Are we REALLY managing radioactive waste safely?

Geology

Configuration and character of the rocks
-the final, most important barrier

↓

Hydrogeology

How water flows through, potentially carrying toxic waste. Driven by the ‘hydraulic head’- topography

↓

‘Safety’ assessment

Guessing the chances that a person or a population in the future could come into contact with the radioactive waste.

The West Cumbrian recipe

Complex site geology

+

High mountains nearby

↓

Fast and unpredictable groundwater flow

↓

Unsafe underground dump

History of search in Britain

- Up to watershed of 1997 Inquiry

International aspects

- Guidelines
- What other countries do

West Cumbria

- Topography
- Geology

Current process

- Political/scientific manipulation
- Safety

History of UK site search up to 1997

British Geological Survey

1979: Host rocks

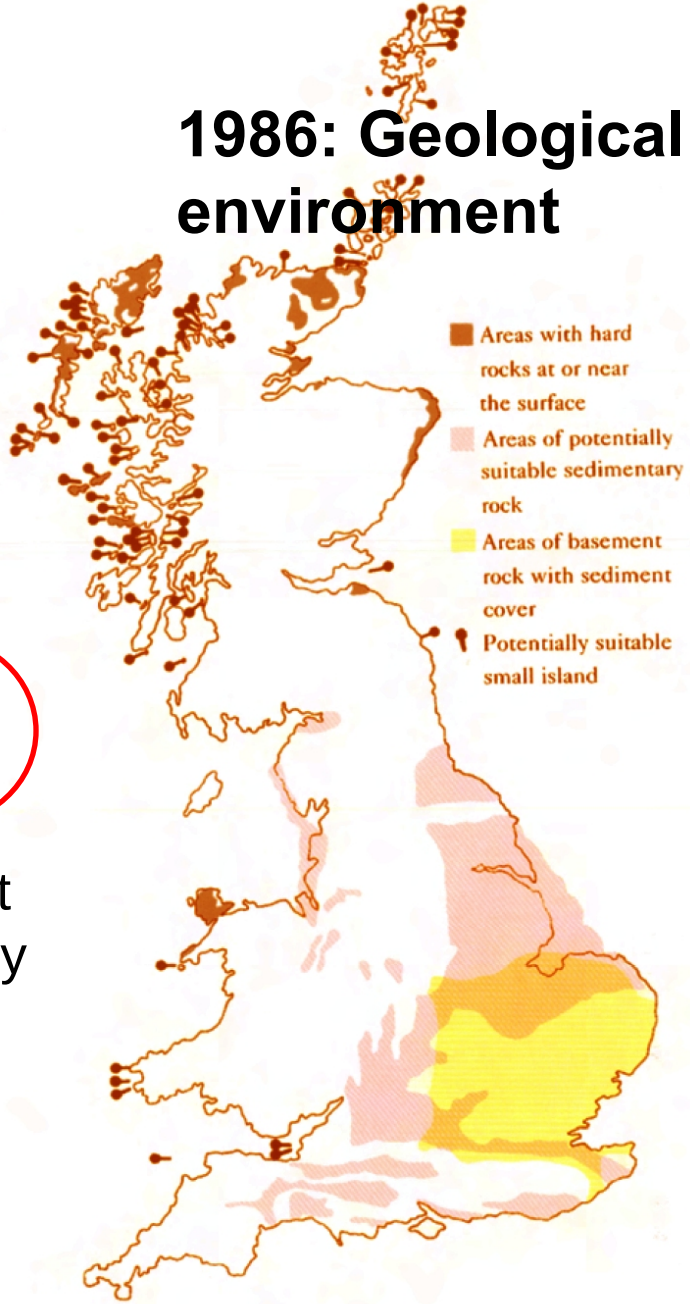
Map showing the distribution of rocks thought to meet the selection criteria and of those areas which have been selected for feasibility studies. Crystalline igneous and metamorphic rocks are stippled, argillaceous rocks are shown with horizontal lines and evaporites with vertical lines. The crystalline rocks include the postulated subsurface outcrops of the granites of northern and south-western England. No rock types meeting the criteria occur in the Shetland Islands.

