

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

International aspects

Guidelines

What other countries do

Geology of **Allerdale**

Political/scientific manipulation

Hubris of nuclear engineers

Some progress made during/since 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

Decisions by the 3 councils postponed

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.

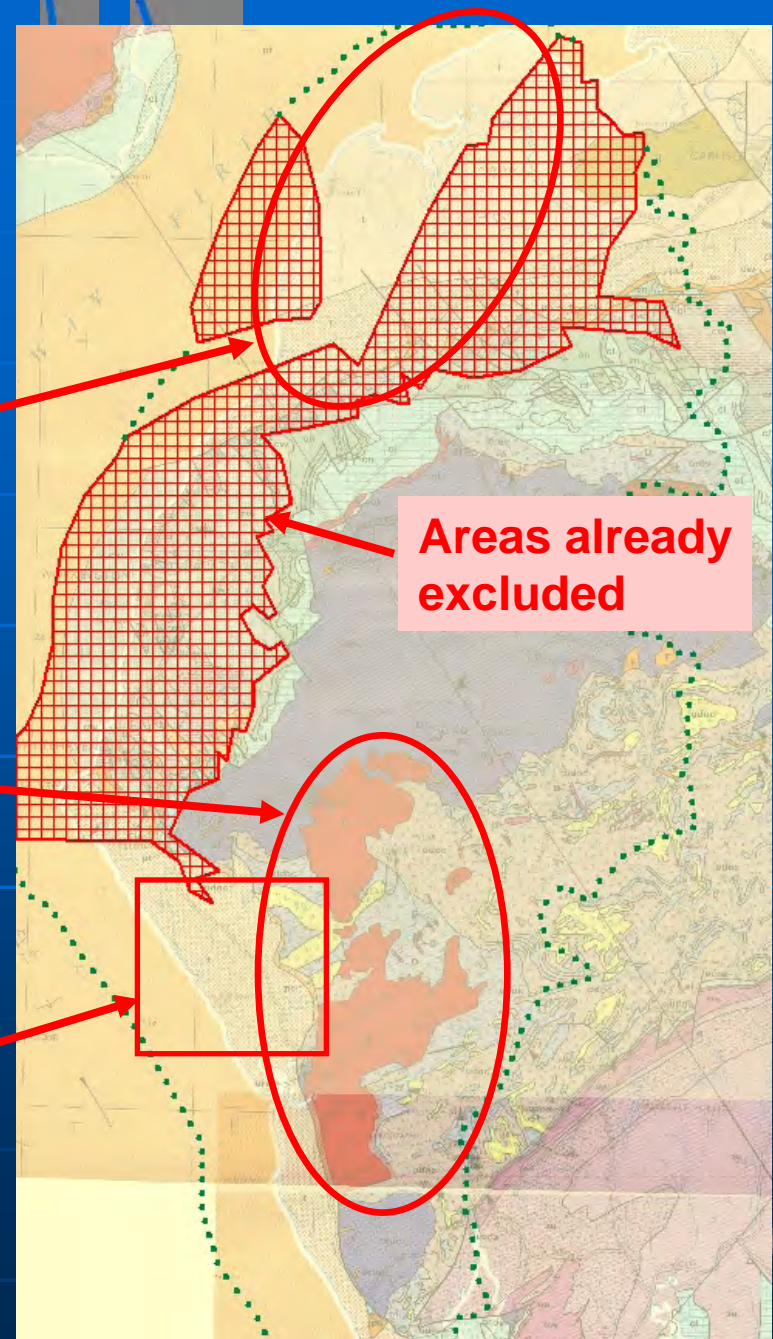
Every locality in West Cumbria has a problem with several of these.

Geology of the areas left in play

**Northern Allerdale –
the Mercia Mudstone
Group**

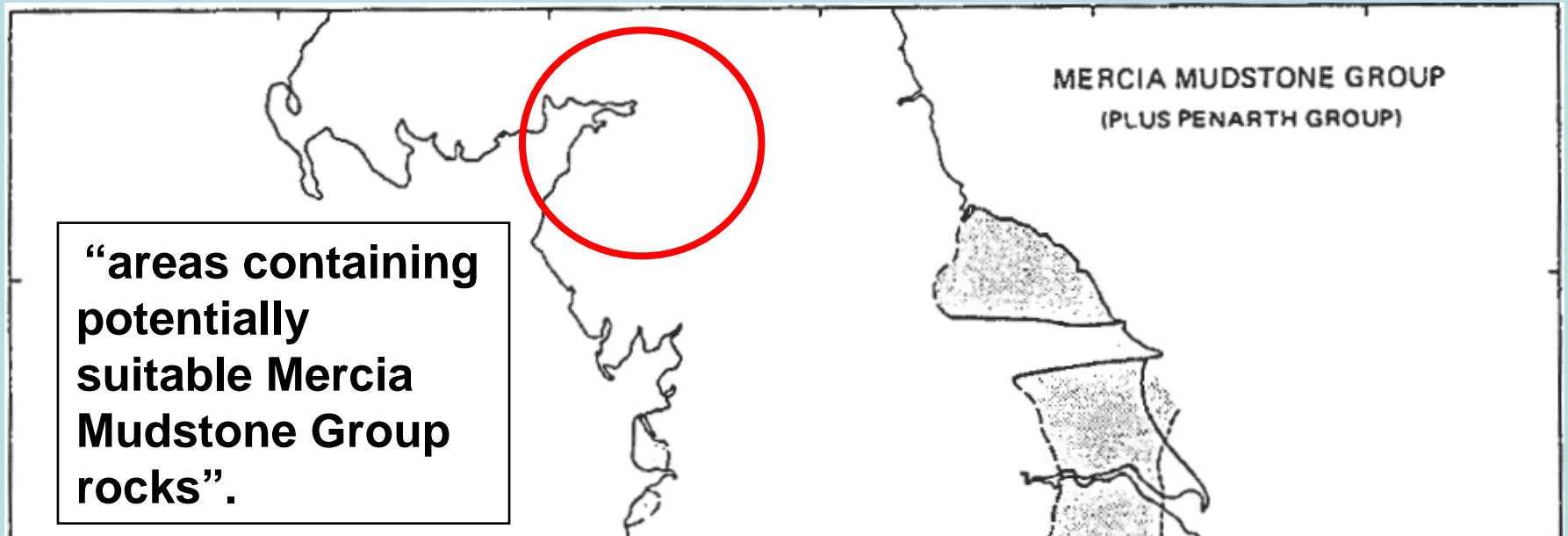
**Eskdale and Ennerdale
granites (red areas)**

Sellafield / Longlands Farm



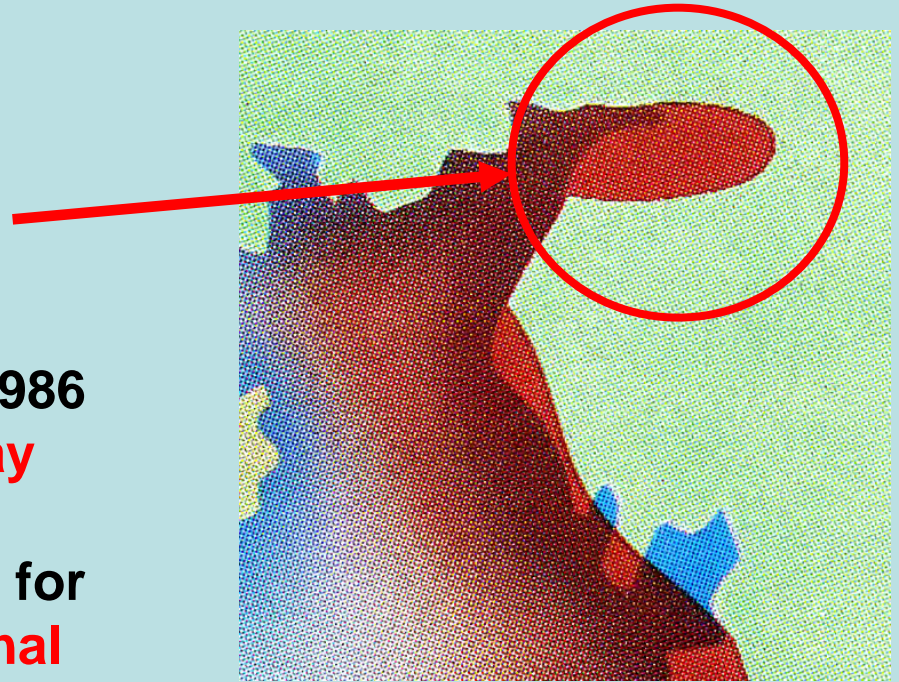
The MMG in Cumbria was excluded by the BGS as a potential host rock during the 1980s national search

Details from the BGS review of 1986

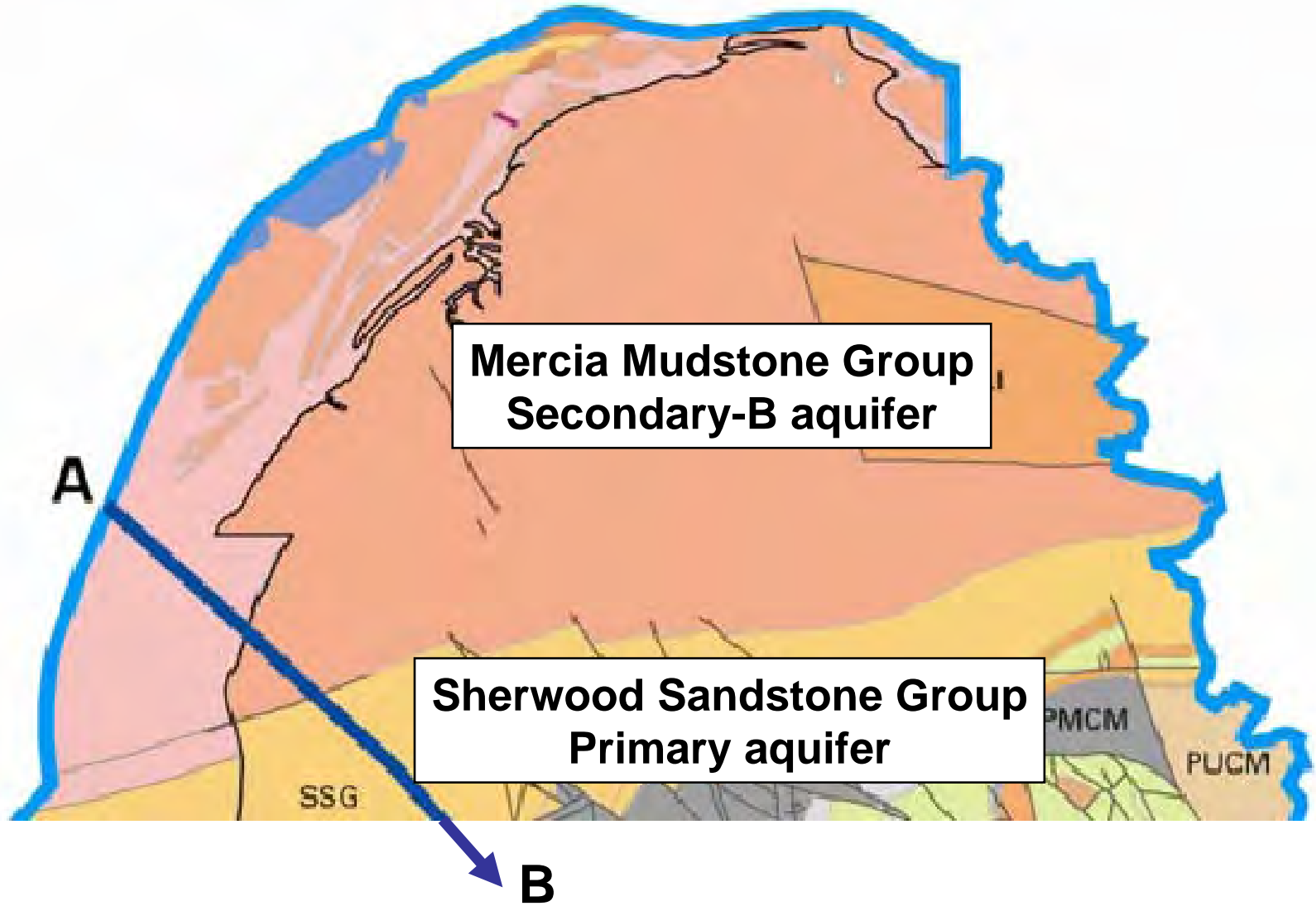


Dr Dearlove:

“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

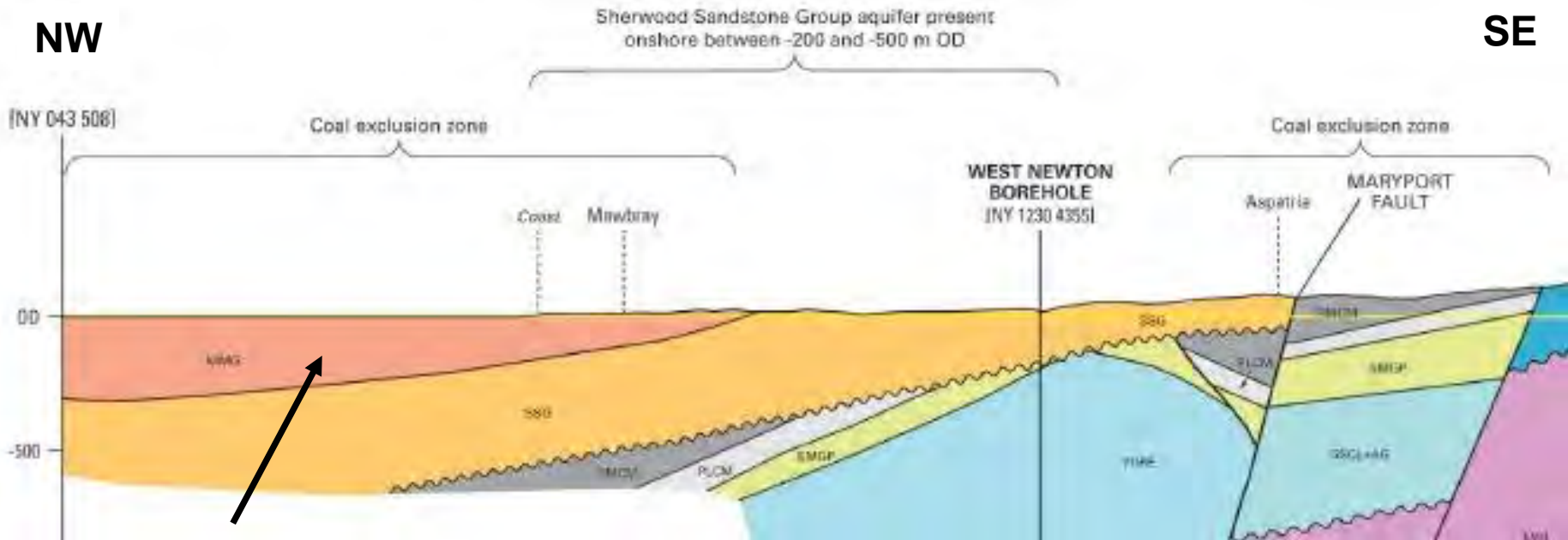


Sediments of northern Allerdale

A cross-section along line AB is shown in the next figure.

