Central Scotland's Potential Shale Gas and Shale Oil Resource

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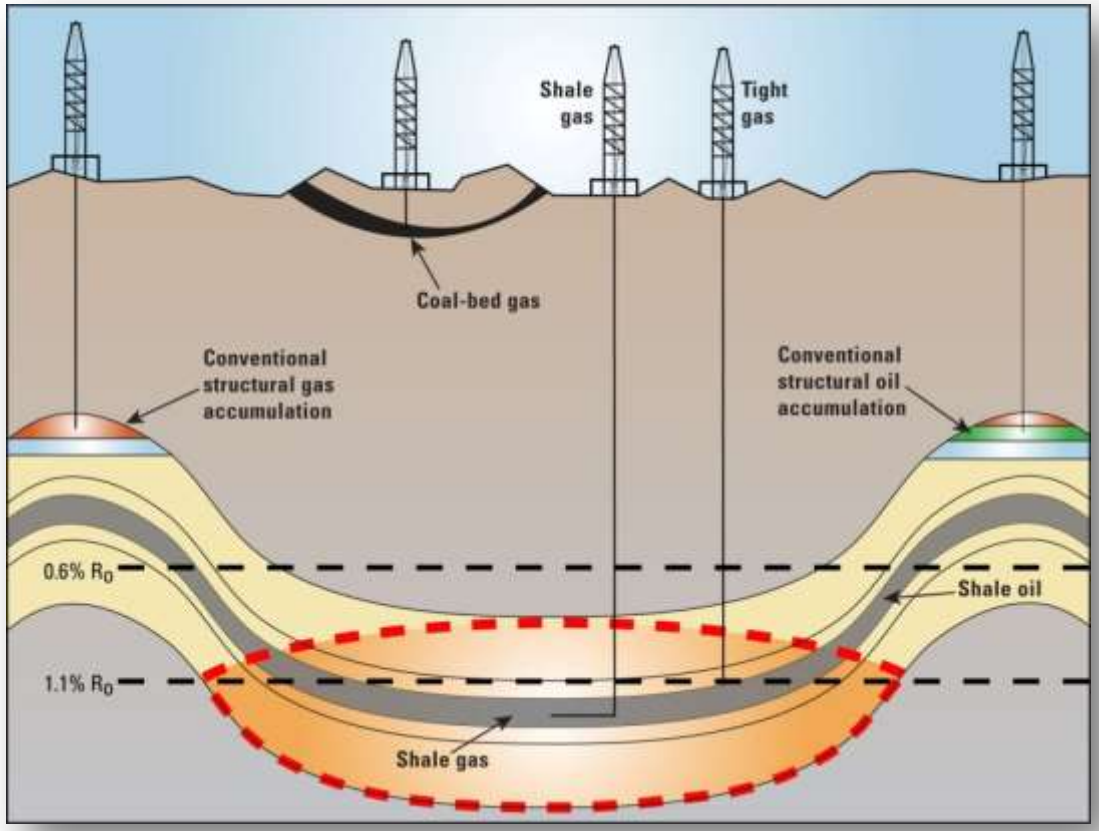
What is shale?

Shales, siltstones and thin sandstones in the Gullane Formation, Linhouse Water, Mid Calder, West Lothian, BGS photo P219686

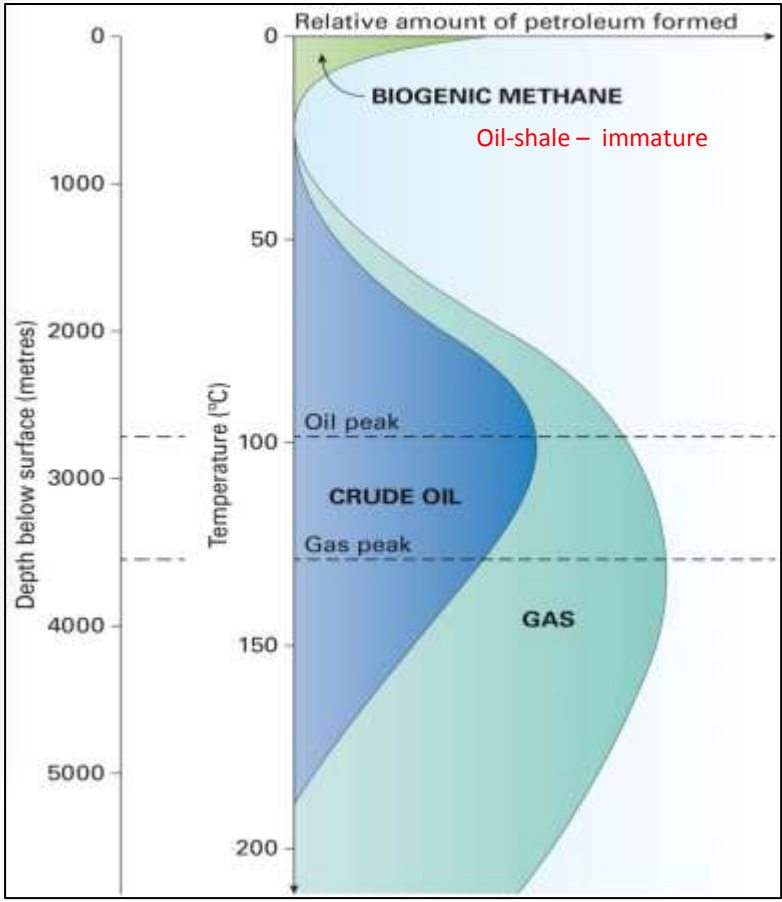
Mudstone and ironstone, West Lothian Oil-Shale Formation, Bargeddie well drill core

- Grey or black, soft
- Fine grained
- Low porosity and permeability
- Commonly rich in organic matter

Shale gas, shale oil (not oil-shale)



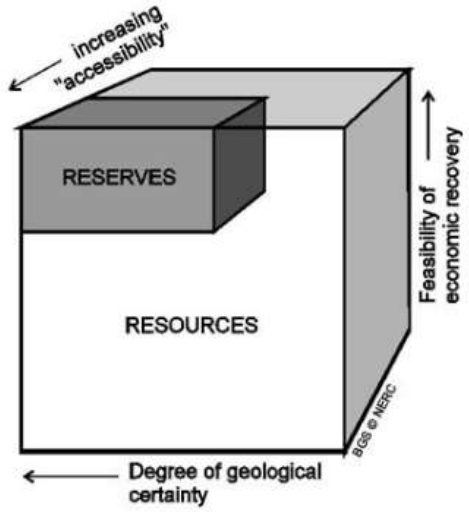
Modified after Gaswirth SB, Marra KR 2014. Bakken, Three Forks largest continuous US oil accumulation, Oil and Gas Journal



Modified from Tissot et al 1974 and McCarthy et al 2011 Schlumberger Oilfield Review article

Structure of talk

- **Geology & shale resource criteria**
- **Results**
- **Implications**

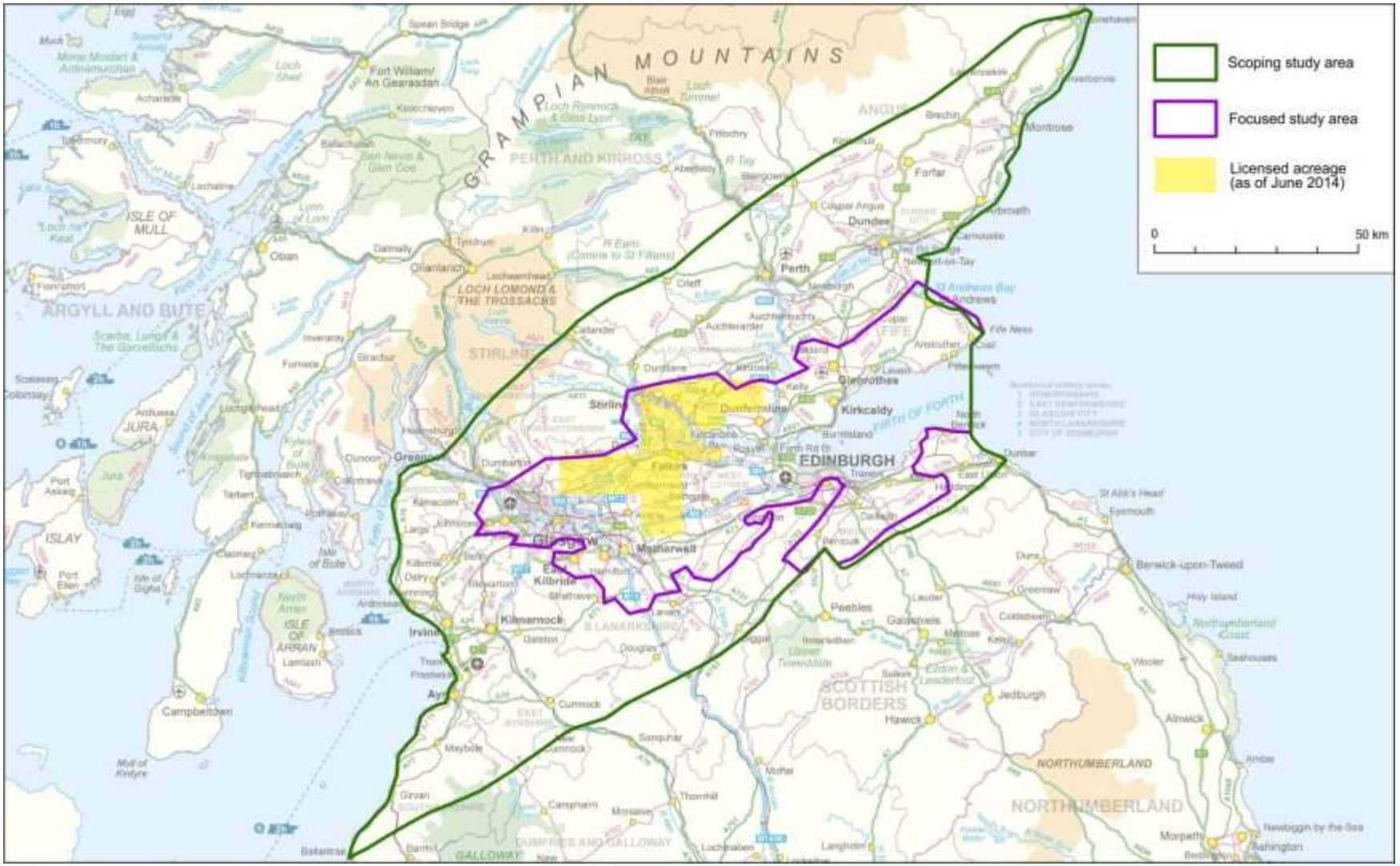


Resources vs reserves

Resource: amount of oil and gas in the source rock

Reserve: oil or gas that can technically and economically be expected to be produced