1979

1986

Areas almost completely disjoint

1986: Geological environment



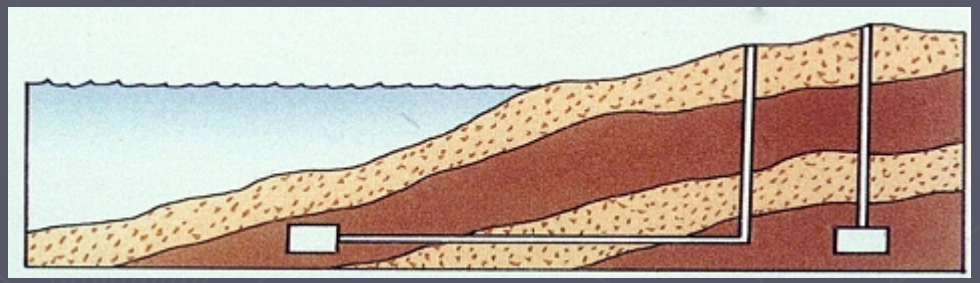
4 Geological environments considered to have potential for ILW repository development (after Nirex)

Two categories relevant to West Cumbria

Irish Sea

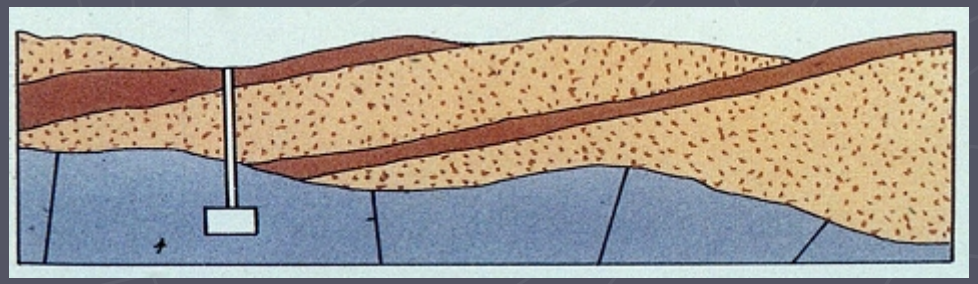
Sellafield

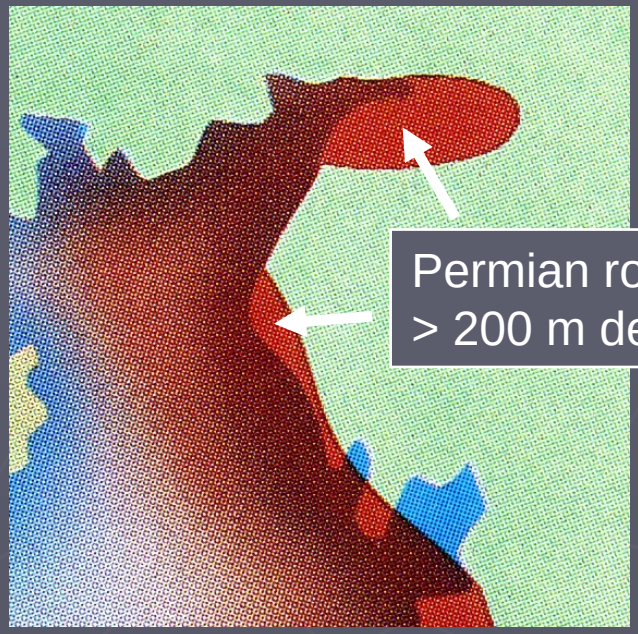
Lake District

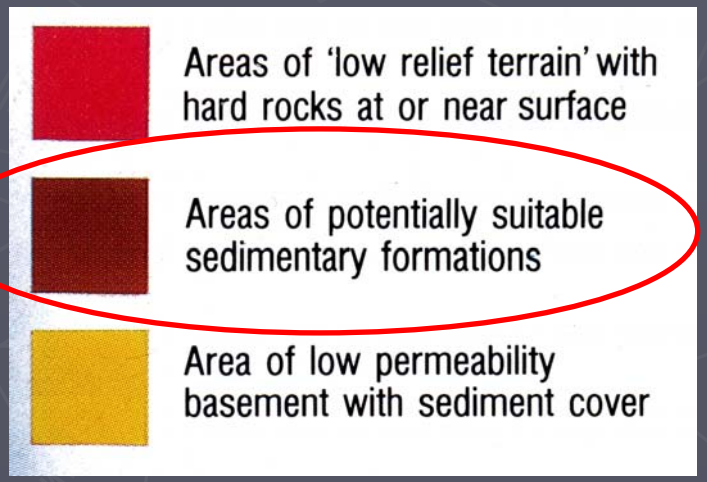


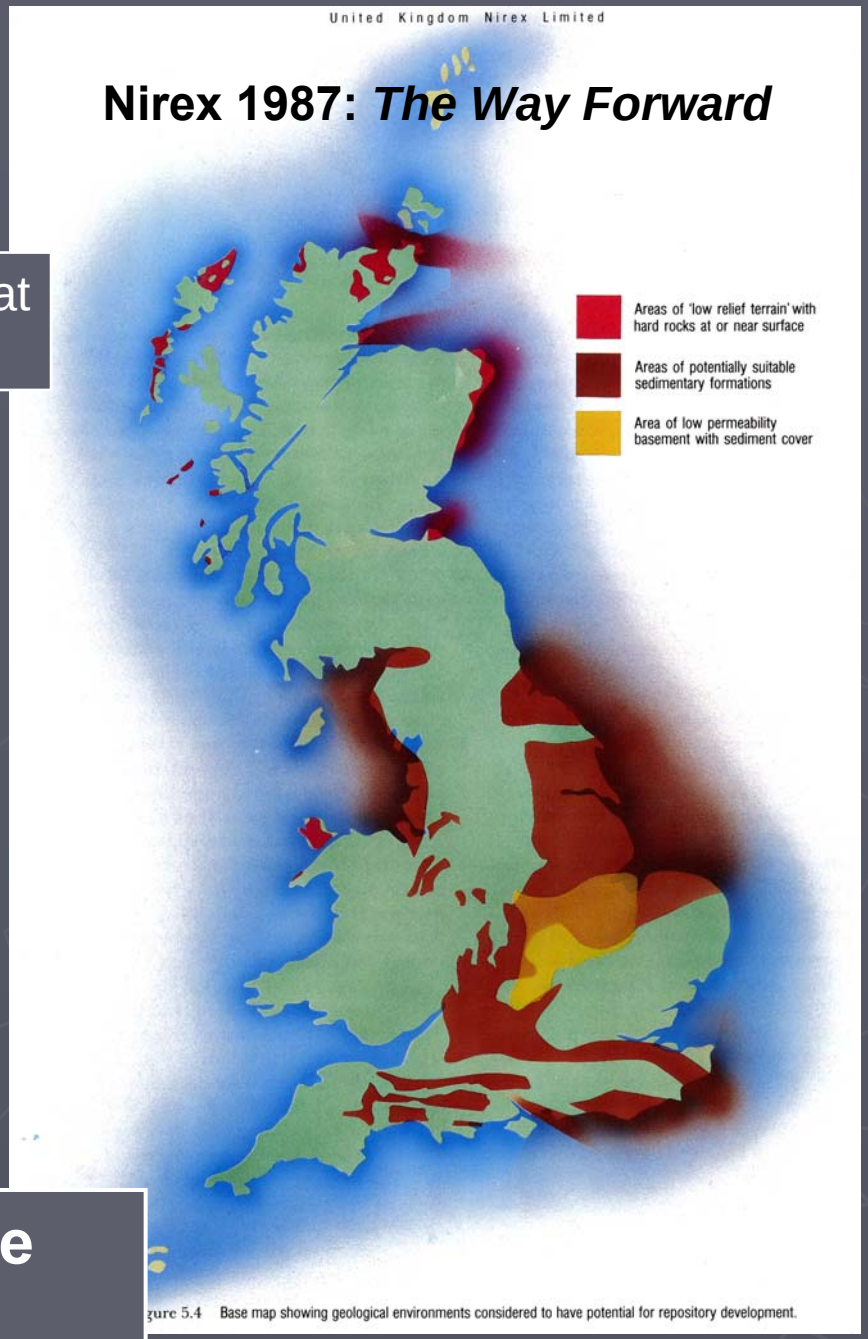
Seaward-dipping sediments – hoped for Permian evaporites

