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

International aspects
Guidelines
What other countries do

Geology of Ennerdale and 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.

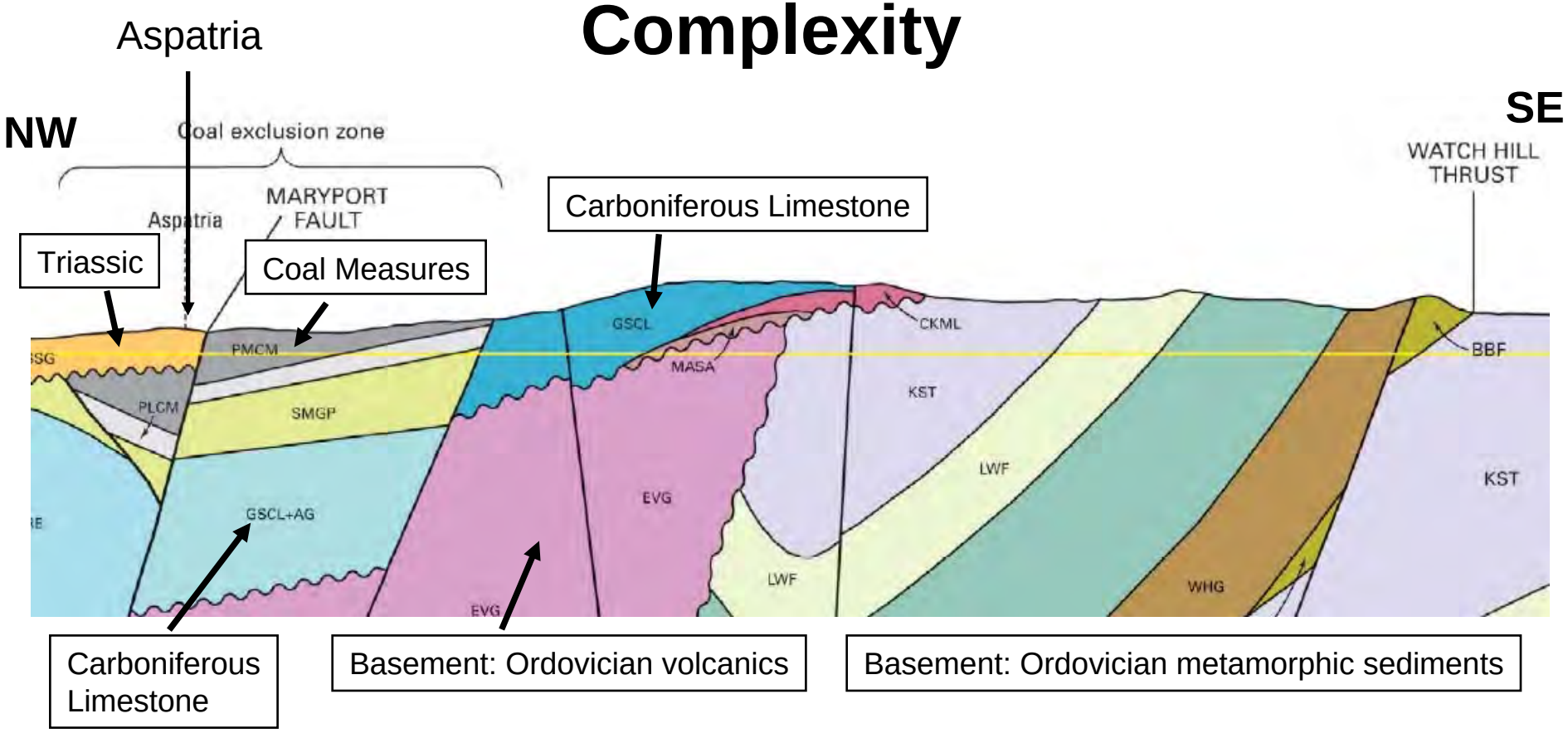
Every locality in West Cumbria has a problem with several of these.

What does complexity mean ?

in the context of a potential repository:

- Variety of lithologies
- Folding
- Angular unconformities
- Faults cutting both basement and cover rocks
- Faults intersecting the ground surface
- Faults intersecting each other at shallow depth
- Three-dimensionality

Complexity



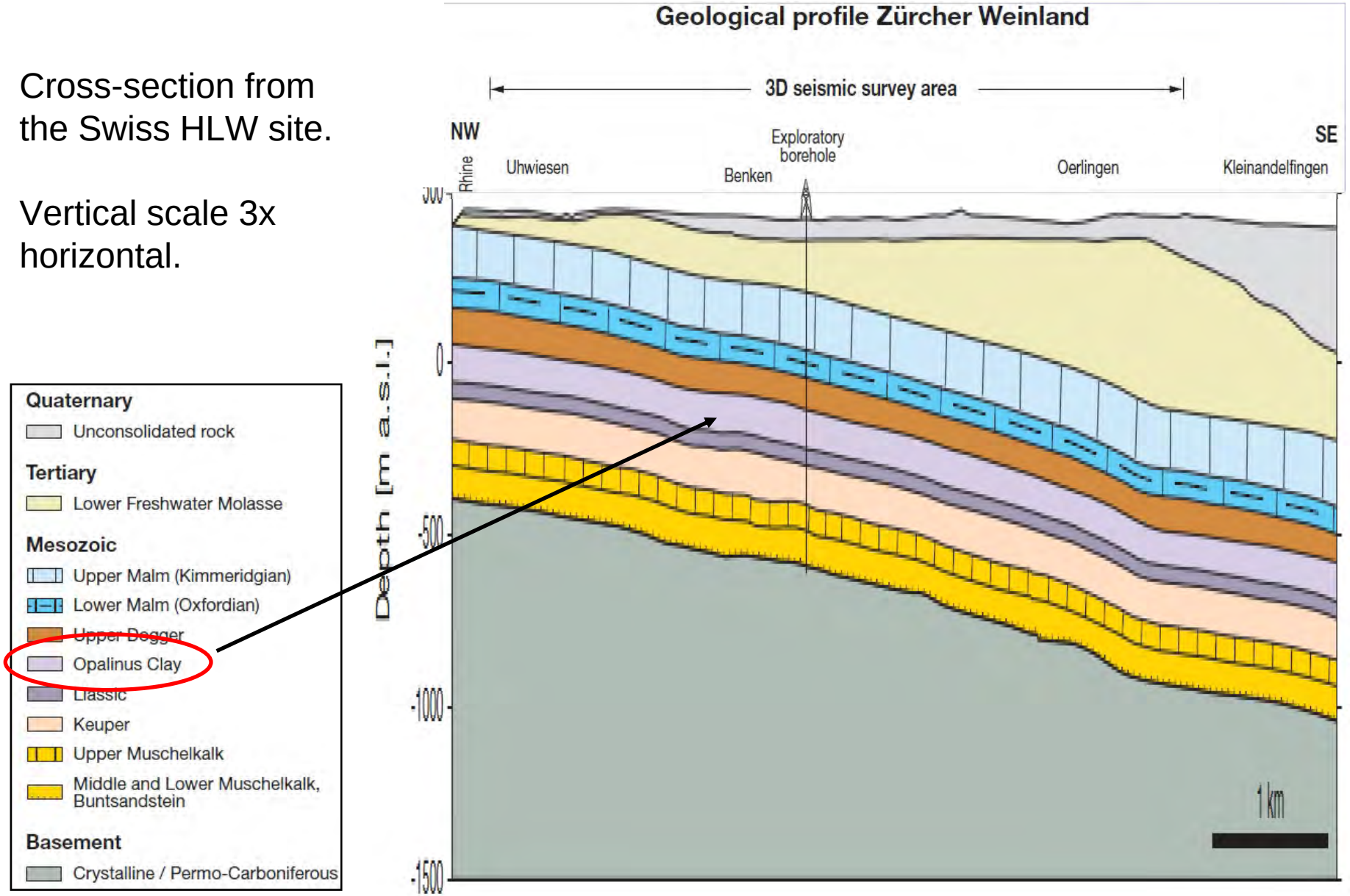
Cross-section through Allerdale from BGS screening report.
Vertical scale 3x horizontal.
Sea level – yellow line; base of section at 1500 m.
Faults are denoted by solid lines, unconformities by wavy lines.

- a good Final Year Honours Geology exam question !

Simplicity: the clay layer site in Switzerland

Cross-section from the Swiss HLW site.

Vertical scale 3x horizontal.

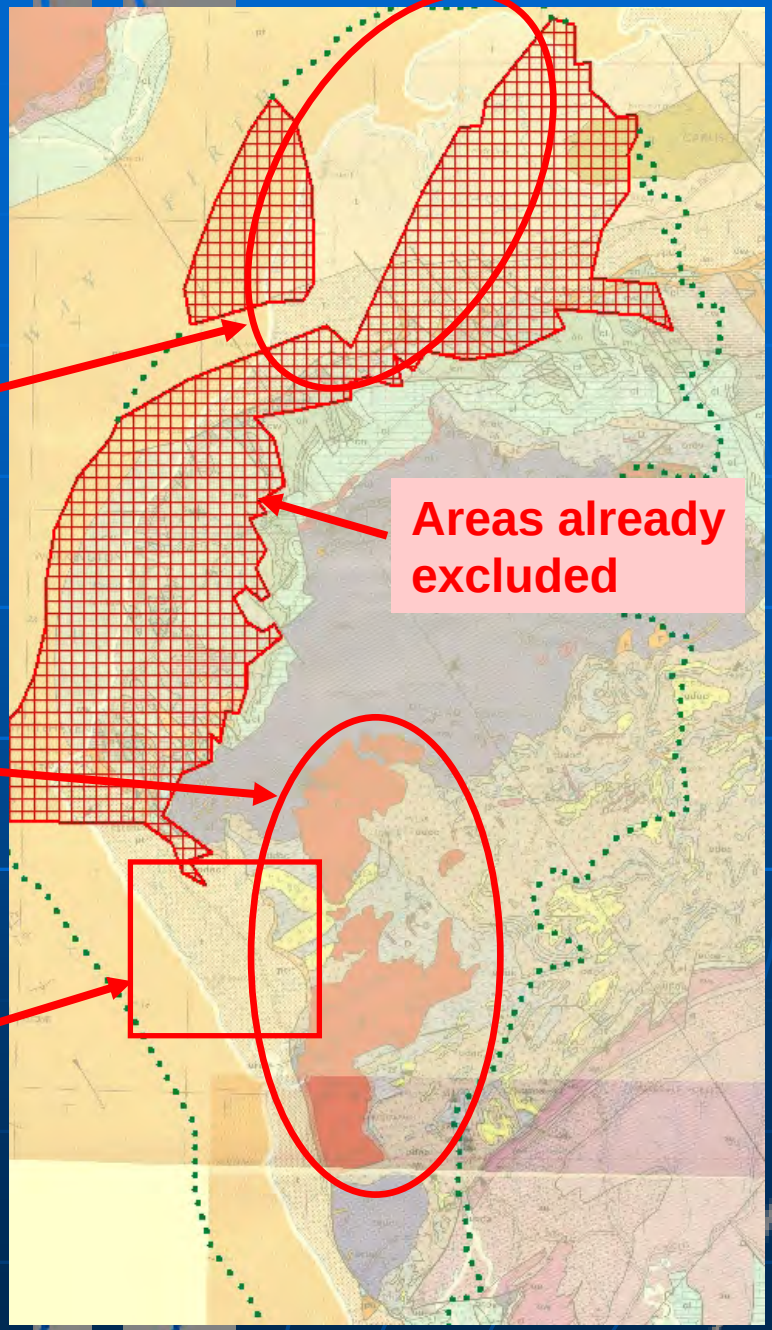


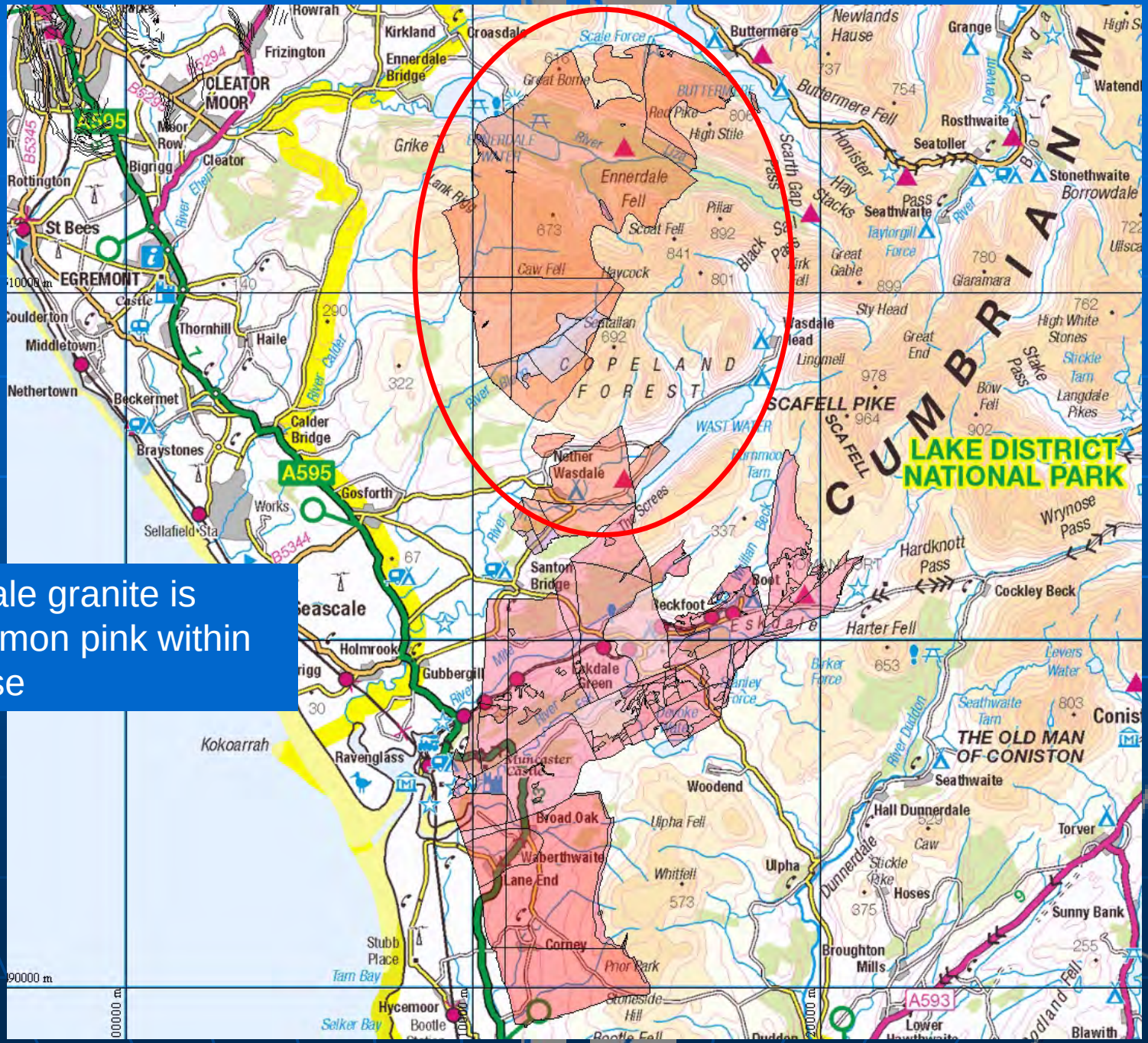
Geology of the areas left in play

Northern Allerdale – the Mercia Mudstone Group

Eskdale and Ennerdale granites (red areas)

Sellafield / Longlands Farm (ancient history or not?)





The Ennerdale granite is shown in salmon pink within the red ellipse

- **Emplacement of waste directly from Sellafield via a 10 km-long tunnel.**
- **The surface of the National Park would be unaffected.**
- **Ennerdale is clearly an area of extreme relief.**

This should be enough to rule it out of consideration, based on international guidelines and practice.

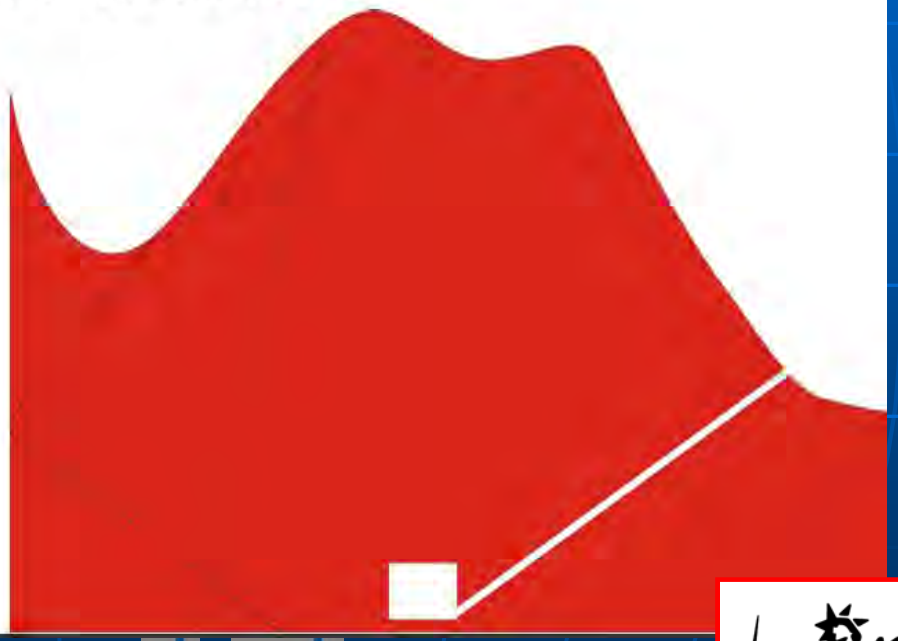
But the BGS has tried to come to the rescue here …

Favourable Geological Situations

Low permeability basement ('hard') rocks

Rocks with low bulk rock permeability rocks at surface, regardless of surface relief

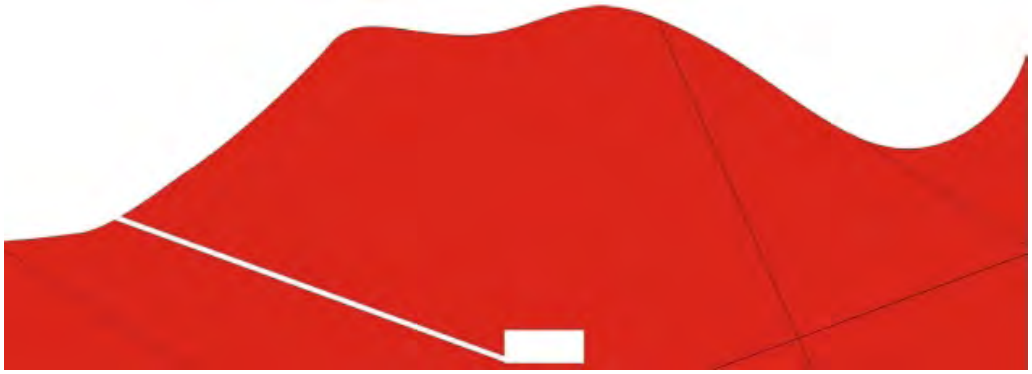
Potential problems of complex geology (sometimes) and short return pathways

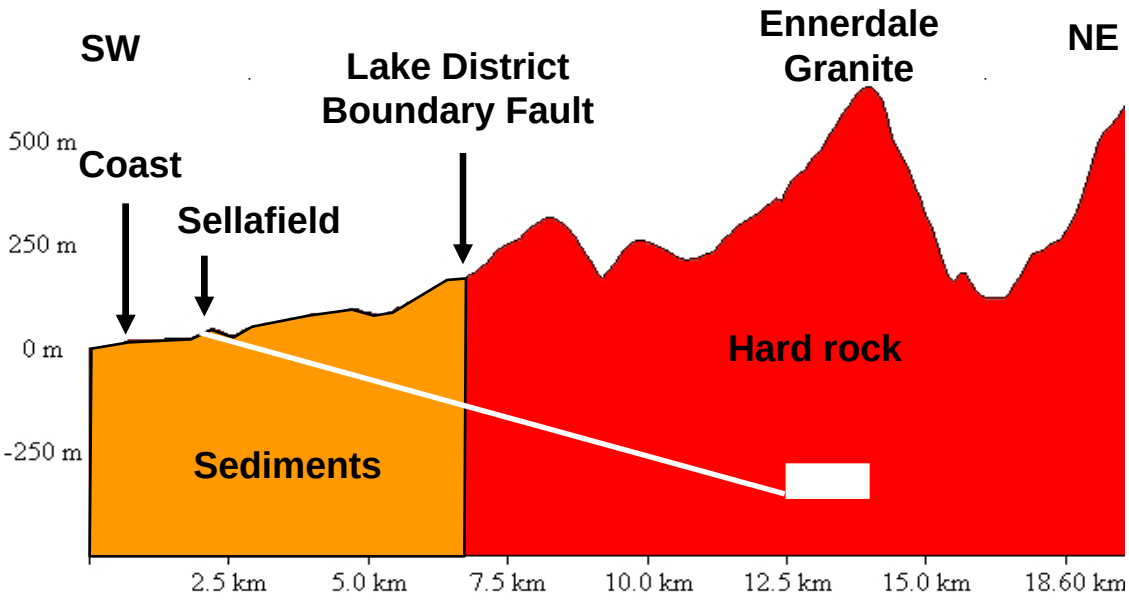


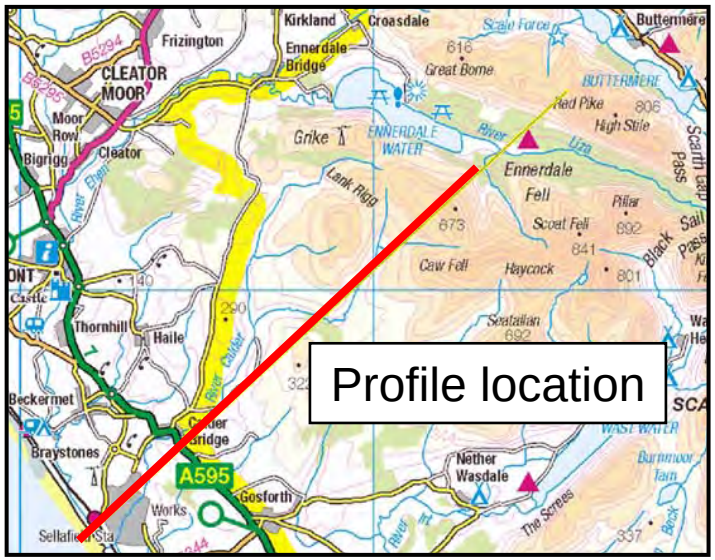
Published BGS cartoon (Shaw 2006, 2010).
This purports to show high-relief mountains as 'favourable'.
But no GDF search guidance supports this concept.