NW

SE



Mercia Mudstone Group

Cross-section: Aspatia to Solway Firth

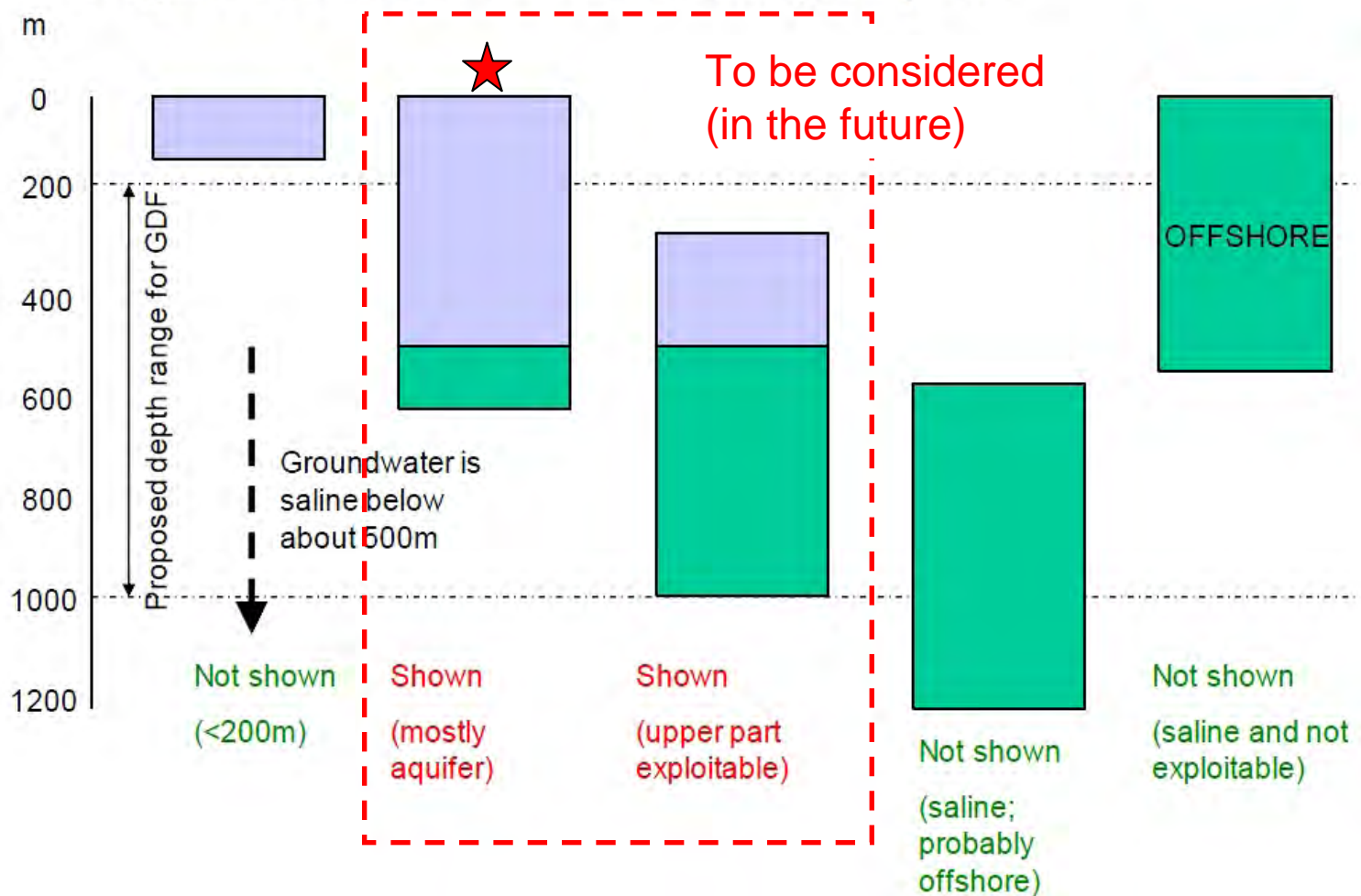
Mercia Mudstone Group

- 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.

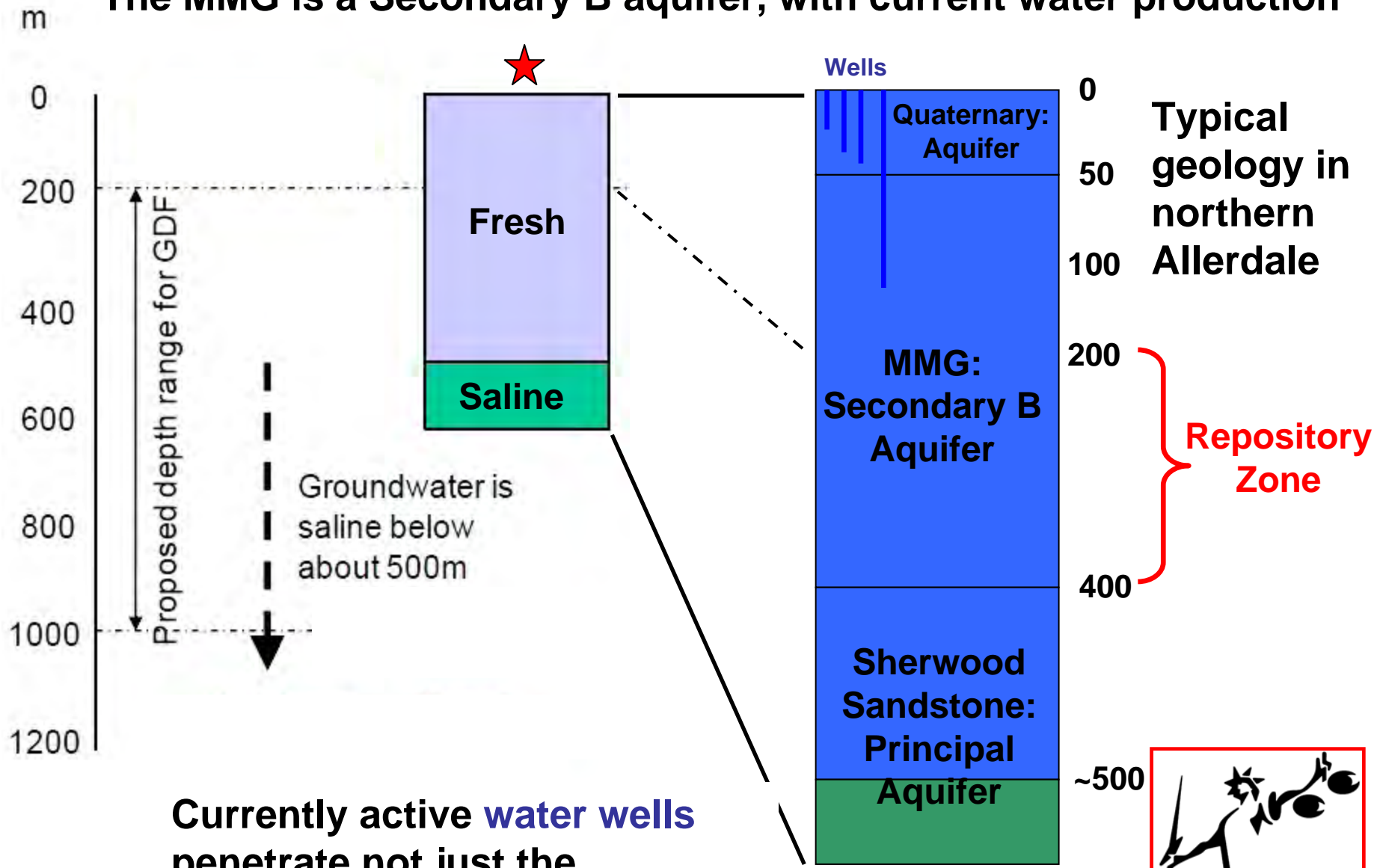
The MMG is an aquifer

Illustrations of where 'aquifer' is marked in Figure 13 in BGS screening report



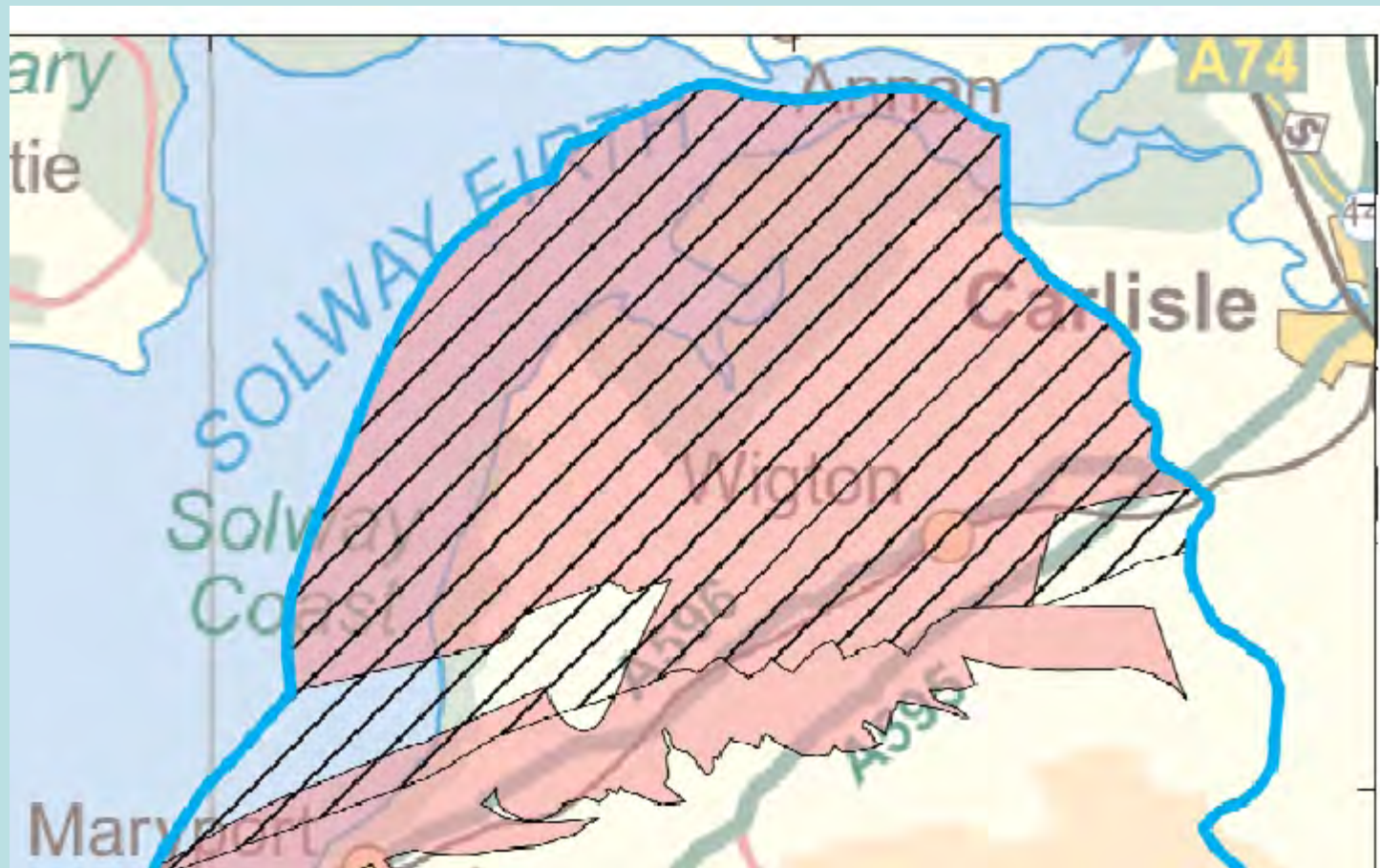
Slide from Adrian Bath: 2011 MRWS geology seminar. In the BGS screening report the MMG is not included in the category of aquifers.