Overview – the Midland Valley of Scotland



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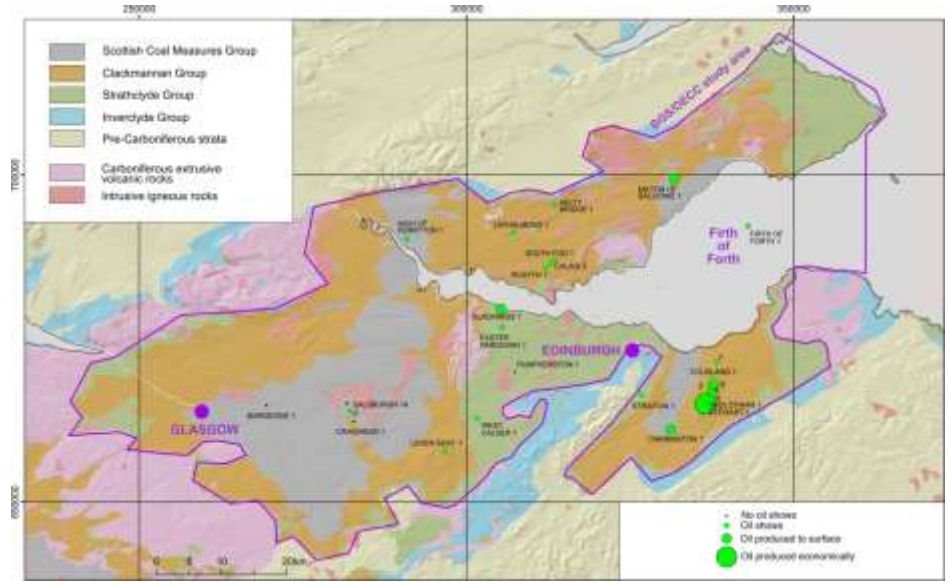
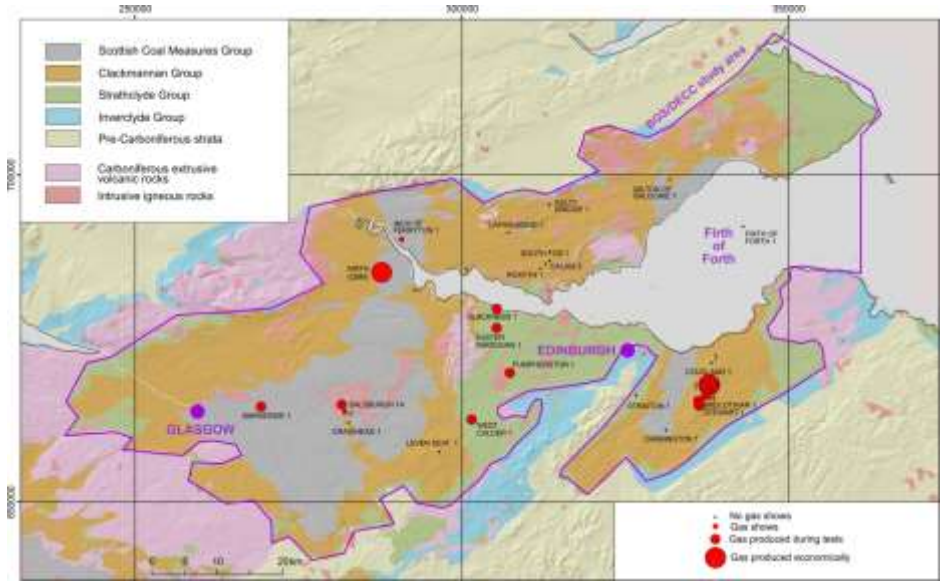
Shale is the source rock for a proven petroleum system

Immature oil shales were quarried or mined near surface and retorted (heated) to release oil

Five Sisters Bing, West Lothian – waste from historic oil-shale workings.

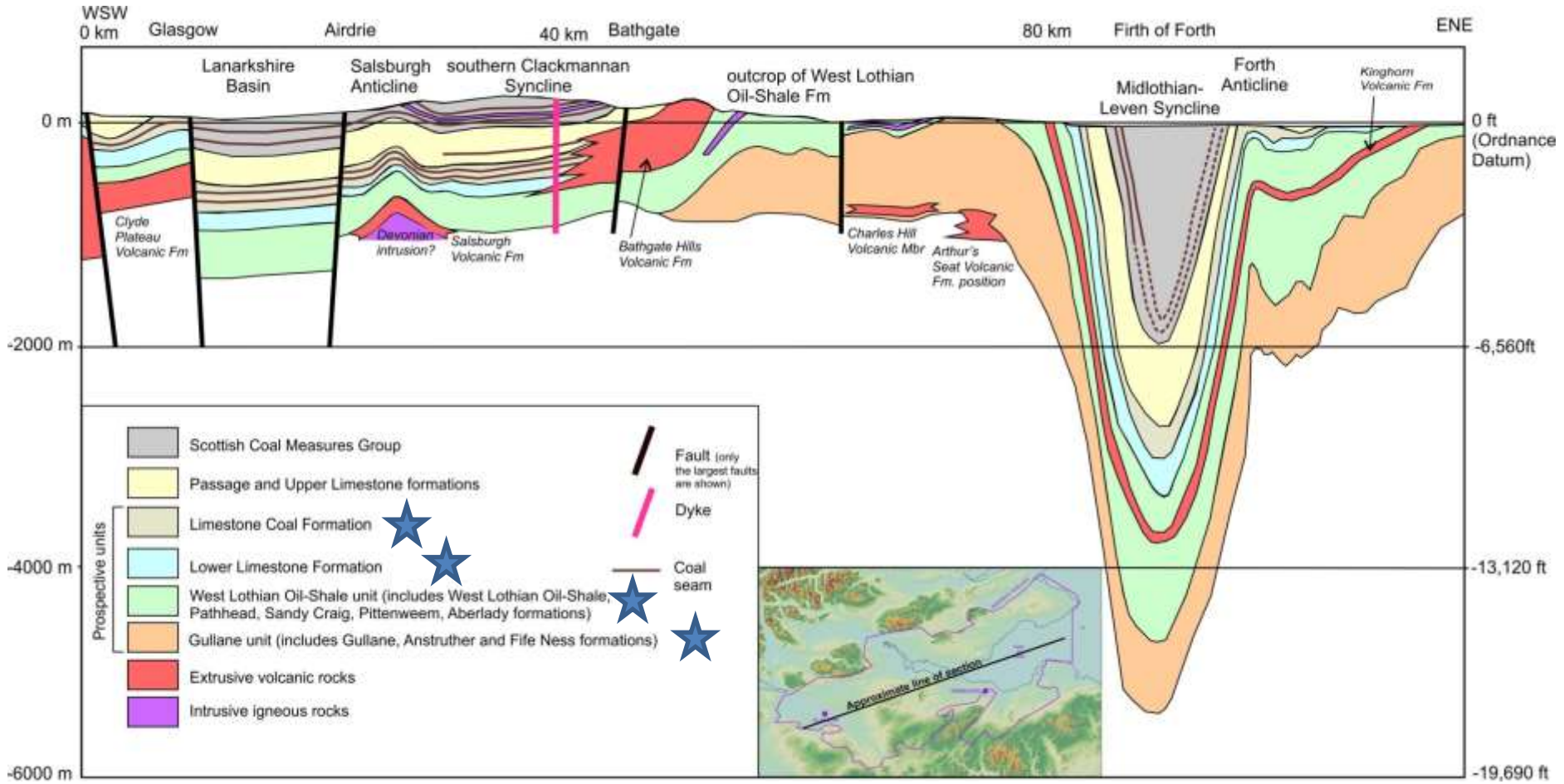


Map of historic oil shows, oil produced to surface and oil produced economically within the study area



Map of historic gas shows, gas produced during tests, and gas produced economically within the study area

