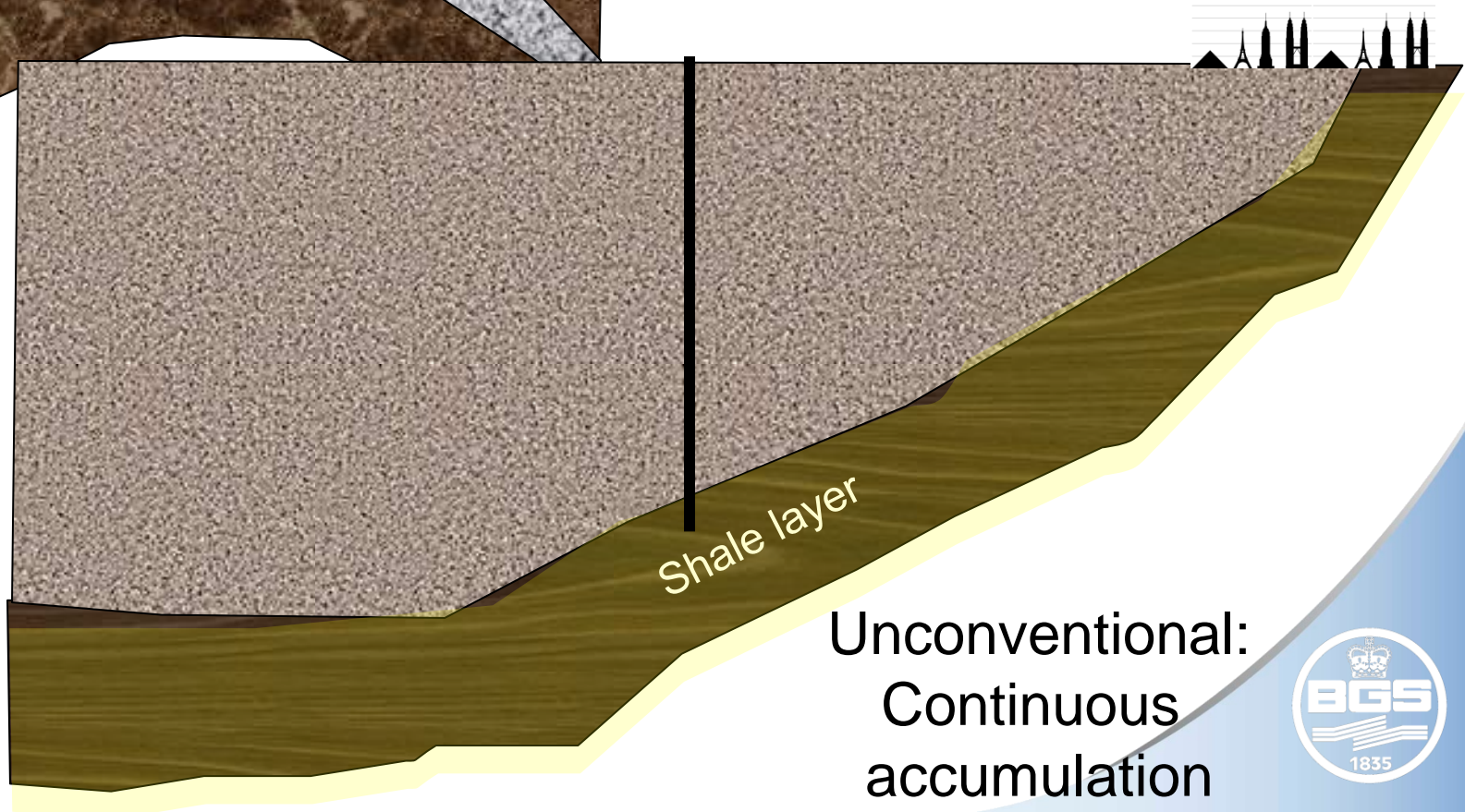
Adsorbed gas and gas in pores



- Pore space gas
- Adsorbed gas
- calculation of gas in place per unit volume
- We have to measure how much shale

