Why West Cumbria is unsuitable for a deep geological nuclear waste facility

International aspects
Guidelines
What other countries do

History of search in Britain
Up to watershed of 1997 Inquiry

West Cumbria
Geology of northern Allerdale
Political/scientific manipulation
Some progress made during MRWS consultation:

Geology put centre-stage of agenda

Arguments reduced to two rock types:

• Eskdale / Ennerdale granites (Copeland)
• Mercia Mudstone Group (Allerdale)

Sellafield now implicitly ruled out
Evolution of international search criteria

The following organisations agree or have agreed on the same set of broad principles:

• IAEA (pre Nirex 1995 Inquiry guidelines)
• British Nuclear Fuels Ltd
• IAEA – new guidelines 2011
• European Union
• British Geological Survey
• Finnish Geological Survey

None of them put voluntarism ahead of a systematic geological search.
Search practice abroad
Geological search for a waste repository

Abroad:
Geology sorted **before** community involvement:

- Belgium
- Canada
- Finland
- France
- Sweden
- Switzerland
- USA

The 2008 White Paper misleads on:

Sweden and Finland
Summary of fundamental criteria

Drawn from research, experience and recommendations here and abroad since the early 1990s:

• The host rock is NOT so important at the first stage.
• The regional setting of the site IS most important.
• Long geological stability.
• Low hydraulic gradients.
• Simple geology.
• Suitable geology precedes community assent / veto.

Every locality in West Cumbria has a problem with several of these.
History of UK site search up to 1997
Sediments were the only suitable formation identified in Cumbria.
Geology of the areas left in play

Northern Allerdale – the Mercia Mudstone Group

Eskdale and Ennerdale granites (red areas)

Sellafield / Longlands Farm (ancient history or not?)

Areas already excluded
Region, District and Site, as defined by Nirex in West Cumbria.

Site and repository pre-selected - but whole region now very well-understood.
Thanks to Marianne Birkby

Directions of Nirex studies

Systematic search guidance

Nirex 1
Region
North of Workington to South of Barrow-Inland Co-Location

Nirex 2
District
Whitehaven to Ravenglass and off shore 10km

Nirex 3
Site
Sellafield Works, Seascale and Sellafield

Nirex 4
Proposed
Longlands Farm, Farm

Systematic search guidance
Sellafield
Longlands Farm
Host rock: Borrowdale Volcanic Group

• £400M spent
• Rejected by Inquiry

Can it be revived?
What lessons can be learned?
Site search: ‘Coastal sediments’ at Sellafield morphed into a ‘BUSC variant’.

List of 437 UK potential sites

1988 search working maps

(Limestone present)
Geology of the areas left in play

- **Northern Allerdale** – the Mercia Mudstone Group
- Eskdale and Ennerdale granites (red areas)
- Sellafield / Longlands Farm

Areas already excluded
The MMG in Cumbria was excluded by the BGS as a potential host rock during the 1980s national search.
Details from the BGS review of 1986

“areas containing potentially suitable Permian rocks”.

“areas containing potentially suitable Mercia Mudstone Group rocks”.
Dr Dearlove:

“Figure 2.1.1 (b) in Smythe's submission identifies the area including the MMG as "areas of potentially suitable sedimentary rocks" following Dr Chapman's 1986 review. Whilst an assessment may have been made at the time to remove this area from the search for potentially suitable sites, additional data have since been acquired that may, or may not, change that view. These data need to be assessed.”

Detail of map from *The Way Forward* (Nirex, 1987), based on the BGS national search of the mid 1980s.
Sediments of northern Allerdale
A cross-section along line AB is shown in the next figure.
• Not previously considered as a host rock by the BGS.
• A site at Anthorn airfield was considered and rejected in 1988.
• Dr Dearlove (MRWS) has introduced the MMG: “I understand from brief discussions with the BGS that the Mercia Mudstones within this area would also form part of the BGS’s “potentially suitable sedimentary formations”.

So the MMG is in play on the basis of hearsay.
The MMG is an aquifer
Slide from Adrian Bath: 2011 MRWS geology seminar. In the BGS screening report, the MMG is not included in the category of aquifers.
The MMG is a Secondary B aquifer, with current water production. Currently active water wells penetrate not just the Quaternary, but also the MMG to more than 100 m depth.
(Oil and gas, coal, etc.)