Geology

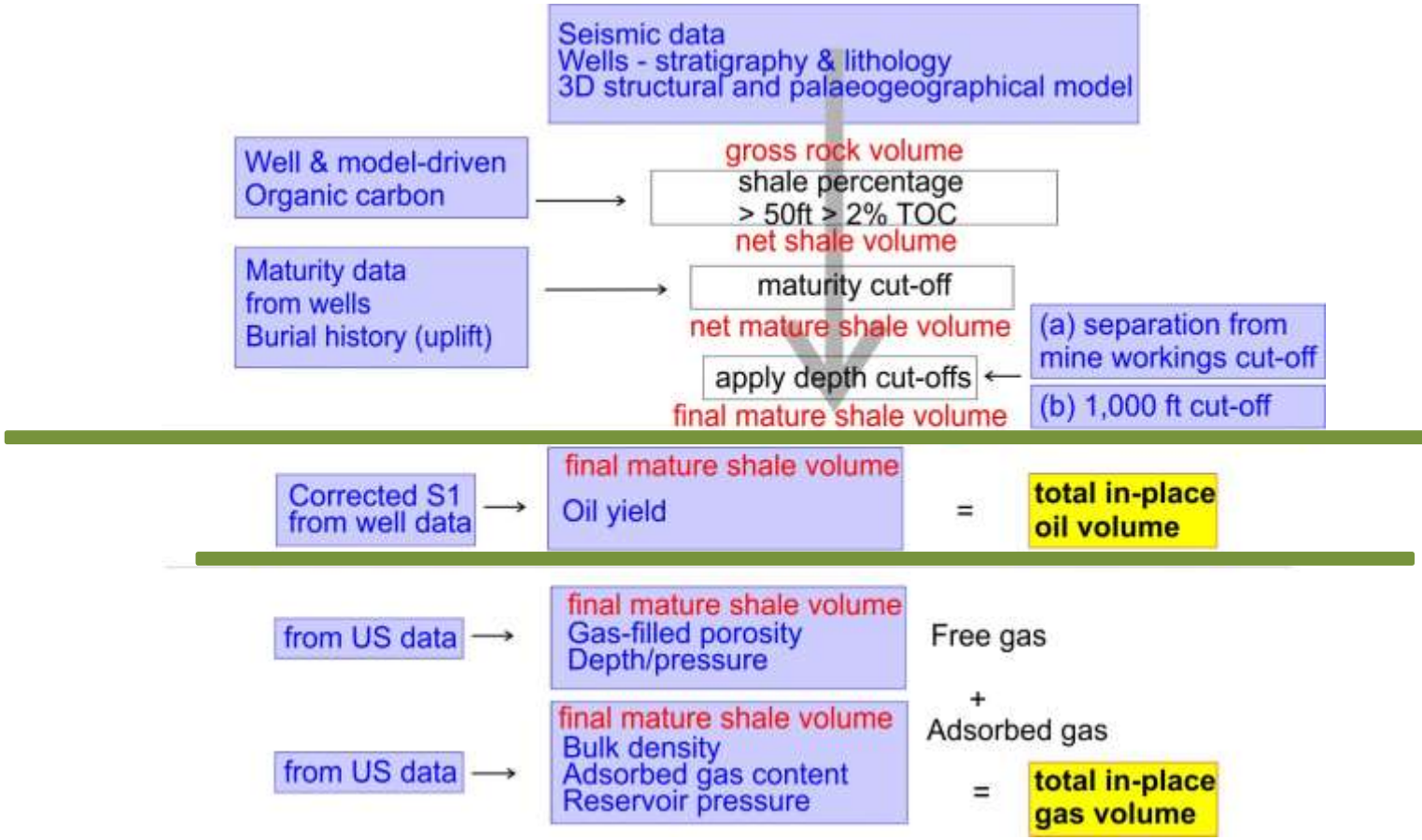


Schematic cross-section to illustrate some of the main geological features. Note the significant vertical exaggeration x10.

Criteria for shale gas/oil plays

- Total organic carbon content (TOC) > 2%
- Shale oil precursor identified
- Thermally mature for oil and gas generation (Vr_o >0.6 and 1.1 % respectively)
- Shale thicknesses > 50 ft (15 m)
- Depths > 1000 m
- Large stable basins
- Type I and II kerogen preferred
- Low clay content
- Organic geochemistry parameters favourable S1, HI. Free oil and free gas

How was the shale resource estimated?

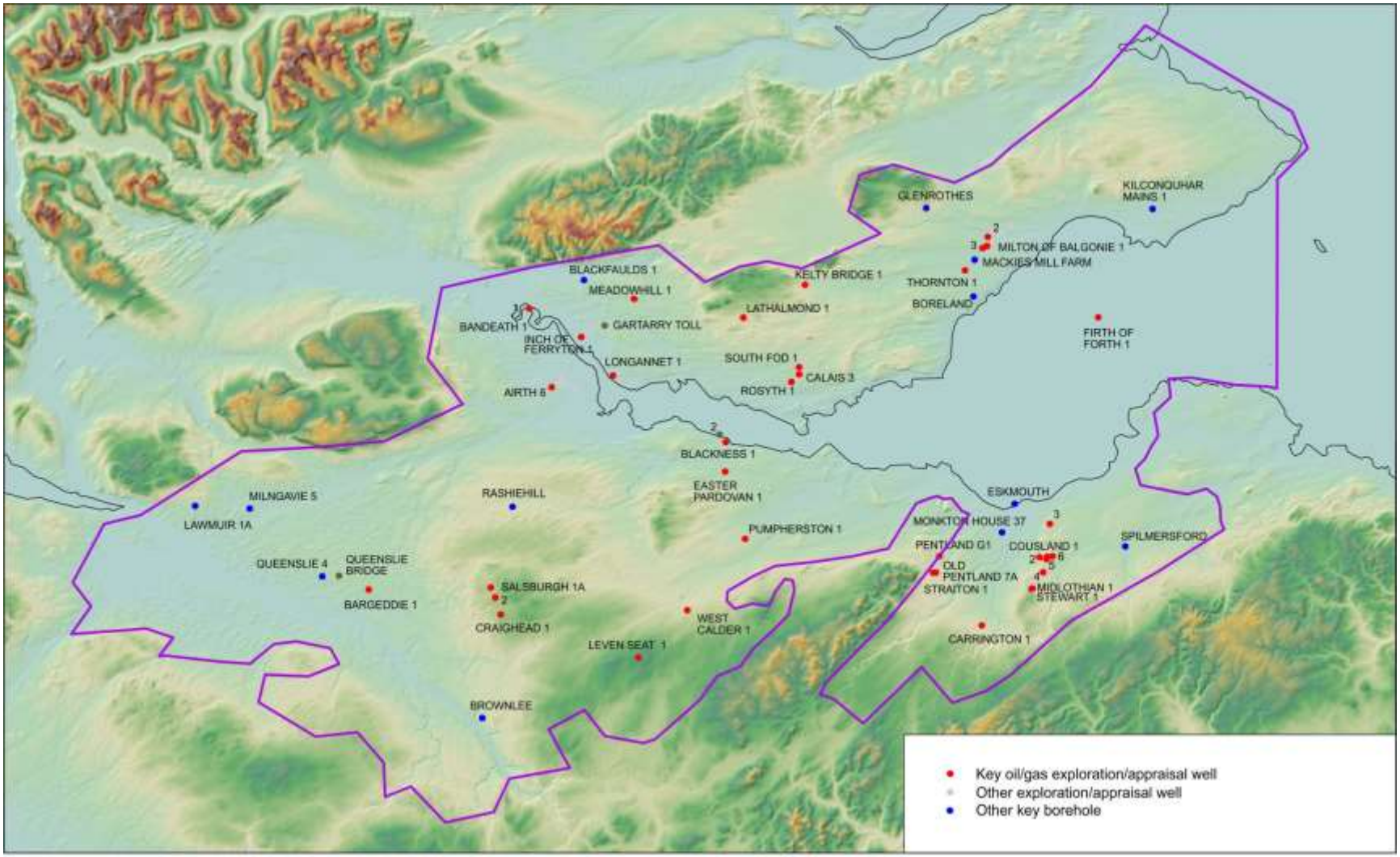


Volume of net, mature shale with TOC > 2% below depth cut-off

Volumes of shale oil and shale gas

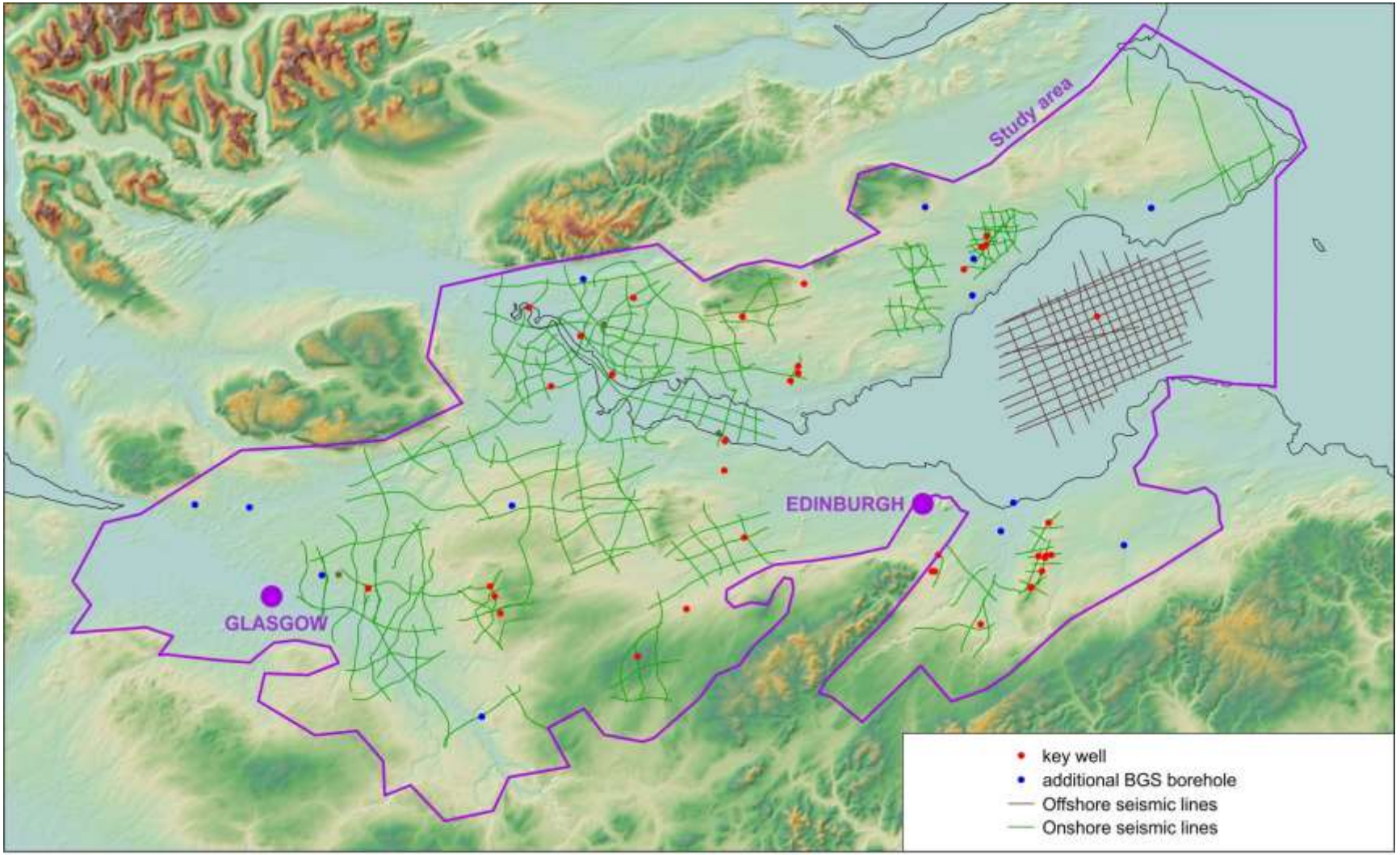
Overview of method used to calculate mature shale gas and shale oil volumes