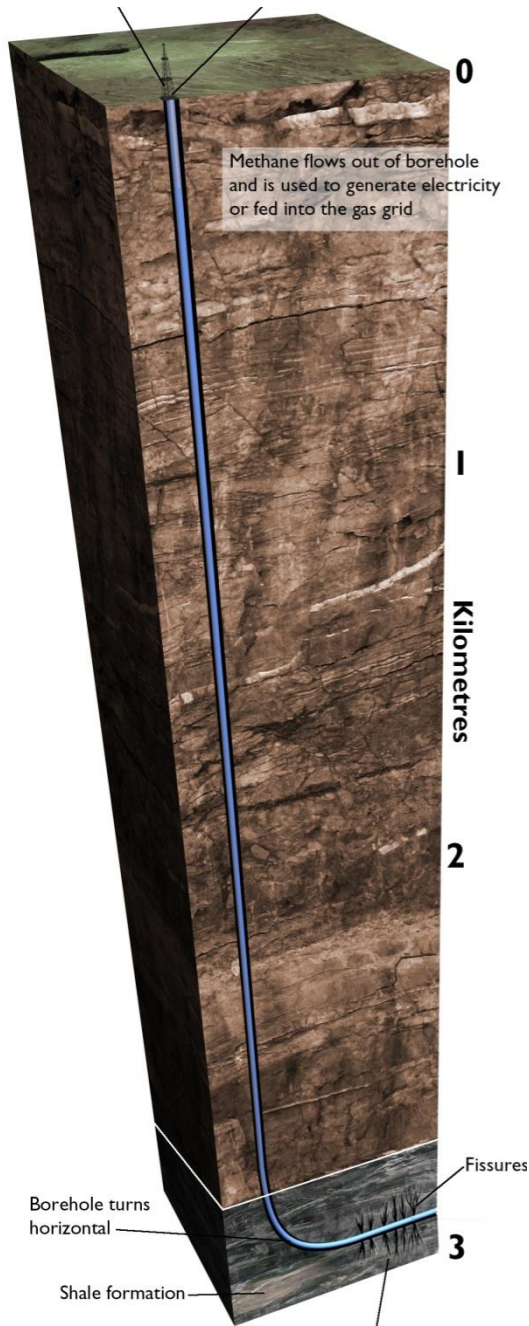


Conventional: Trap



Unconventional:
Continuous
accumulation

Fracking basics



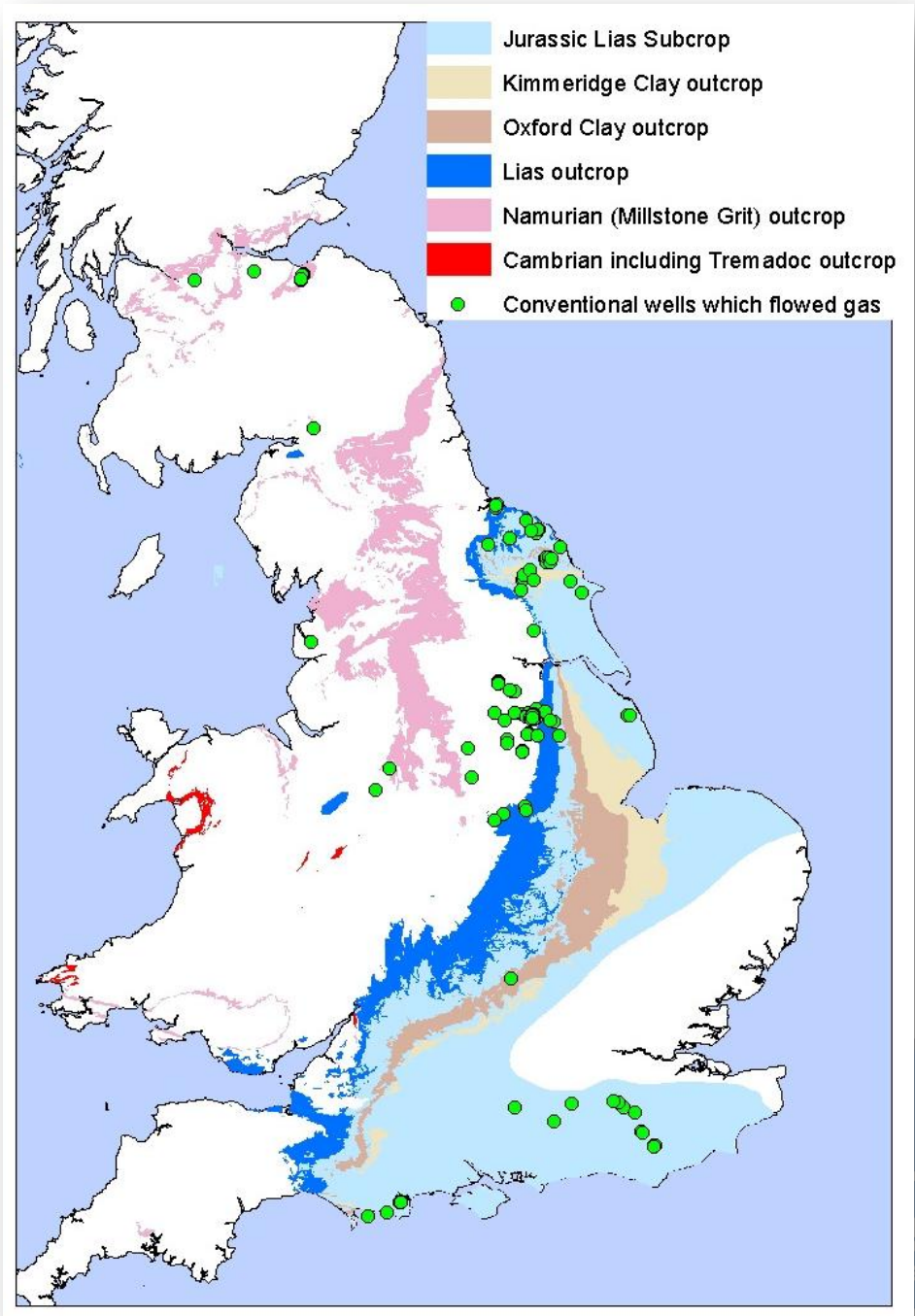
- Cracks the shale
- High pressure water or nitrogen, 350-700 bar (350 to 700 atmospheres)

Where is it?



Where is it?

- Lower Carboniferous around the Pennines *and offshore*
- Three Jurassic layers in the Weald and Wessex
- Upper Cambrian in the Midlands
- ? Lower Palaeozoic black slate Wales and SW England



How much?

- Very varied estimates according to whether
 - Reserves
 - Resource
- BGS early estimate 150 BCM
- BGS are doing a new estimate for the Blackpool area and the UK
- Contact DECC for more information



BGS publications 2010-11 DECC website

THE UNCONVENTIONAL HYDROCARBON RESOURCES OF BRITAIN'S ONSHORE BASINS - SHALE GAS Promote UK 2011

THE UNCONVENTIONAL HYDROCARBON RESOURCES OF BRITAIN'S ONSHORE - SHALE GAS

Legend:

- Conventional gas
- Associated gas
- Outcrop of formation best shale gas potential
- Kimmeridge Gr.
- Oxford Clay Fr.
- Lias
- Subs.
- Namurian (Car)
- includes Upper Bowland Shale
- Cambrian/Tri.

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THE UNCONVENTIONAL HYDROCARBON RESOURCES OF BRITAIN'S ONSHORE BASINS - COALBED METHANE

THE UNCONVENTIONAL HYDROCARBON RESOURCES OF BRITAIN'S ONSHORE - COALBED METHANE (CBM)

Legend:

- CBM Developments
- CBM wells
- Shoals of reproductive coalfield
- Shallow coal with less than 1000m
- Deep coal between 90m and 1200m
- Deep coal more than 1200m
- Next Gas Developments

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UK data and analysis for shale gas prospectivity