Comparison of the BGS '*favourable geological situation*' of high-relief hard rock with a repository in the Ennerdale granite, linked directly by a 10 km tunnel to Sellafield. The repository (white rectangle, schematic) would be about 400 m below the level of Ennerdale Water.

BGS hard rock cartoon, reversed







Actual topographic profile from the coast to the head of Ennerdale Water (vertical exaggeration x7.5).

Comments

The BGS cartoon was first published by Dr Richard Shaw in 2006.

It conforms to no national or international guidelines, nor to overseas practice.

NERC (of which the BGS is a component body) has tried to explain that it conforms to a 2009 Environment Agency “key” document.

This suggests that either:

- Dr Shaw has remarkable powers of precognition, or
- It is evidence for predetermination.

Predetermination

means:

- NDA and/or BGS had by 2006 selected Ennerdale as a possible site,
- Nowhere else in England fits the BGS cartoon,
- Subsequent exercise to manipulate quasi-scientific opinion in favour of such a site.

Implications for the Ennerdale area of the National Park

Stage 5 - investigations:

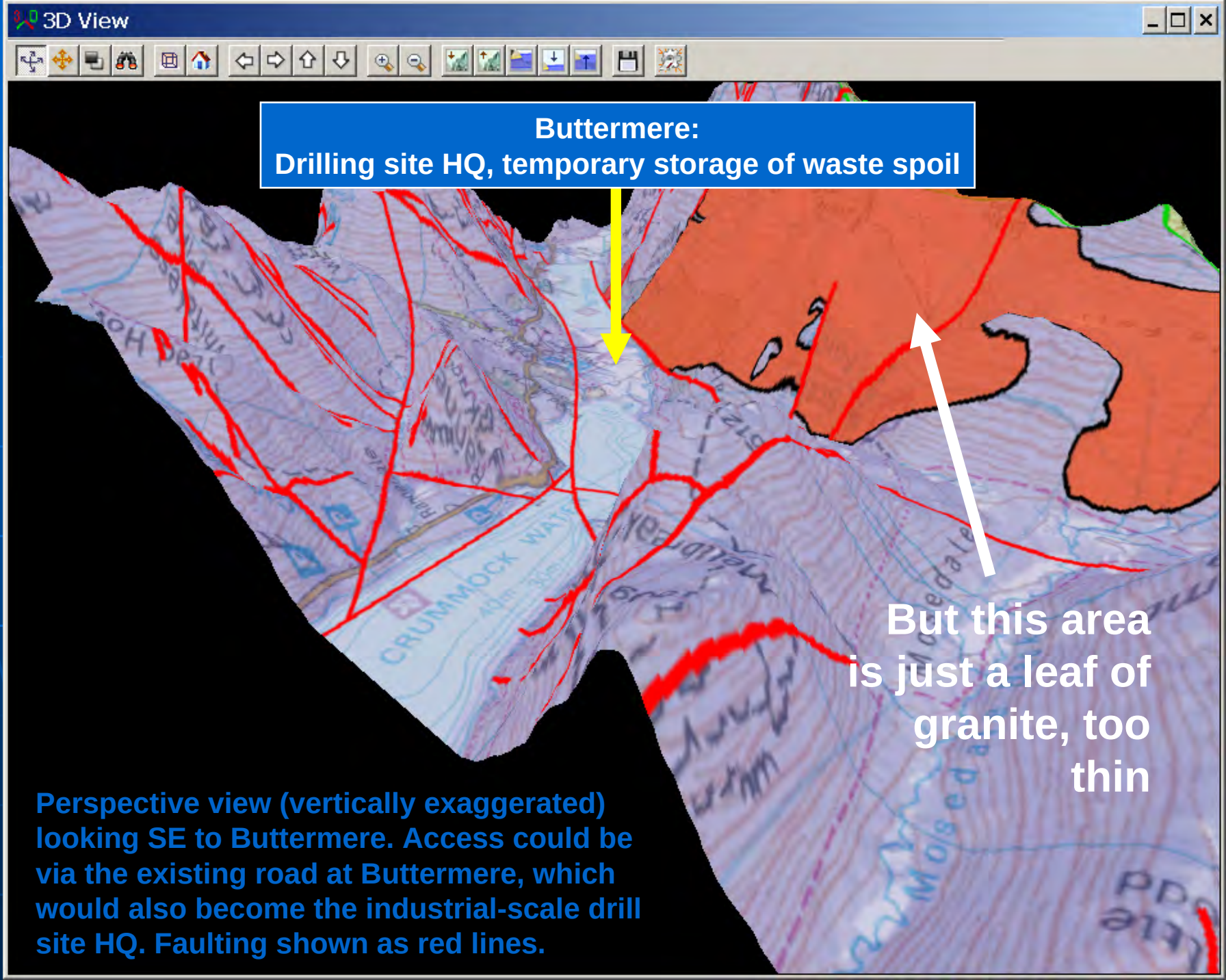
Industrial activity in an around the area of the granite, for the following approximate periods:

- Opening up of several roadways onto the mountain - permanent
- Surface seismic reflection survey – 1-2 years
- Drilling of the granite for investigation – 10 years

Stage 6 - construction:

- Excavation of 3 vertical shafts above the selected GDF location
- Building of surface works – permanent
- Drilling of 2-3 access tunnels from Sellafield to the GDF

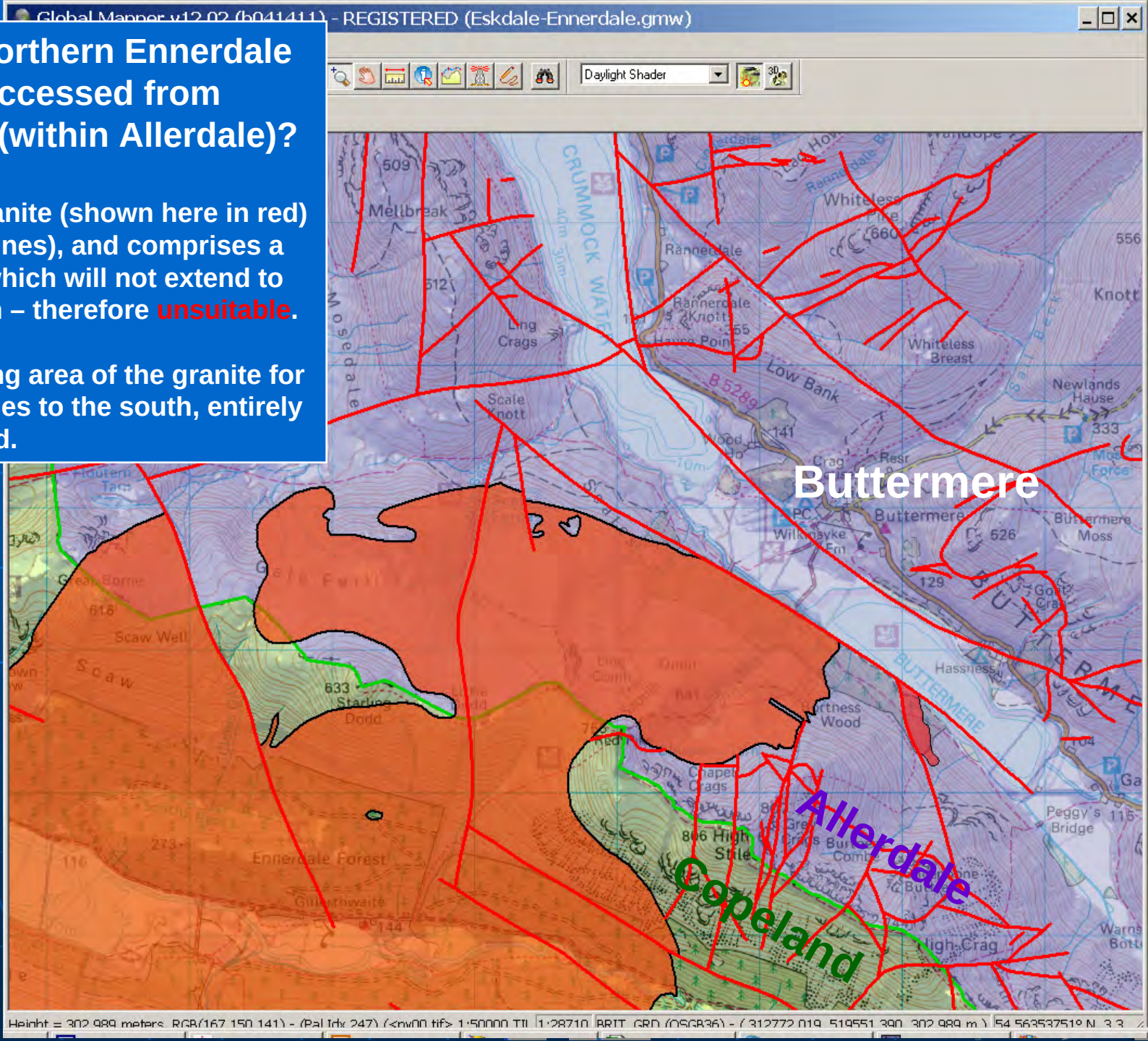
By ‘permanent’ is meant for a period of 200 years or more that the GDF would be in operation. Only after the GDF is closed could the surface works above be removed.


3D View
Buttermere:
Drilling site HQ, temporary storage of waste spoil
But this area is just a leaf of granite, too thin
Perspective view (vertically exaggerated) looking SE to Buttermere. Access could be via the existing road at Buttermere, which would also become the industrial-scale drill site HQ. Faulting shown as red lines.

Could the northern Ennerdale granite be accessed from Buttermere (within Allerdale)?

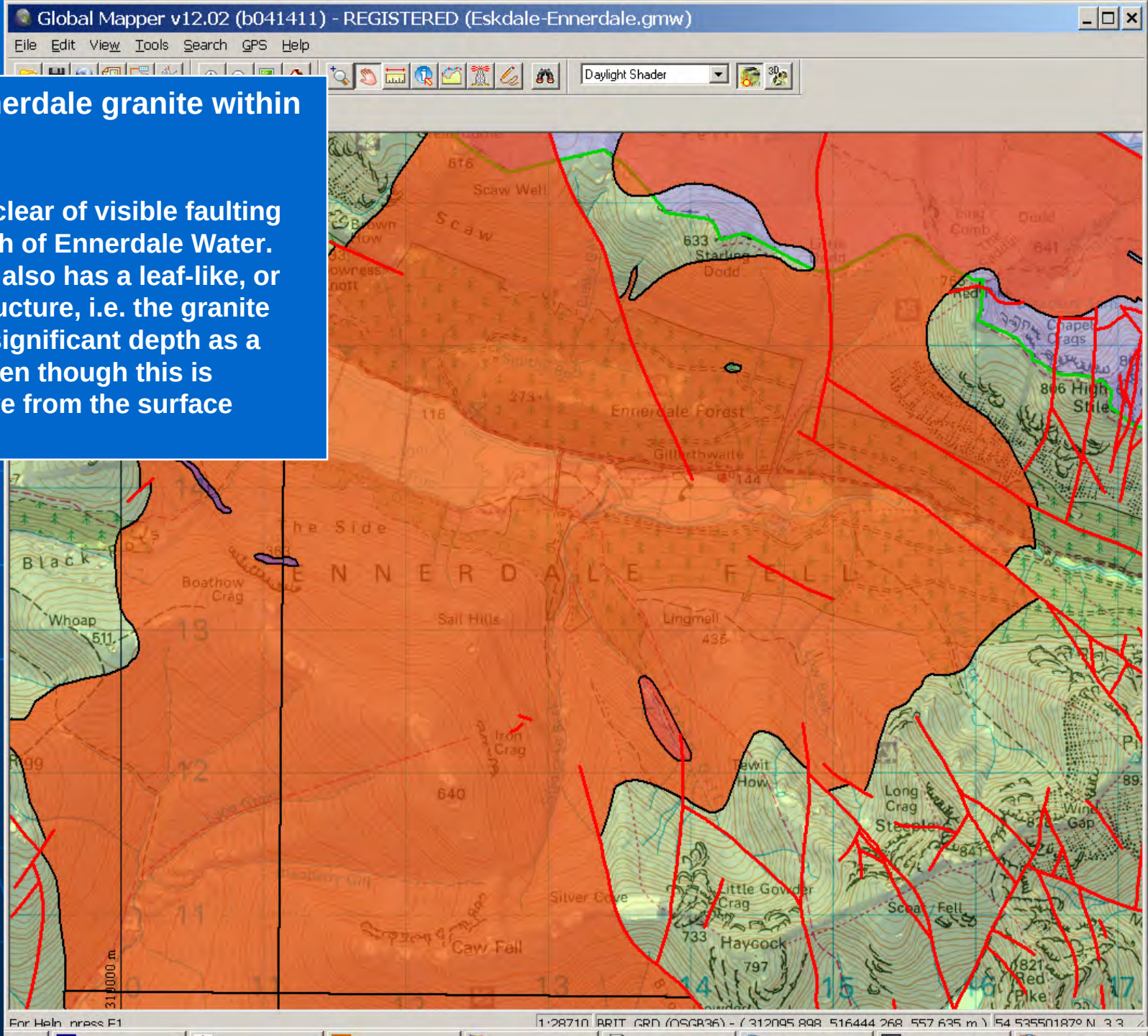
Yes, but the granite (shown here in red) is faulted (red lines), and comprises a leaf structure which will not extend to any great depth – therefore **unsuitable**.

So the remaining area of the granite for consideration lies to the south, entirely within Copeland.



Northern Ennerdale granite within Copeland:

It seems to be clear of visible faulting (red lines) south of Ennerdale Water. But it probably also has a leaf-like, or 'cedar-tree' structure, i.e. the granite extends to no significant depth as a single body, even though this is difficult to prove from the surface geology alone.



MRWS Stage 5
"*Surface investigations on remaining candidates*"

Stage 5 will comprise:

- Surface seismic investigations (2D and 3D reflection seismic),
- Drilling of 20-30 deep boreholes into the granite, to a depth of 1000 m or so.

Various engineering, geological and geophysical tests will be carried out in the boreholes.

By analogy with the Nirex Longlands Farm investigations and practice abroad, this phase will take at least 10 years.

3D seismic reflection survey of Ennerdale

This survey is essential to try to image the granite body and faulting in three dimensions.

It would be preceded by 2D test surveys.

Terrain is extreme, ruling out the vibroseis energy source used in the Nirex trial 3D seismic survey at Longlands Farm in 1994.

Had that site not proved to be too complex and unpredictable, a full 3D survey covering 10-20 sq km would have been planned.

The only alternative energy source is dynamite placed in drilled shot-holes. This is what would be used over Ennerdale.

Four vibroseis trucks on duty at Longlands Farm.

3D dynamite survey - alternative scenarios

There are two fundamental parameters:

- Density and resolution of data
- Depth of penetration

We need penetration to 2 km, and a horizontal resolution of 10 m or better in the x and y directions. In a high-resolution survey (which is the case here) we hope to resolve geological features vertically down to a few metres.

There are (at least) two feasible methods:

(1) Caterpillar truck-mounted drilling rig:

- Shot holes 10-20 m deep
- Good penetration
- Fewer holes required

(1) Hand-held ‘slim-hole’ drilling machine

- Energy penetration doubtful, but compensated for by
- More holes (each 1 m deep) into granite

3D dynamite survey - geometry

(indicative figures only)

Area to be surveyed:	25 sq km incl. border fringe
Shot and receiver line spacing	20 m
Receiver interval	20 m
Shot interval (truck)	40 m
Shot interval (hand-held)	20 m
Resulting horizontal resolution	10 m x 10 m

Basically, the shots and receivers lie at points on a 20 m square grid, but with the truck-mounted rig we only shoot every second position.

Modern recording equipment can deploy several thousand recording channels – for example 50 lines of 100 channels each (5000 channels), thus covering an area of 1 x 2 = 2 sq km.

3D dynamite survey – some logistics

NB: whole mountain out of bounds to public for > 1 year.

Caterpillar truck-mounted drilling rig:

- 25 x 25 holes = 625 per sq km, at 40 m spacing
- Total no. of holes = 15625 to min. 10 m depth
- Air percussion drilling to avoid need for water lubrication

OR

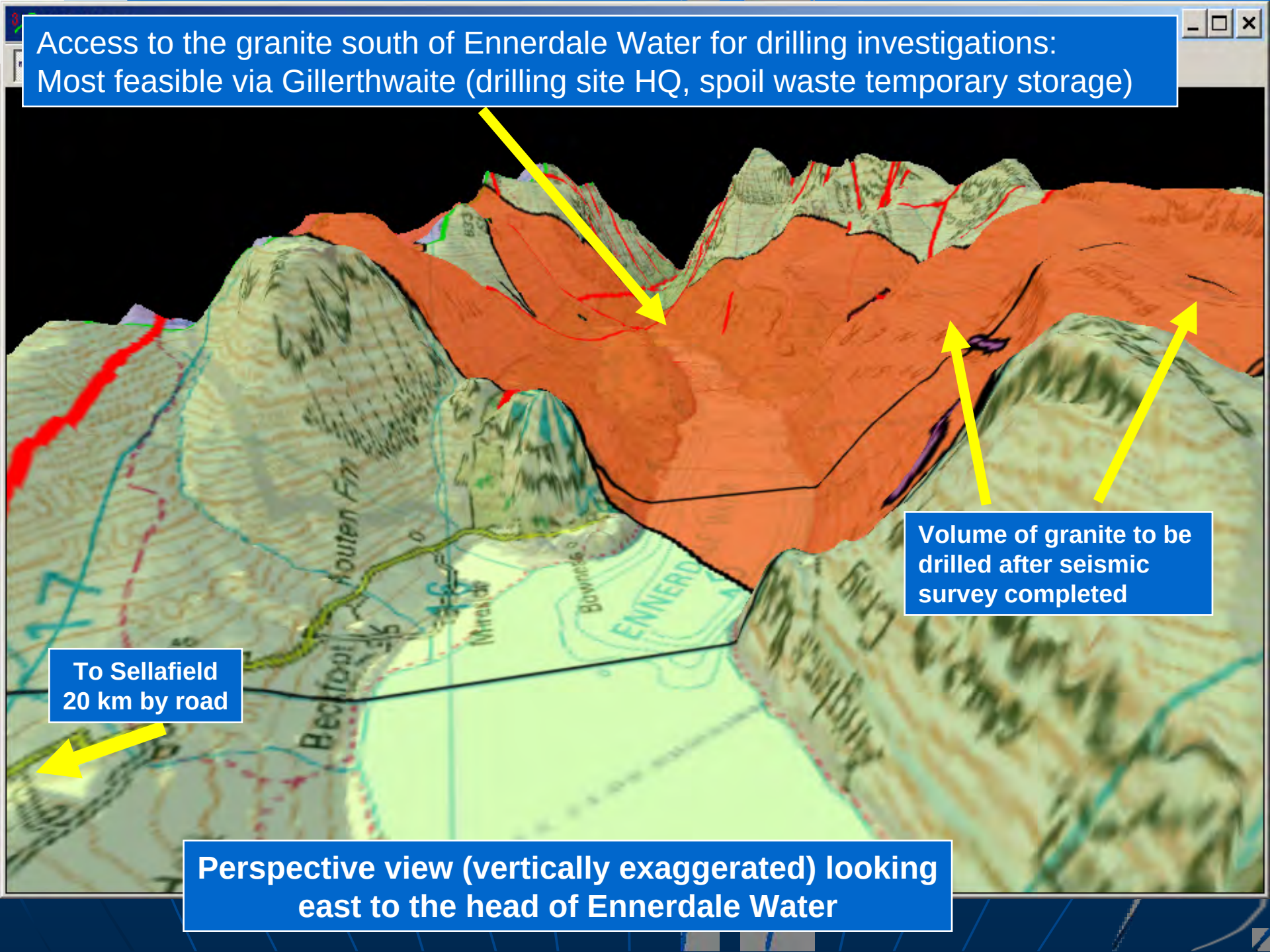
Hand-held 'slim-hole' drilling machine(s):

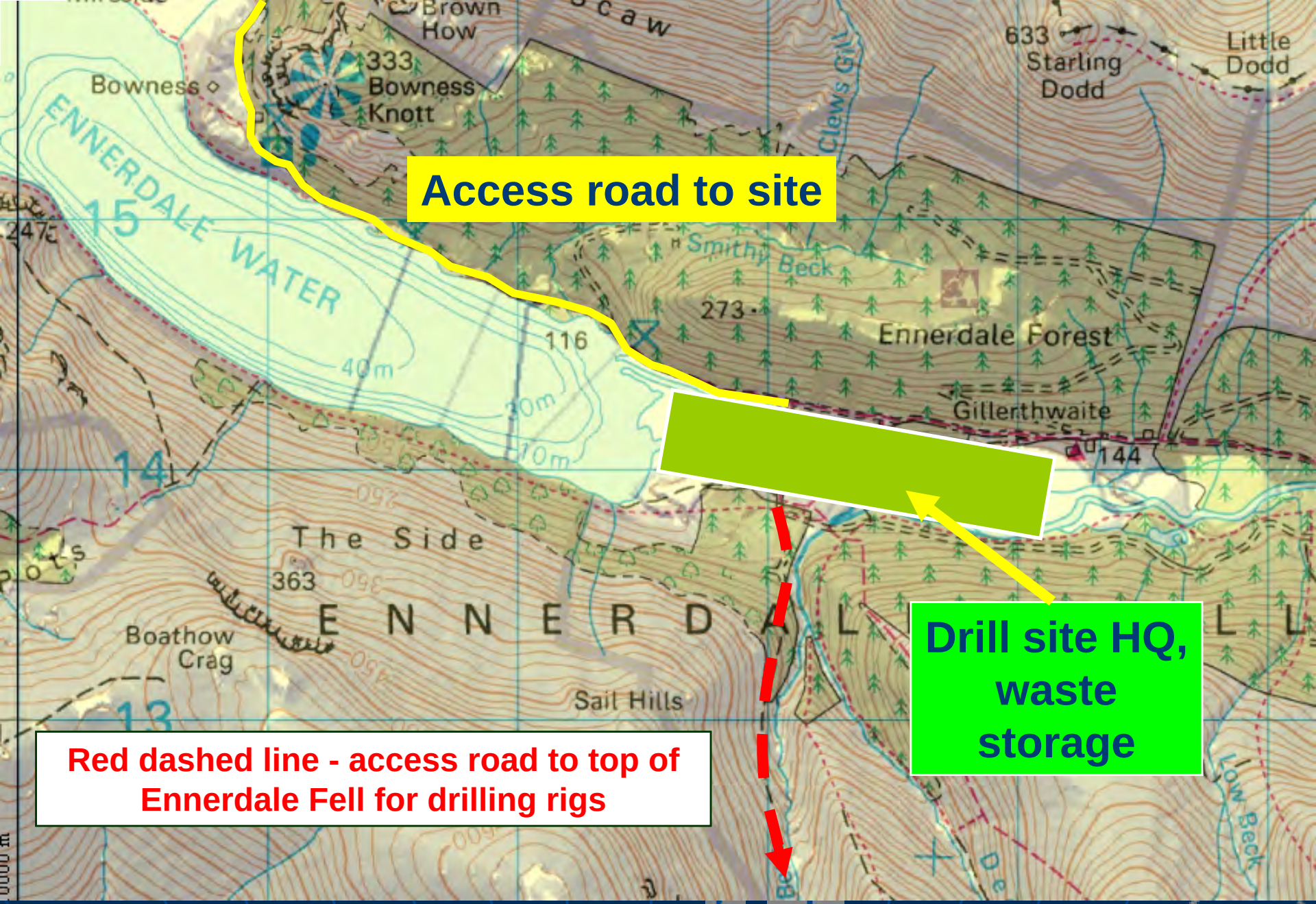
- 50 x 50 = 2500 holes per sq km, at 20 m spacing
- Total no. of holes = 62,500 to 1 m depth