Wells/boreholes studied



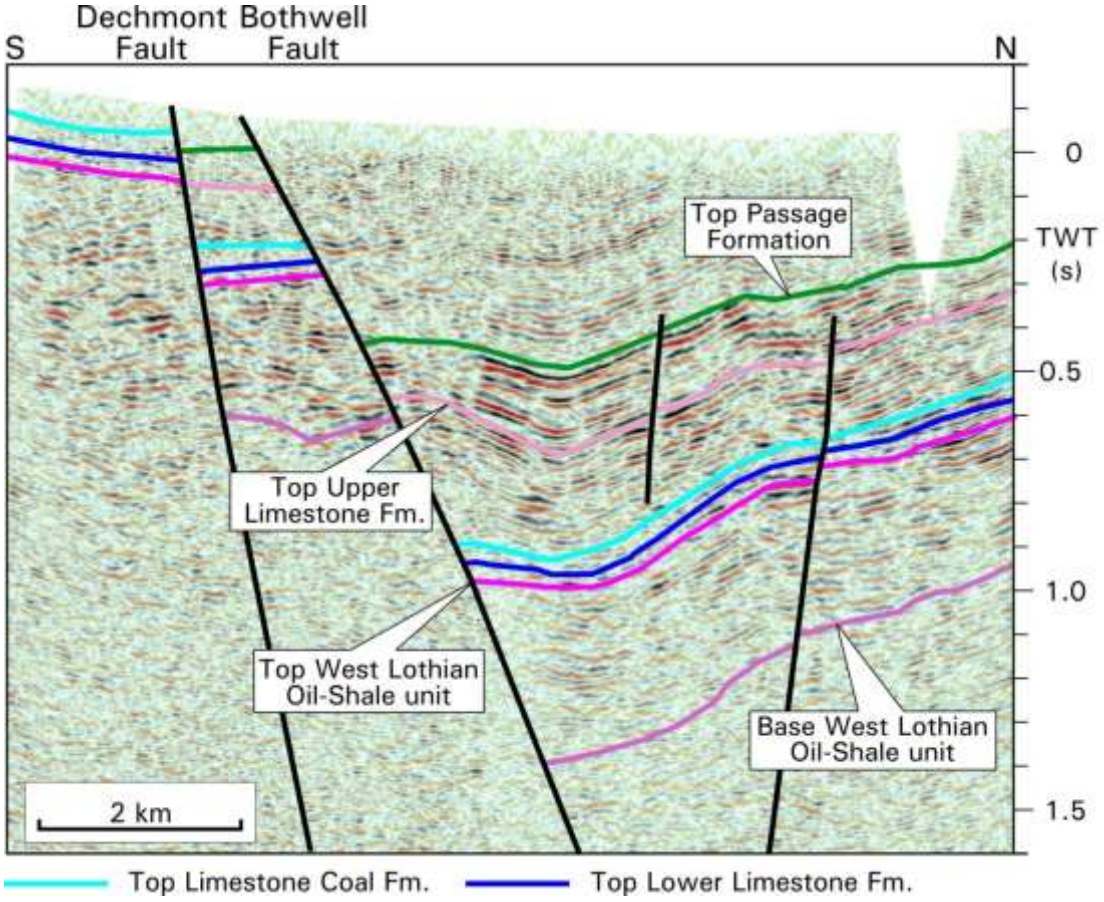
Distribution of the key wells and other deep boreholes used in the Midland Valley of Scotland study

Seismic data studied



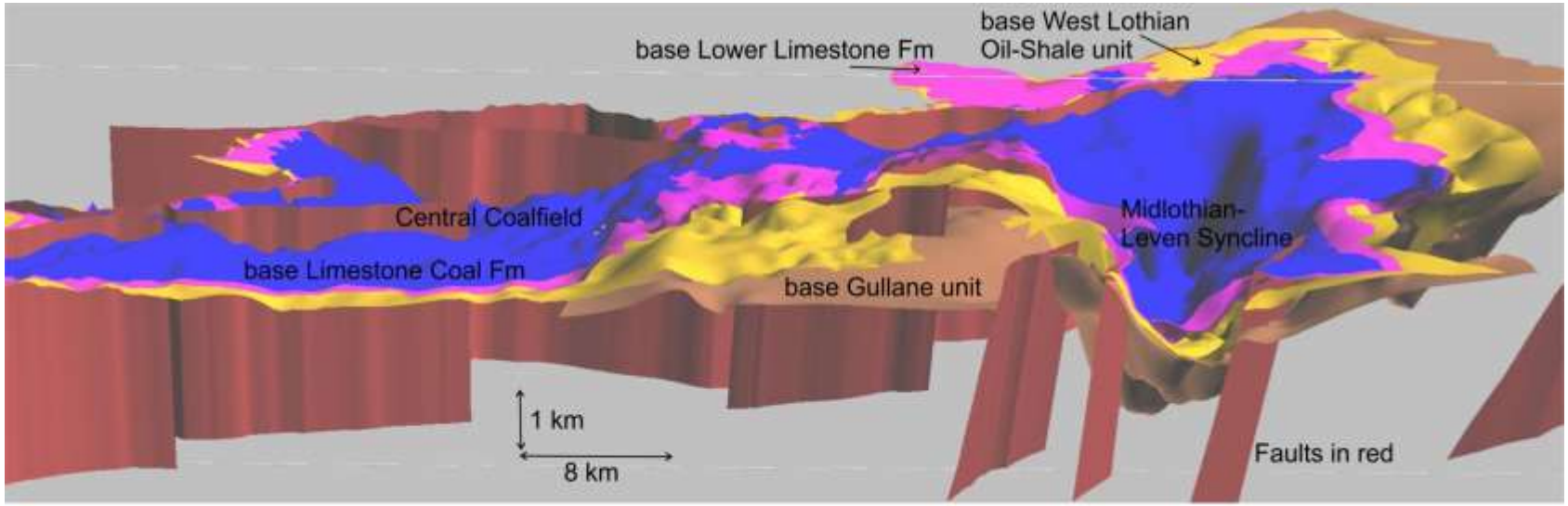
Location of 2D seismic profiles used to assess the shale potential of the Midland Valley of Scotland study area

Seismic line example

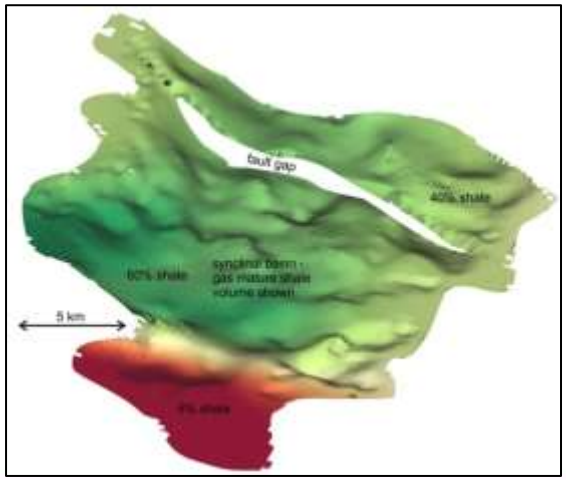


Seismic line showing a syn-depositional half-graben bounded by the Bothwell and Dechmont faults in the Lanarkshire Basin.