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Abstract: Organic-rich shale contains significant amounts of gas held within fractures and micropores and adsorbed onto organic matter. In the USA shale gas extracted from regionally extensive units such as the Barnett Shale currently accounts for 6% of gas production and is likely to reach 30% by 2015. Shale gas prospectivity is controlled by the amount and type of organic matter held in the shale, its thermal maturity, burial history, microporosity and fracture spacing and orientation. Potential targets range in age from Cambrian to the late Jurassic, within the main UK organic-rich black shales; younger shales have been excluded because they have not reached the gas window, but they may possess a biogenic gas play. A geographic information system, showing the distribution of potential reservoir ranks, has been created by combining information on hydrocarbon shows, thermal maturity, fracture orientation, gas composition, and isotope data to identify potentially prospective areas for shale gas. Some of these data are shown as graphs and maps, but crucial data is lacking because earlier exploration concentrated on conventional reservoirs. The prospects include Lower Palaeozoic shale basins on the Midland Microcontinent (a high risk because no conventional gas has been proved in this play), Mississippian shales in the Pennine Basin (the best prospect associated with conventional fields and high maturity), Permian shales in the Staßfurt and Northumberland Basin system (high risk because no conventional gas discoveries exist) and Jurassic shales in Wessex and Waidale basins (small conventional fields, slightly potential here).

Keywords: shale, gas, maturity, thickness, source rock and reservoir

Organic-rich shale contains significant amounts of gas held within fractures and micropores and adsorbed onto organic matter. In the USA, shale gas extracted from regionally extensive units such as the Barnett Shale accounts for c. 6% of gas production. The success of US shale gas exploitation (over 28 000 wells producing c. 380 × 10⁹ SCF per year) has stimulated significant interest in identifying potential reservoirs throughout the world. The depth range of the US shale gas plays extends down to 4500 m at present. Selley (1987, 2005), far-sightedly, advocated shale gas exploration in the UK, based on Upper Devonian gas fields of the Appalachian Basin, which have been producing since 1821. However, in the past decade the Mississippian Barnett Shale of the Fort Worth Basin has become the most productive shale gas reservoir in the USA. US shales generally, and the Barnett Shale in particular, provide good analogues for potential shale gas plays in the UK, which has thick Mississippian shales both on and offshore; therefore the geology and geochemistry of the Barnett Shale are discussed briefly below.

The Barnett Shale

The Barnett Shale Formation (354–323 Ma) of the Fort Worth Basin is up to 300 m thick and underlies an area of c. 13 000 km² (Fig. 1). It contains c. 2.5 × 10¹² SCF of proven gas reserves held in a low porosity and very low permeability shale matrix. Permeability is in the micro- to millidarcy range and porosity rarely exceeds 6%.

Shale Formation is still in excess of 4000 psi.

The Fort Worth gas-bearing shale structure, Lower Palaeozoic Midcontinent, Fig. 1. The shale overlies Ordovician and can be subdivided into the Barnett, separated by the Marble Falls Limestone, also of Mississippian age, which is conformable with a thick succession of overlying Pennsylvanian sediments. Sedimentary structures suggest that the main shale units were deposited by distal turbidity flows in a sediment-starved anoxic basin environment. The Carboniferous sequence is truncated by a Cretaceous unconformity above the Variscan unconformity. The Ouachita (Variscan) fold belt lies at right angles to the Mueseler Arch and impinges on the Fort Worth Basin in the SE.

The three main factors controlling prospectivity of the Barnett are the thermal maturity, thickness and total organic carbon (TOC) content of the shale (Zhao *et al.* 2007). Local and regional structures such as joints, folds and faults control fracture porosity and thus influence production potential at a variety of scales. Most natural fractures are sealed but these can potentially be exploited by artificial fracturing techniques (Bowker 2007) to improve flow rates around a well. Siltystone bands and chert nodules can also affect prospectivity locally.

The Newark East shale gas field lies up-dip west of the depocentre of the Barnett Shale in the wedge between the Mueseler Arch and the Ouachita (Variscan) fold belt (Fig. 1; Pollastro *et al.* 2004). The rest of the depocentre lies under the Fort Worth–Dallas conurbation. The Barnett Shale also produces oil from the area to the NW (Fig. 1), where overlying conventional reservoirs are also present.

In a similar tectonic position the Bar. South shale gas field is

VINING, B.A. & PICKERING, S. C. (eds)
Petroleum Geology: From Mature Basins to New Frontiers – Proceedings of the 7th Petroleum Geology Conference.