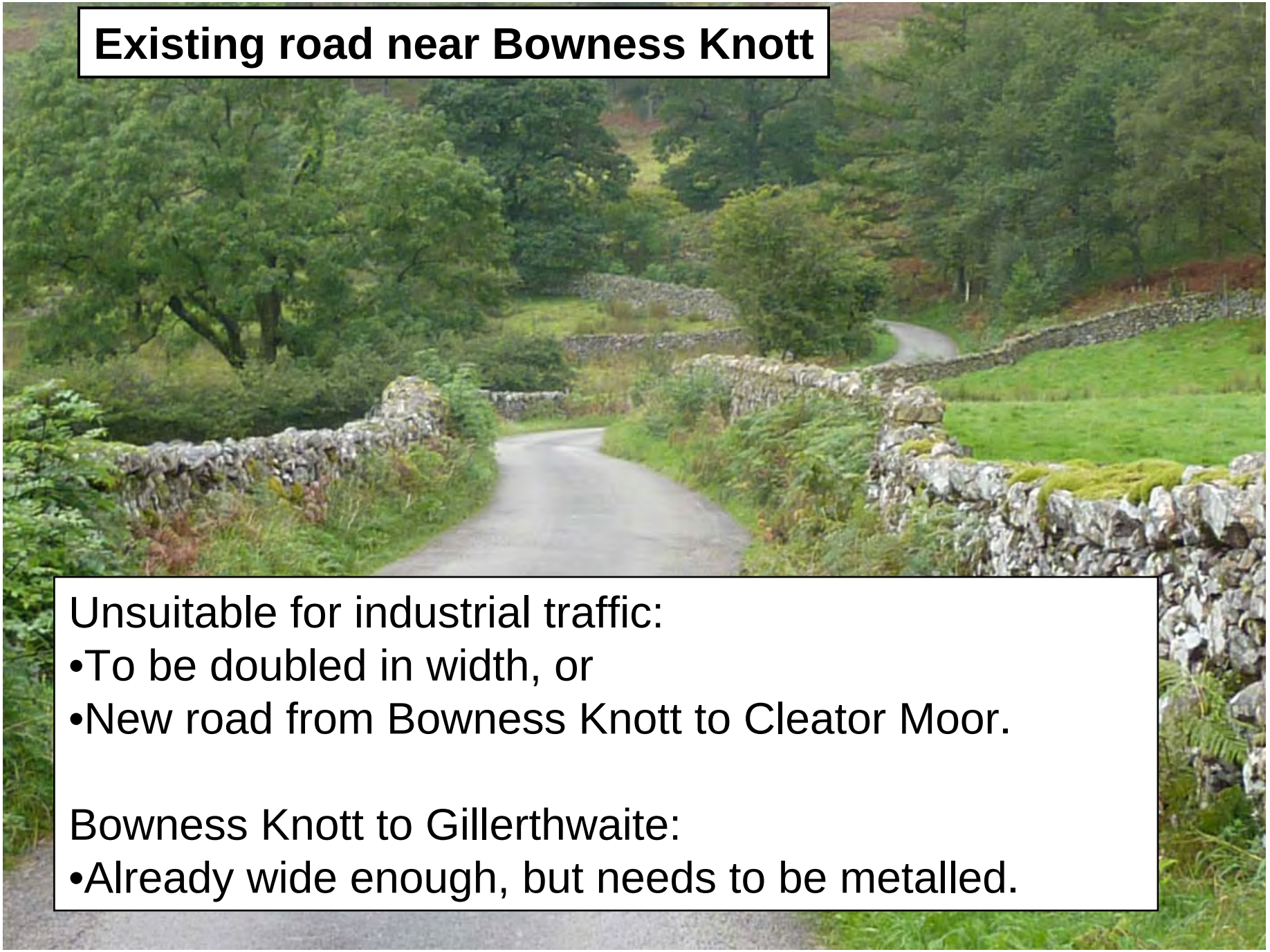
Holes can be drilled weeks or months in advance, and even charged with dynamite well in advance of the recording phase.

The above figures suggest that a truck-mounted drilling operation is too impracticable, even if the number of holes quoted above were halved or quartered.

Experiments on hard rock in Sweden suggest that a hand-held drill can achieve 20 holes per day. Assuming 10 hand machine crews operating simultaneously → 310 days work.


Access to the granite south of Ennerdale Water for drilling investigations:
Most feasible via Gillerthwaite (drilling site HQ, spoil waste temporary storage)
Volume of granite to be drilled after seismic survey completed
To Sellafield
20 km by road
Perspective view (vertically exaggerated) looking east to the head of Ennerdale Water


Access road to site
Drill site HQ, waste storage
Red dashed line - access road to top of Ennerdale Fell for drilling rigs
Brown How
Bowness
333
Bowness Knott
Scaw
Clews Gill
633
Starling Dodd
Little Dodd
ENNERDALE WATER
15
247
Smithy Beck
273
116
Ennerdale Forest
40m
30m
10m
Gillerthwaite
144
14
The Side
363
E N N E R D A L
Boathow Crag
13
Sail Hills
Low Beck



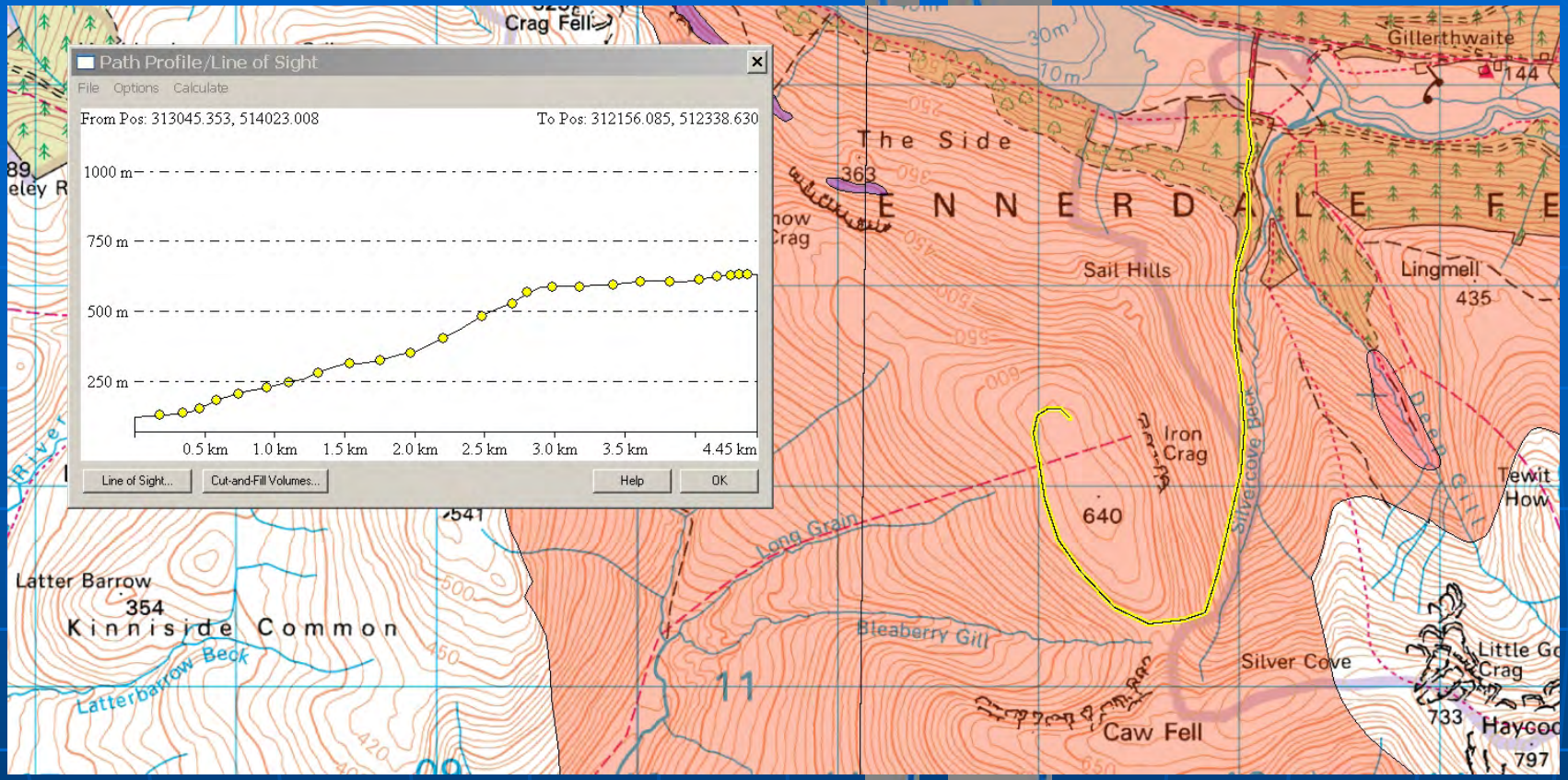
Existing road near Bowness Knott

Unsuitable for industrial traffic:

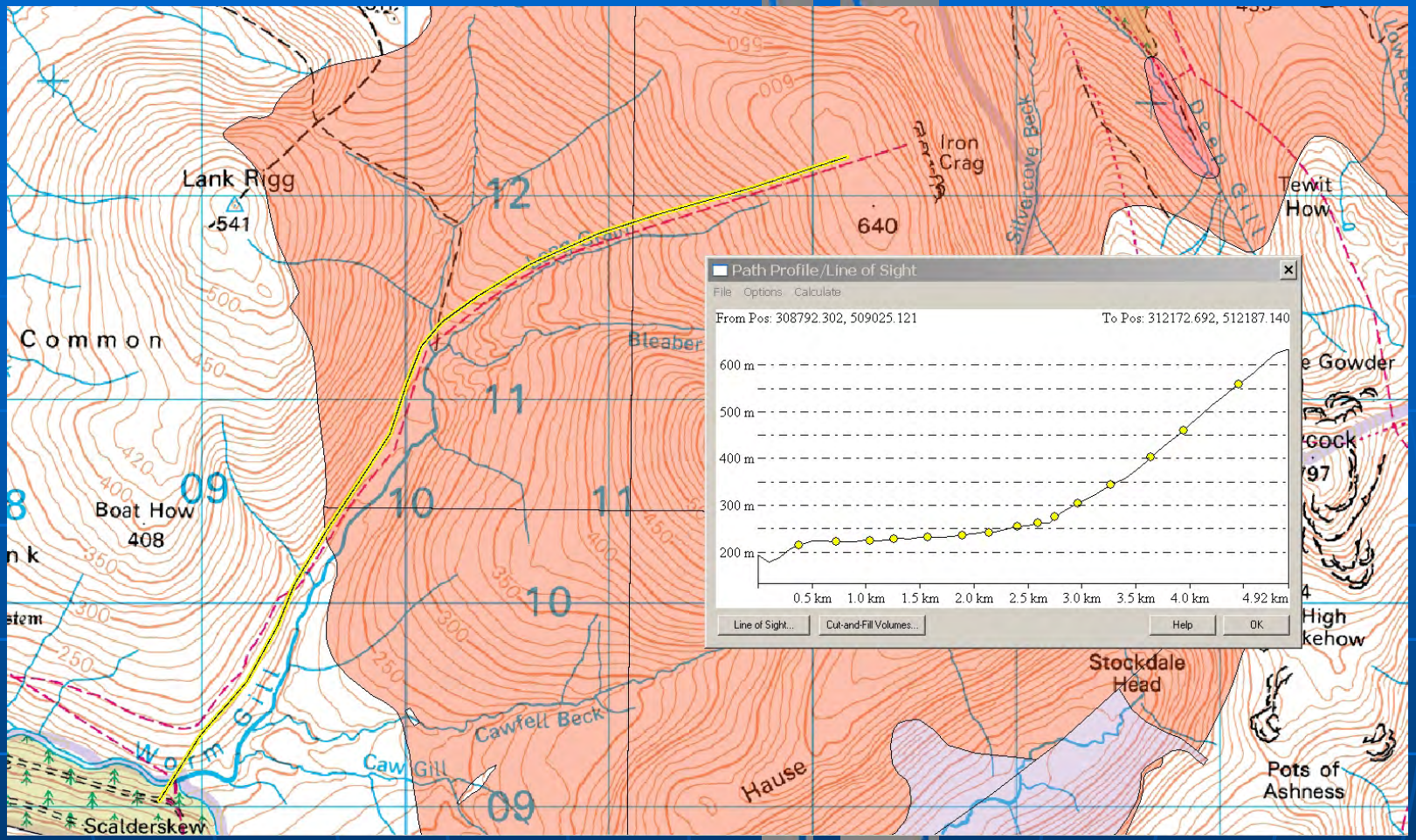
- To be doubled in width, or
- New road from Bowness Knott to Cleator Moor.

Bowness Knott to Gillerthwaite:

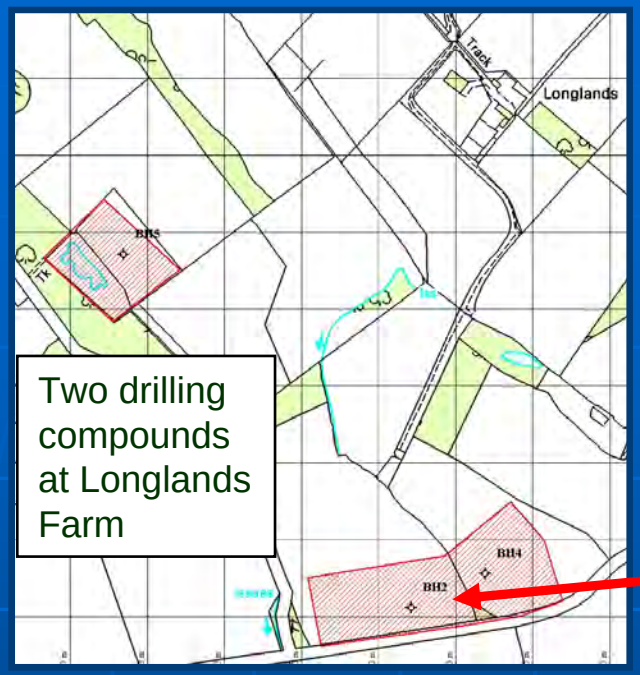
- Already wide enough, but needs to be metalled.



Gillerthwaite to top of Ennerdale Fell:
Roadway spirals clockwise round the back of Iron Crag.
Maximum gradient – 1 in 4.4 (23%).

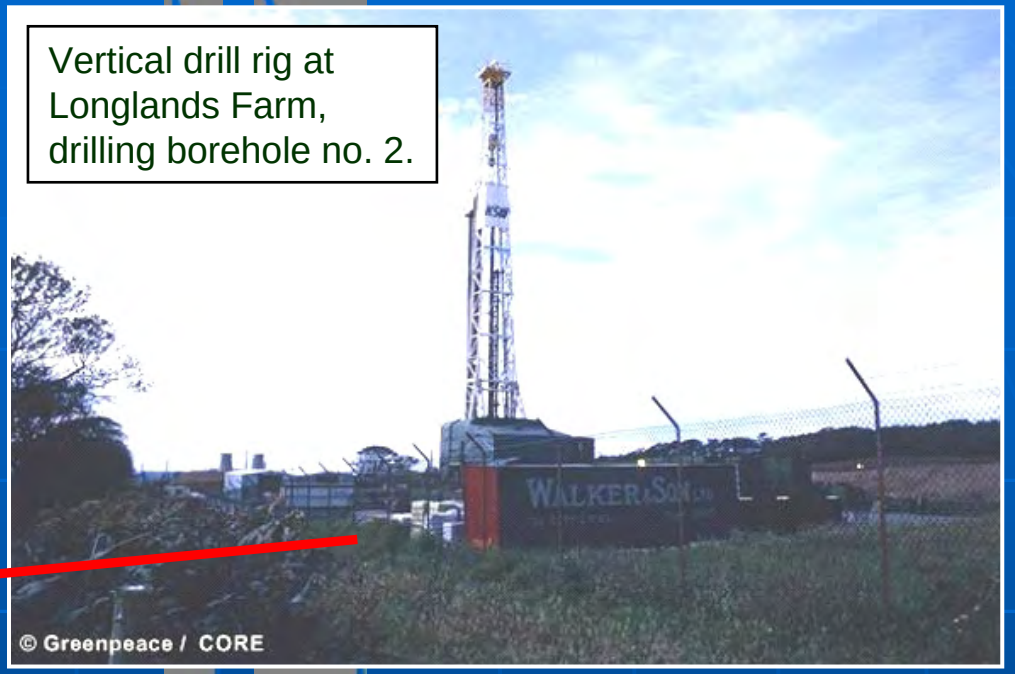


Alternative:
Roadway from Scalderskew to the top of Ennerdale Fell.
Maximum gradient of 1 in 4.0 (25%).



Two drilling compounds at Longlands Farm

Vertical drill rig at Longlands Farm, drilling borehole no. 2.



Drilling at the Nirex Longlands Farm site in the 1990s demonstrates that the rig needs a flattish compound area of about 100 m x 100 m (=1 Ha - red diagonal hatching in map above; OS grid shown at 100 m interval). The two compounds shown slope at about 1 in 10 to the SW.

A single compound could be used for drilling boreholes in several different directions with a specialised inclined drilling rig (right).

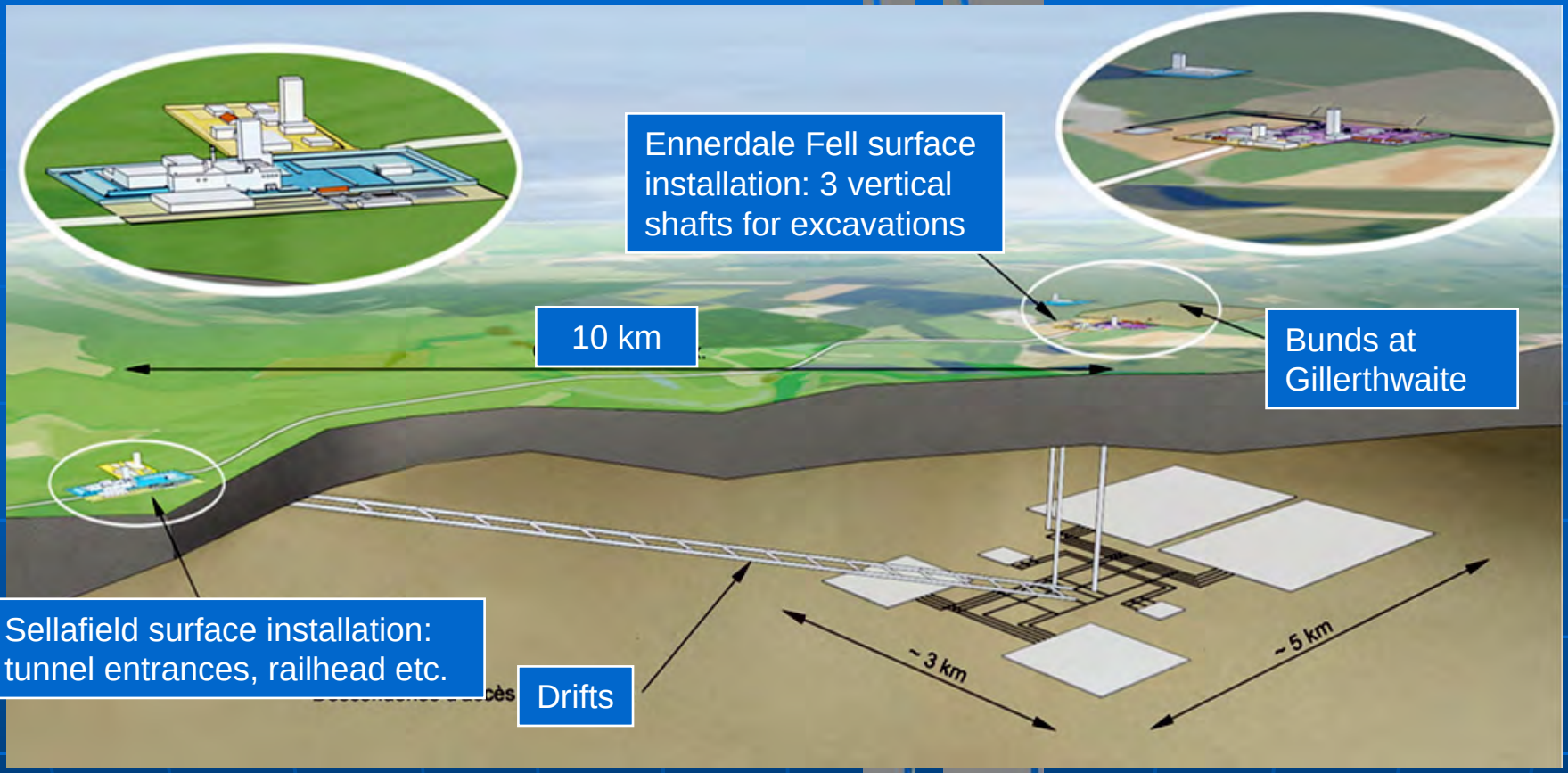
Rigs like those shown are brought in, disassembled, in 10-20 lorry loads. The roadways constructed around the Longlands Farm site vary from 5 to 10 m in width.