Basement under sedimentary cover (BUSC)



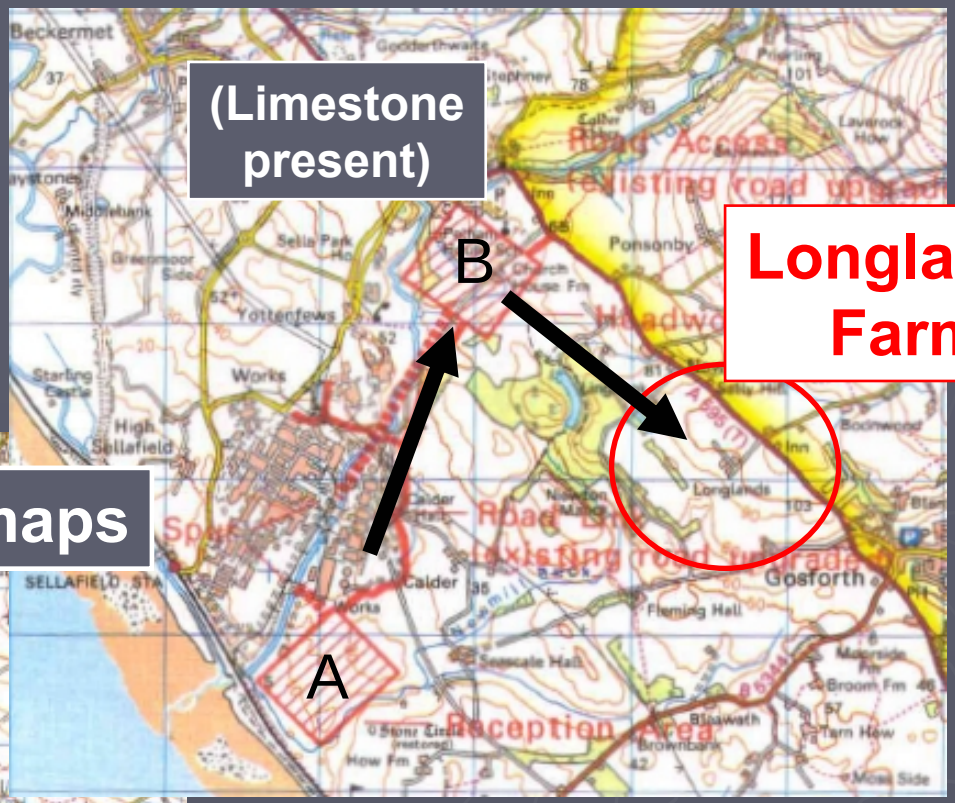






<u>Sediments</u> were the only suitable formation identified in Cumbria

Site search: ‘Coastal sediments’ at Sellafield morphed into a ‘BUSC variant’.