BGS draft screening report, July 2010: all of northern Allerdale is completely excluded (minerals), AND partially excluded (groundwater).
BGS screening report:

Volume A of the Sherwood Sandstone is excluded.

But since the MMG is an aquifer it must also be excluded.
The MMG is in an oil and gas exploration province
### BGS draft screening report

#### Natural resources

<table>
<thead>
<tr>
<th>Criteria</th>
<th>To be applied as exclusion criteria (Y/N)?</th>
<th>Reasons/explanations and qualifying comments (from Table B1, Defra, 2008)</th>
<th>Assessment of the geology of the Partnership area judged against the criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Yes</td>
<td>Intrusion risk to depth, only when resource at &gt;100m depth</td>
<td>Includes areas of the Cumbrian (Workington/Whitehaven) Coalfield and Coal Measures, at depth, in the Solway Basin</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>Yes</td>
<td>Intrusion risk to depth</td>
<td>Known oil and gas fields lie to the south of the area [check Solway Basin]; some areas of the Sherwood Sandstone, at depth, might be regarded as prospective</td>
</tr>
</tbody>
</table>

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**Oil and gas exclusion area**

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[Map image with labeled areas for Solway Coast, Carlisle, Wigton, and A74.]
### Table B1: Summary table of initial sub-surface screening criteria

<table>
<thead>
<tr>
<th>Natural resources</th>
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<th>Reasons/explanations and qualifying comments</th>
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<td>Coal</td>
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<tr>
<td>Oil and gas</td>
<td>Yes</td>
<td>Intrusion risk to depth</td>
</tr>
</tbody>
</table>

Defra White Paper 2008 – the only mention of oil and gas

Refers to **JOINT REPORT OF THE CRITERIA PROPOSALS GROUP (CPG) AND THE CRITERIA REVIEW PANEL (CRP)**
(b) Oil and gas

The UK has been thoroughly explored for gas/oil resources, many oilfields have been developed and their distribution is well known. The extent of future exploration and exploitation is difficult to judge and will be dependent on market prices for oil and development of new theories on oil genesis/traps that might lead to novel areas being explored in future.

It is not feasible to predict possible future exploration areas for exclusion but it is appropriate to exclude areas from consideration based on the extent of known oil and gas fields. It is the risk of intrusion into the repository in conjunction with the loss of future oil and gas resource that is addressed by this exclusion.

So the BGS draft screening report was correct to exclude northern Allerdale
BGS exclusion area (red hatching) with the total area of former or current hydrocarbon exploration licences superimposed (diagonal ruling).

So why have rational groundwater and oil/gas exclusions not been consistently applied?
Is the MMG well understood?

Dr Dearlove (MRWS) claims that the area still needs to be assessed – and by the BGS
Survey data required to scope out the Mercia Mudstone Group in Allerdale

2D seismic programme:

100 km onshore, mainly following roads

Cost: £800,000

+ 15 km offshore
  (? If opportune: £25,000)

Three boreholes to 500 m:

Fully cored and logged

Cost: £1,500,000

Total cost (incl. interpretation): c. £2.5M
Existing survey data over Mercia Mudstone Group in Allerdale

**2D seismic data:**
More than 150 km onshore
+ many km offshore

**Boreholes:**

*Abbeytown (1876)*
Geology available to 311 m

*Silloth-1A oil well (1973)*
Fully logged to 1330 m.

*Silloth-2 geothermal well (1982)*
Fully cored and logged to 351 m.

*Westnewton-1 oil well (1983)*
Fully cored and logged to 1976 m.

+ several water wells into MMG, plus gravity and aeromagnetic maps etc.

- All interpreted and published by BGS before the 1986 national search
Results known in time for the 1986 assessment and published by BGS:

- Simple shallow basin
- Cut by large faults

So the geological structure is simple, but fundamentally unsuitable
Is the MMG a good clay rock?
The move to clay

- Internationally, there is a developing preference for clay host rocks:
  - diffusion-controlled transport;
  - self-healing fractures;
  - preservation of past evolution;
  - ‘explorability’.
- UK researchers developed many of the concepts and methodologies currently being applied at clay sites elsewhere.
- However
  - there is a 20-year gap in our own knowledge base;
  - EBS designs must be tailored accordingly.