3D geological model for rock volumes

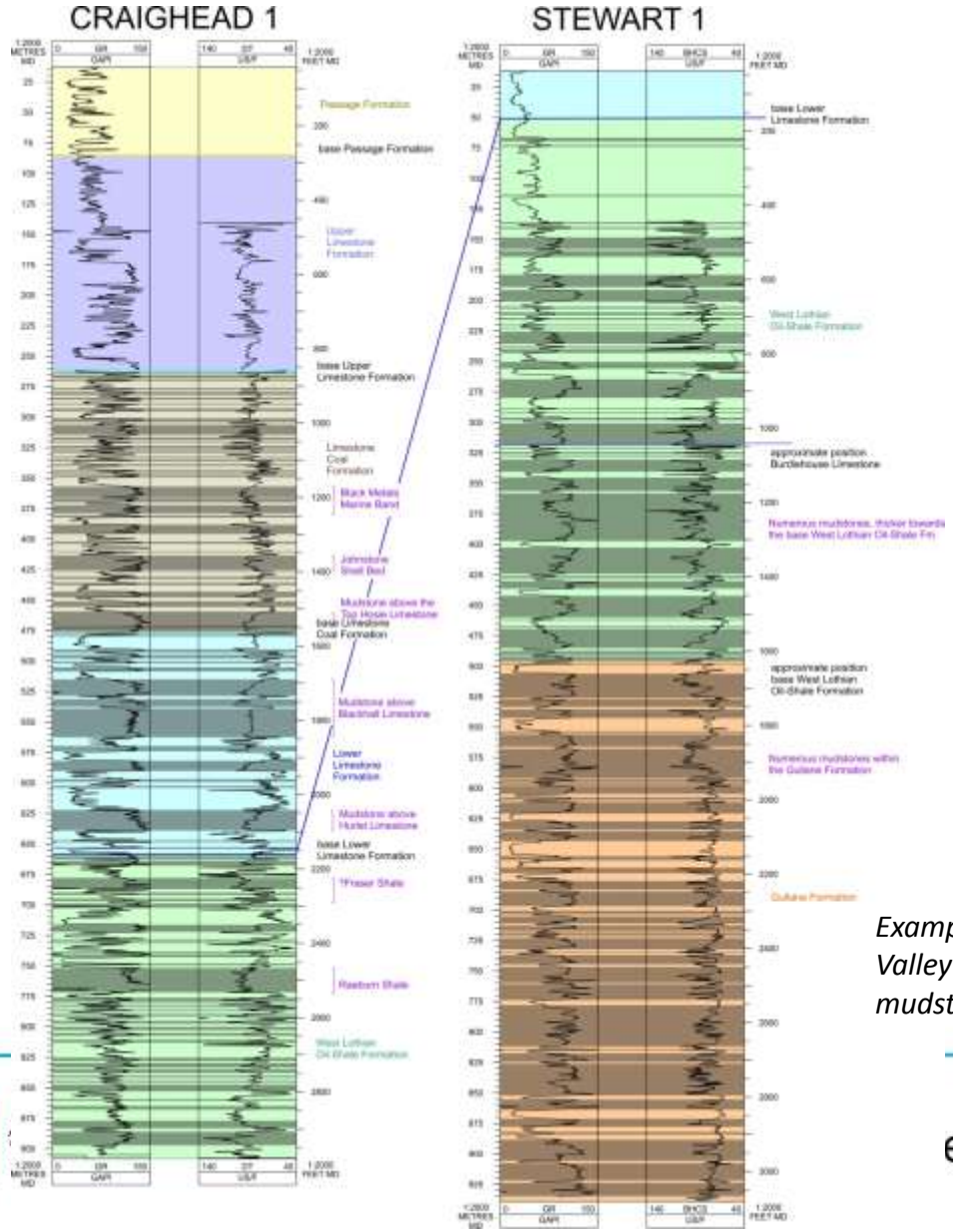


Example of an east-west slice of the 3D geological model, vertical exaggeration x3



Resultant modelled rock volume mature for shale gas for one unit in the Central Coalfield. The volume has properties such as percentage of shale

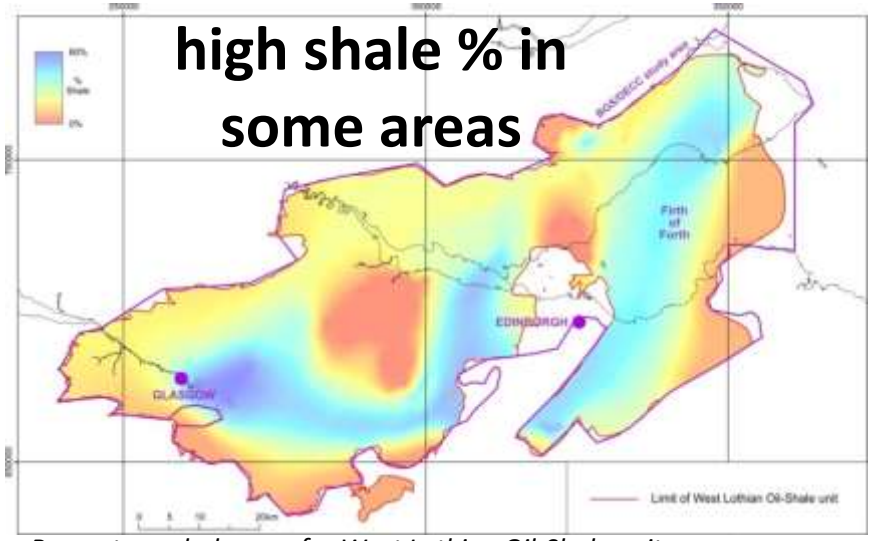
Percentage of shale, in a stacked succession



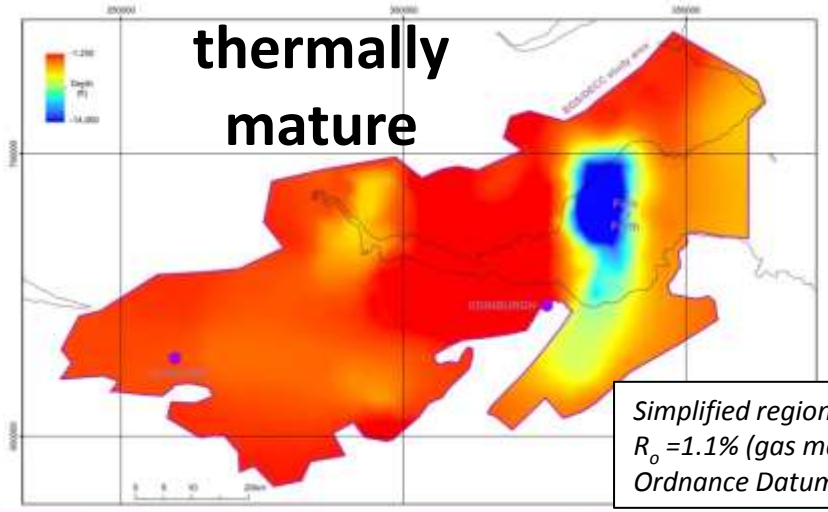
- Shale % varies
- Stacked shales interbedded with other rock types

Example of two well logs illustrating the character of the Midland Valley of Scotland prospective shale succession as numerous mudstones (grey) within a stacked sequence.

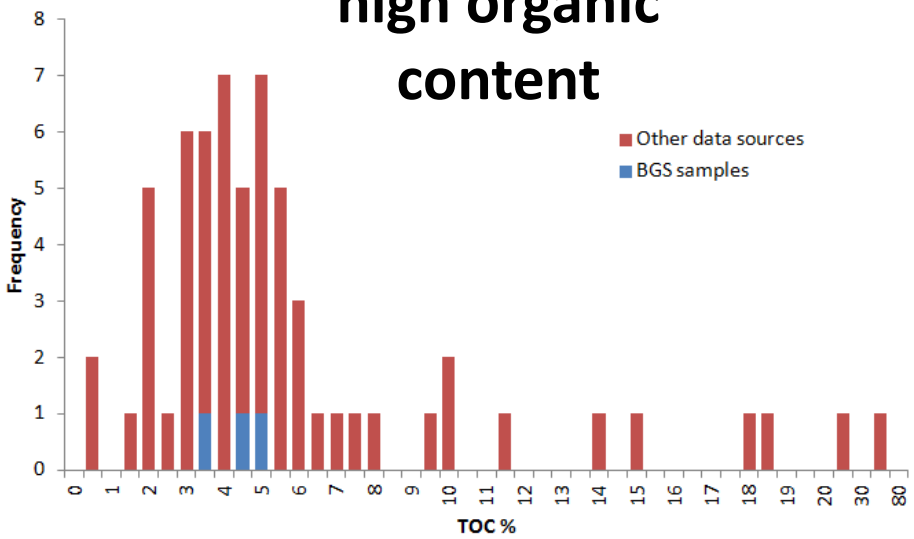
Estimating the mature shale volume - applying the criteria



Percentage shale map for West Lothian Oil-Shale unit.

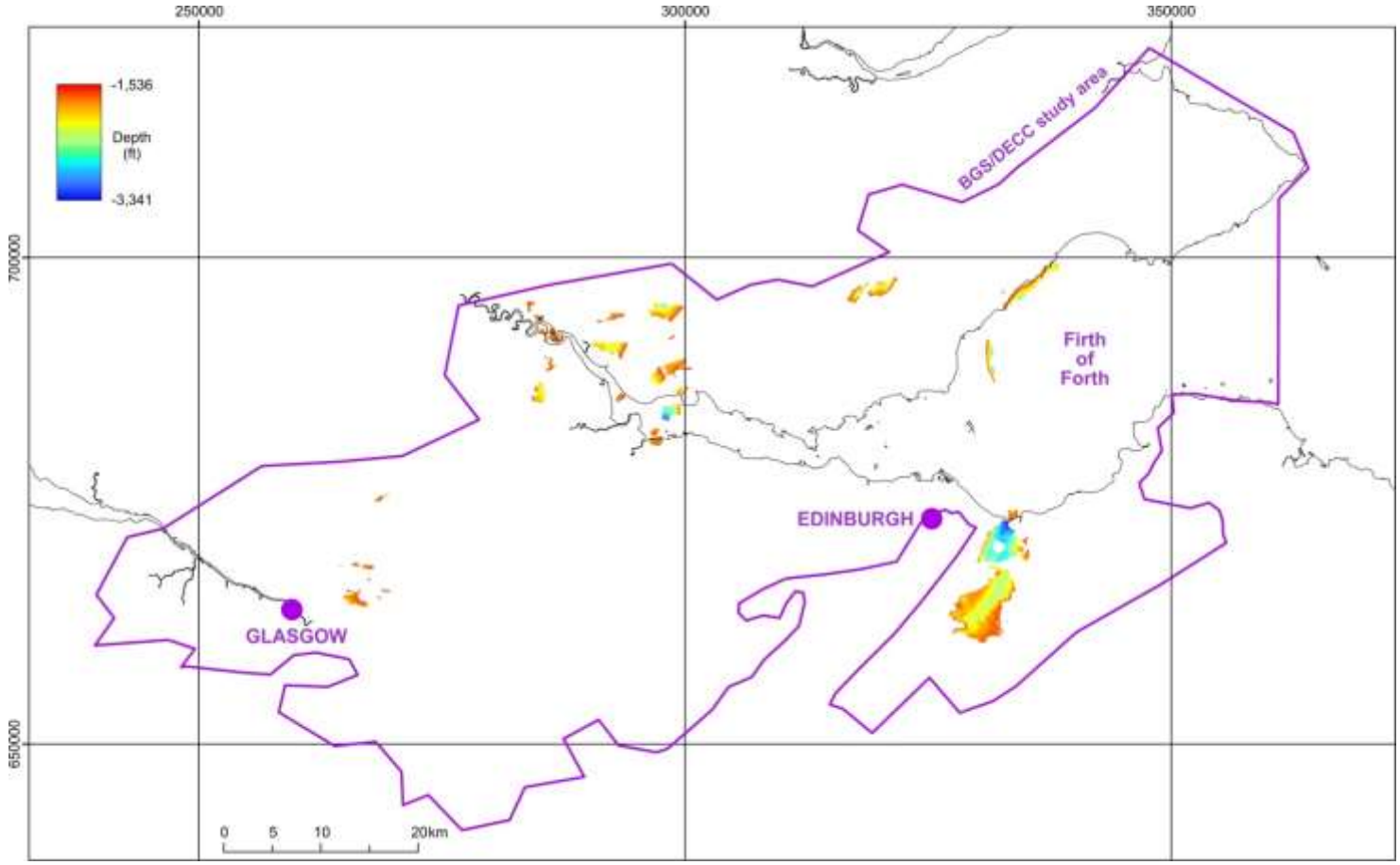


Simplified regional overview of estimated depth to R_o =1.1% (gas mature) in feet referenced to Ordnance Datum.