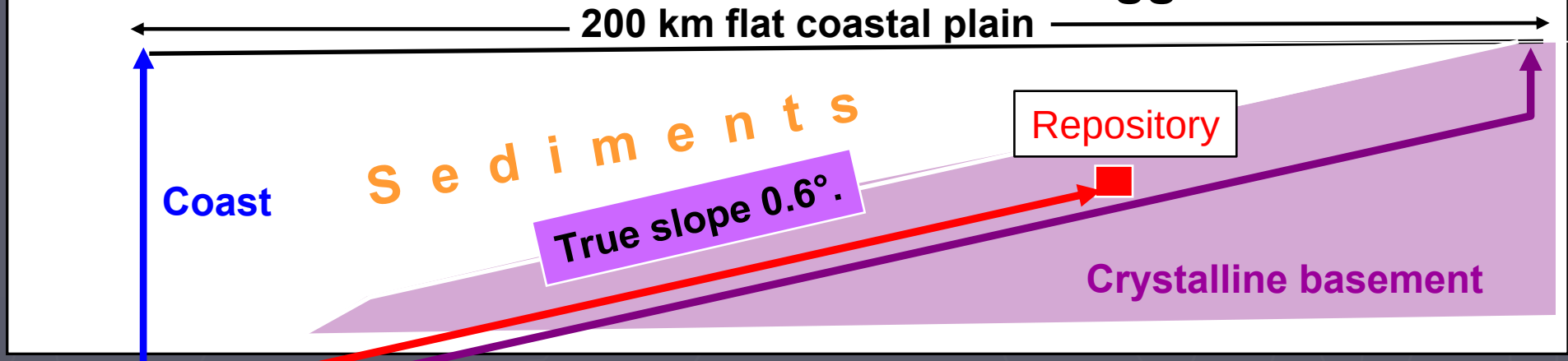


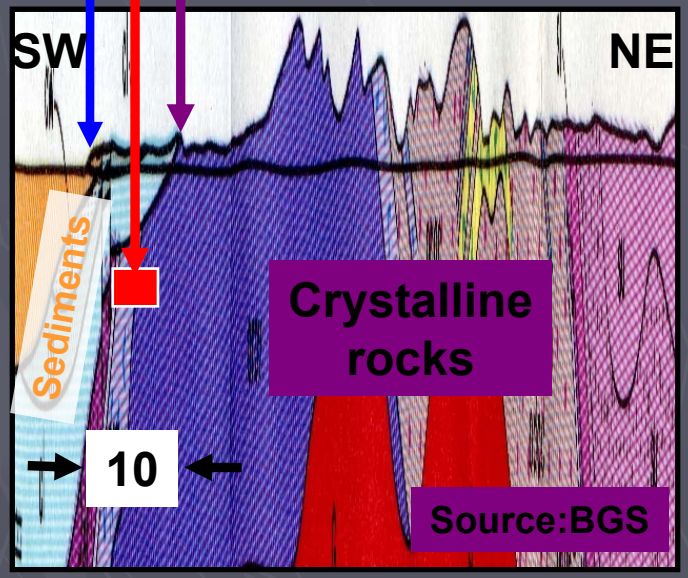
361	North Rona	Small island	A	420	Salisbury Plain	Ex-AOS inland	D
362	Norton Barracks	Inland	A	421	Samphrey	Small island	B
363	Norton Manor Camp	Inland	A	422	Sanda	Small island	B
364	Nuneaton	Inland	A	423	Sandhurst	Inland	A
365	Oakington	Inland	A	424	Sandray	Small island	G
366	Odiham RAF	Inland	A	425	Scalpay	Small island	B
367	Ogborne St George	Inland	A	426	Scampton RAF	Sedim. inland	C
368	Oigh Sgeir	Small island	F	427	Scarba	Small island	A
369	Old Dalby	Inland	A	428	Scarp	Small island	A
370	Old Park Barracks	Inland	A	429	Scoor	Ex-AOS coastal	D
371	Old Sarum	Inland	A	430	Southorpe USAF	Sedim. inland	E
372	Oldbury	Ex-AOS coastal	D	431	Sealand Range	Coastal	A
373	Ollerton	Sedim. inland	C	432	Seighford	Inland	A
374	Orfordness	Coastal	A	433	Sellafield (-A)	Sedim. coastal	H
375	Oronsay	Small island	A	434	Sennybridge	Ex-AOS inland	D
376	Oronsay	Small island	B	435	Shawbury	Inland	A
377	Osgodby Moor	Sedim. inland	F	436	Shellingford Afd	Inland	A
378	Ossington Afd	Sedim. inland	B	437	Shiant Islands	Small island	B
379	Otmoor	Inland	A	438	Shoeburyness	BUSC coastal	F
380	Otterburn	Ex-AOS inland	D	439	Shrivenham	Ex-AOS inland	C

Page 4 of 5

List of 437 UK potential sites

True BUSC cross-section at vertical exaggeration x 10





Geological cross-section from Windermere to the Solway

So-called 'BUSC variant' at Longlands Farm:

- Horizontal compressed by x 20.
- Terrain higher by x 20.
- Dip (tilt) higher by x 40.

Distortion of 20 x 20 = 400.

Result: groundwater flow far too vigorous and complex – this is not a BUSC environment.

What's wrong with the Sellafield site (Longlands Farm)

- Not in the list of 437
- Not BUSC (nor any other suitable type)
- Regional topography too severe
- BVG not true hard rock
- Highly complex volcanics
- Highly faulted
- Three-dimensional
- Overlain by aquifers

- Fast, unpredictable flow
- Therefore unsafe

After £400M spent in West Cumbria
+ £10M at the Inquiry itself in 1995-96

The Inquiry Inspector

FINAL CONCLUSIONS

"8.53 The indications are, in my judgement, still overwhelmingly that this site is not suitable for the proposed repository, and that investigations should now be moved to one of the more promising sites elsewhere."