Inclined drill rig at Longlands Farm (used for the ‘PRZ’ boreholes)

MRWS Stage 6
"*Underground operations*"

Stage 6 is the excavation of the repository or GDF, in the event that a viable safety case could be made from the results of Stage 5.

The following diagrams are merely outline sketches, based on published information on the French site at Bure, and rock volumes discussed in the Entec report of October 2010.



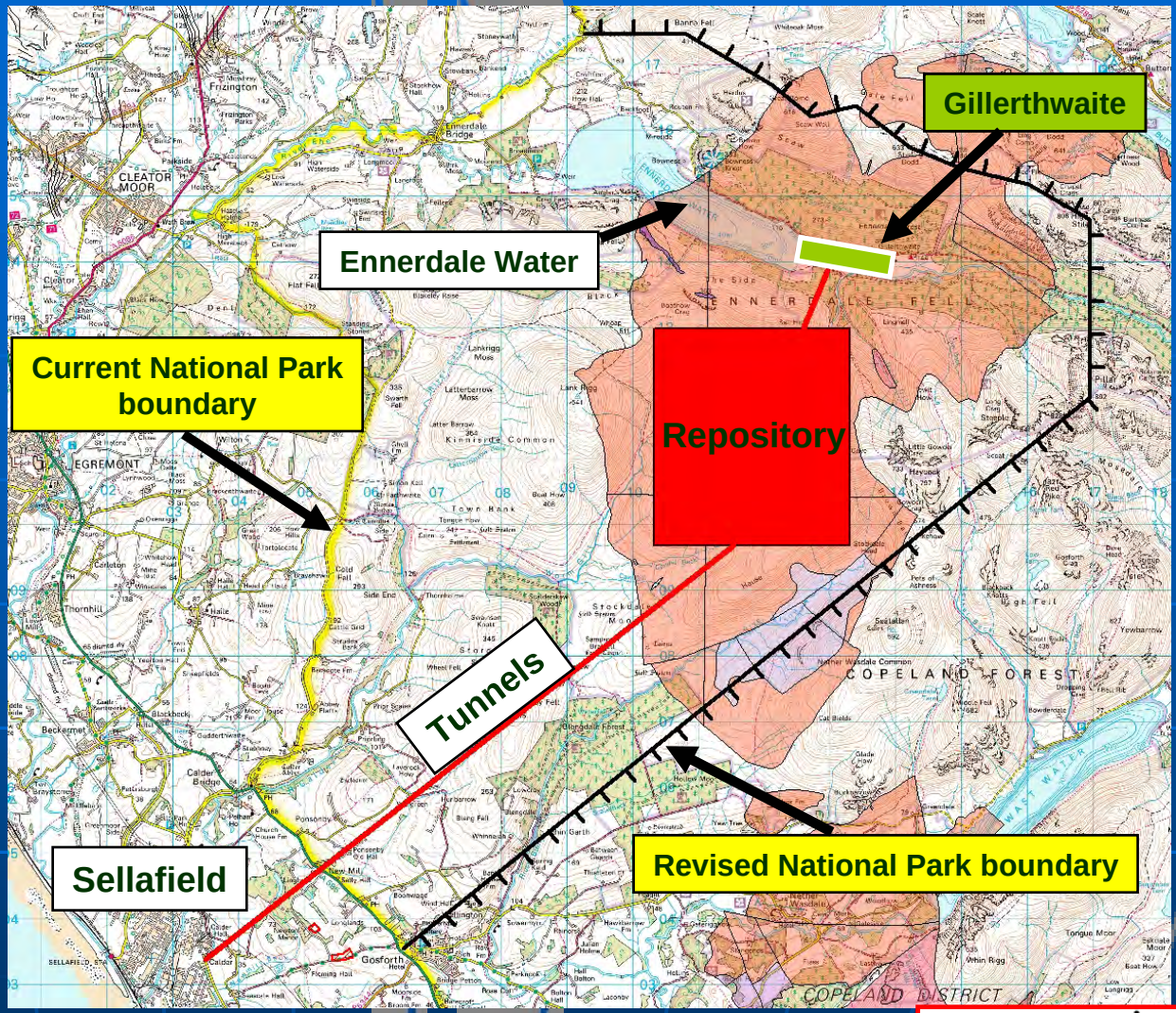
MRWS Stage 6
Construction of a repository below Ennerdale Fell

Schematic 3D view of the proposed French waste repository in clay at Bure, with English labels overlain, to illustrate how this would apply to the Ennerdale granite. The French subsurface area is about 5 x 3 = 15 km^2. In Ennerdale this area would be about 10 km^2.

The topography in West Cumbria is clearly much more extreme than shown here.

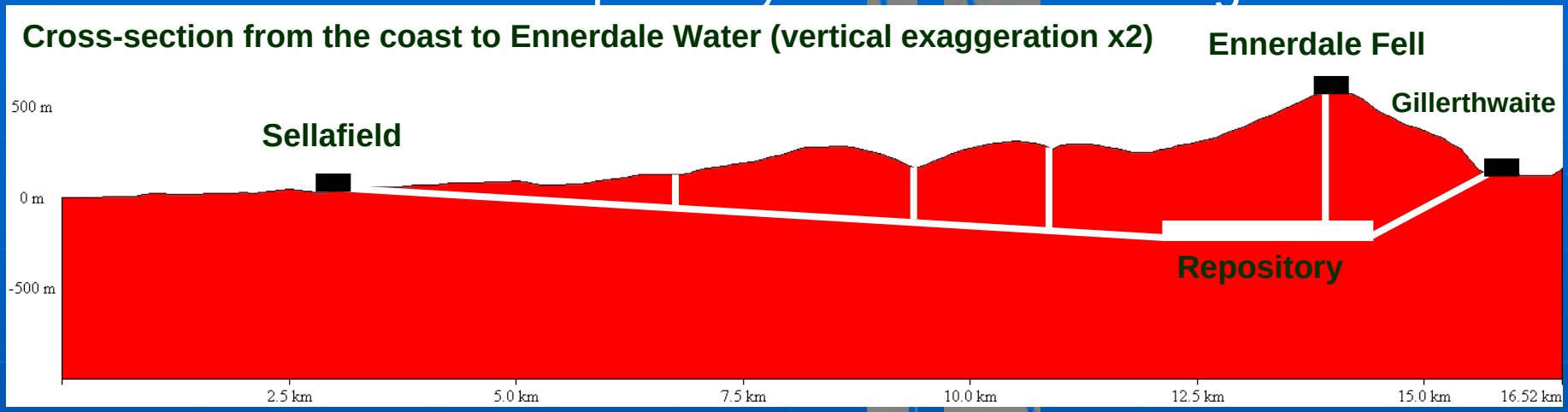
A 10 sq km repository is shown here. It may be difficult or impossible to emplace a larger one.

Given the disruption to the National Park, and the need for long-term security of the surface installations, it would be logical to remove the Ennerdale granite area entirely from the park. The area shown here to be removed is about 115 sq km, or 5% of the park's area.



? LEGAL CHALLENGE

Schematic of repository in the Ennerdale granite



It is impossible to construct such a repository purely by tunnelling from Sellafield. Likely permanent features would include:

- Roads over Ennerdale Fell
- Headworks on top of the Fell during excavation of vertical shafts
- Base at Gillerthwaite for access to the fell
- Tunnels from Gillerthwaite to the repository
- 10 km tunnels (‘drifts’) from Sellafield to repository for waste emplacement
- Emergency escape/ventilation shafts to surface

The repository would begin to be used while parts of it are still under excavation. The French nuclear safety agency has pointed to the importance of keeping the miners and the nuclear workers separate undergound.

Google Earth aerial view looking ENE from the western slope of Lank Rigg, at 2200 m eye elevation. The drift headworks and the vertical shaft headworks from the Bure diagram have been superimposed on Gillerthwaite and the top of Ennerdale Fell, respectively.

Ennerdale granite: summary

Unsuitable because of:

- Extreme topography
- Near-impossible access and logistics for geological/geophysical studies
- Likely complex internal structure
- Probably not big enough to accommodate a GDF > 10 sq km
- Therefore unpredictable and unsafe as a GDF

Further reasons to rule it out:

- It is a minor aquifer (water well at Nether Wasdale)
- Unavoidable pollution of Ennerdale Water
- Transformation of part of the National Park
- Permanent scarring of Ennerdale Fell

Relevant legislation:

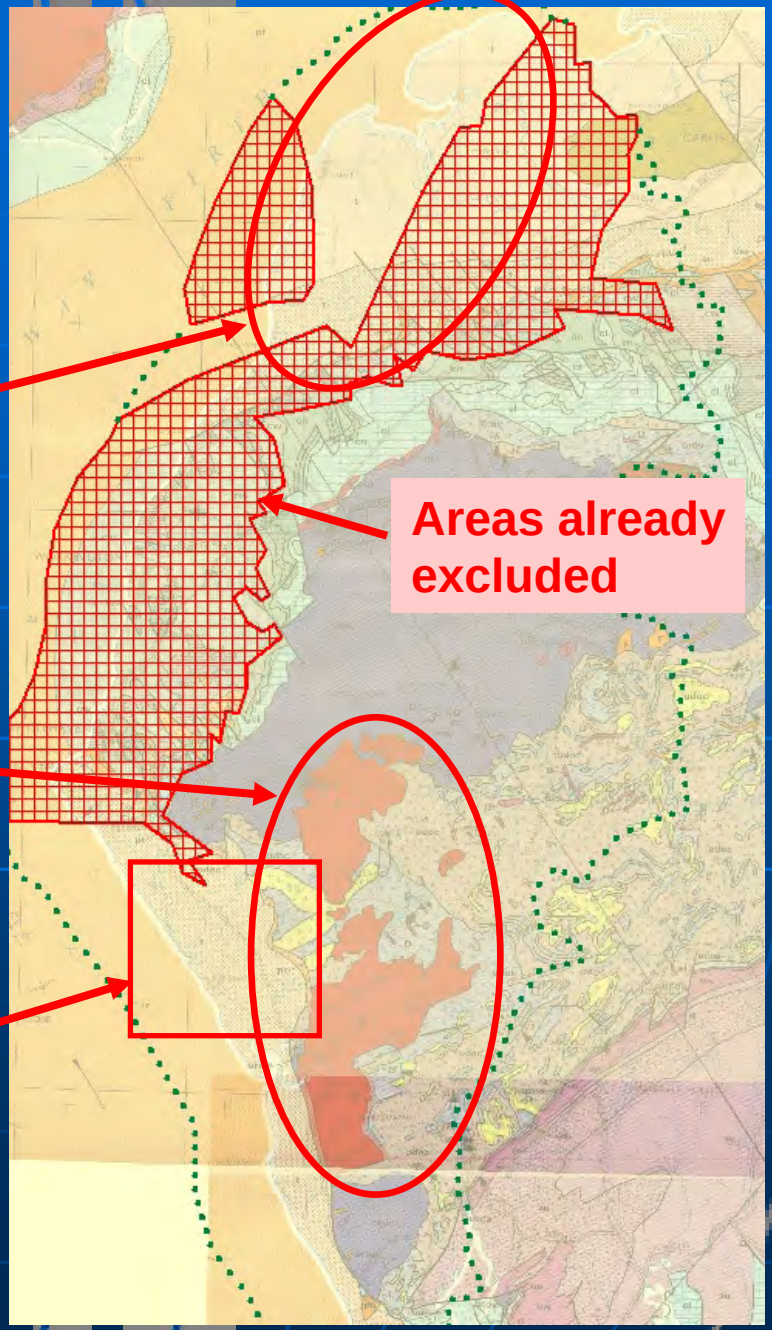
Ennerdale is a critical Public Water Supply for west Cumbria
Ennerdale Fell and Ennerdale itself are both SSSIs
The River Ehen when it leaves Ennerdale is a SAC
Ennerdale Fell is owned by the National Trust

Geology of the areas left in play

Northern Allerdale – the Mercia Mudstone Group

Eskdale and Ennerdale granites (red areas)

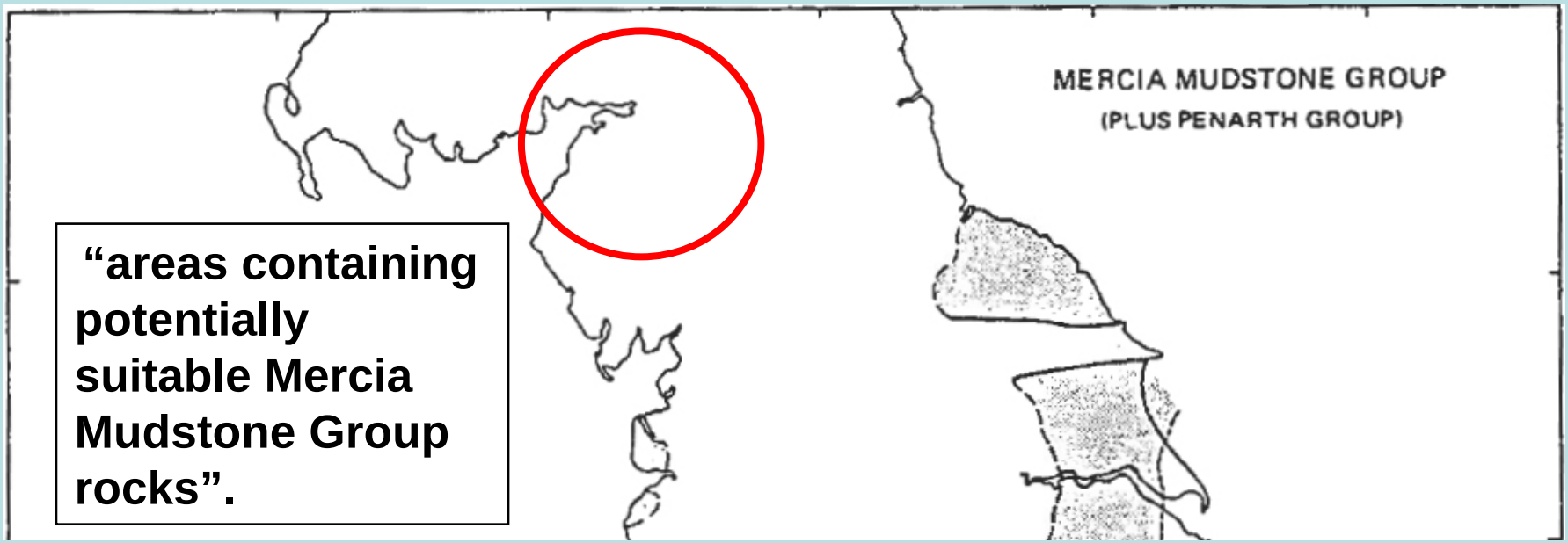
Sellafield / Longlands Farm



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

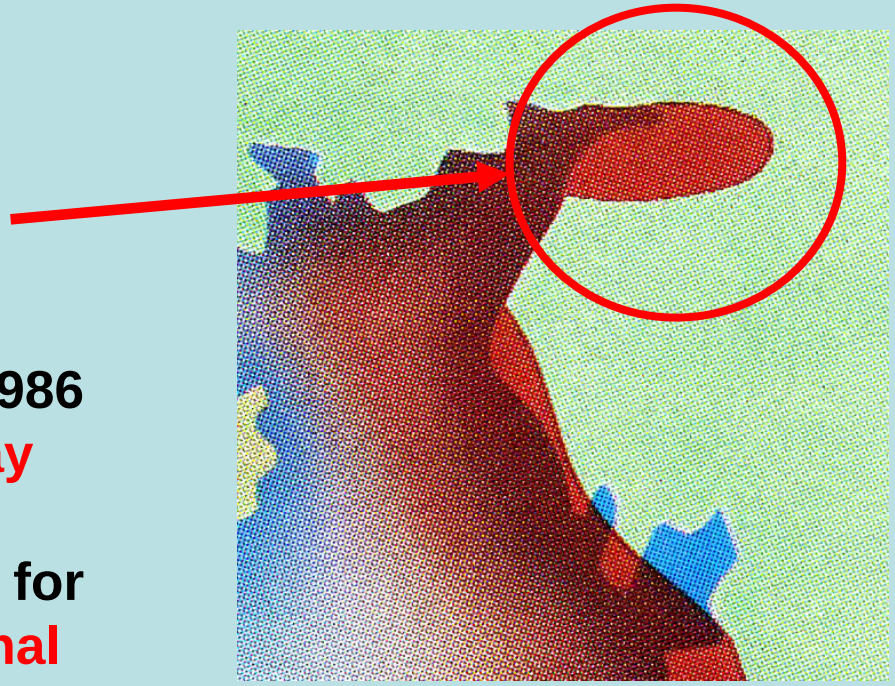
"areas containing potentially suitable Permian rocks".



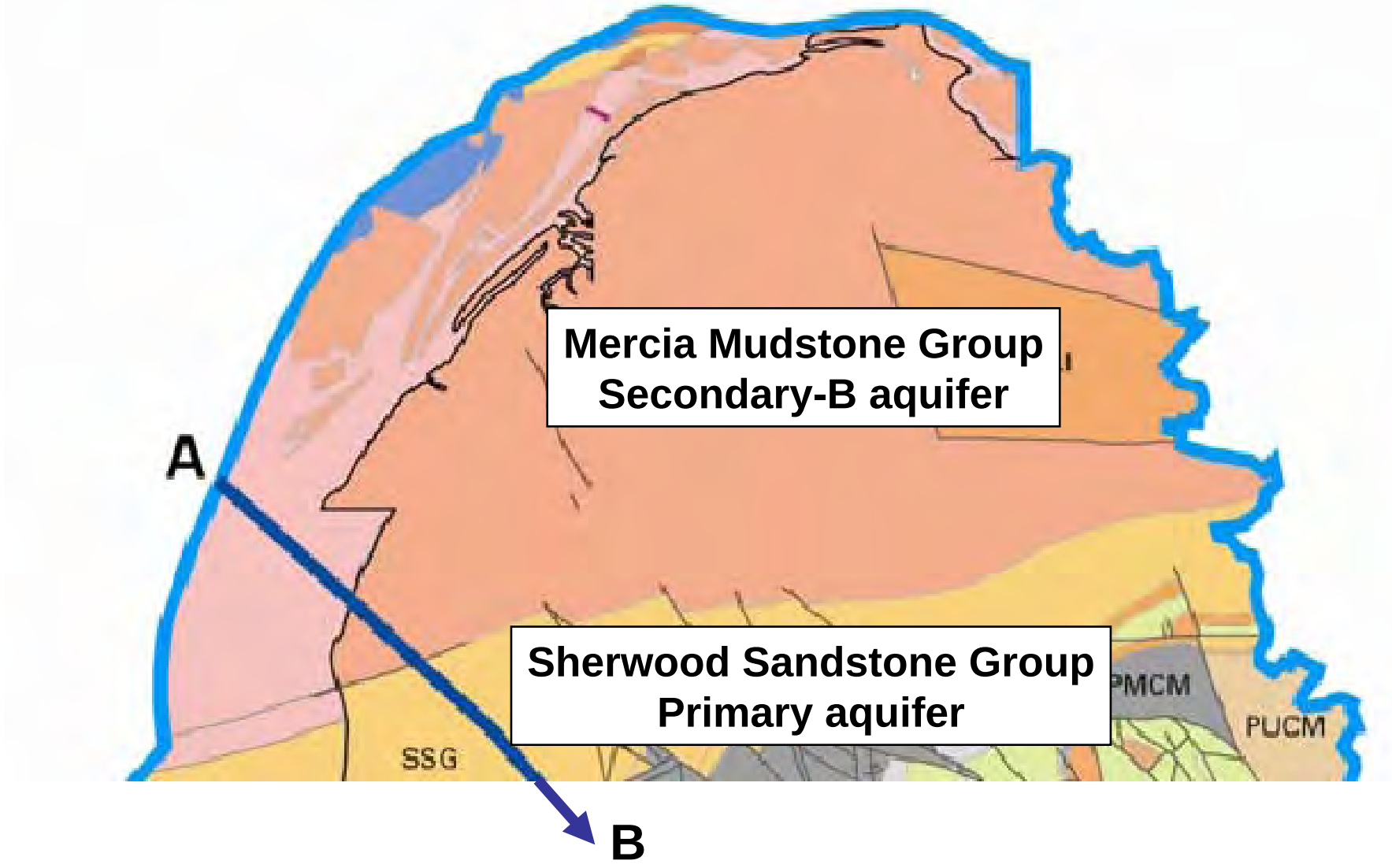
"areas containing potentially suitable Mercia Mudstone Group rocks".

Dr Dearlove:

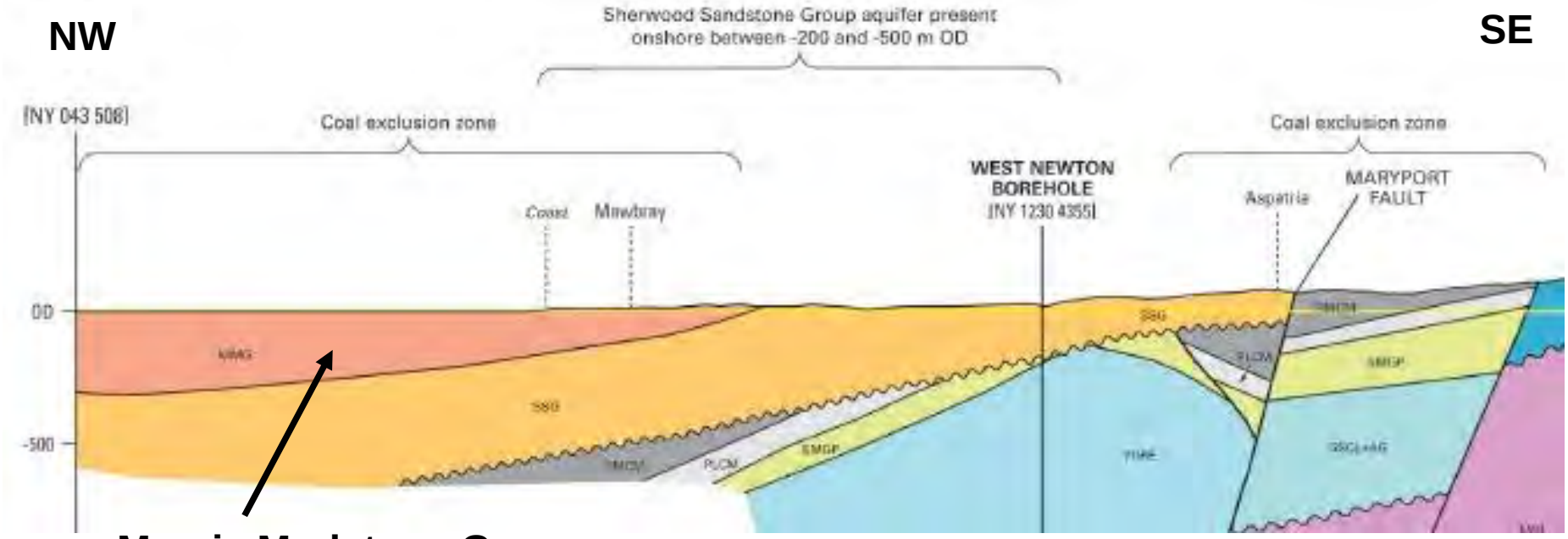
“Figure 2.1.1 (b) in Smythe's submission identifies the area including the MMG as "areas of potentially suitable sedimentary rocks" following Dr Chapman's 1986 review. Whilst an assessment may have been made at the time to remove this area from the search for potentially suitable sites, additional data 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.