Graphics courtesy Adrian Bath (BGS ©NERC)
Highways Agency report on UK clays, 2006

“strata considered to behave as ‘stiff plastic clays’ are generally of Jurassic age or younger. These include, for example, the

• Upper Lias Clay,
• Oxford Clay,
• Weald Clay,
• Kimmeridge Clay,
• Gault Clay and
• London Clay.

Older mudrocks of Triassic and Carboniferous age, such as the Mercia Mudstone, are usually too indurated to be considered as clays.”
Mercia Mudstone Group (MMG)
Comparison with Europe

Three European countries have each found a good clay host rock.

Is the MMG up to the job?

The crucial factor is the **hydraulic conductivity**
- How fast the water can flow through the rock

- First, a word on logarithmic scales ...
Annual pay (£) on a logarithmic scale

Logarithmic scale: Each unit of the scale is a factor of 10 increase to the right

Basic UK state pension £5K

Average UK Pay £25K

Average UK GP £110K

Typical US CEO £6M

Highest US CEO £80M

Average UK child’s pocket money £300

David Beckham £25M
Hydraulic conductivities: Synthesis

Switzerland (Opalinus Clay)

France (Callovo-Oxfordian clay)

Belgium (Boom Clay)

England

London Clay

Oxford Clay

Gault Clay

Lias Clay

Mercia Mudstone

Desirable range

Increasing intrinsic permeability (hydraulic conductivity)

Log hydraulic conductivity (Log k) +14 m/s
What the relatively high permeability of the MMG means

50 m Opalinus Clay above repository
Say 1 million years to travel 50 m
Permeability 1 unit
This is a SAFE repository

300 m MMG above repository
Permeability 6 – 8 units
How long to reach surface?
What the relatively high permeability of the MMG Means for escape of toxic waste to the surface

<table>
<thead>
<tr>
<th>Switzerland</th>
<th>Allerdale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slowness of travel: 20,000 year/m</td>
<td>Slowness of travel: 20,000 year/m</td>
</tr>
<tr>
<td>Divided by 1</td>
<td>Divided by 100,000 to 10,000,000</td>
</tr>
<tr>
<td>Multiplied by 50 m thick</td>
<td>Multiplied by 300 m thick</td>
</tr>
<tr>
<td>= 1 million years</td>
<td>= from 60 years to 8 months</td>
</tr>
</tbody>
</table>

UNSAFE
Mercia Mudstone Group (MMG)
Conclusions on permeability

• The MMG is NOT a clay rock

• The MMG is “poorly permeable and is classified as a Secondary B Aquifer” (BGS screening report)

• Its permeability is far too high

• So the MMG is unacceptable as a host rock
- and that is before the faulting (red) is taken into consideration. Only the two major faults are shown.
Where would facilities be sited in northern Allerdale?
Mercia Mudstone Group: target rock for waste dump
Confined to area between BGS excluded zones (red hatching).

The target zone is mostly below 10 m above sea level, so the permanent entrance works would have to be on the higher ground to the south, with 5-10 km long tunnels to the north. But the excavation works could be on the low ground. Red lines – faults; mid-blue lines – depth contours of base of MMG.
Permanent entrance works (?hundreds of years) on higher ground. Excavation works (? 20 years or more) on low ground, along with resulting permanent spoil heaps.
3D view of the proposed French waste repository in clay, applied to Allerdale. NB Allerdale subsurface area 20-23 km².

**Southern works** on higher ground (greater than 10 m above sea level). **Northern works** sited on the very low ground (where MMG thickest). **Spoil heaps** stored in bunds nearby.
Will opposing parish councils and the areas of outstanding national beauty count?
Mercia Mudstone Group: target rock for waste dump
Confined to area between BGS excluded zones (red hatching).

Underground footprint of dump, c. 20 sq km.

NB Placement of the rectangles is arbitrary

Bunds (if 5 m high)

Surface installations

We need to store 15 million cu. m. of useless excavation spoil ....
The Great Pyramid of Cheops (or Kheops) at Giza, Egypt volume 2,500,000 cu. m., 140 m high. London Routemaster bus is shown for scale.