… the end for Sellafield, one might reasonably think.

Evolution of international search criteria

(Summary)

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 draft guidelines**
- **European Union**
- **British Geological Survey**
- **Finnish Geological Survey**

None of them put voluntarism ahead of a systematic geological search.

Search practice abroad

The **Government White Paper (2008)** misleads on what it calls ‘the Finnish experience’:

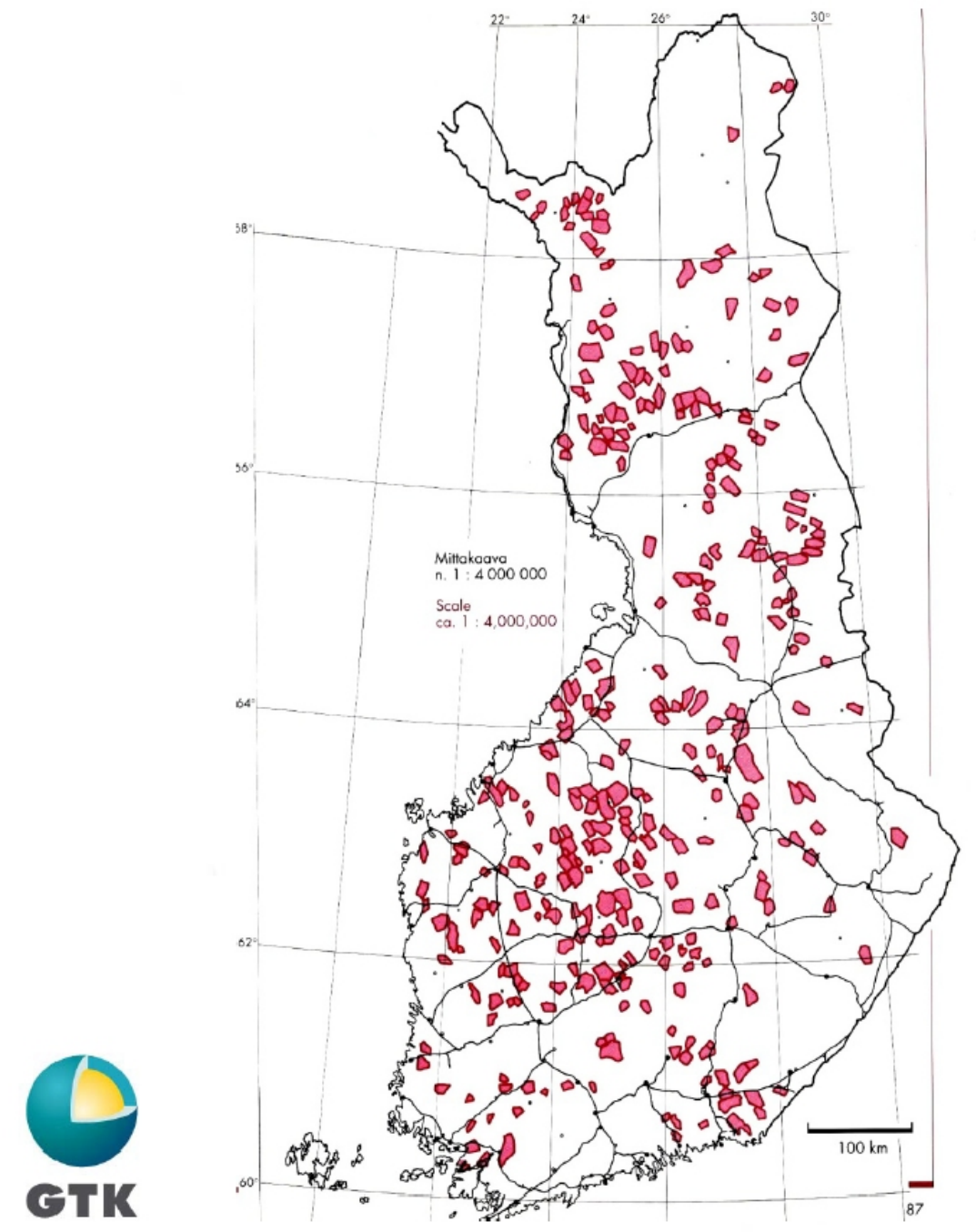
“*In 1983 TVO … drew up a list of 101 potential sites and undertook a consultation process with the affected communities. This resulted in the identification in 1985 of 5 potential ‘volunteer’ sites at which more detailed investigations were carried out …*”

- Insinuating that it was a voluntarist process.