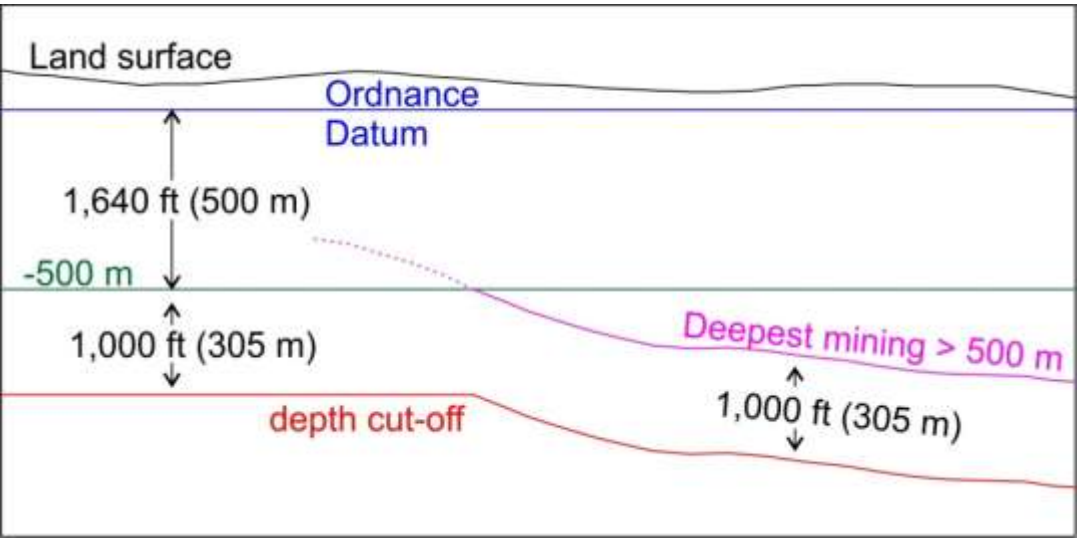
Histogram showing the distribution of TOC measurements (n=62) in the Lower Limestone Formation.

Extent of >500m deep mine workings



Extent and deepest depth of mine abandonment plans greater than 1,640 ft (500 m) relative to Ordnance Datum based on data licensed from The Coal Authority, plus mine abandonment plan information collated by BGS in the Firth of Forth.

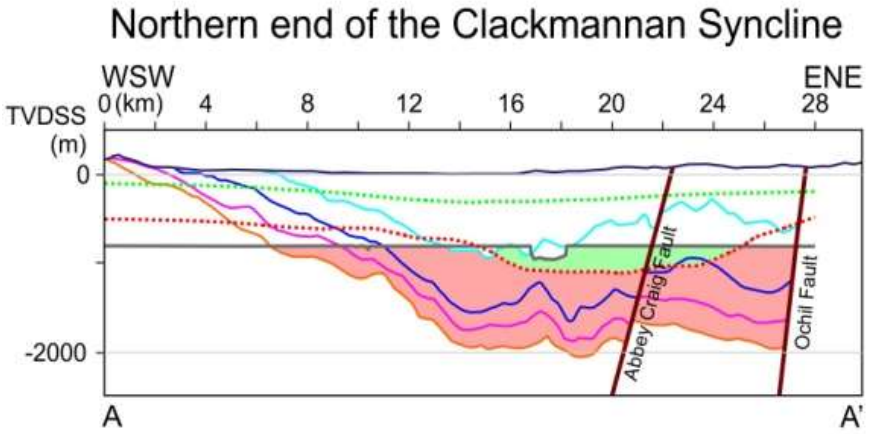
Depth cut-off



Sketch illustrating the depth cut-off used in the resource calculation

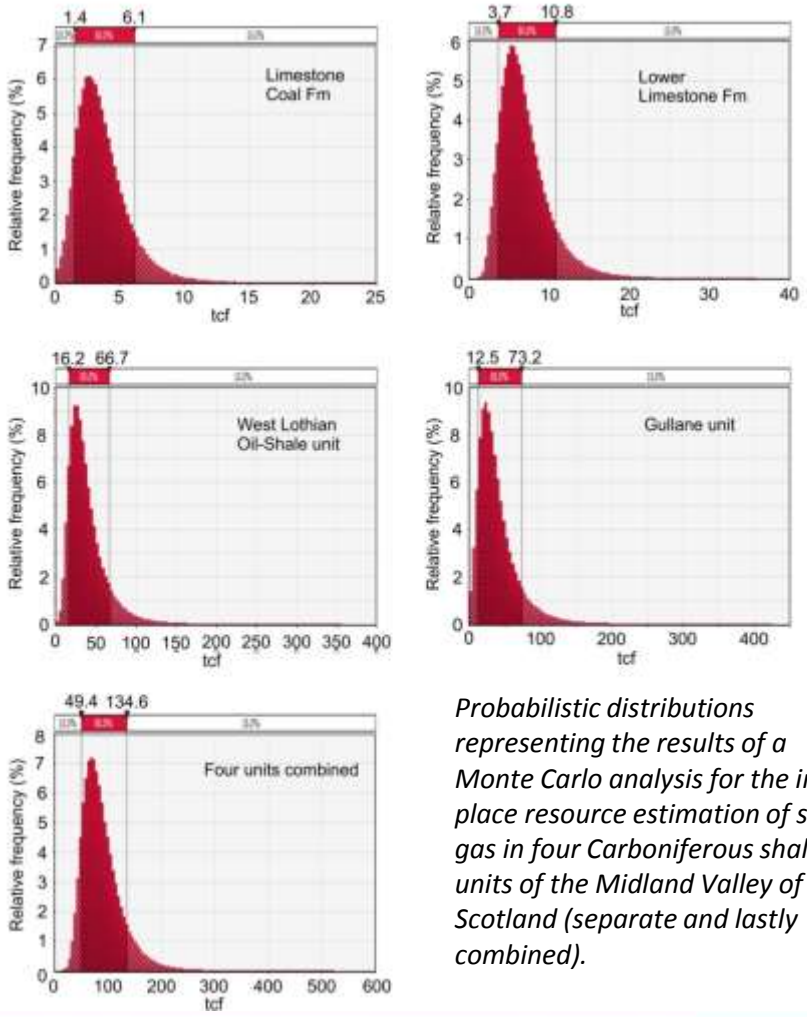
From 3D model rock volumes to…

estimated volumes of shale rock that are mature for oil or gas and have organic contents > 2% below the depth cut-off



Cross-section showing maturity and mining-related depth cut-off surfaces as output from the 3D geological model.

Calculation



Probabilistic distributions representing the results of a Monte Carlo analysis for the in-place resource estimation of shale gas in four Carboniferous shale units of the Midland Valley of Scotland (separate and lastly combined).

Fairly simple equations are used to calculate shale oil and shale gas in place

Calculations are performed to give a range to reflect uncertainty

Results

The **total in-place gas resource** for the Carboniferous shales across the Midland Valley of Scotland beneath the mining-related depth cut-off is