VINING, B. A. & PICKERING, S. C. (eds) *Petroleum Geology: From Mature Basins to New Frontiers – Proceedings of the 7th Petroleum Geology Conference*, 1087–1088. DOI: 10.1144/00710187 © Petroleum Geology Conference Ltd. Published by the Geological Society, London.



Environmental impact



Very few peer-reviewed papers

Methane contamination of drinking water accompanying gas-well drilling and hydraulic

Stephen G. Osborn, J

*Center for Global Change, Biology Department, Duke University, Durham, NC

Edited by William H. Schlesinger

Directional drilling and hydraulic fracturing have increased the Marcellus and Utica shale gas wells and uptake New York methane contamination gas extraction. In active wells within 1 km, average in drinking-water wells gas well and were 19.2 explosion hazard, in contrast to nonproduction sites geologic formations and 1.1 mg L⁻¹ (P < 0.001) methane in shallow groundwater for active than for non production sites (P < 0.0001). Flux of methane to higher are consistent with deep geochronology from gas in shallow samples from shale isotopic signatures, reflect thermogenic methane as a source of drinking-water turning fluids. We conclude possibly—regulation are of shale-gas extraction at groundwater (organic) water chemistry.



Methane unrelated

Lisa J. Molofsky, John A. Connor, Shahla K. Farhat, GSI Environmental Inc, Houston

Albert S. Wylie Jr., Tom Wagner, Cabot Oil & Gas Corp, Pittsburgh

Results from more than 1000 samples of gas in drinking-water wells in Pennsylvania with a clear correlation face topography. Specifically, water exhibit significantly lower methane in upland

LIDAR BARE-EARTH

Area of Pennsylvania



Drilling of organic shale in the Appalachian region in Pennsylvania and Marcellus formation in

www.sgi.org/igj/010_1073

Osborn et al. 2011

Molofsky et al. 2011

Oswald and M. Bamberger Jan 2012: two instances of correlation between gas-drilling activity and mortality rates in livestock

NEWS SOLUTIONS, Vol. 22(1) 51-77, 2012

Scientific Solutions

IMPACTS OF GAS DRILLING ON HUMAN AND ANIMAL HEALTH

MICHELLE BAMBARGER ROBERT E. OSWALD

ABSTRACT

Environmental concerns surrounding drilling for gas expansion of shale gas drilling operations. Controversy over impact of drilling on air and water quality has pitted industry and scientists against individuals and groups concerned with environmental protection and public health. Because animals often are exposed conditions to air, soil, and groundwater and have more frequent reproductive cycles, animals can be used as sentinels to monitor impacts to human health. This study involved interviews with animal owners who live near gas drilling operations. The findings illustrate which aspects of the drilling process lead to health problems and suggest modifications that would lessen but not eliminate impacts. Complete evidence regarding health impacts of gas drilling cannot be obtained due to incomplete testing and disclosure of chemicals and manufacturing agreements. Without rigorous scientific study, the gas drilling boom sweeping the world will remain an uncontrolled health experiment on an enormous scale.

Keywords: hydraulic fracturing, shale gas drilling, veterinary medicine, environmental toxicology

A vital point: does preliminary evidence of harm become definitive evidence of harm? When someone asks, "We were not aware of the dangers of these chemicals back then," whom do they mean by we? —Sandra Stutzgaber, *Living Downstream* (Da Capo Press, 2010)

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COMMENT

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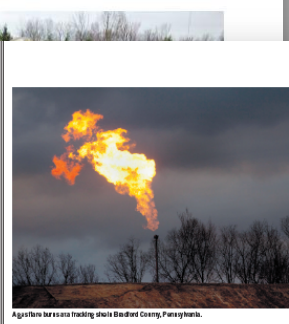
A drilling site

NEWS FOCUS
The South African array, for example, it may be politically expedient, but it is also scientifically driven. "Energy board chairman John Womersley 19 building on existing solar projects in both countries, he says, the SCAAD first phase will be even more powerful than originally planned. Operating across two sites will add no more than 10% to the projected €300 million cost of phase one, according to Womersley. South Africa and Australia have already each invested around US\$100 million in their respective pilot projects, and the board concluded that this added capability makes the additional investment worthwhile. First observations from these phase-one facilities could come by the end of the decade.