The MMG is a Secondary B aquifer, with current water production



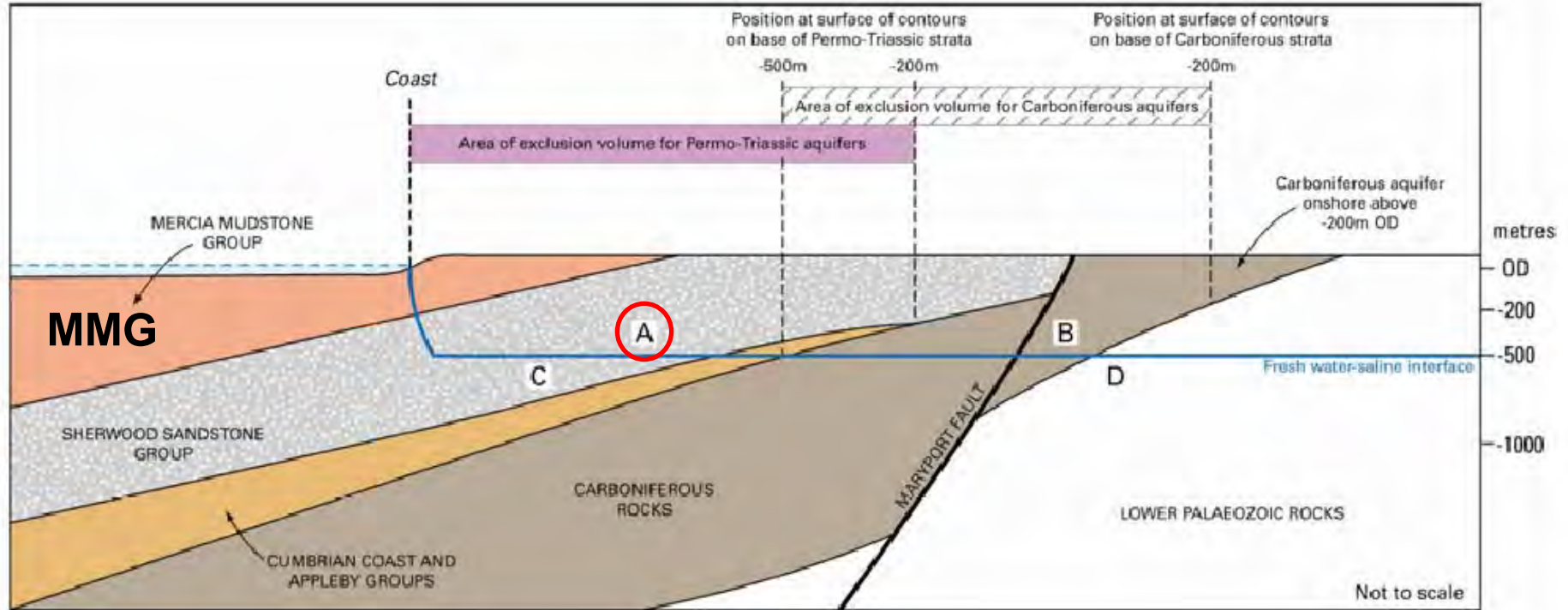
Currently active **water wells** penetrate not just the Quaternary, but also the MMG to more than 100 m depth.





(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.**

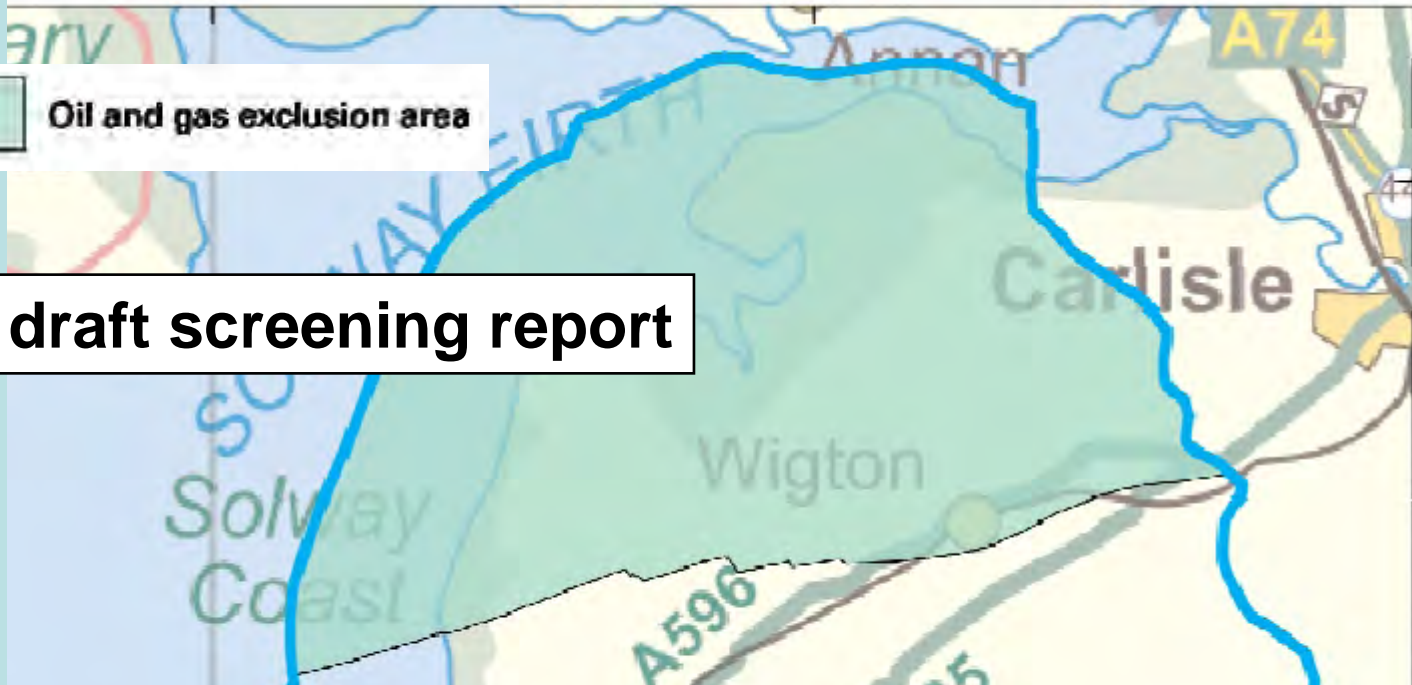
But since the MMG is an aquifer it must also be excluded

The MMG is in an
oil and gas
exploration
province



Oil and gas exclusion area

BGS draft screening report



Criteria	To be applied as exclusion criteria (Y/N)?	Reasons/explanations and qualifying comments (from Table B1, Defra, 2008)	Assessment of the geology of the Partnership area judged against the criteria
Natural resources			
Coal	Yes	Intrusion risk to depth, only when resource at >100m depth	Includes areas of the Cumbrian (Workington/Whitehaven) Coalfield and Coal Measures, at depth, in the Solway Basin
Oil and gas	Yes	Intrusion risk to depth	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

Table B1: Summary table of initial sub-surface screening criteria

	To be applied as exclusion criteria?	Reasons/explanations and qualifying comments
Natural resources		
Coal	Yes	Intrusion risk to depth, only when resource at >100m depth
Oil and gas	Yes	Intrusion risk to depth

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)**

JOINT REPORT OF THE CRITERIA PROPOSALS GROUP (CPG) AND THE CRITERIA REVIEW PANEL (CRP)

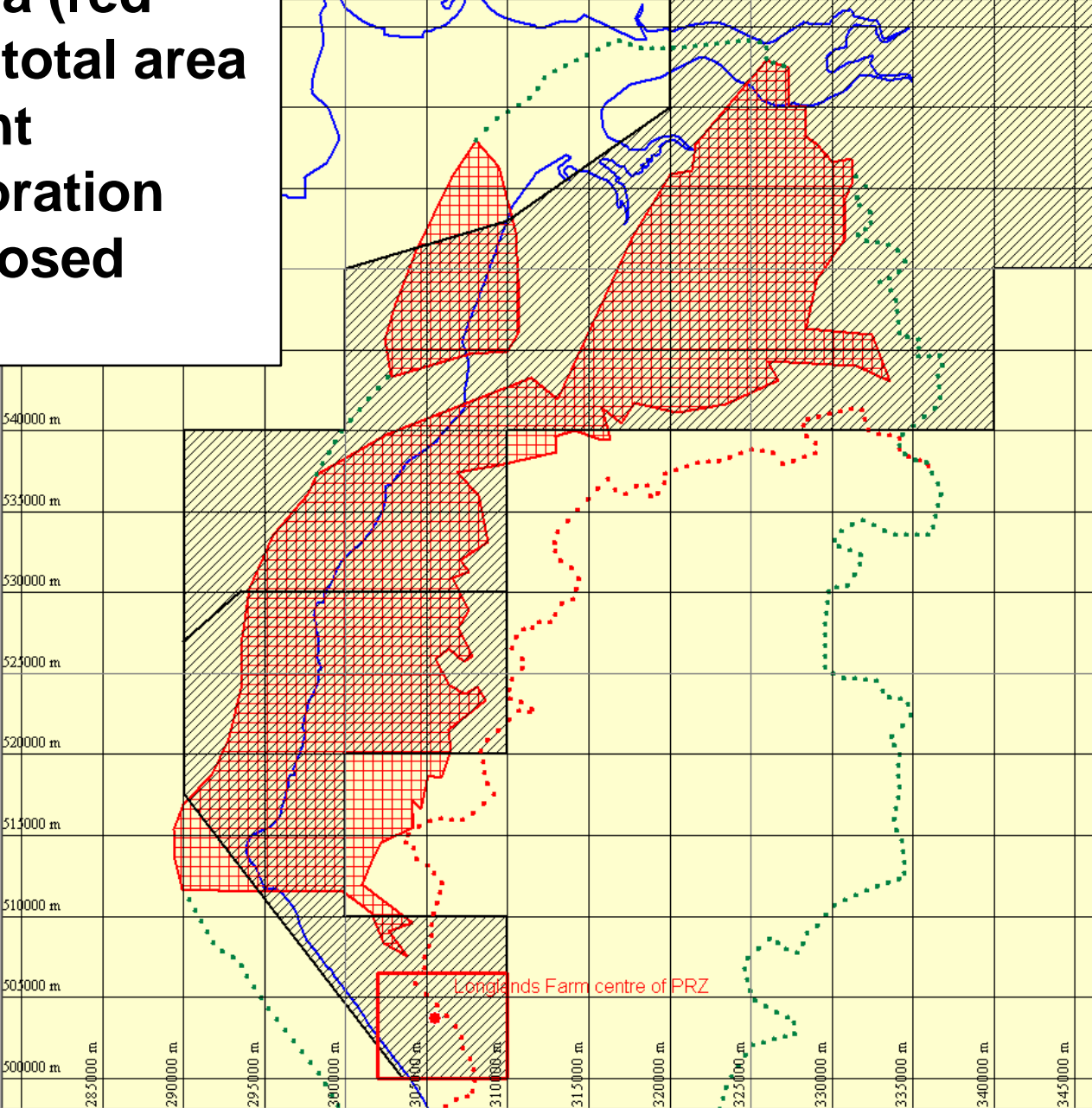
(b) Oil and gas

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

Hypothetical 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**)