Cross-section: Aspatria to Solway Firth

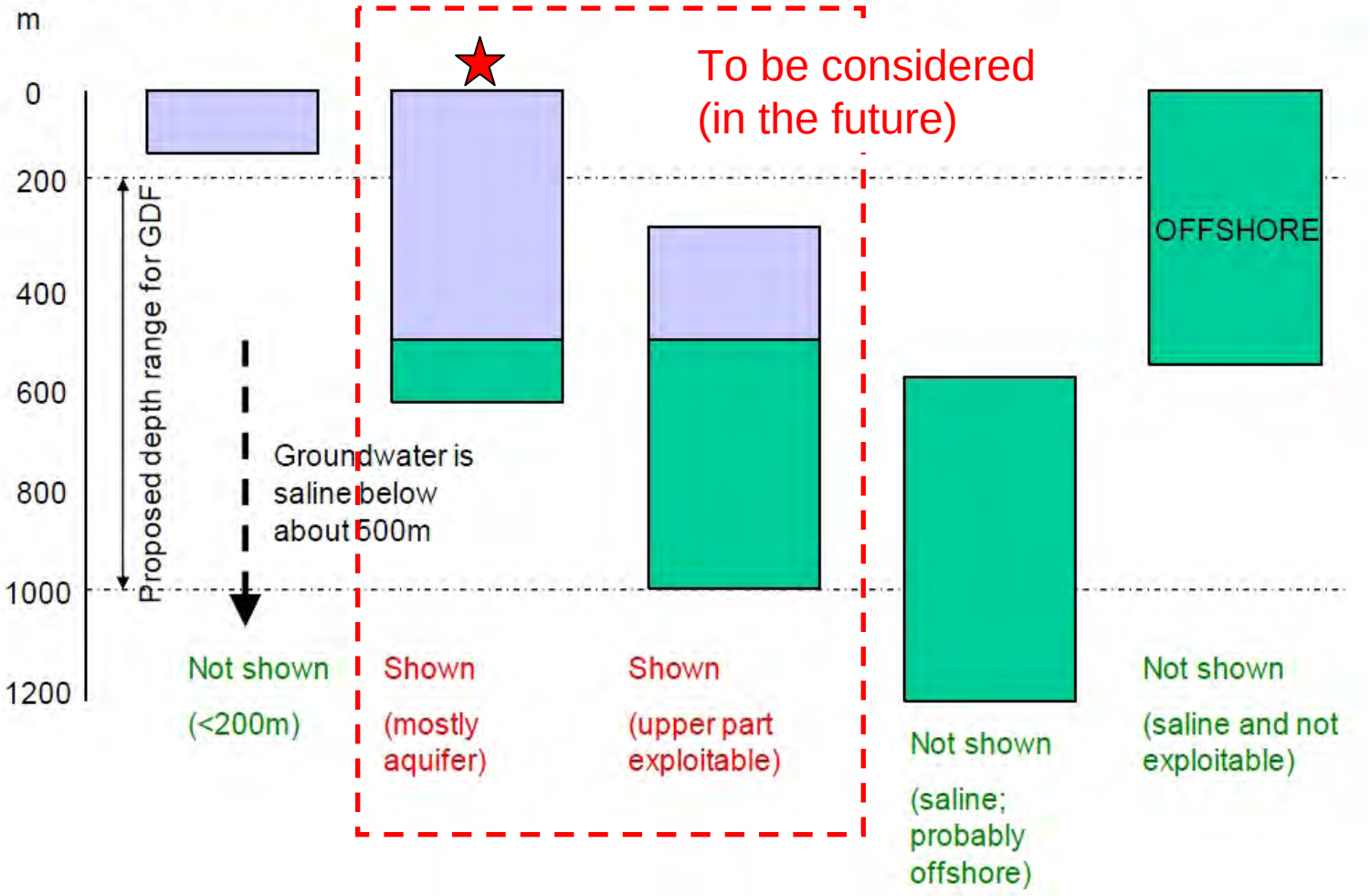
Mercia Mudstone Group

- **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.

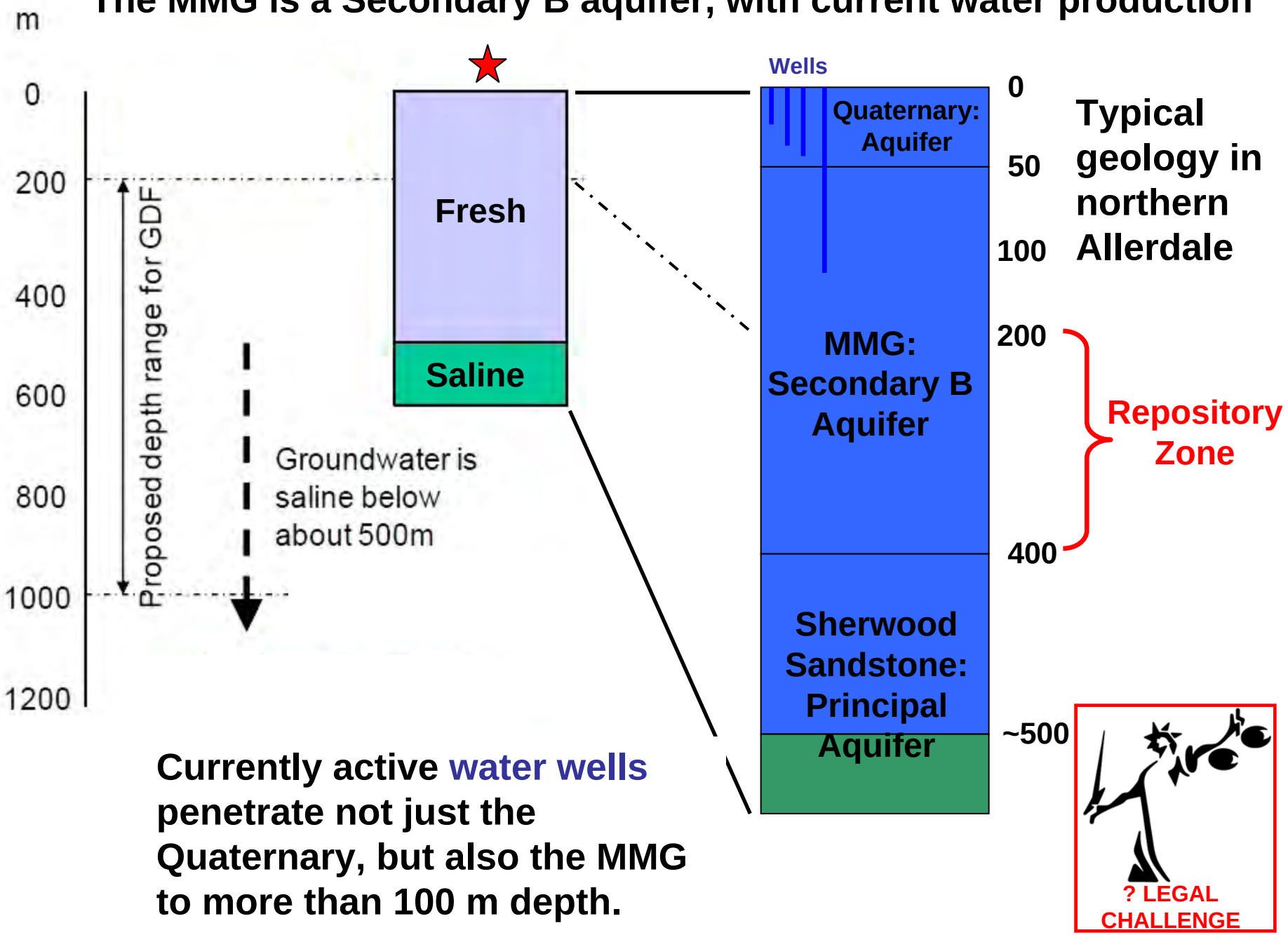
The MMG is an aquifer

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

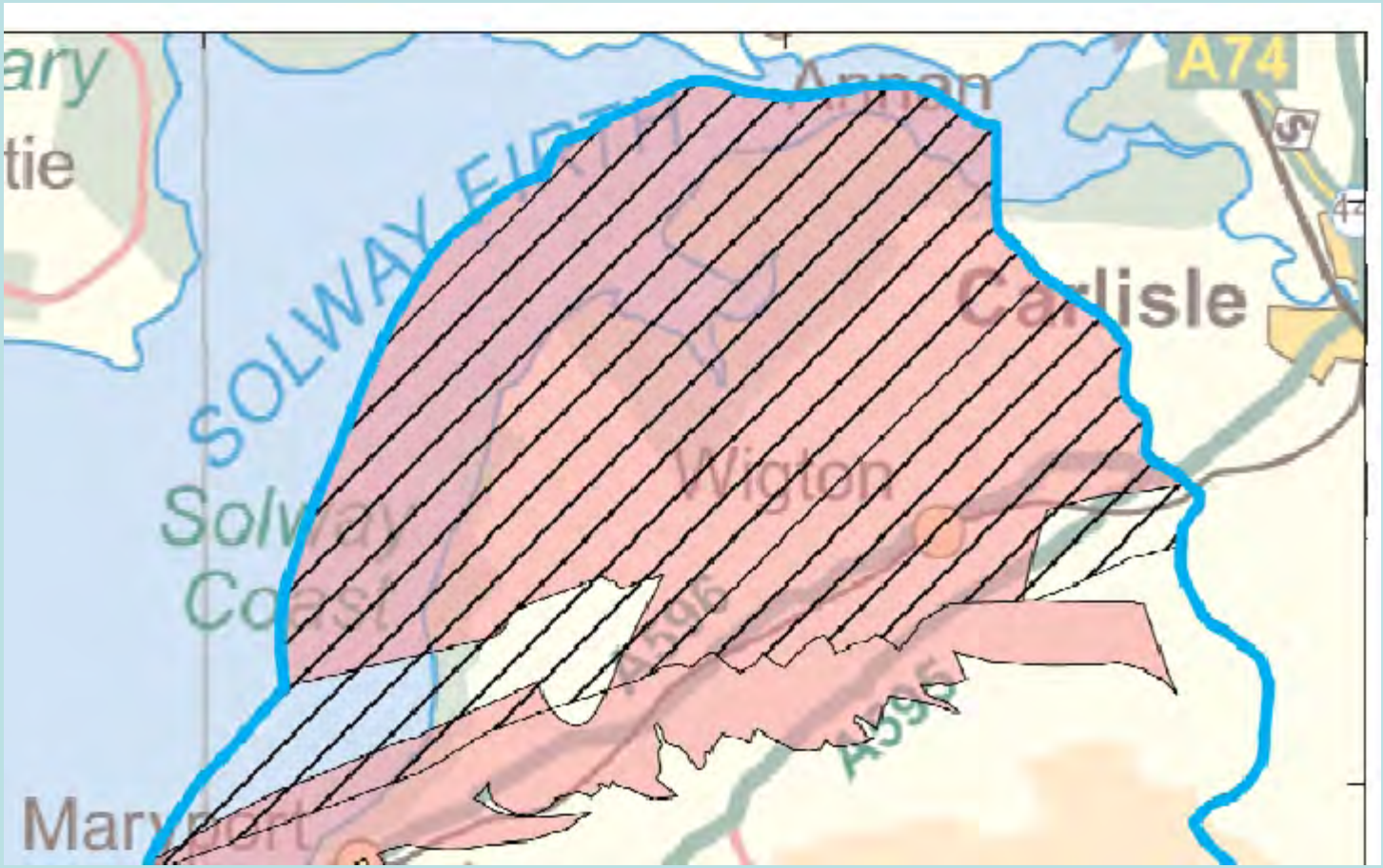


Slide from Adrian Bath: 2011 MRWS geology seminar. In the BGS screening report the MMG is not included in the category of aquifers.

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

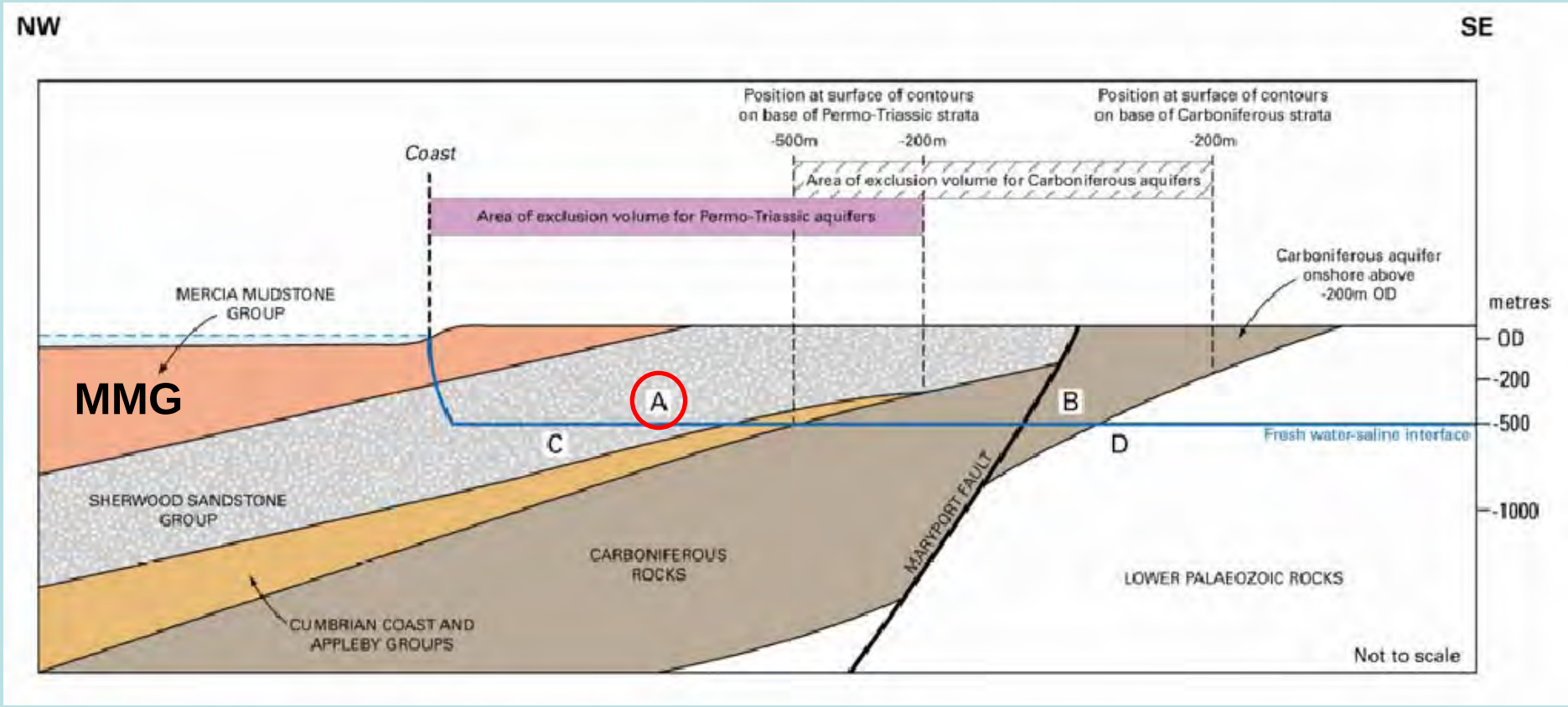


Currently active water wells penetrate not just the Quaternary, but also the MMG to more than 100 m depth.



(Oil and gas, coal, etc.)

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



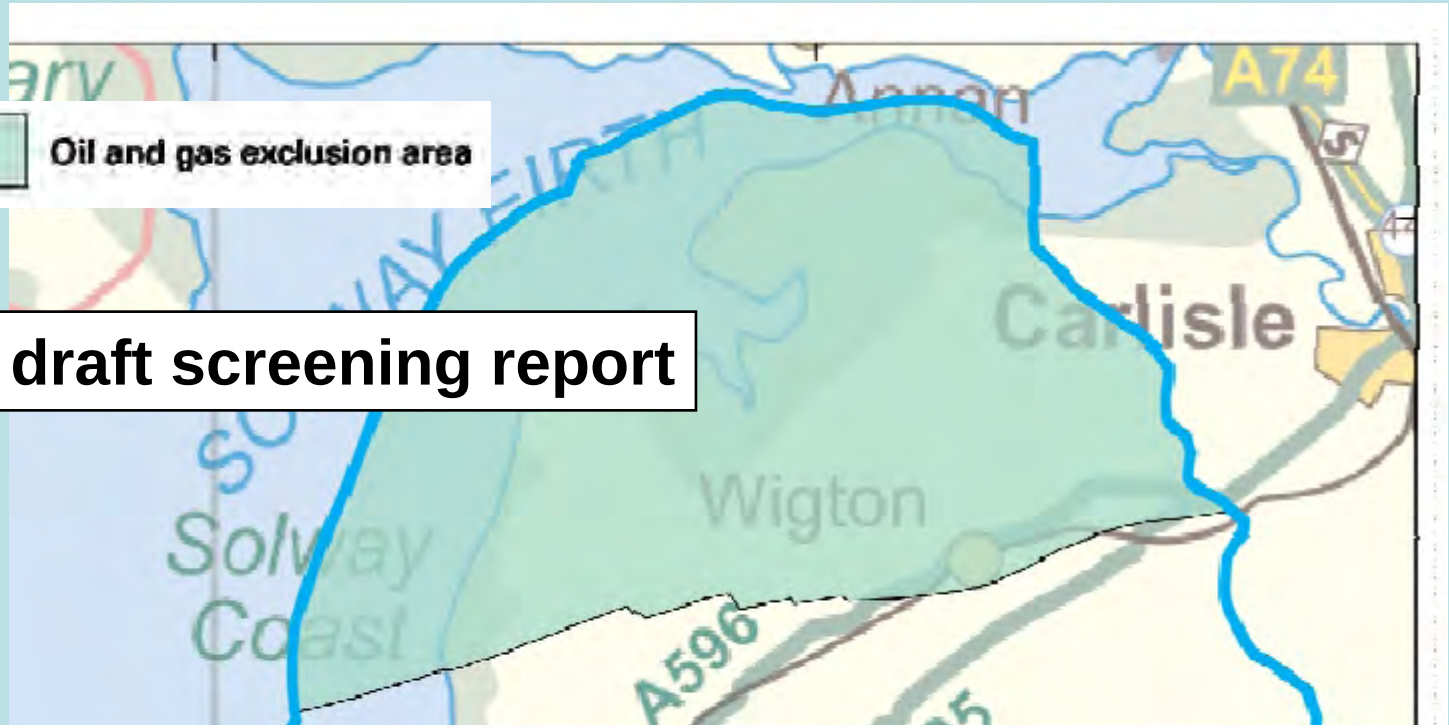
BGS screening report:

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

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

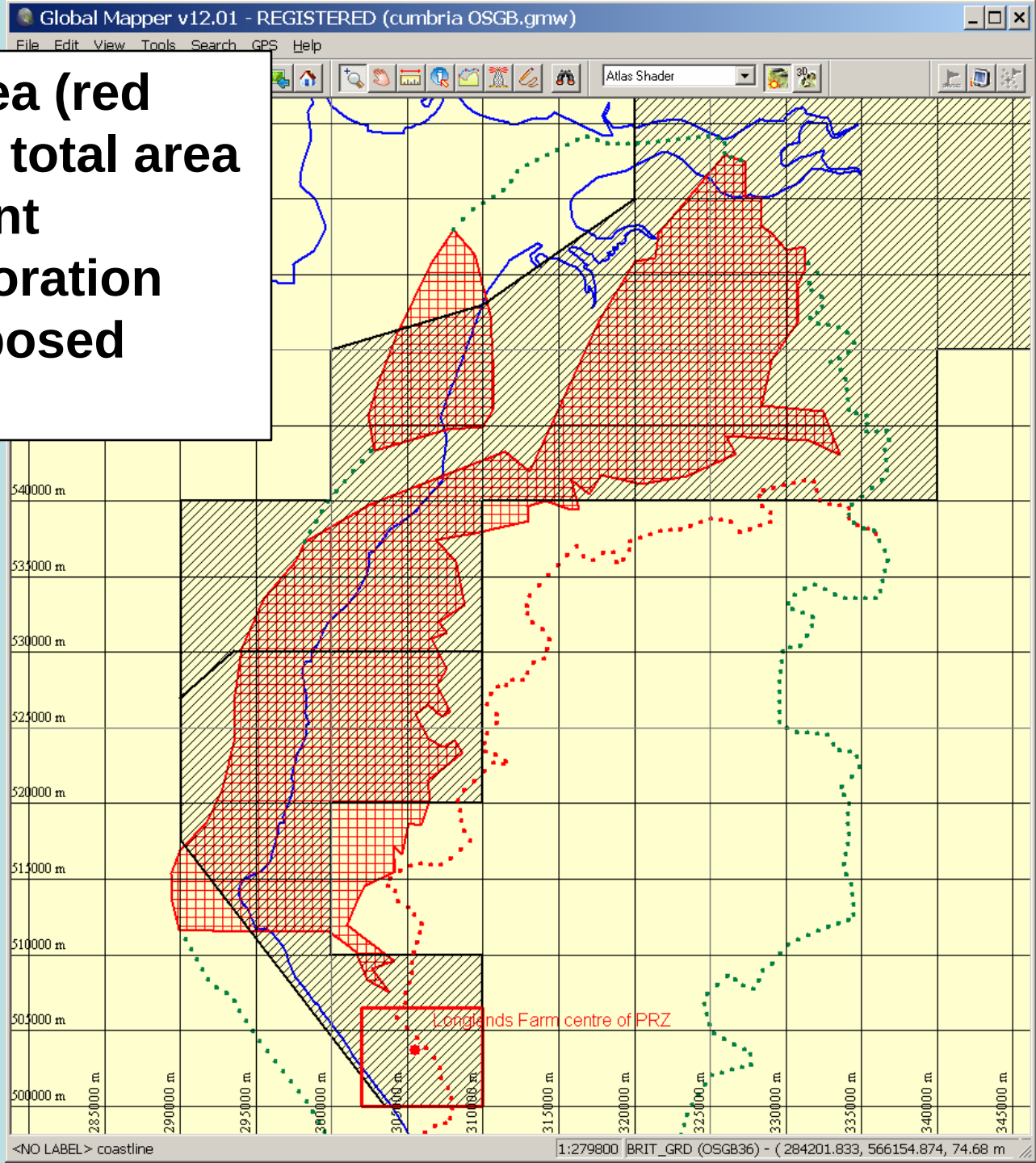
The UK has been thoroughly explored for gas/oil resources, many oilfields have been developed and their distribution is well known. The extent of future exploration and exploitation is difficult to judge and will be dependent on market prices for oil and development of new theories on oil genesis/traps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