TOWER BELL In phase two, the rest of the dishes will be assembled in South Africa and eight other African countries, along with mid-frequency aperture arrays that fill an obvious gap between the antennas and the dishes. Meanwhile, Australia will build the observing radio antennas. As the SCAAD grows, it will require an ever-increasing amount of electricity, delivered through networking and interconnecting resources to channel and crunch its data. "Because we don't have a detailed design yet for phase two, it was next to impossible to estimate the cost," says Tronconi. But Benjamin Schmidt, a Nobel-prize-winning astronomer at Australia's National University in Canberra, says that the figures he has seen suggest that the cost increase from mounting the project at both sites "is likely to be low."

In the current environment that a tough sell, Schmidt wants to be sure that budget shortfalls or other problems make the entire investment. The SCAAD plan would be a considerable investment. Albert J. Zylber, director of the Jodrell Bank Centre for Astrophysics near Manchester, UK, notes that as well as requiring coordination across six time zones, the project will essentially be creating two separate telescopes at two separate locations. With limited international funding, "they may end up competing with each other," he says. Despite their concerns, Zylber, Schmidt and other project supporters have agreed to sign the site. "When I heard the announcement, I actually suddenly decided that it's a good thing," says Andrew Lawrence, an astronomer at the University of Edinburgh, UK. Lawrence and others think that the compromise is crucial to making the project's first phase a reality. "By settling the long-running site dispute at this phase two would ever be built," he cautions. "It's a fantastic idea, but still a long way from reality." NEWS 100

POINT Yes, it's true National gas contracts fit environment, say Robert
Natural gas from wells with oil and coal still supply adds until a switch to run fuel plants, and the shale rock formation (which is mostly methane)



Agathia barrens heating their Bradford Camp, Pennsylvania.

Fracking boom spurs environmental audit

As hydraulic fracturing unlocks new gas reserves, researchers struggle to understand its health implications.

BY KYLE THOMPSON

The Ohio, a Midwestern state hit hard by recession, the promise of an energy boom driven by hydraulic fracturing, or fracking, would seem to be a sure route to financial health. But not so certain is whether the technique has an impact on human health. Fracking uses high-pressure fluids to fracture shale formations deep below ground, releasing the natural gas trapped within. With the number of gas wells in Ohio that use fracking set to mushroom from 77 to more than 2,300 in the next three years, the state is the latest to try to regulate a rapidly growing industry while grappling with a serious knowledge gap. "We do not know what substances—and at what levels—people near the gas fields are exposed to in the air and water, and what their health threat they might pose."

In a post-fracking concerns, Ohio legislators passed a bill on 24 May, awaiting signing by the state governor as Nature went to press, that requires companies to disclose the chemicals they use during the fracking process and during the construction and servicing of the wells. However, the bill does not compel companies to disclose a complete list of ingredients in their fracking fluid before it is pumped underground. Some of these ingredients are deemed trade secrets, positions that trouble environmental groups and increase the problem for researchers trying to understand the risks. "There's a real lack of data," says John A. Hahn, senior adviser on public health at the National Institute of Environmental Health Sciences in Washington, D.C. Last month he discussed research strategies for analyzing the health impacts of gas extraction. "There's a lot of variability from region to region, in the kinds of structures that need to be used for the specific geology."

Fracking fluids are primarily water and sand, but they also contain chemical additives that aid the horizontal fracturing of shale and the release of natural gas. Some components,



Concerns about shale gas



**Independent (peer-reviewed) science:
assess risk**

Low risk

Things we
don't have to
worry about

High risk

Things we need to regulate
carefully for public safety
and public opinion



Conclusions

- Shale is a common rock
- Holds a lot of old organic material (carbon)
- Britain might have substantial potential for shale gas
- Concerns over environmental impact
- Peer-reviewed independent science has a special role in building regulator, investor and **public** confidence



Shale Gas Project

BRITISH GEOLOGICAL SURVEY

<http://www.bgs.ac.uk/research/energy/shalegas/>