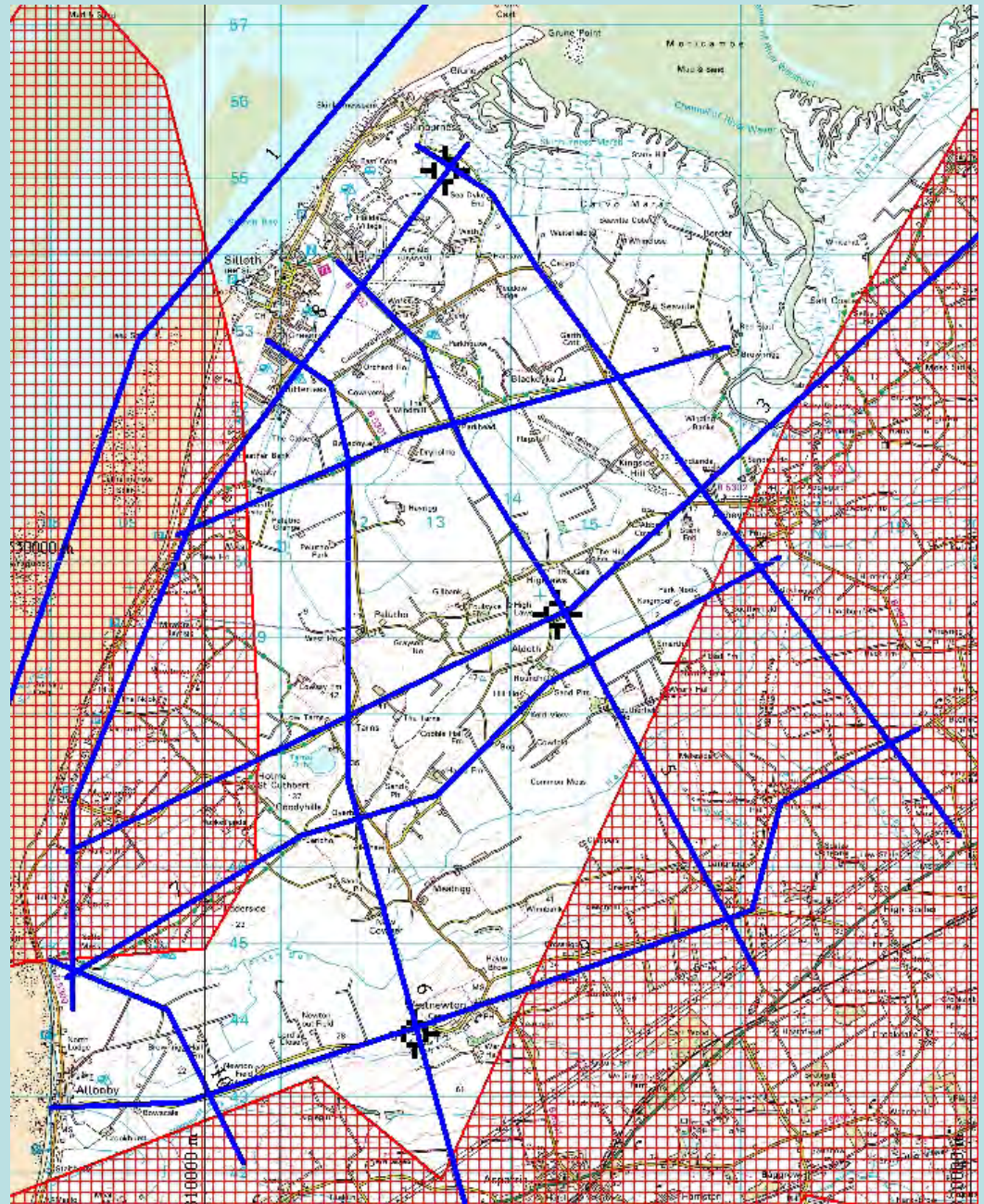
Three boreholes to 500 m:

Fully cored and logged

Cost: **£1,500,000**

Total cost (including interpretation):

£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

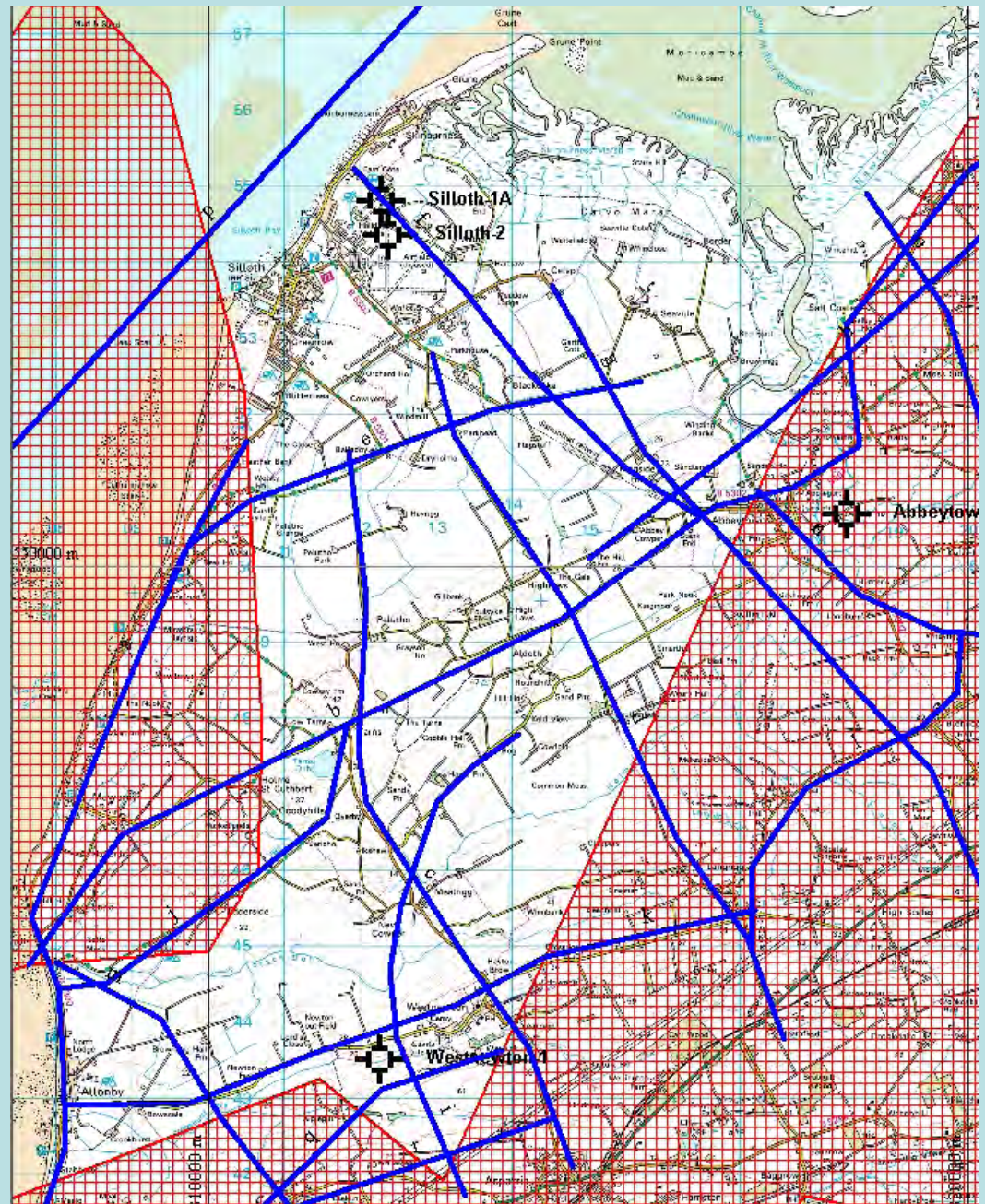
Silloth-1A oil well (1973)
Fully logged to 1330 m.

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.

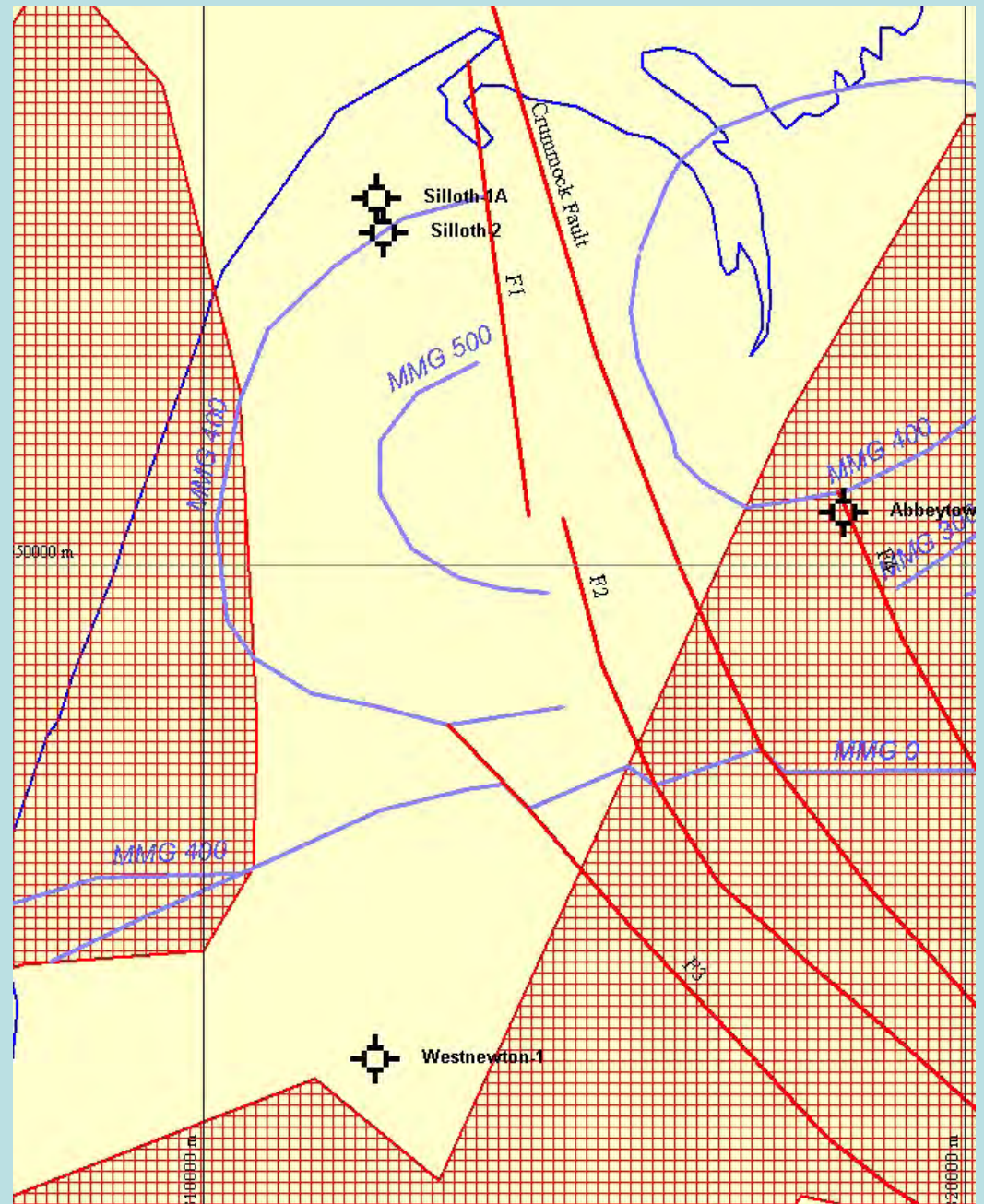
**- All interpreted and
published by BGS before
the 1986 national search**



Results known in time
for the 1986
assessment and
published by BGS:

- Simple shallow basin
- Cut by large faults

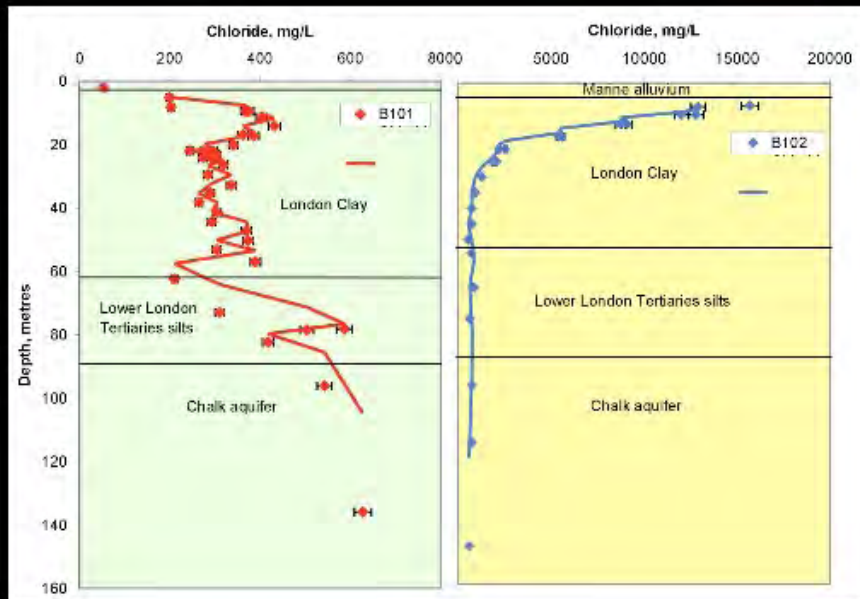
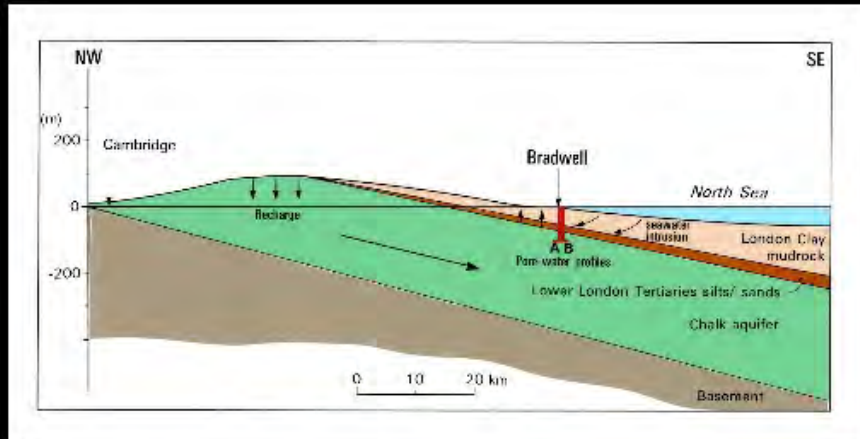
So the geological
structure is simple, but
fundamentally
unsuitable



Is the MMG a good clay
rock?