Survey data required to scope out the Mercia Mudstone Group in Allerdale

2D seismic programme:

100 km onshore, mainly following roads

Cost: £800,000

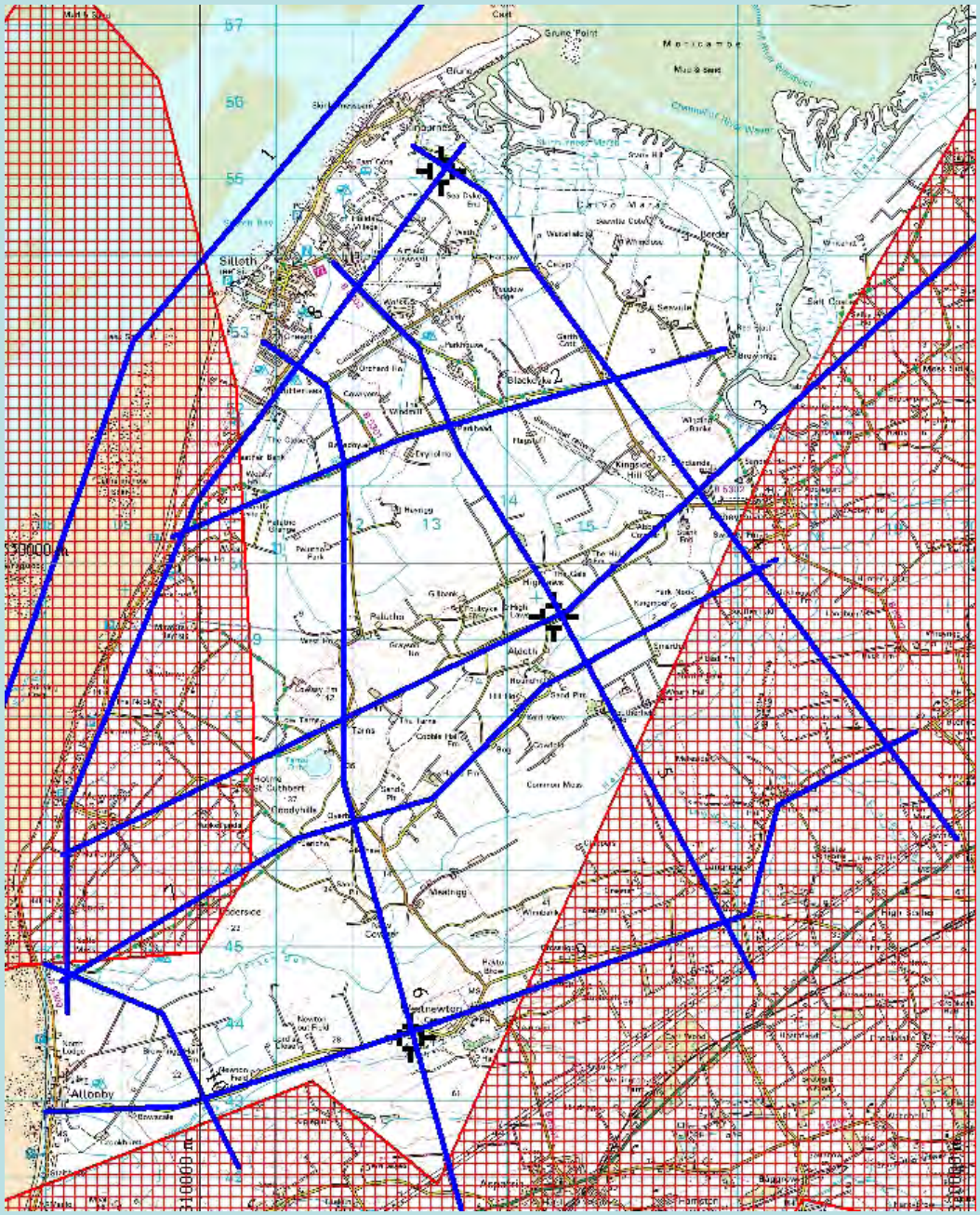
+ 15 km offshore
(? If opportune: £25,000)

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

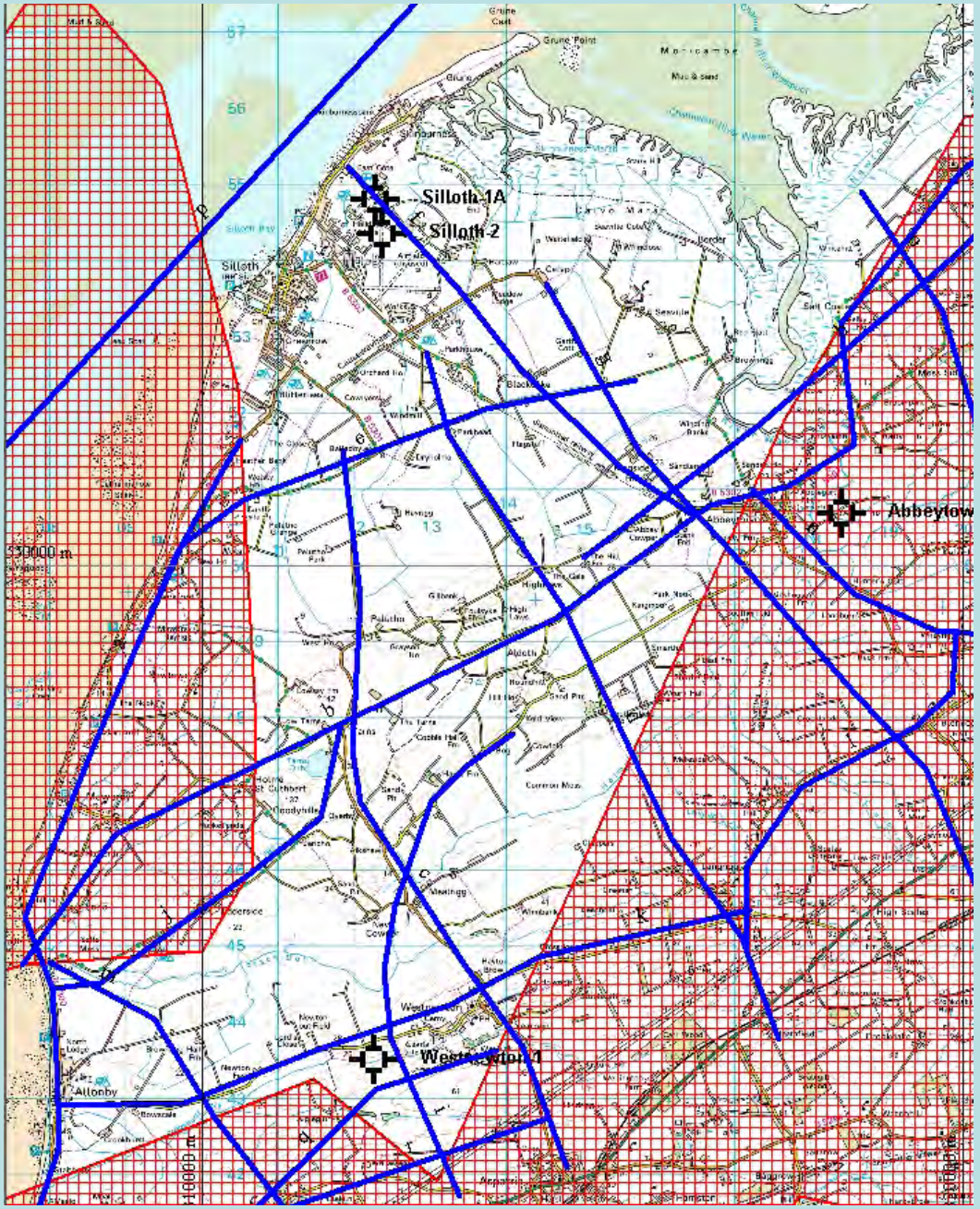
Silloth-1A oil well (1973)
Fully logged to 1330 m.

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.

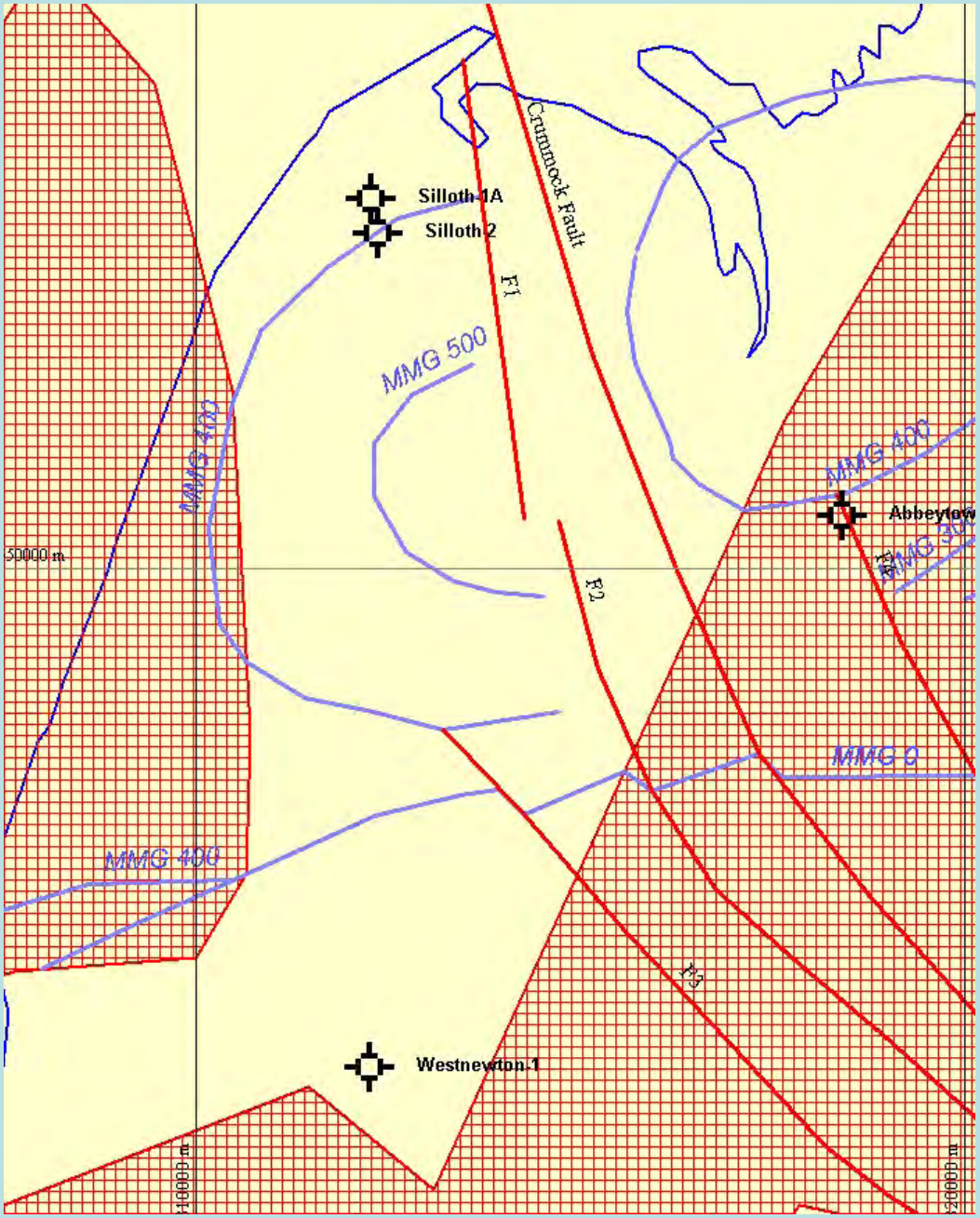
- All interpreted and published by BGS before the 1986 national search



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

-Simple shallow basin
-Cut by large faults

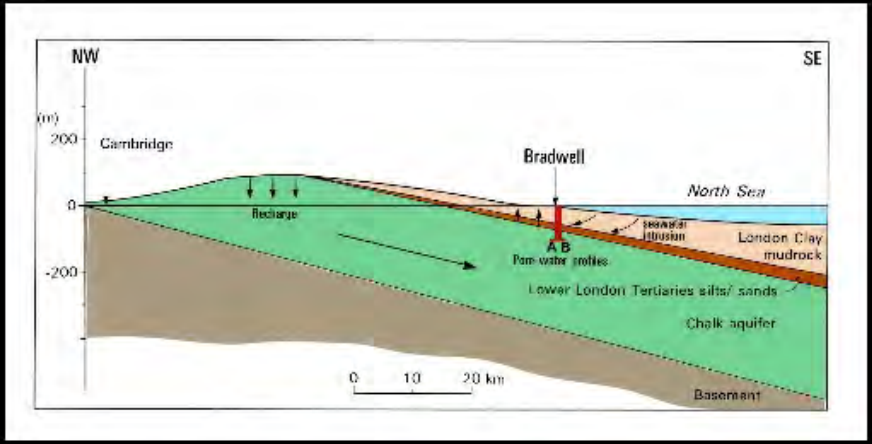
So the geological structure is simple, but fundamentally unsuitable

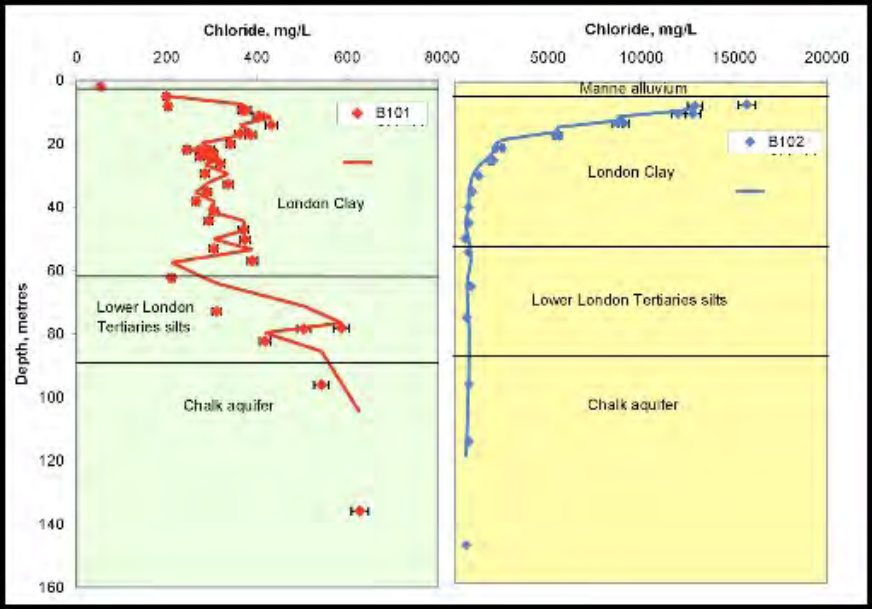


Is the MMG a good clay rock?

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

David Beckham £25M

UK average Pay £25K

Average UK GP £110K

Average UK child's pocket money £300

Basic UK state pension £5K

Typical US CEO £6M

Highest US CEO £80M

0 (£1)
1
2 (£100)
3
4 (£10,000)
5
6 (£10M)
7
8 (£100M)
9
10

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

Mercia Mudstone

Desirable range

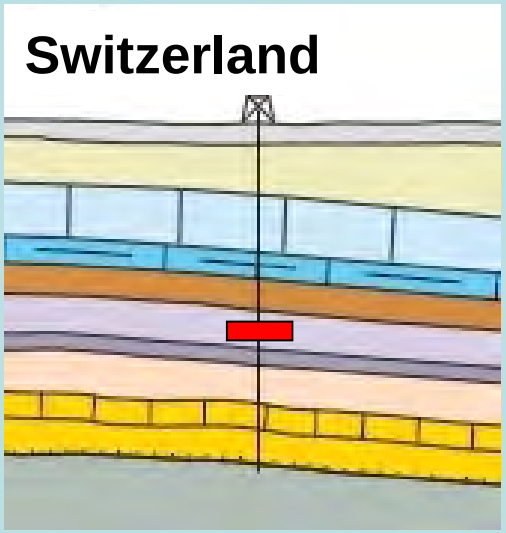
Increasing intrinsic permeability (hydraulic conductivity)

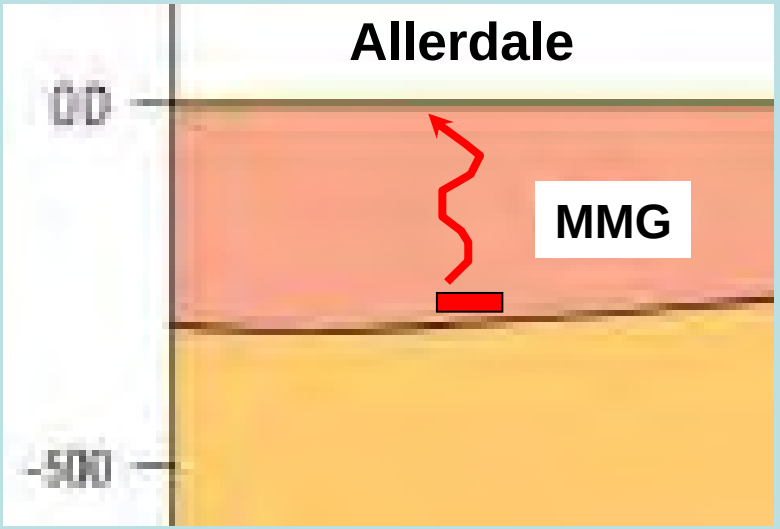
0 1 2 3 4 5 6 7 8 9 10

Log hydraulic conductivity (Log k) +14 m/s

What the relatively high permeability of the MMG means

Repository





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 ?