Spoil heaps will not be pyramids but flat-topped mounds called *bunds*. Allerdale dump will produce 6 pyramids of spoil. If 5 m high some 4 sq km (= 400 Ha = 1000 acres) required.
Managing 15 million cu. M. of spoil could be a major groundwater contamination problem

BGS Regional geochemistry atlas
Chromium in stream sediment

“over the Solway Plain, a marked area of high and very high Cr values … covers much of the area, although there are areas with low Cr values … such as between Allonby and Kirkbride, east of Silloth. … The Triassic rocks must therefore be the main Cr source”
Professor Smythe appears to have misunderstood my comments that “a proper evaluation of the available data has not yet been undertaken”. In my opinion, and that of Mr Colin Knipe, only the BGS is capable of making this assessment, and until the BGS undertake and publish such a review the area must remain potentially suitable.

It is primarily on this basis that I suggest that the MMG cannot be rejected at this stage of the MRWS Partnership process as a potential GDF host rock. I also agree with Mr Knipe’s comments that, whilst not currently ruled out, the prospect of finding sufficient volume of suitable rock in the MMG is not promising, it CANNOT AT THIS STAGE BE ENTIRELY RULED OUT.
Scientific conclusion
Mercia Mudstone Group - unsuitable

1. Not previously considered as a host rock by the BGS.
2. Introduced by MRWS in 2011 on hearsay.
3. Current hydrocarbon exploration - should have been excluded.
4. Regional hydraulic gradient is high (but acceptable).
5. Undesirably shallow depth of between 200 and 500 m.
6. Geology is well understood due to oil industry exploration.
8. Very high in chromium (toxic spoil heaps?).
9. The groundwater is fresh.
10. Exploited as an aquifer.
11. Hydraulic conductivity is 100,000-1,000,000 times too high.
12. A leaky seal (cap rock) for hydrocarbons.
13. Cut by large faults which may act as water conduits.
14. Geothermal anomaly – Solway area might have potential.

The MMG might have been introduced as a debating tactic by MRWS - but we cannot be sure.
Misinformation or Non-information?
British Geological Survey (BGS) - advocacy by subterfuge

2002: (Hearsay) BGS director supports return to Sellafield.

2006: BGS: ‘rather more than 30%’ of the UK is potentially suitable.

2006: BGS: high hard-rock mountains are a ‘favourable’ location.

2010: Crucial screening criteria (oil, water) removed.

2011: (Hearsay) MMG now considered a potential host rock by BGS.

2012: ‘Geological Society of London’ support for MRWS process actually emanates from one BGS board member + two employees.

2012: Richard Shaw (BGS) states on BBC radio that West Cumbria “offers potential”.

If Stage 4 goes ahead: Can we trust the BGS?
Review of the geological submissions by Dr Jeremy Dearlove of FWS, commissioned by MRWS, June 2012.

Smythe, Haszeldine, McDonald, Knipe: c. 500 pages of geological evidence
Scrutiny of the process?

Committee on Radioactive Waste Management (CoRWM)

Letter to Colin Wales, March 2012

Response to question about voluntarism before geology:

“It could be argued that the British process has also screened out unsuitable geology before asking communities to volunteer."

…

Your sincerely, Robert Pickard, Chair of CoRWM”
Committee on Radioactive Waste Management (CoRWM)

“... no credible scientific case to support the contention that all of West Cumbria is geologically unsuitable.”

This is NOT TRUE:

• We DO know – it’s a highly studied area
• No stone has been left unturned
• NOWHERE is suitable
• MRWS stage 4 has been done
Decision points – the slippery slope
Each step postpones the real decision: Is the area suitable?

Memo to Councils: once you’re in, you’re in

- Councils locked in from here on
- Govt. to BGS: “Within the Partnership area, where are the most promising localities?”
- Point of no return - BGS starts drilling
- A site is selected

2. Unsuitability screening
3. Decision to participate
4. Desk studies
5. Surface research
6. Underground
Allerdale:

? National centre for encapsulation of waste before burial?
Cumbria CC

Allerdale BC

Copeland BC

Economy

Environment

Dubious benefits

? National sacrifice
Fin