From David Savage, 2006

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.**”*

NB local name for Solway MMG is **Stanwix Shale**

Mercia Mudstone Group (MMG)

Comparison with Europe

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

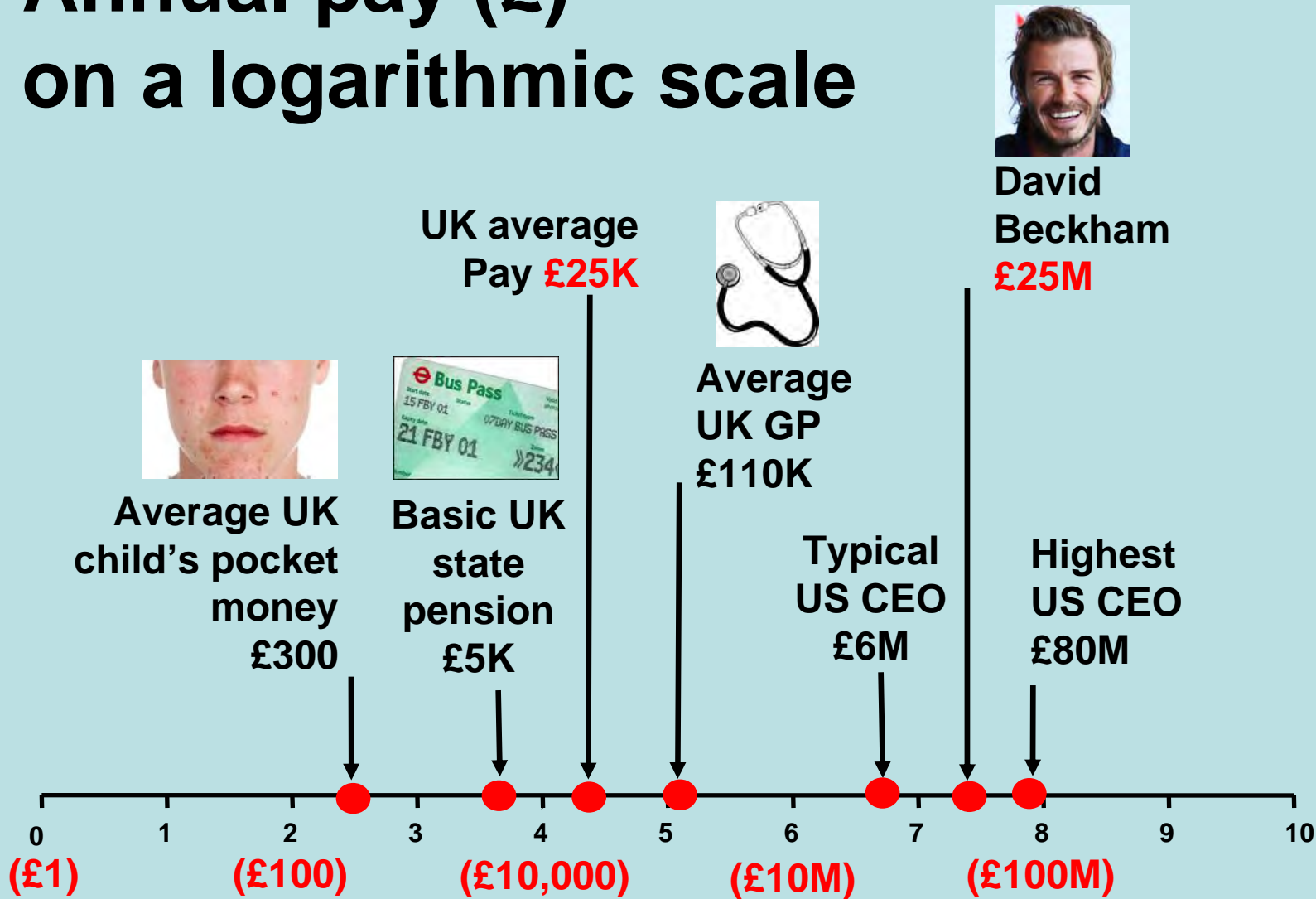
Is the MMG up to the job?

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

Hydraulic conductivities: Synthesis



Switzerland (Opalinus Clay)



France (Callovo-Oxfordian clay)



Belgium (Boom Clay)

Abroad

England



London Clay



Oxford Clay



Gault Clay



Upper



Lower

Lias Clay



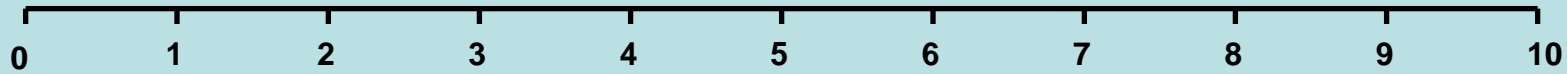
Desirable range



Mercia Mudstone

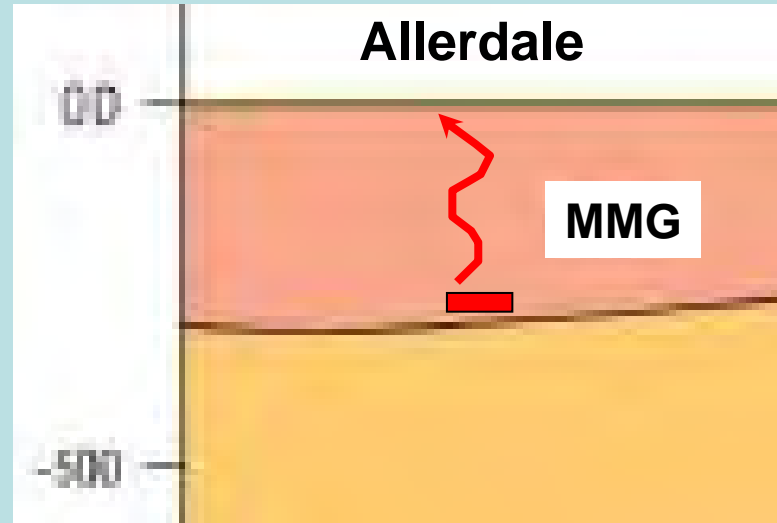
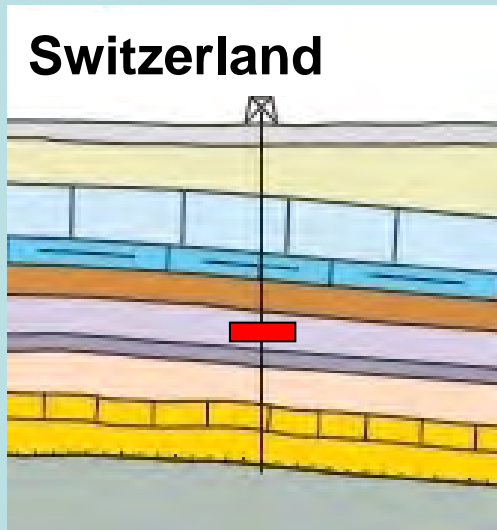


Increasing intrinsic permeability (hydraulic conductivity)



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 ?

Switzerland



50 m thick
Safe for 1 million years

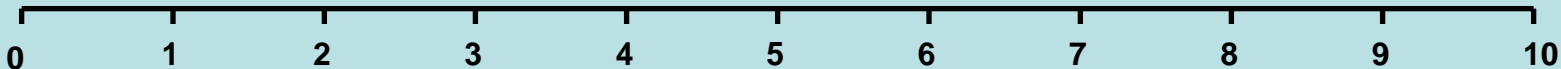
Uncertainty:
100,000 years
10 million years

**Safety of Swiss and
Allerdale sites:**
Time for escape of toxic
waste to the surface

Mercia Mudstone
300 m thick
Safe for 6 years
Uncertainty:
8 months
60 years



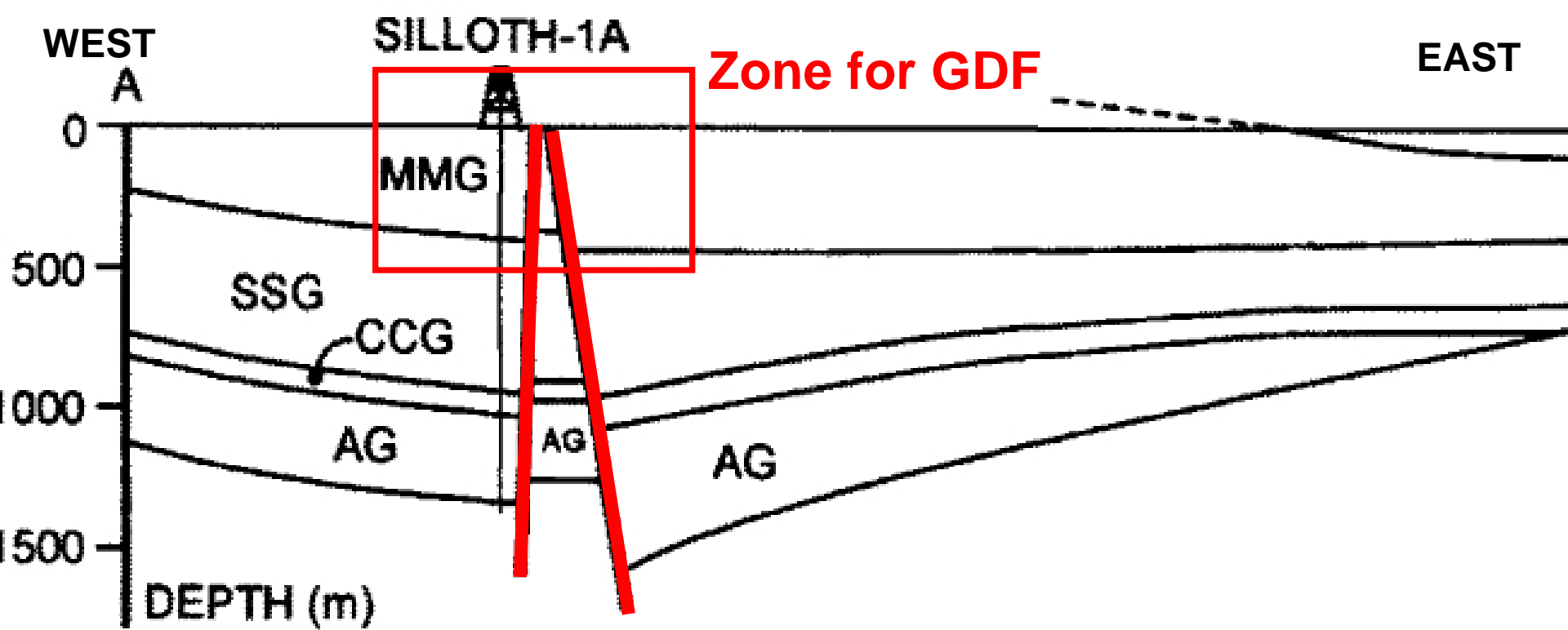
→ Increasing permeability



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





BGS cross-section through northern Allerdale

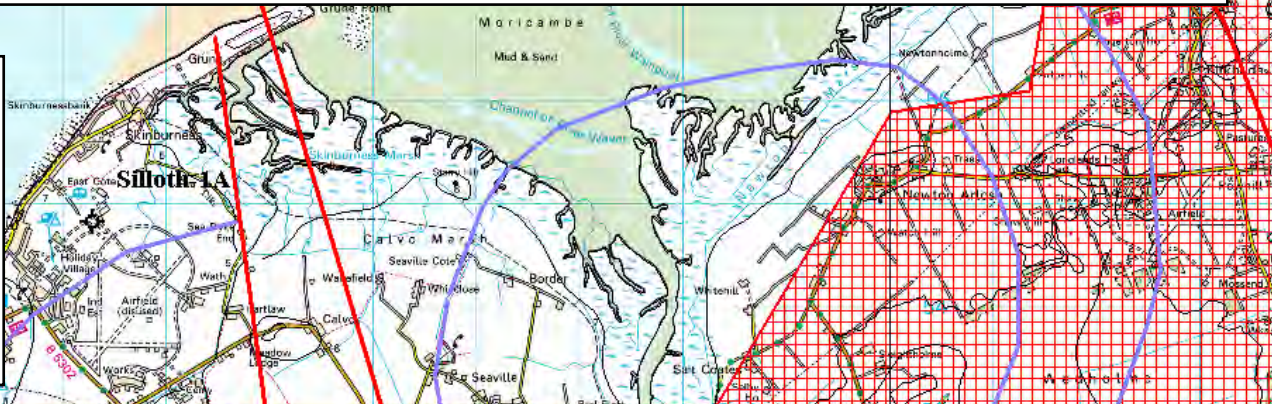
- and that is before the faulting (**red**) is taken into consideration. Only the two major faults are shown.

Where would surface
installations 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.