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

Switzerland

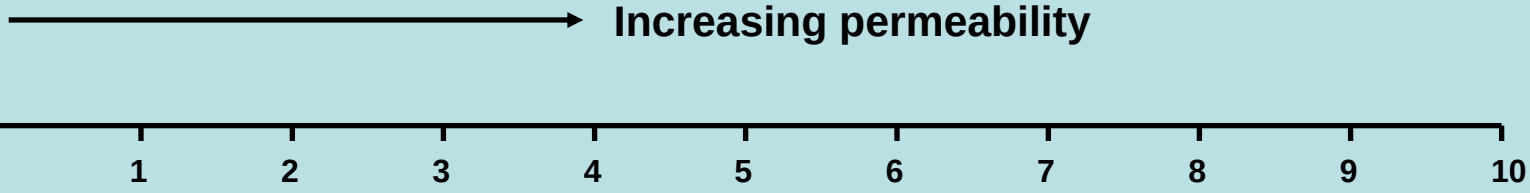
50 m thick
Safe for 1 million years

Uncertainty:
100,000 years
10 million years

Mercia Mudstone

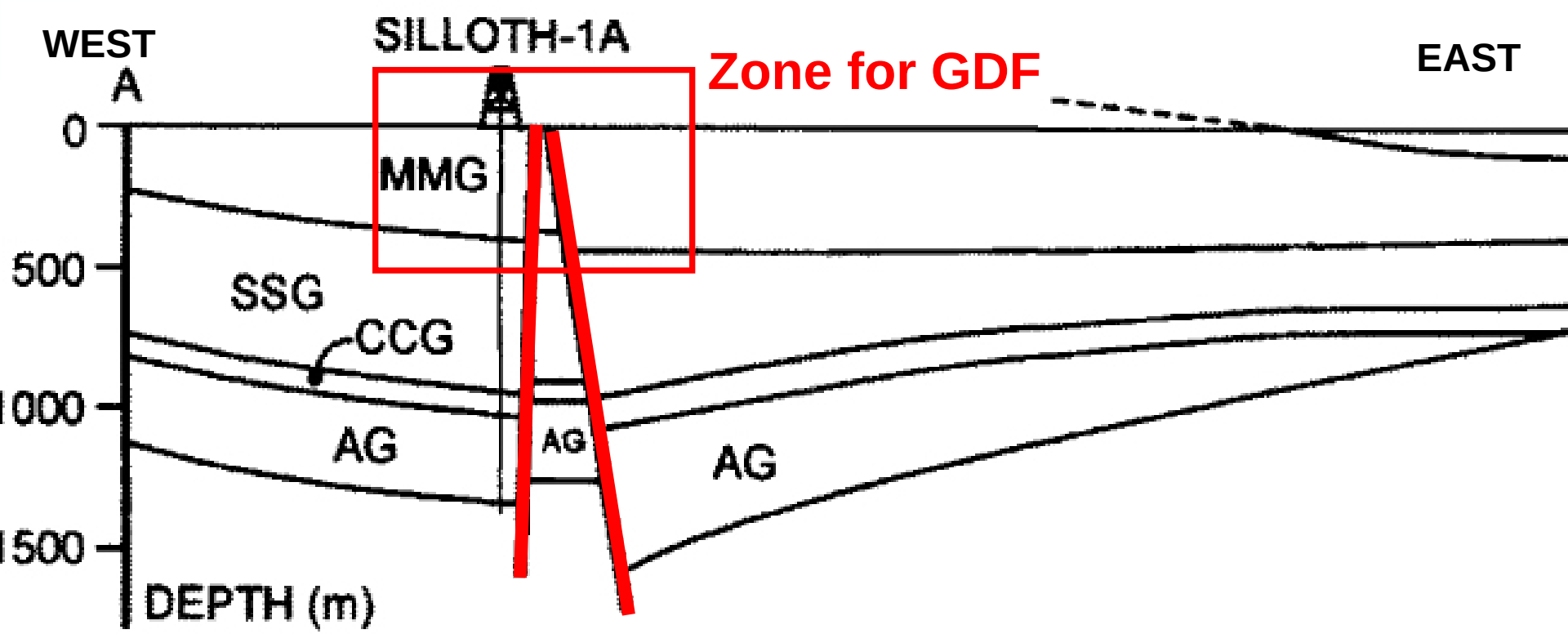
300 m thick
Safe for 6 years

Uncertainty:
8 months
60 years



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

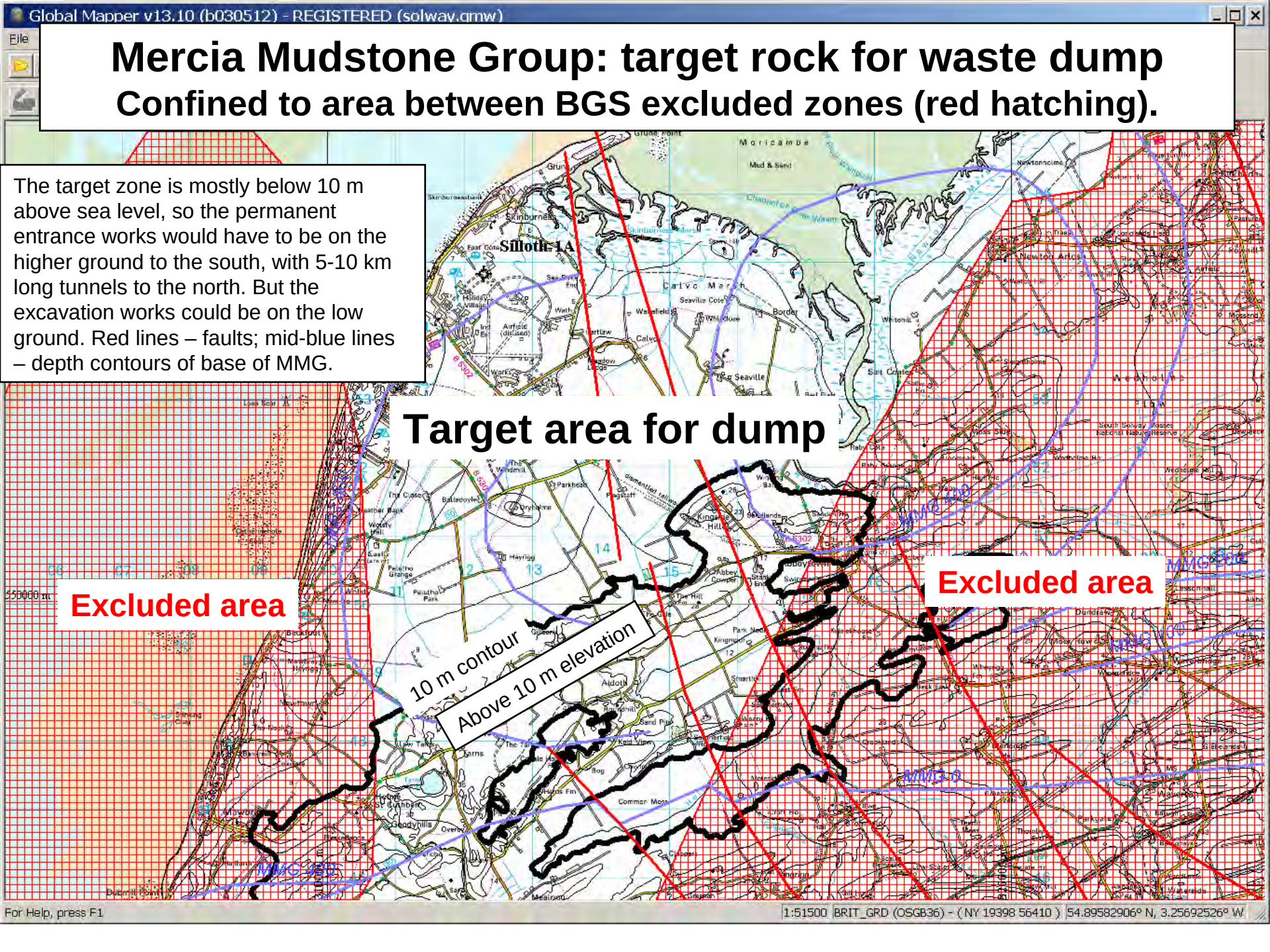
- and that is before the faulting (red) is taken into consideration. Only the two major faults are shown.

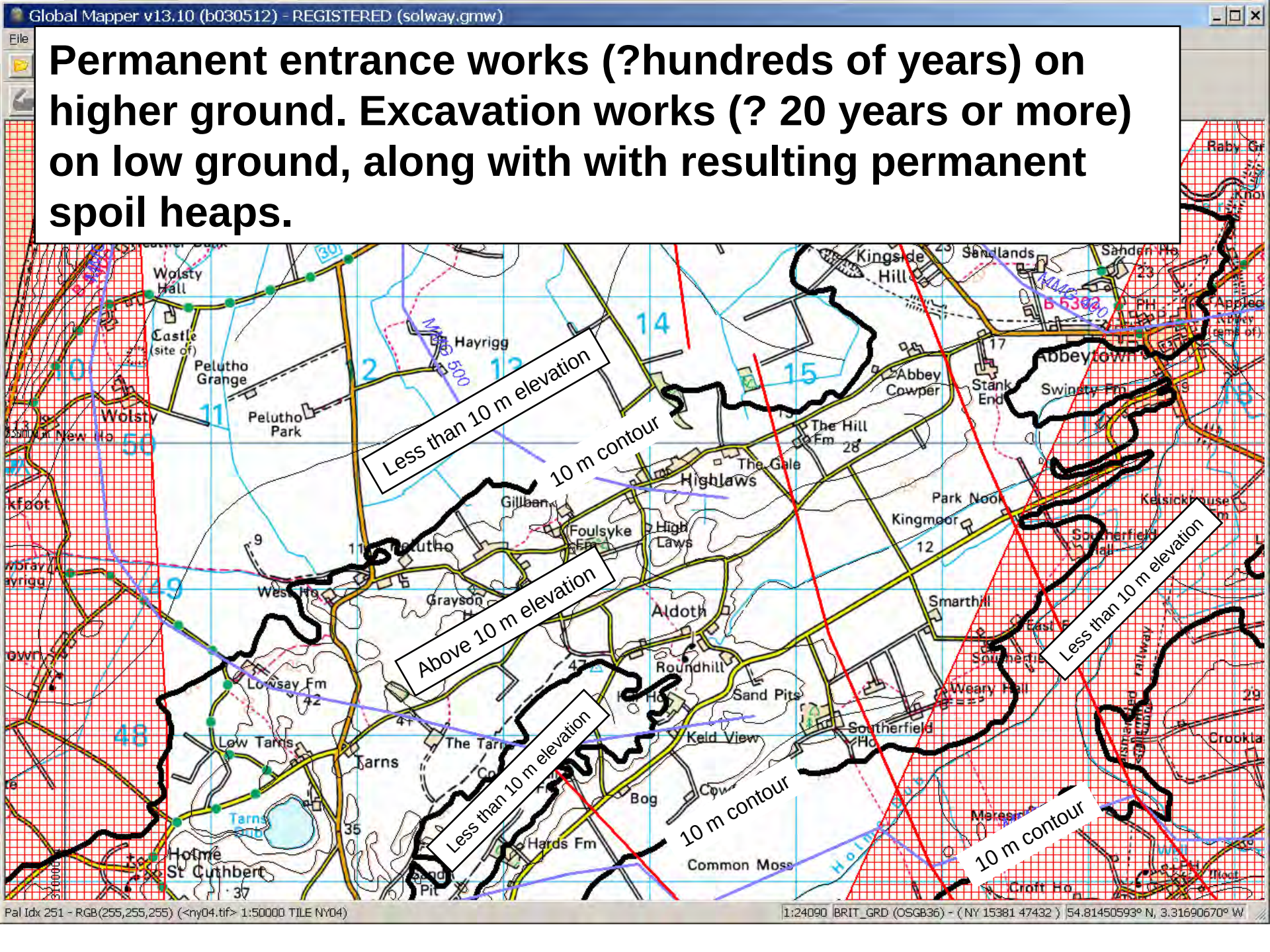
Where would surface installations be sited in northern Allerdale?

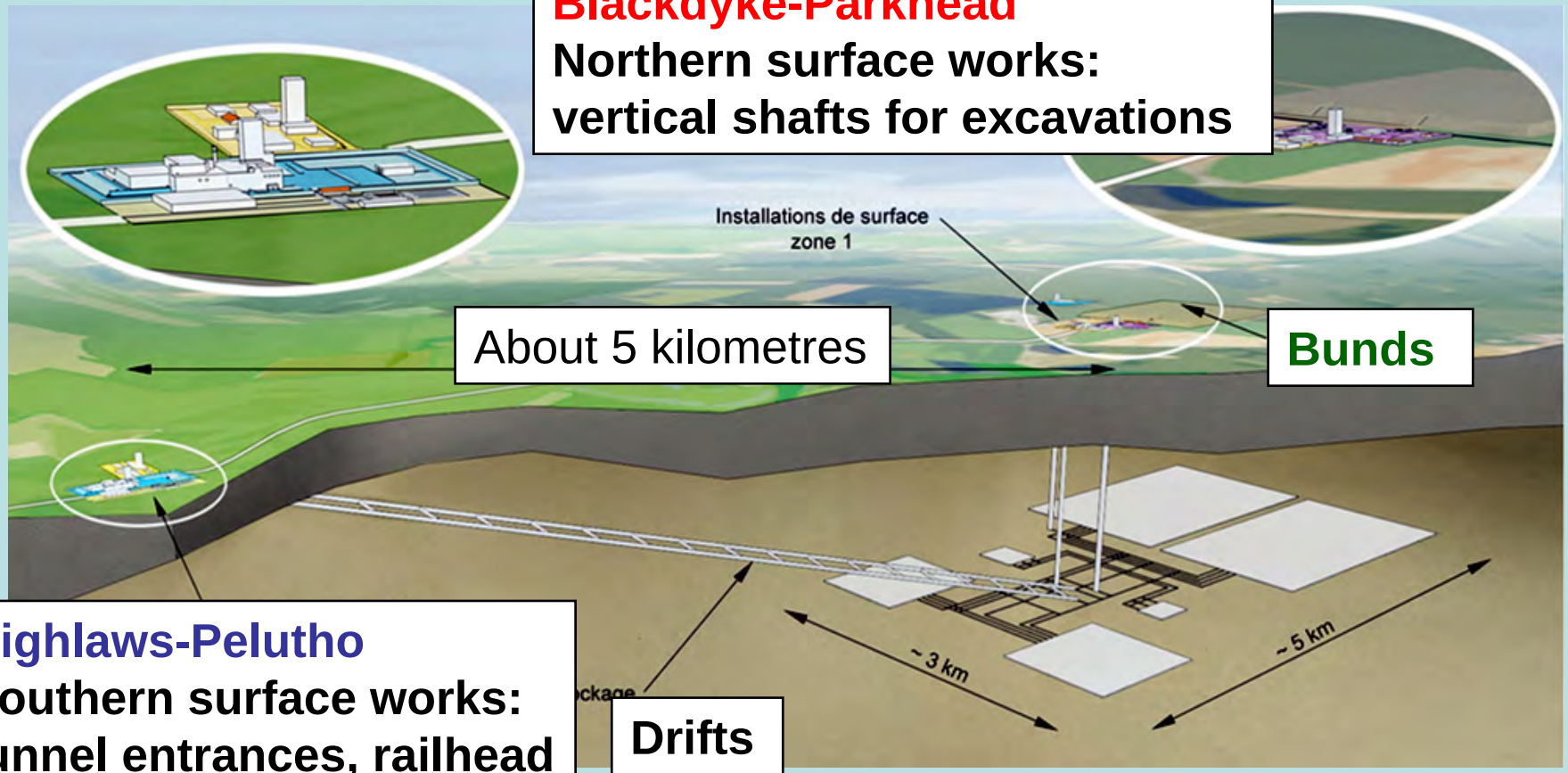
Mercia Mudstone Group: target rock for waste dump

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.




Global Mapper v13.10 (b030512) - REGISTERED (solway.gmw)
File
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.
Less than 10 m elevation
10 m contour
Above 10 m elevation
Less than 10 m elevation
Less than 10 m elevation
10 m contour
10 m contour
Wolsty Hall
Castle (site of)
Pelutho Grange
Pelutho Park
Hayrigg
Kingside Hill
Sandlands
Abbey Cowper
Abbeytown
Swinsty Fm
The Hill Fm
The Gale
Highlaws
Gillban
Foulsyke Fm
High Laws
Park Nook
Kingmoor
Kelsick House
Southerfield
Smarthill
Aldoth
Roundhill
Sand Pits
Weary Hall
Southerfield
Keld View
Lowsay Fm
Low Tarns
Tarns
Bog
Hards Fm
Common Moss
Holme St Cuthbert
Croft Ho
Crookla
Pal Idx 251 - RGB(255,255,255) (<ny04.tif> 1:50000 TILE NY04)
1:24090 BRIT_GRD (OSGB36) - (NY 15381 47432) 54.81450593° N, 3.31690670° W

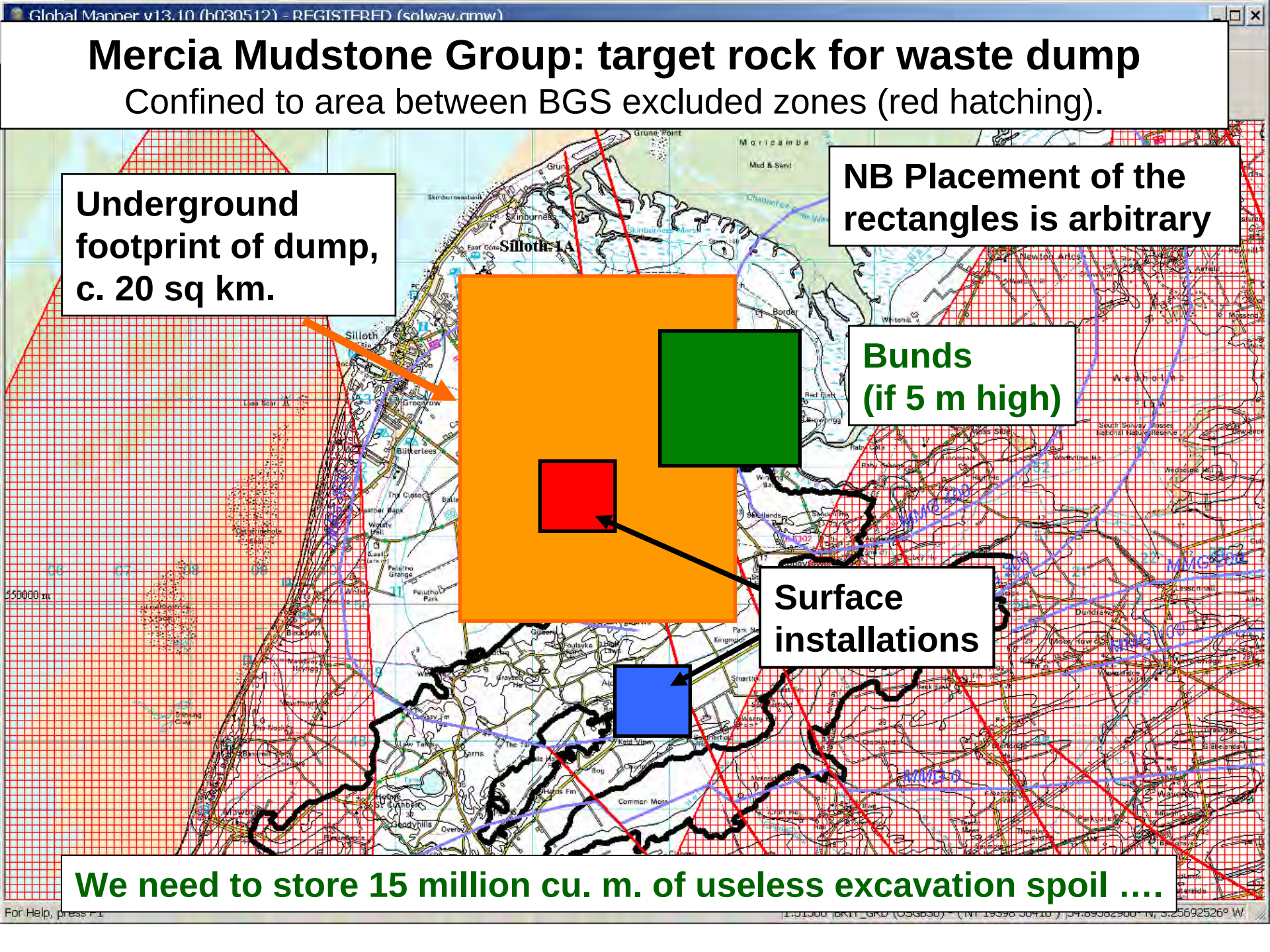


3D view of the proposed French waste repository in clay, applied to Allerdale. NB Allerdale subsurface area 20-23 km^2.

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).

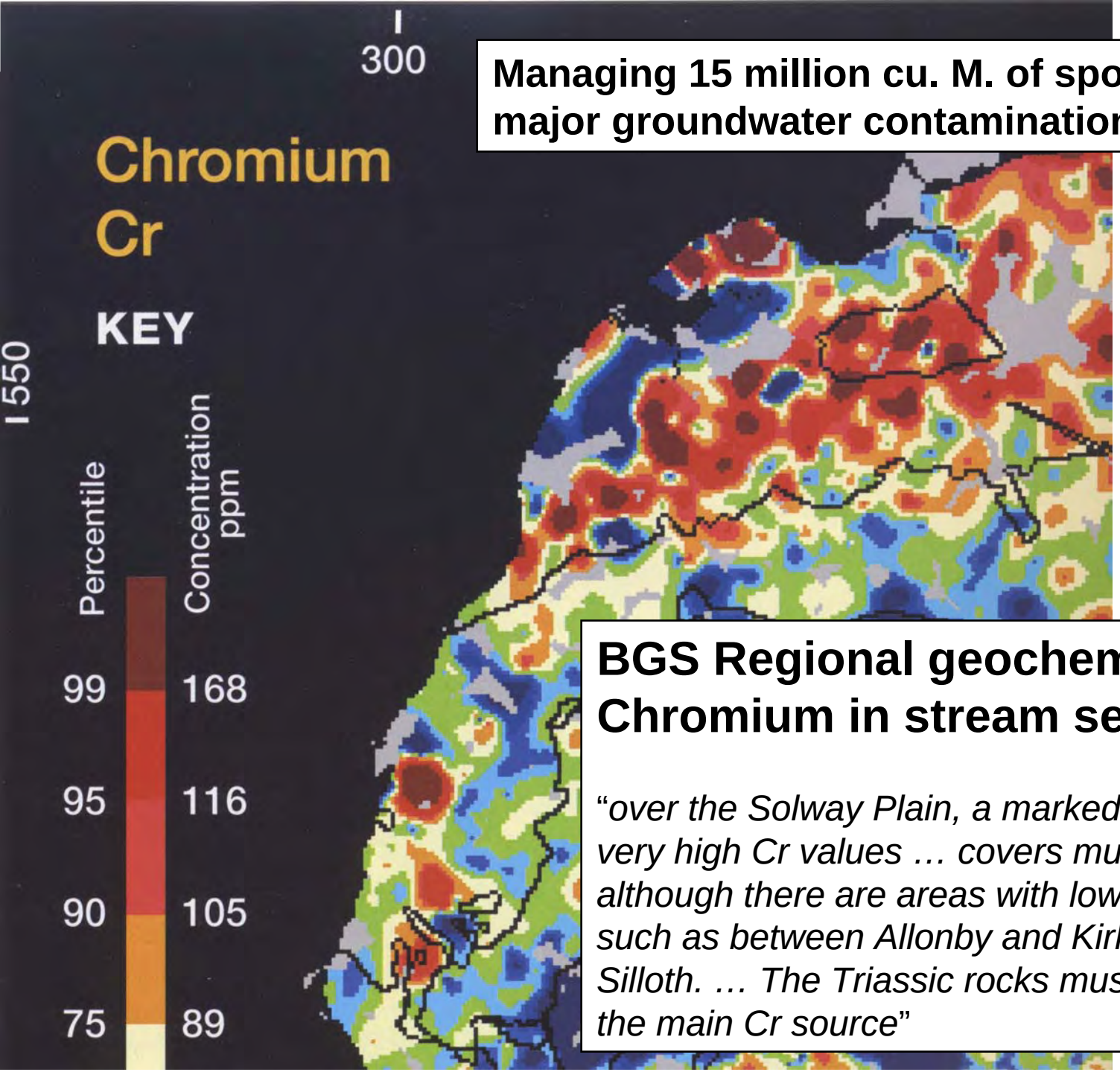


The construction waste problem

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.

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*"

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 <u>AT THIS STAGE</u> 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?

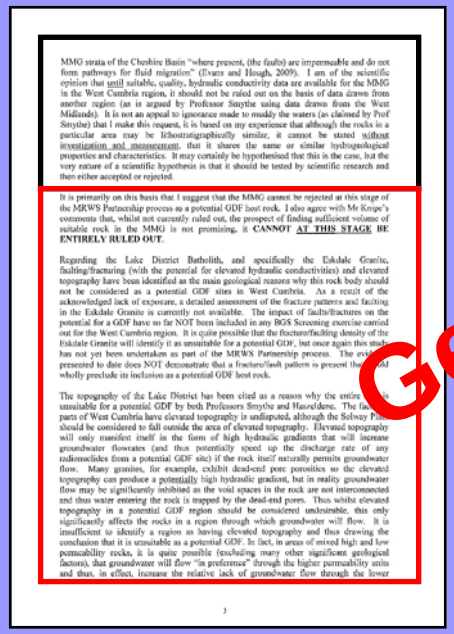
British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL


FWS CONSULTANTS LTD
Environmental and Geological Consultants

Dear Mr Bennett

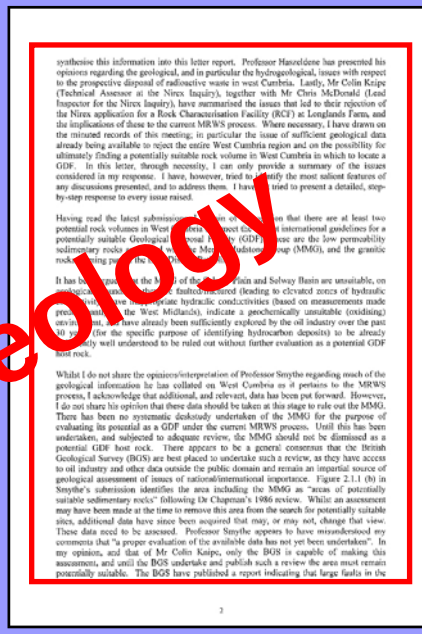
ACTION 5: GEOLOGICAL DOCUMENT REVIEW OF CONSULTATION SUBMISSIONS


MMG strata of the Cheshire Basin "where present, (the faults) are impermeable and do not form pathways for fluid migration" (Evans and Hough, 2009). I am of the scientific opinion that until suitable, 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 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.**

Regarding the Lake District Batholith, and specifically the Eskdale 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 sites in West Cumbria. As a result of the acknowledged lack of exposure, a detailed assessment of the fracture patterns and faulting in the Eskdale Granite is currently not available. The impact of faults/fractures on the potential for a GDF have so far NOT been included in any BGS Screening exercise carried out for the West Cumbria region. It is quite possible that the fracture/faulting density of the Eskdale 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/fault pattern is present that would wholly preclude its inclusion as a potential GDF host rock.