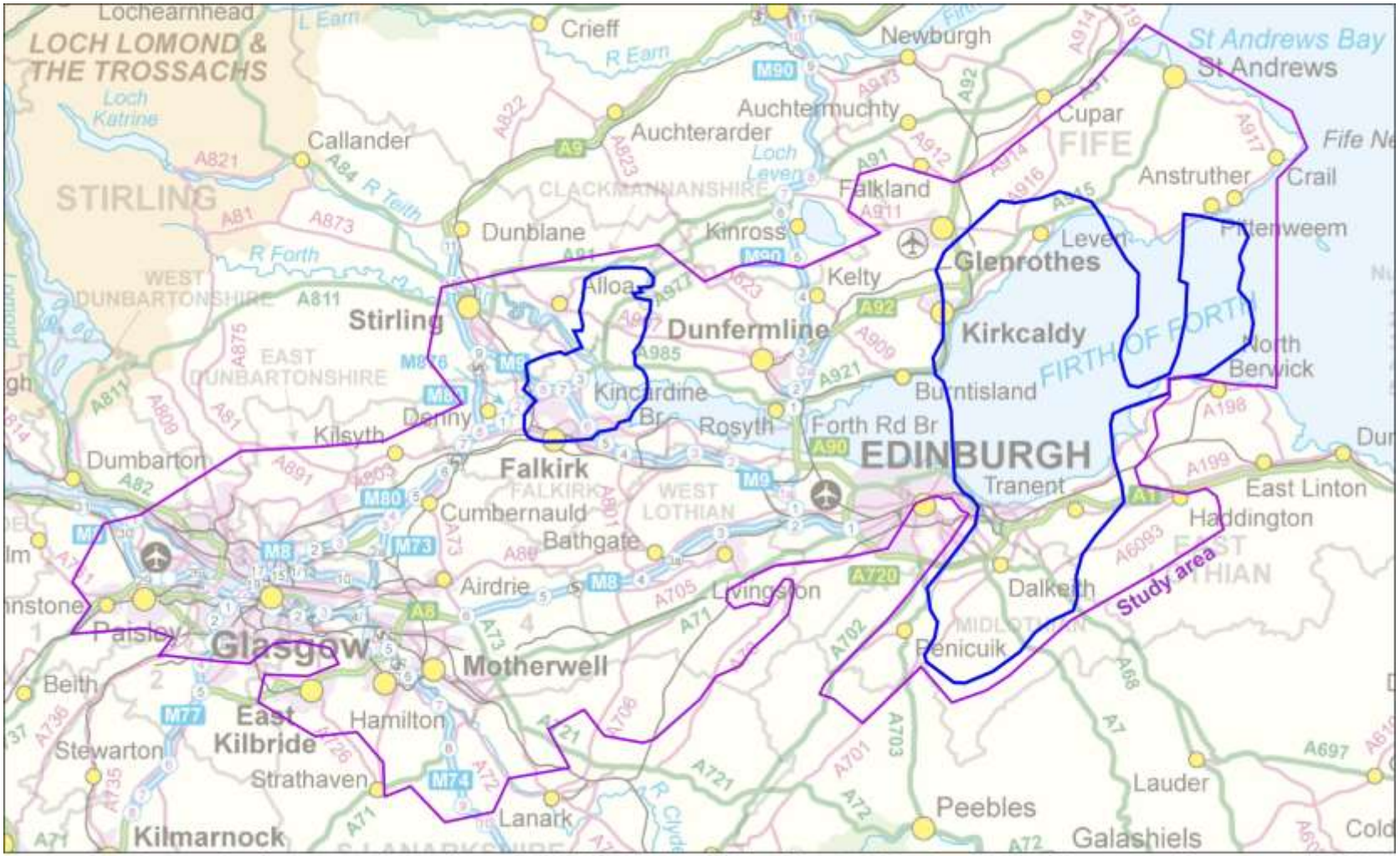
49.4 – 80.3 – 134.6 tcf (1.40 – 2.27 – 3.81 tcm) (P90 – P50 – P10).

The **total in-place oil resource** for the Carboniferous shales across the Midland Valley of Scotland beneath the mining-related depth cut-off is

3.2 – 6.0 – 11.2 billion bbl (421 – 793 – 1,497 million tonnes) (P90 – P50 – P10).

(The resource figures equate to around 10-30 years UK oil and gas production – but note reserve/extractable amounts are likely to be much smaller)

Area prospective for shale oil



Area considered prospective for oil-mature Carboniferous shale (in blue), Midland Valley of Scotland. Contains Ordnance Survey data ©Crown copyright 2014.

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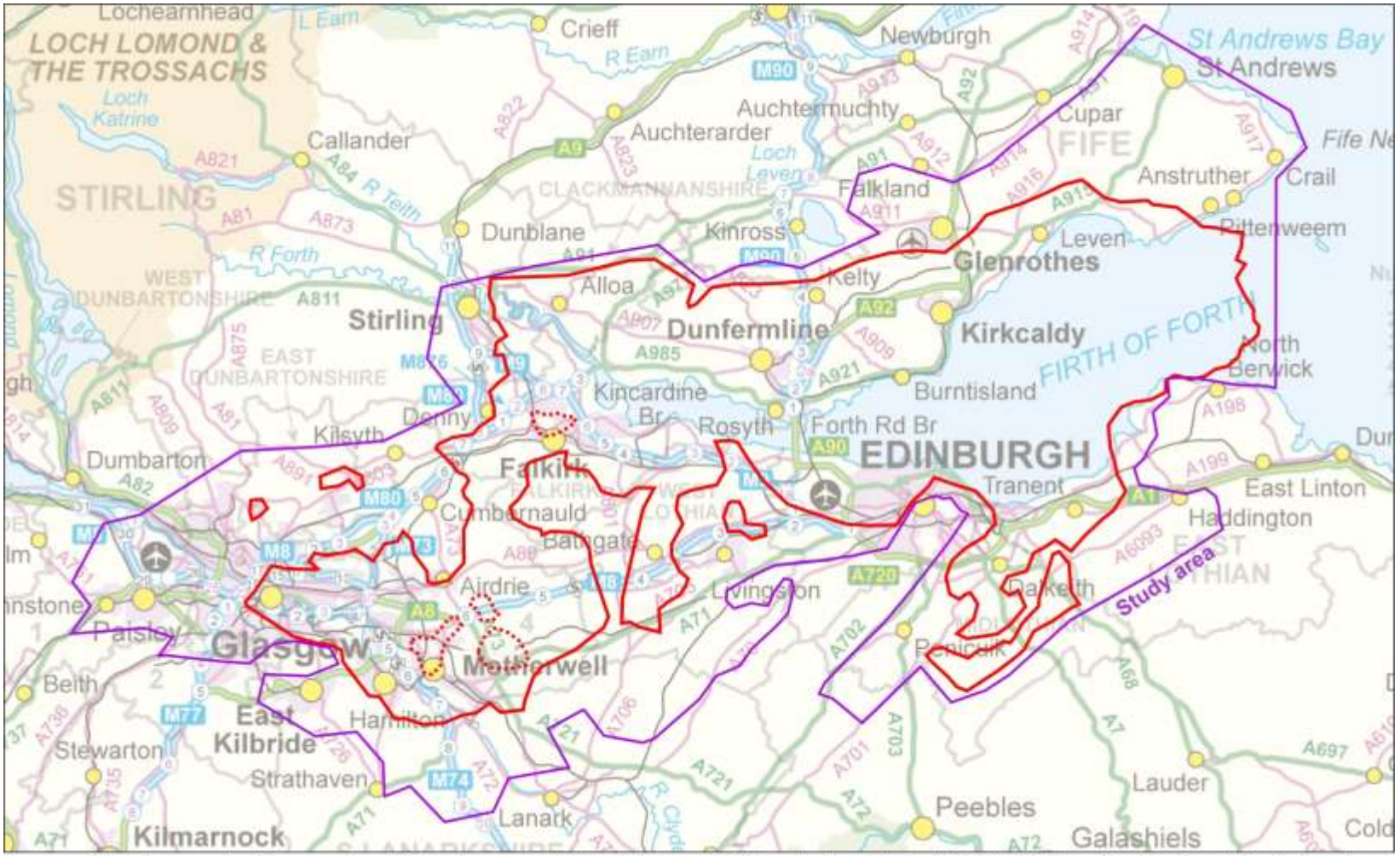
Area prospective for shale gas



Area considered prospective for gas-mature Carboniferous shale (in red, holes within the extent are dashed), Midland Valley of Scotland in relation to the urban areas of central Scotland. Contains Ordnance Survey data ©Crown copyright 2014.

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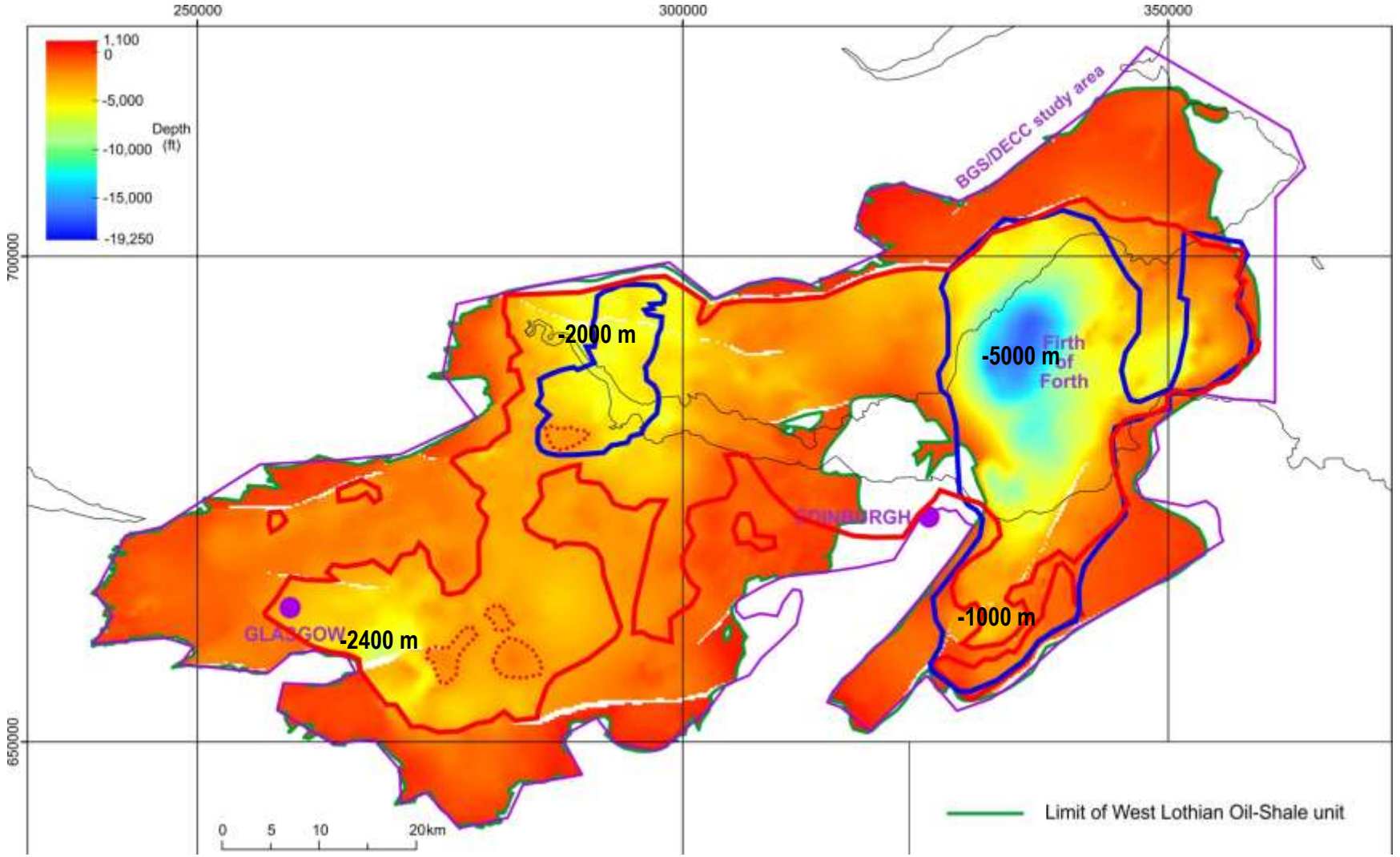
Depth to prospective shale gas resource