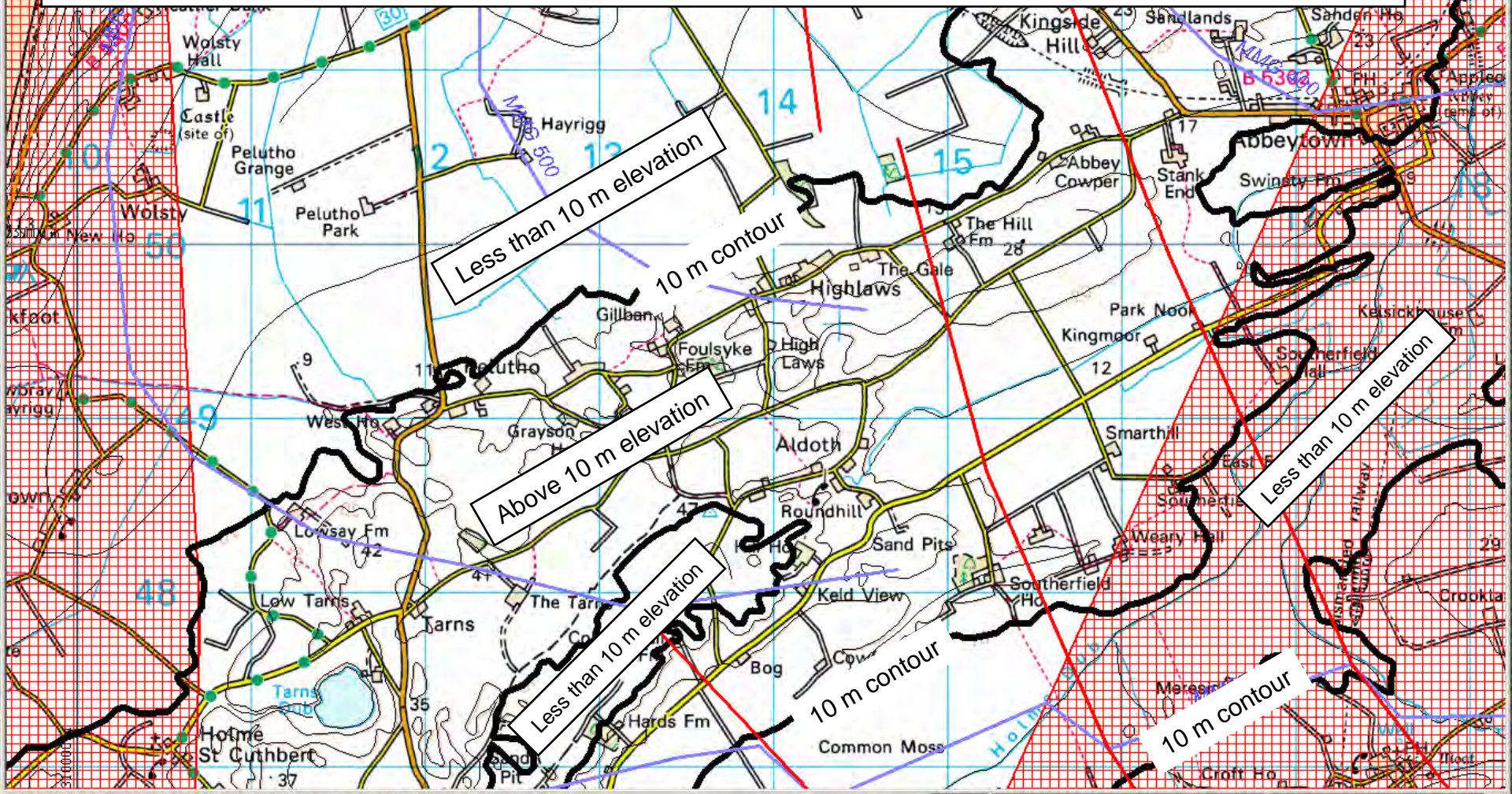
Target area for dump

Excluded area

Excluded area

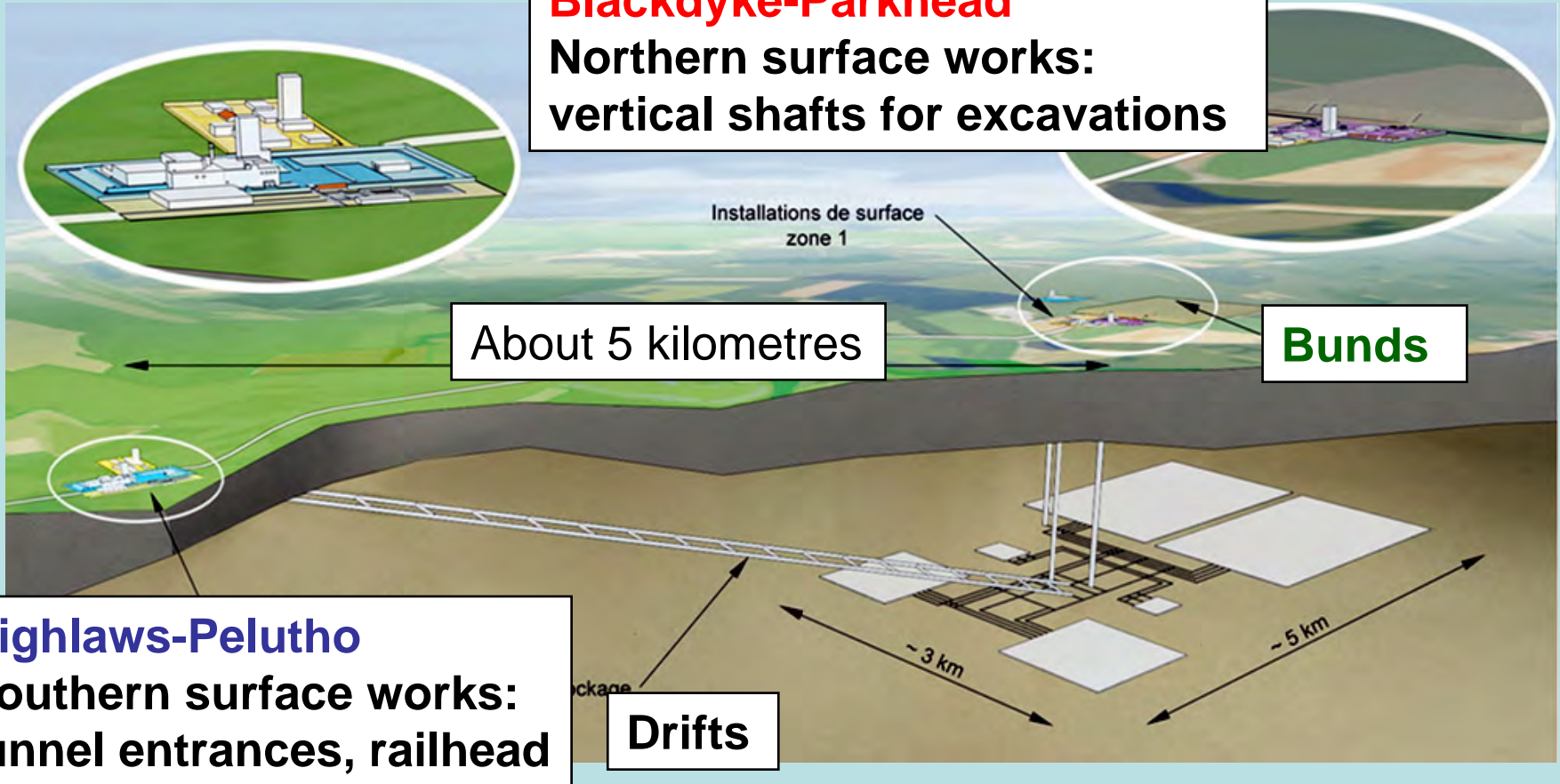
10 m contour
Above 10 m elevation

Permanent entrance works (?hundreds of years) on higher ground. Excavation works (? 20 years or more) on low ground, along with with resulting permanent spoil heaps.



Blackdyke-Parkhead

Northern surface works:
vertical shafts for excavations



Highlaws-Pelutho

Southern surface works:
tunnel entrances, railhead

Drifts

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.

Mercia Mudstone Group: target rock for waste dump

Confined to area between BGS excluded zones (red hatching).

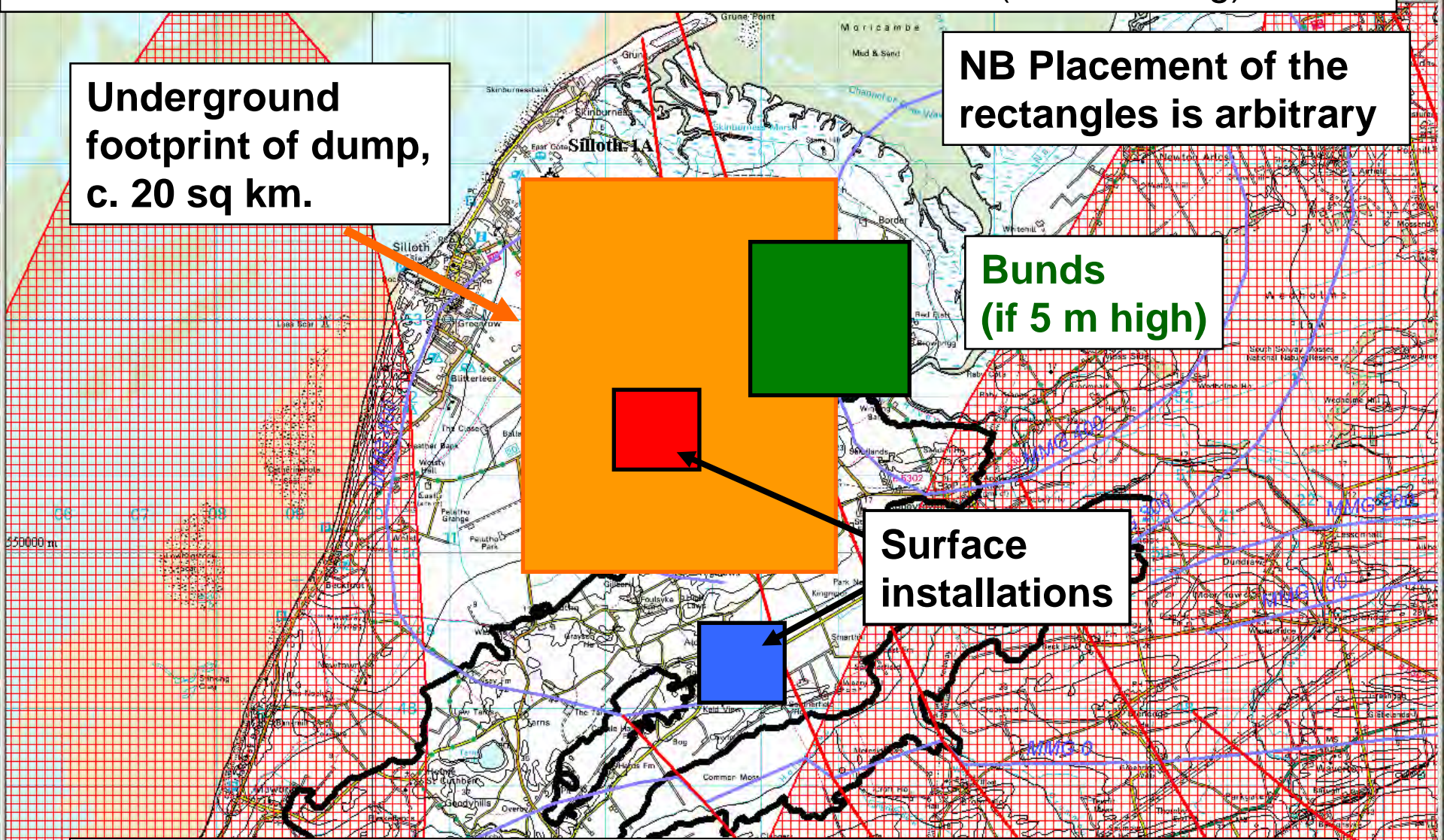
Underground footprint of dump, c. 20 sq km.

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
construction
waste
problem**



**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.**

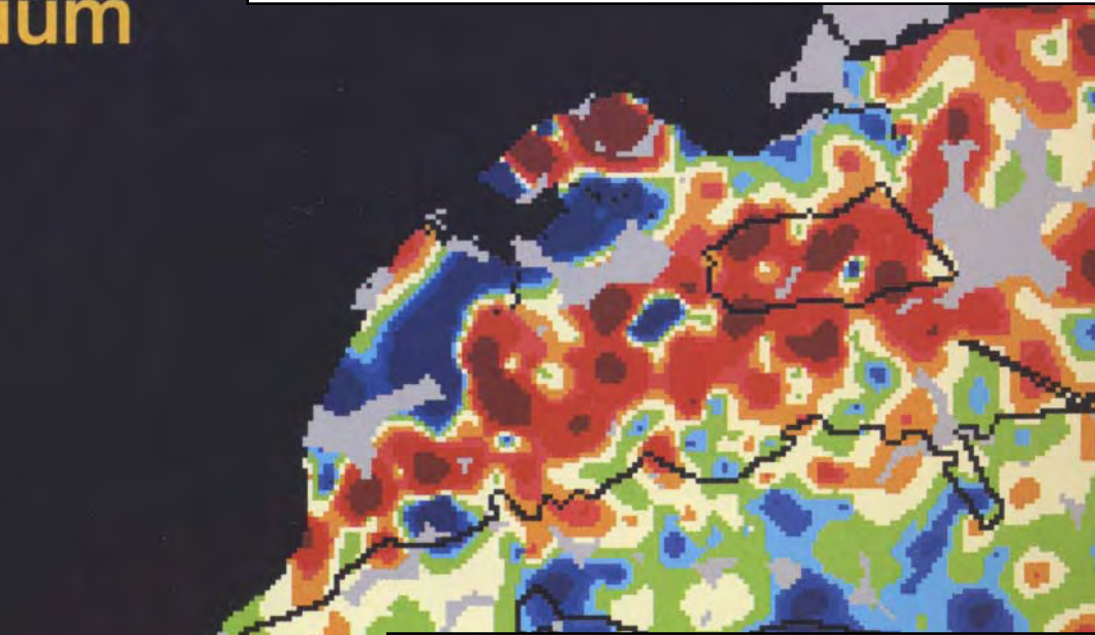
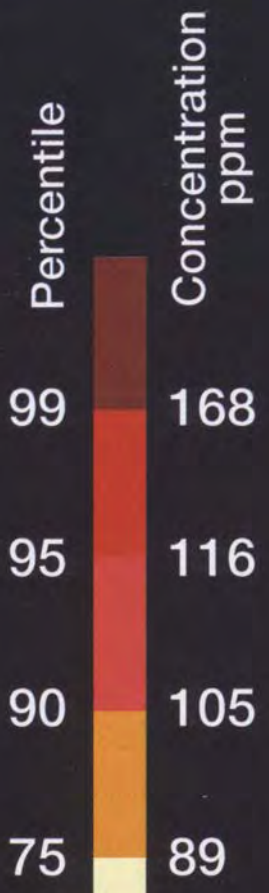
I
300

Managing 15 million cu. M. of spoil could be a major groundwater contamination problem

Chromium Cr

KEY

I
550



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”

Mercia Mudstone Group

The MRWS 'review' by Dr Dearlove

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 perhaps acceptable).**
- 5. Undesirably shallow depth of between 200 and 500 m.**
- 6. Geology is well understood due to oil industry exploration.**
- 7. Haematite-bearing red beds – oxidising environment.**
- 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 – potential in Solway area.**

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/Nirex: ‘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: BGS now allegedly considers MMG to be a potential host rock.