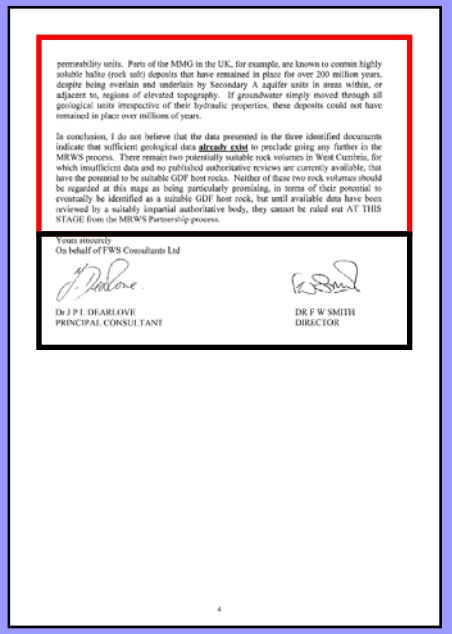
The topography of the Lake District has been cited as a reason why the entire region is unsuitable for a potential GDF by both Professors Smythe and Haszeldine. The fact that parts of West Cumbria have elevated topography is undisputed, although the Solway Plain should be considered to fall outside the area of elevated topography. Elevated topography will only manifest itself in the form of high hydraulic gradients that will increase groundwater flowrates (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 porosities 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 (excluding many other significant geological factors), that groundwater will flow "in preference" through the higher permeability units 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 Knipe (Technical Assessor at the Nirex Inquiry), together with Mr Chris McDonald (Lead Inspector for the Nirex Inquiry), have summarised the issues that led to their rejection of the Nirex 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 minuted 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, through necessity, I can only provide a summary of the issues considered in my response. I have, however, tried to identify the most salient features of any discussions presented, and to address them. I have also tried to present a detailed, step-by-step response to every issue raised.

Having read the latest submissions [illegible] that there are at least two potential rock volumes in West Cumbria [illegible] international guidelines for a potentially suitable Geological [illegible] (GDF) [illegible] are the low permeability sedimentary rocks [illegible] Mercia Mudstone Group (MMG), and the granite rock [illegible]

It has been [illegible] the [illegible] of the Cheshire Basin and Solway Basin are unsuitable, on [illegible] that the [illegible] faults/fractured (leading to elevated zones of hydraulic [illegible] [illegible] separate hydraulic conductivities (based on measurements made [illegible] the West Midlands), indicate a geochemically unsuitable (oxidising) environment, [illegible] have already been sufficiently explored by the oil industry over the past 30 years (for the specific purpose of identifying hydrocarbon deposits) to be already [illegible] well understood to be ruled out without further evaluation as a potential GDF host rock.

Whilst I do not share the opinions/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 deskstudy 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 adequate 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 oil industry and other data outside the public domain and remain an impartial 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 Dr Chapman's 1986 review. While 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 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. 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 halite (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

Dr J P L DEARLOVE
PRINCIPAL CONSULTANT

DR F W SMITH
DIRECTOR

Geology

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Environmental and Geological Consultants

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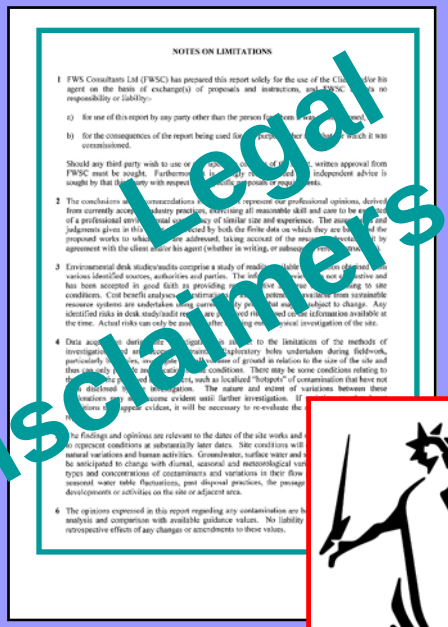
Review of the geological submissions by Dr Jeremy Dearlove of FWS, commissioned by MRWS, June 2012.

Smythe, Haszeldine, McDonald, Knipe: c. 500 pages of geological evidence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b) for the consequences of the report being used for [illegible] which it was commissioned.

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2 The conclusions and recommendations [illegible] represent our professional opinions, derived from currently accepted industry practices, exercising all reasonable skill and care to be expected of a professional environmental consultancy of similar size and experience. The assessments and judgments given in this report are limited by both the finite data on which they are based and the proposed works to which they relate addressed, taking account of the [illegible] by agreement with the client and/or his agent (whether in writing, or subsequently).

3 Environmental desk studies/audits comprise a study of readily available [illegible] various identified sources, authorities and parties. The information [illegible] has been accepted in good faith as providing [illegible] conditions. Cost benefit analyses [illegible] resource systems are undertaken using currently [illegible] identified risks in desk study/audit reports are [illegible] the time. Actual risks can only be assessed [illegible]

4 Data acquired during [illegible] investigation [illegible] particularly [illegible] than [illegible] conditions. There may be some conditions relating to [illegible] not disclosed [illegible] investigation. The nature and extent of variations between these locations may [illegible] evident until further investigation. [illegible] appear evident, it will be necessary to re-evaluate the [illegible]

5 The findings and opinions are relevant to the dates of the site works and [illegible] to represent conditions at substantially later dates. Site conditions will [illegible] natural variations and human activities. Groundwater, surface water and [illegible] be anticipated to change with diurnal, seasonal and meteorological [illegible] types and concentrations of contaminants and variations in their flow [illegible] seasonal water table fluctuations, past disposal practices, the passage [illegible] developments or activities on the site or adjacent area.

6 The opinions expressed in this report regarding any contamination are [illegible] analysis and comparison with available guidance values. No liability [illegible] retrospective effects of any changes or amendments to these values.

Legal disclaimers

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 :

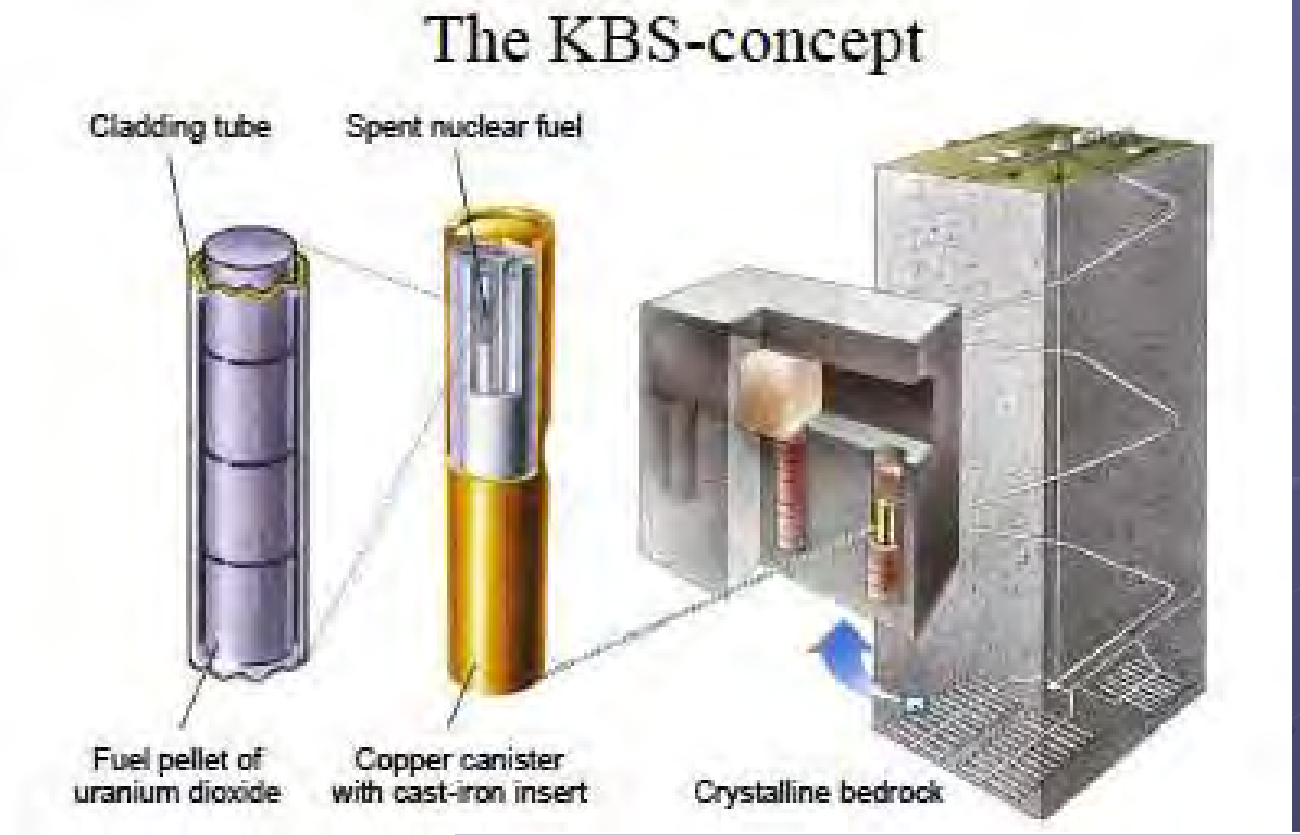
- **We DO know – it’s a highly studied area**
- **No stone has been left unturned**
- **NOWHERE is suitable**
- **MRWS stage 4 has been done**

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**



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**.

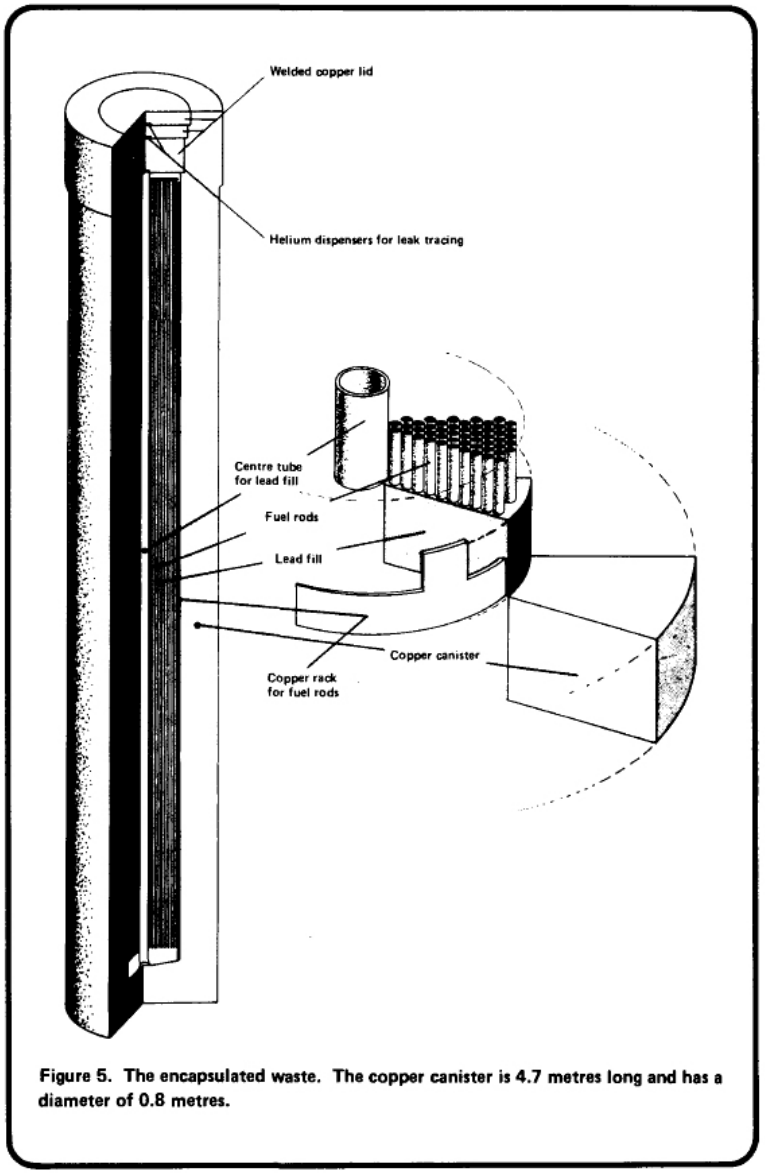


Figure 5. The encapsulated waste. The copper canister is 4.7 metres long and has a diameter of 0.8 metres.

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.

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.

Strål säkerhets myndigheten

Swedish Radiation Safety Authority

mkg

Miljöorganisationernas kärnavfallsgranskning

Swedish NGO Office for Nuclear Waste Review

[NB The UK has neither of these]

Strål säkerhets myndigheten
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
Miljöorganisationernas kärnavfallsgranskning
Swedish NGO Office for Nuclear Waste Review

MKG interprets these results

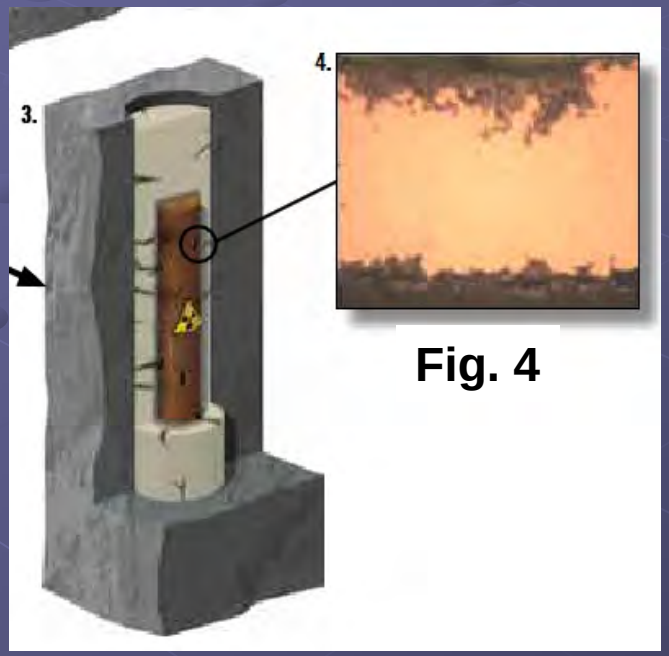


Fig. 4

"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

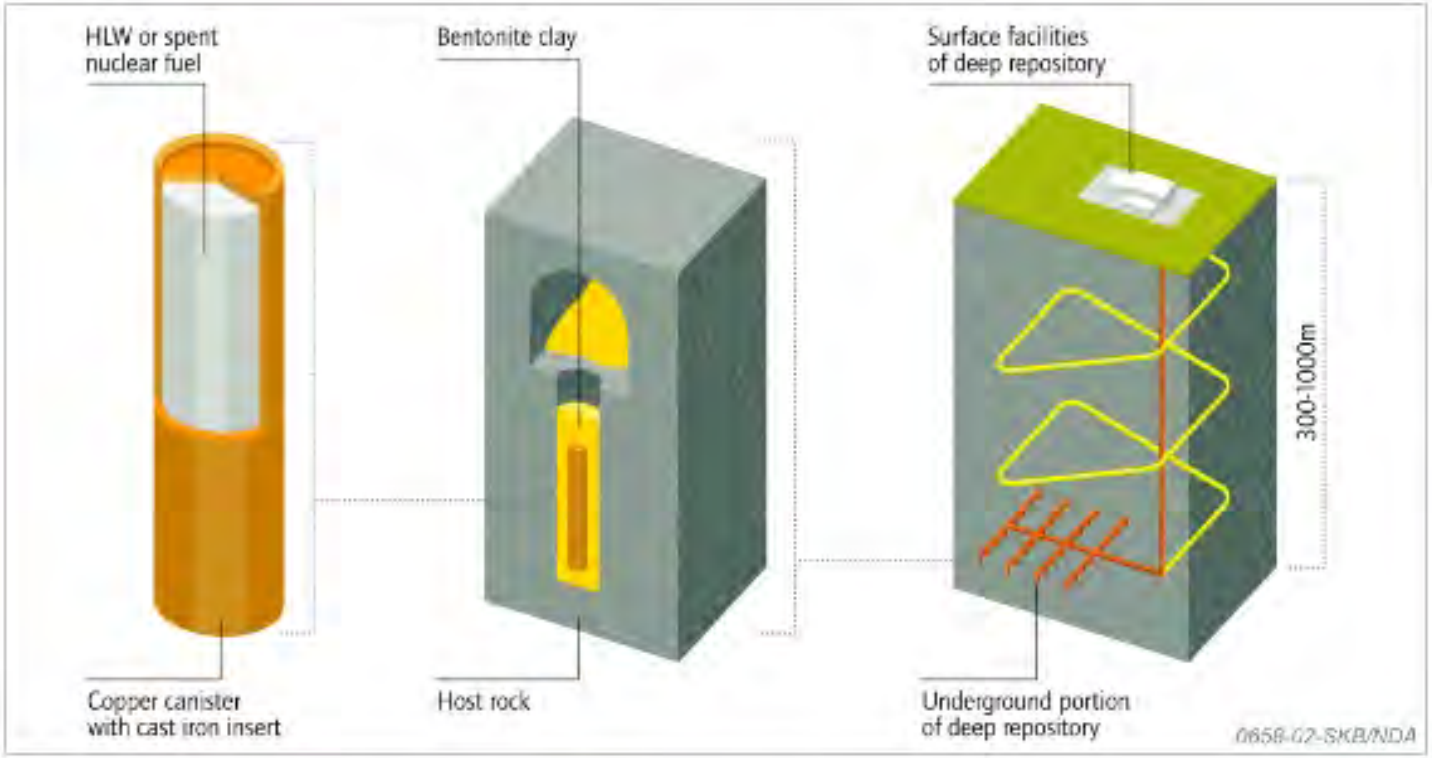
"The BGS has reviewed the characteristics of existing ILW/LLW disposal concepts and the geological factors relating to packaged HLW/spent fuel (KBS-3 concept) and believes that the geological conditions that would be suitable for the former will also be appropriate for the isolation of the latter."

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.

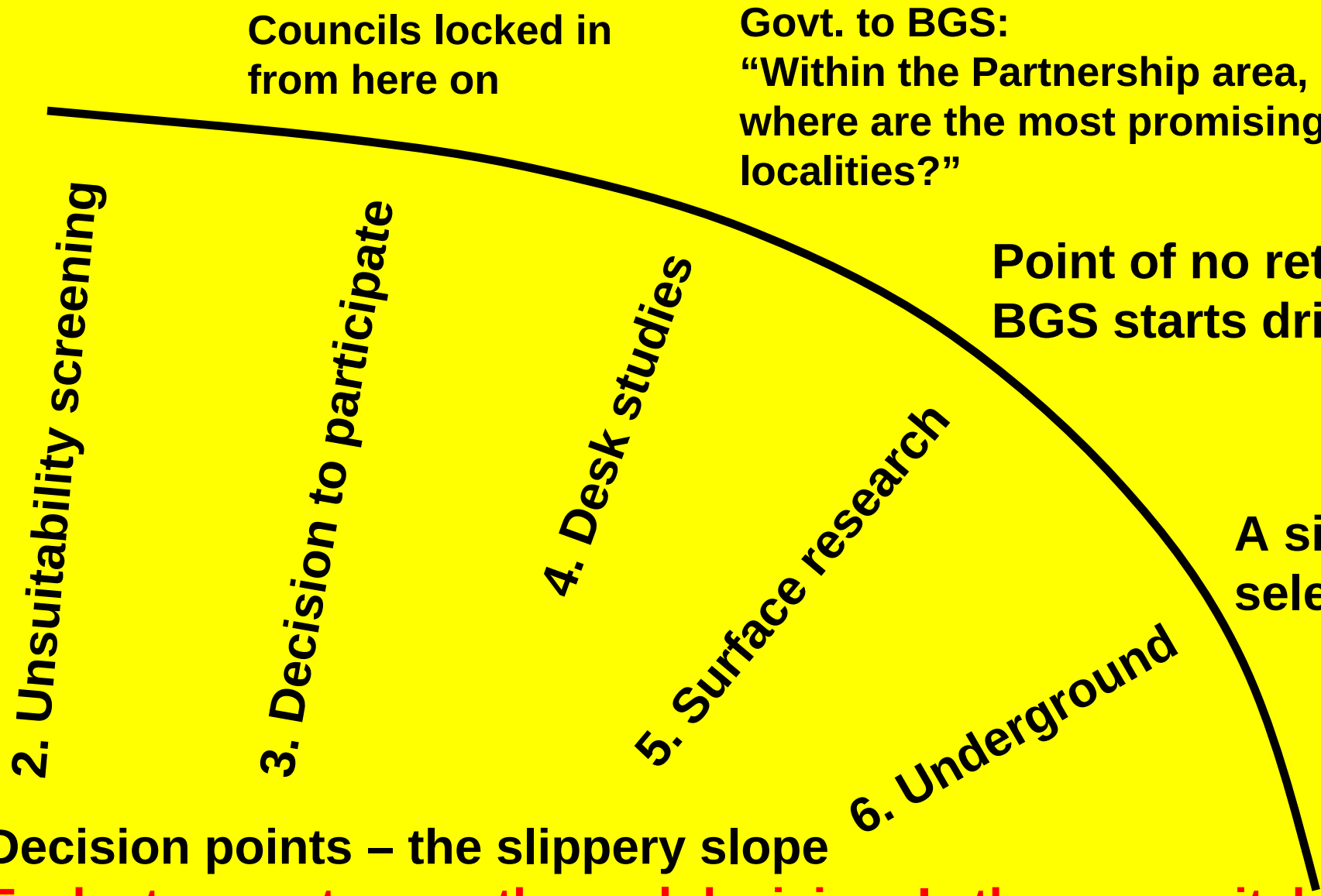
Evidently the NDA is still working with the KBS-3 concept for the UK, despite its intrinsic shortcomings, and despite the declaration by the BGS. The V-suffix means the vertical emplacement option.

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



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.**

END

Fin