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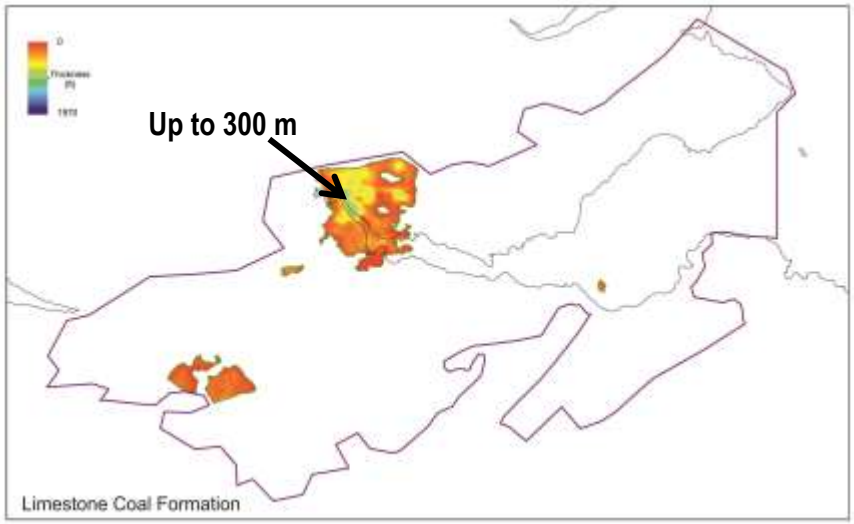
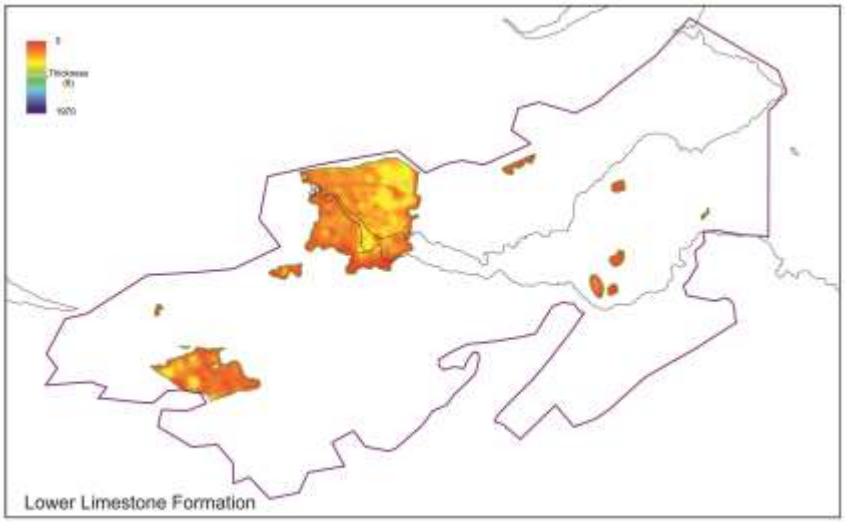
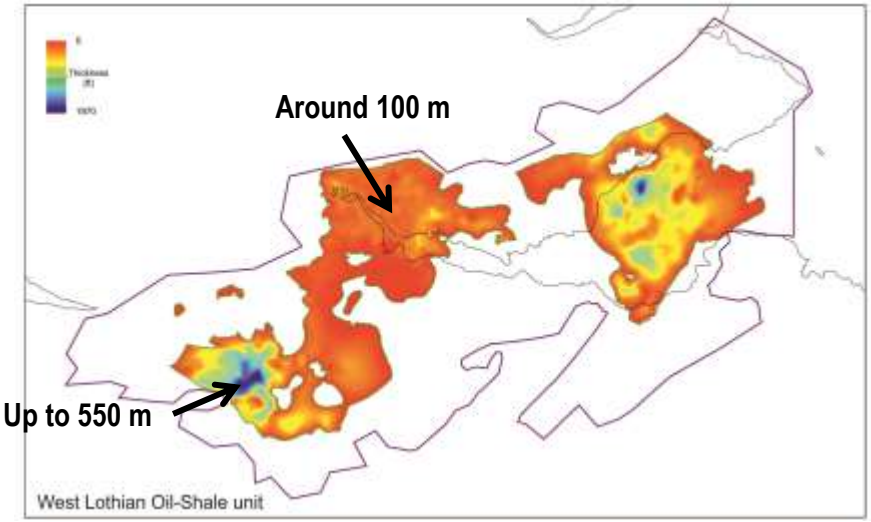
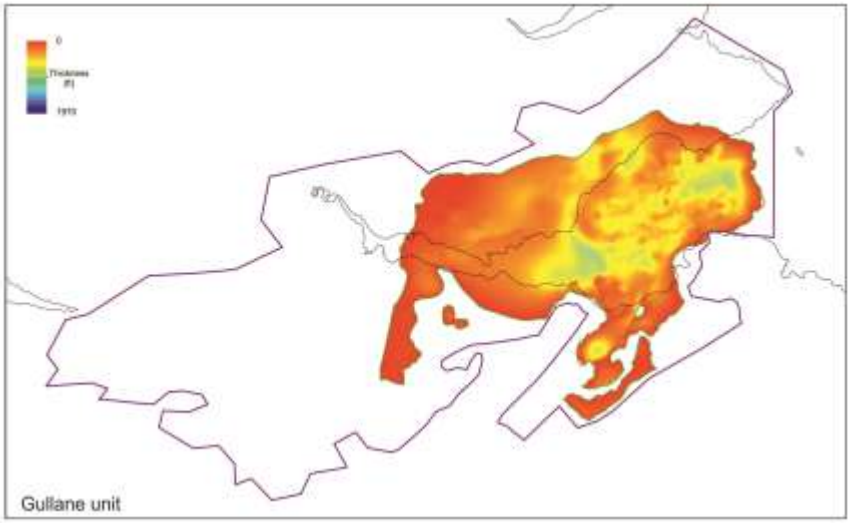
Thicknesses of net mature shale - shale gas









Net mature thickness and distribution of potential shale gas units in the Midland Valley of Scotland using the mining-related cut-off.

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Implications and Conclusions

Positive shale play characteristics	Lacking data or to be studied further
High Total Organic Carbon (TOC)	Faulting, geological complexity
Mature shale at suitable depths	Proximity to old mine workings
Proven hydrocarbon system	Character of oil and gas produced from dominantly non-marine Type I and III kerogen
Stacked shales - numerous opportunities from one well	Shale mineralogy - in a stacked play

Within the mapped prospective areas:

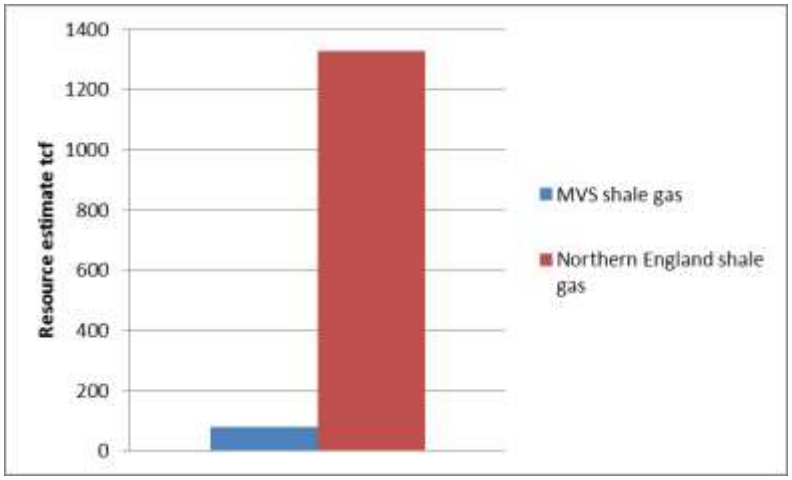
- net mature shale thickness
- shale quality (TOC, bed thickness, kerogen type)
- reliability of the estimation

at any location and depth is highly variable, dependent on data availability and geology.

i.e. some areas are much more favourable for exploration than others

Implications and Conclusions

The volumes of gas estimated to be in-place is much smaller than for Northern England



Exploratory drilling and flow testing from the shale rocks within the basin is required before an estimate can be made of the amount of shale oil and shale gas that might ultimately be recoverable

Regulatory, environmental and societal considerations have not been incorporated into this geological resource assessment

This was a regional scale study - given the geological variability future geological studies should focus at local scale e.g. key questions on recovery/reserve, environmental impact etc

The report and datasets can be downloaded from the DECC website at https://www.gov.uk/oil-and-gas-onshore-exploration-and-production#seismic-and-wells

Background information is available at the BGS website http://www.bgs.ac.uk/research/energy/shalegas/home.html

Ongoing/future BGS work

BGS undertakes a range of shale gas/oil research including:

- *Baseline methane monitoring of groundwater*
- *Seismic monitoring*
- *Organic geochemistry*
- *Fractures, rock physics, anisotropy etc*

Please get in touch if you require further information or have ideas for future work