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 ?



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14/29/09/161/06

18 June 2012

Mr R Haszeldine
and West Cumbria MRWS Partnership
Cupfield Through Centre
Catharine Street
WHITHAVEN
Cumbria
CA26 7JL

Date of Report

ACTION 5. GEOLOGICAL DOCUMENT REVIEW OF CONSULTATION SUBMISSIONS

As requested, I have undertaken a review of the following three documents:

- Smythe, D.K.: Response to West Cumbria MRWS Consultation. Who is their nuclear waste repository should not be sited in Cumbria.
- Haszeldine, B.S.: Response to West Cumbria MRWS Consultation. Geological disposal of radioactive waste in West Cumbria.
- Points of MRWS Steering Group including discussion with the Lead Inspector and Technical Advisor from the HSE Inquiry.

The purpose of this review was to provide comment on whether these documents change my previously held opinions regarding the level and type of geological information that is available for West Cumbria with respect to the current Stage 2 of the MRWS process, principally whether these documents indicate sufficient geological data already exists to preclude going any further in the MRWS process and whether or not there is a realistic prospect of a potentially suitable site being located within West Cumbria.

Since my last documented response to the geological consultation process, Professor Smythe has provided additional data, and his personal opinion/interpretation of these data, in a series of published documents and public lectures. I understand he has completed all the additional information into the submission document identified above. I have also participated in a number of the public consultation meetings and have received a wide variety of questions/opinions/interpretations/feedback on the geological information available on West Cumbria as it relates to Stage 2 of the MRWS Process. I have tried to

MMO areas of the Cheshire Basin "where present, (the faults) are impermeable and do not form pathways for fluid migration" (Evans and Hoagth, 2009). In all of the scientific opinion that I still reliable, quality, hydraulic conductivity data are available for the MMG in the West Cumbria region, it should not be ruled out on the basis of data drawn from another region (as is argued by Professor Smythe using data drawn from the West Midlands). It is not an appeal to ignorance made to muddy the waters (as claimed by Prof Smythe) that I make this request, it is based on my experience that although the rocks in a particular area may be lithostratigraphically similar, it cannot be stated without investigation and measurement, that it shares the same or similar hydrogeological properties and characteristics. It may certainly be hypothesised that this is the case, but the very nature of a scientific hypothesis is that it should be tested by scientific research and then either accepted or rejected.

It is primarily on this basis that I suggest that the MMG cannot be rejected at this stage of the MRWS Partnership process on a potential GDF host rock. I also agree with Mr Kripe'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.**

Regarding the Lake District Batholith, and specifically the Eklakle Granite, faulting/fracturing with the potential for elevated hydraulic conductivities and elevated topography have been identified as the main geological reasons why this rock body should not be considered as a potential GDF site in West Cumbria. As a result of the acknowledged lack of exposure, a detailed assessment of the fracture patterns and faulting in the Eklakle Granite is currently not available. The impact of faults/fractures on the potential for a GDF have to go far NOT been included in any BGS Screening exercise carried out for the West Cumbria region. It is quite possible that the fracture/fracturing density of the Eklakle Granite will identify it as unsuitable for a potential GDF, but once again this study has not yet been undertaken as part of the MRWS Partnership process. The evidence presented to date does NOT demonstrate that a fracture/flow pattern is present that would wholly preclude its inclusion as a potential GDF host rock.

The topography of the Lake District has been cited as a reason why the entire area is unsuitable for a potential GDF by both Professors Smythe and Haszeldine. The fact that parts of West Cumbria have elevated topography is undisputed, although the Selwyn Pass should be considered to fall outside the area of elevated topography. Elevated topography will only manifest itself in the form of high hydraulic gradients that will increase groundwater flow rates (and thus potentially speed up the discharge rate of any radionuclides from a potential GDF site) if the rock itself naturally permits groundwater flow. Many granites, for example, exhibit dead-end pore geometries so the elevated topography can produce a potentially high hydraulic gradient, but in reality groundwater flow may be significantly inhibited as the void spaces in the rock are not interconnected and thus water entering the rock is trapped by the dead-end pores. Thus whilst elevated topography in a potential GDF region should be considered undesirable, this only significantly affects the rocks in a region through which groundwater will flow. It is insufficient to identify a region as having elevated topography and thus drawing the conclusion that it is unsuitable as a potential GDF. In fact, in areas of mixed high and low permeability rocks, it is quite possible (including many other significant geological factors), that groundwater will flow "in preference" through the higher permeability areas and thus, in effect, increase the relative lack of groundwater flow through the lower

synthesise this information into this letter report. Professor Haszeldine has presented his opinions regarding the geological, and in particular the hydrogeological, issues with respect to the prospective disposal of radioactive waste in west Cumbria. Lastly, Mr Colin Kripe (Technical Advisor at the Nires Inquiry), together with Mr Chris McDonald (Lead Inspector for the Nires Inquiry), have summarised the issues that led to their rejection of the Nires application for a Rock Characterisation Facility (RCF) at Longlands Farm, and the implications of these to the current MRWS process. Where necessary, I have drawn on the minutes records of this meeting, in particular the issue of sufficient geological data already being available to reject the entire West Cumbria region and on the possibility for ultimately finding a potentially suitable rock volume in West Cumbria in which to locate a GDF. In this letter, though necessary, I can only provide a summary of the issues considered in my responses. I have, however, tried to identify the most salient features of any discussions presented, and to address them. I have tried to present a detailed, step-by-step response to every issue raised.

Having read the latest submissions, together with the international guidelines for a potentially suitable GDF host rock, the geological and hydrogeological data available for a potentially suitable GDF host rock in the MMG, and the granite rock body in the Lake District.

It has been pointed out that the geological data and Selwyn Basin are unsuitable, on geological grounds, for a GDF. This is based on the fact that the Selwyn Basin is a faulted area (leading to elevated areas of hydraulic conductivity) and the Selwyn Basin is a faulted area (leading to elevated areas of hydraulic conductivity). The West Midlands indicate a geochemically unsuitable (oxidising) environment, but this has already been sufficiently explored by the oil industry over the past 30 years (for the specific purpose of identifying hydrocarbon deposits) to be already fully well understood to be ruled out without further evaluation as a potential GDF host rock.

Whilst I do not share the opinion/interpretation of Professor Smythe regarding much of the geological information he has collated on West Cumbria as it pertains to the MRWS process, I acknowledge that additional, and relevant, data has been put forward. However, I do not share his opinion that these data should be taken at this stage to rule out the MMG. There has been no systematic desktop undertaken of the MMG for the purpose of evaluating its potential as a GDF under the current MRWS process. Until this has been undertaken, and subjected to subsequent review, the MMG should not be dismissed as a potential GDF host rock. There appears to be a general consensus that the British Geological Survey (BGS) are best placed to undertake such a review, as they have access to all industry and other data outside the public domain and retains an important source of geological assessment of issues of national/international importance. Figure 2.1.1 (b) in Smythe's submission identifies the area including the MMG as "areas of potentially suitable sedimentary rocks" following the 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. Professor Smythe appears to have misinterpreted my comments that "a proper evaluation of the available data has not yet been undertaken". In my opinion, and that of Mr Colin Kripe, only the BGS is capable of making this assessment, and until the BGS undertake and publish such a review the area most remain potentially suitable. The BGS have published a report indicating that large faults in the

permeability units. Parts of the MMG in the UK, for example, are known to contain highly soluble brine (rock salt) deposits that have remained in place for over 200 million years, despite being overlain and underlain by Secondary A aquifer units in areas within, or adjacent to, regions of elevated topography. If groundwater simply moved through all geological units, irrespective of their hydraulic properties, these deposits could not have remained in place over millions of years.

In conclusion, I do not believe that the data presented in the three identified documents indicate that sufficient geological data already exist to preclude going any further in the MRWS process. There remain two potentially suitable rock volumes in West Cumbria, for which insufficient data and no published authoritative reviews are currently available, that have the potential to be suitable GDF host rocks. Neither of these two rock volumes should be regarded at this stage as being particularly promising, in terms of their potential to eventually be identified as a suitable GDF host rock, but until available data have been reviewed by a suitably impartial authoritative body, they cannot be ruled out AT THIS STAGE from the MRWS Partnership process.

Yours sincerely
On behalf of FWS Consultants Ltd

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Review of the geological submissions by Dr Jeremy Dearlove of FWS, commissioned by MRWS, June 2012.

Smythe, Haszeldine, McDonald, Kripe: c. 500 pages of geological evidence

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- The opinions expressed in this report regarding any contamination are based on analysis and comparison with available guidance values. No liability irrespective of effect of any changes or amendments to these values.



? LEGAL CHALLENGE

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

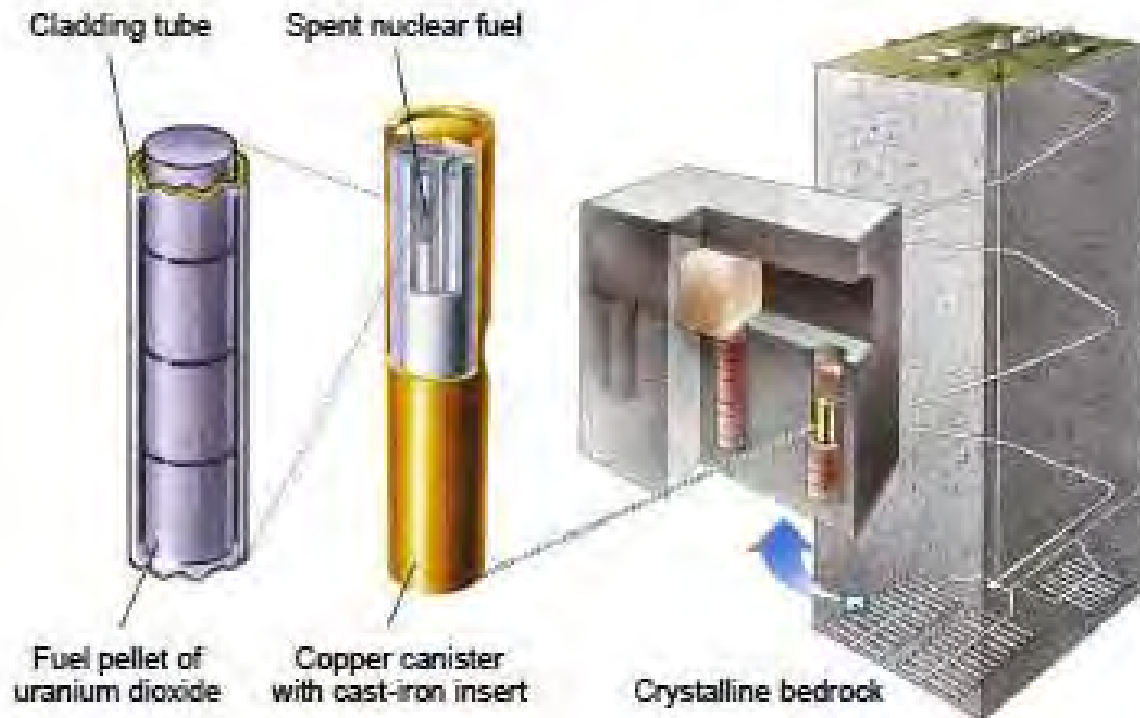
The Swedish KBS-3 nuclear waste repository concept:

Problems and implications for the UK

This disposal concept has been adopted by the UK for high-level waste and spent fuel.

- Is it suitable – yes / no ?**
- Confusion reigns in DECC (as usual)**
- Arrogant optimism of nuclear engineers**

The KBS-concept



Swedish KBS-3 repository concept:

- Fuel placed in isolating copper canisters
- With a high-strength cast iron insert.
- Canisters are surrounded by bentonite clay
- In individual deposition holes at 500 m depth
- In granitic bedrock.

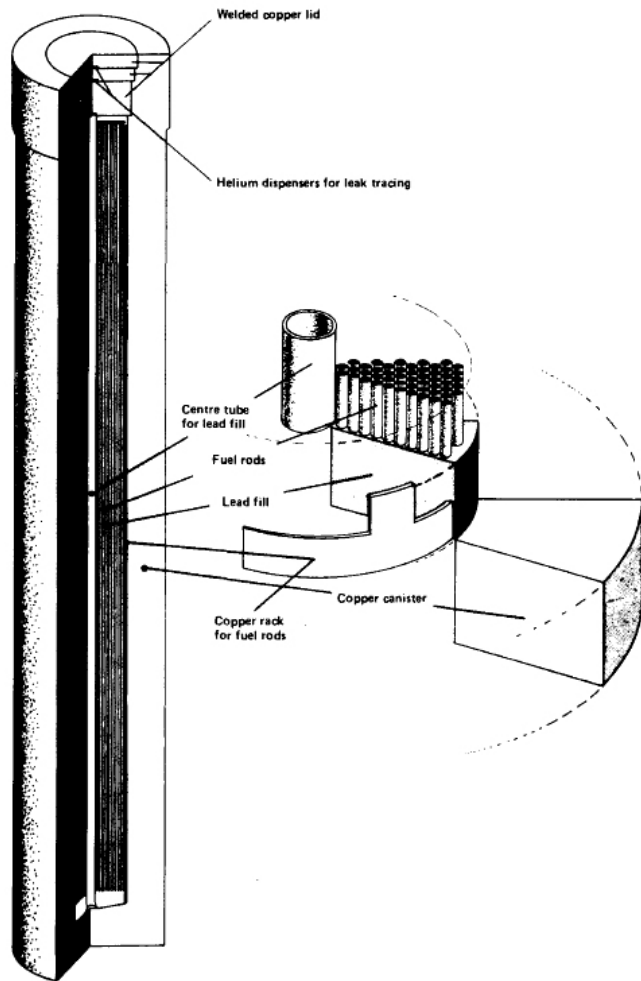


Figure 5. The encapsulated waste. The copper canister is 4.7 metres long and has a diameter of 0.8 metres.

Original KBS copper cylinder:

Wall thickness of copper:

- 1977 – 20 cm (left)
- 1983 – 10 cm
- 1999 – 5 cm

Is the progressive reduction in thickness justified, or merely expedient?

Current copper cost per cylinder (5 cm) = \$18K

TABLE 7. Calculated canister dissolution times (yr).

KBS-I:

Titanium (6 mm)	$>10^4$	} pinhole >500
Lead (100 mm)	$>10^6$	
Borosilicate glass	$3 \times 10^4 - 3 \times 10^6$	

KBS-II:

Copper (200 mm)	$>10^6$
Lead (interstitial)	not accounted for
Zircaloy (~1 mm)	not accounted for
Uranium dioxide	$\sim 10^6$ (carbonate complex)
Alumina (corundum)	$>10^4$

This table shows that a 20 cm thick Cu canister is supposed to last for **more than 1 million years.**

Source: Rydberg (1981); KBS-2 is for spent fuel.

Technical Report

TR-99-06

Main Report
Summary

Deep repository for spent nuclear fuel

SR 97 - Post-closure safety

November 1999

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Swedish Nuclear Fuel
and Waste Management Co
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SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19



Further confidence in KBS-3

SR 97, published 1999

“Canister corrosion”

“Copper is very stable in the environment in a deep repository. The only known copper corrodant that has been identified in deep Swedish groundwaters is sulphide. Initially, oxygen is also present in the buffer and the tunnel backfill, as is sulphate which can be converted to sulphide. Soon after deposition, small quantities of nitric acid could also conceivably be formed by radiolysis of the buffer’s pore water.

Pessimistic rough calculations show that none of these factors threatens canister isolation, even in a million-year perspective. Nor has any mechanism that could lead to a local corrosion attack been identified.”

BUT

Sweden has a robust and independent safety authority, SSM (as does France),

and

funds an independent NGO office (MKG) to scrutinise work.



[NB The UK has neither of these]



Strålsäkerhetsmyndigheten

Swedish Radiation Safety Authority

... and the SSM has recently shown that this confidence in KBS-3 is unfounded

SSM report on copper
(Macdonald and Sharifi-Asl 2011):

“Accordingly, **the assumption that copper will be immune during the anoxic storage period is untenable**, despite the fact that native deposits of copper do occur in granitic formations. The success of the KBS-3 program must rely upon the multiple barriers being sufficiently impervious that the corrosion rate be reduced to an acceptable level.

...

If the proposed corrosion scenario posed by SKB is correct, that the rate of copper corrosion is determined by the rate of mass transport of sulfide ion through the bentonite buffer, the question must then be asked: **“Why use copper?”** “Would not a less expensive and hence more costeffective alternative, such as steel, suffice?” Answers to these questions possibly lie outside of the realm of corrosion science.”

MKG interprets these results

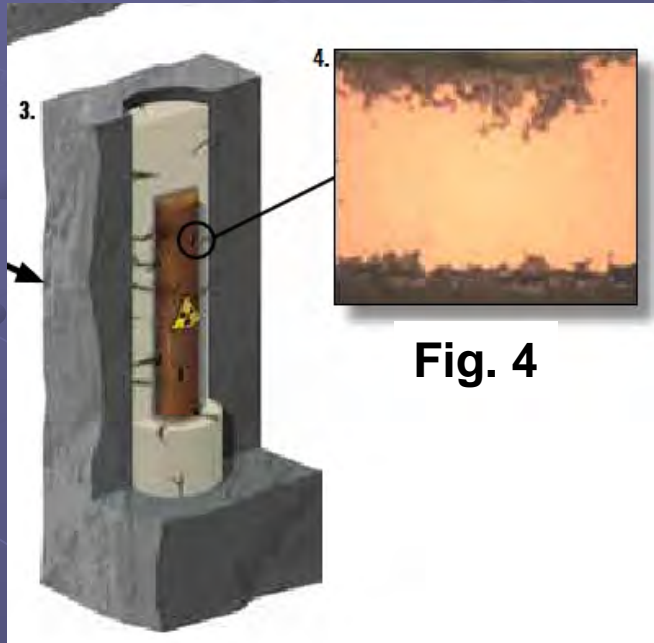


Fig. 4

“Why the KBS method will not work”

“After the emplacement of the canisters and clay the oxygen in the repository is quickly consumed by bacteria and chemical processes. The fundamental assumption in the KBS method is that very little corrosion takes place in an oxygen-free environment. The canister walls are 5 centimetres thick and **only a millimetre or two of the copper is supposed to corrode in a million years.**”

Pitting can result in penetration

Once copper begins to corrode, the process can proceed quickly through so-called pitting, which gives pox-mark indentations in the surface. The risk of pitting has led critical researchers to fear that **the copper canisters may start to leak after only some hundreds of years — instead of after hundreds of thousands of years. (Fig 4).”**

Is the UK adopting the KBS-3 concept, or not?

Joint BGS/Nirex statement, March 2006

“The BGS has reviewed the characteristics of existing ILW/LLW disposal concepts and the geological factors relating to packaged HLW/spent fuel (KBS-3 concept) and believes that the geological conditions that would be suitable for the former will also be appropriate for the isolation of the latter.”

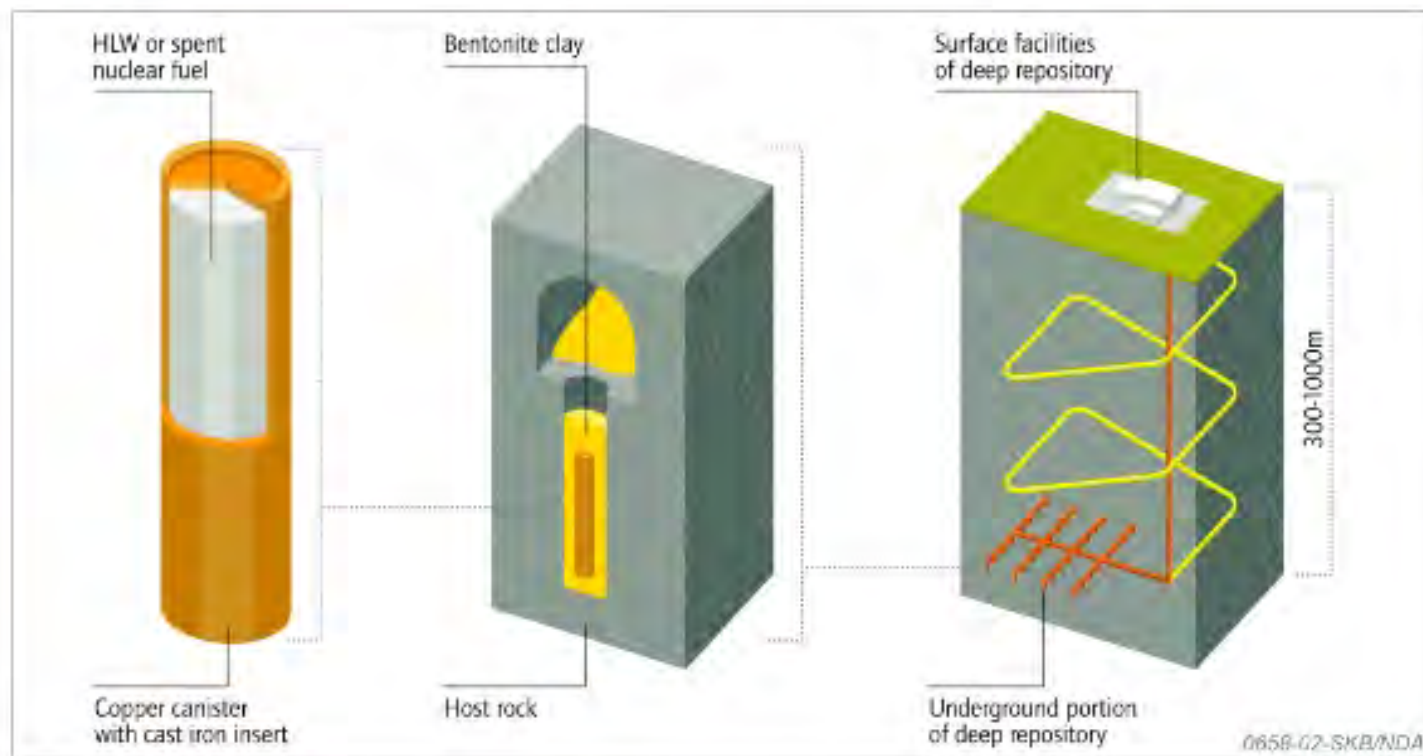
CoRWM doc 2456 Sep08

BGS response to CoRWM (Committee on Radioactive Waste Management) questions:

“BGS do not think the KBS-3 concept is applicable to the UK situation due to the combination of the UK’s geology and variety of waste forms.”

So the British Geological Survey (BGS) has changed its mind about KBS-3 in under three years.

Figure A2 Illustration of the KBS-3V Concept (SKB, Sweden – as adapted by the Nuclear Decommissioning Authority, 2010)



Source: Nuclear Decommissioning Authority (NDA) (2010)

But the NDA still appears to think that the KBS-3 concept is applicable in the UK

Entec for NDA, October 2010

Table 1.1 Illustrative geological disposal concepts

Host rock	Illustrative Geological Disposal Concept Examples ^a	
	ILW/LLW	HLW/SF
Higher strength rocks ^a	UK ILW/LLW Concept (NDA, UK)	KBS-3V Concept (SKB, Sweden)
Lower strength sedimentary rock ^b	Opalinus Clay Concept (Nagra, Switzerland)	Opalinus Clay Concept (Nagra, Switzerland)
Evaporites ^c	WIPP Bedded Salt Concept (US-DOE, USA)	Salt Dome Concept (DBE-Technology, Germany)

Notes:

- a Higher strength rocks – the UK ILW/LLW concept and KBS-3V concept for SF were selected due to availability of information on these concepts for the UK context.

Evidently the NDA is still working with the KBS-3 concept for the UK, despite its intrinsic shortcomings, and despite the declaration by the BGS. The V-suffix means the vertical emplacement option.

Conclusions and lessons to be learned

- The KBS-3 concept is fundamentally flawed
- The UK has not got a viable encapsulation concept
- The final, and most important, barrier remains the geology

The pronouncements of nuclear engineers about the performance of their 'Engineered Barriers' such as KBS-3 are grossly optimistic.



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?”

2. Unsuitability screening

3. Decision to participate

4. Desk studies

5. Surface research

6. Underground

Point of no return -
BGS starts drilling

A site is
selected

Decision points – the slippery slope

Each step postpones the real decision: Is the area suitable?

3. Decision to participate

Councils locked in from here on.

4. Desk studies

BGS has stated West Cumbria “*offers potential*” – so can hardly now change its view.

5. Surface research

Point of no return - contractors start drilling.

6. Underground

An unsuitable site is selected.

All the above open to legal challenge on various grounds
- not just geological unsuitability



Conclusions and lessons to be learned

The UK is now 25 years behind Sweden, Finland and France.

It should:

- Stop searching for a repository site in the most unsuitable area in England.
- Undertake 25 years of proper research into both **encapsulation** and **geological siting**.
- Prioritise building **interim (100 years) safe surface storage at Sellafield**.

Fin