[TVO is Teollisuuden Voima Oy, the company then responsible for nuclear waste disposal]

Site search in Finland started by a systematic search of the whole country.

327 regional bedrock blocks were identified (red areas).



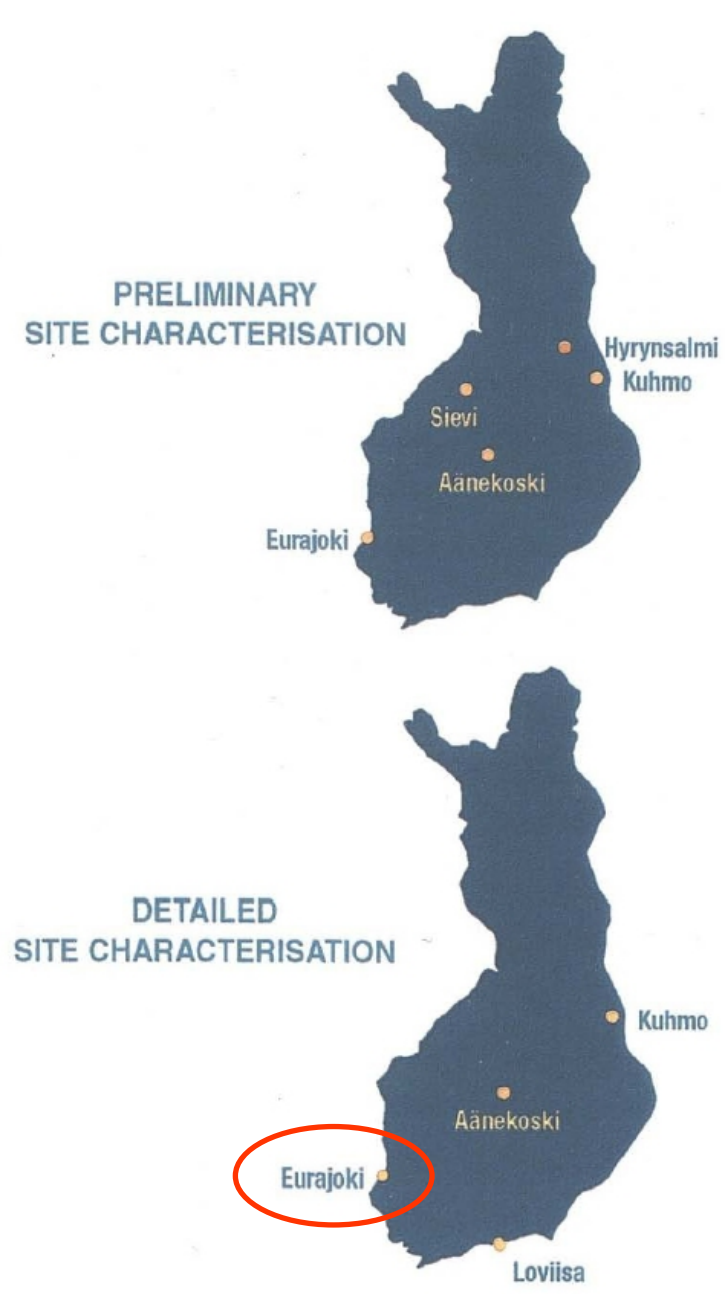
GTK

Site search in Finland:

The regional blocks were sieved down to five sites (upper map) which were subjected to site characterisation.

Two sites were withdrawn, but a third added to give four sites (lower map).

Municipal vetoes resulted in the withdrawal of the two most northerly sites. Olkiluoto in Eurajoki municipality was chosen in 2000.



Sweden:

Staged site selection based on geology, but with:
- Local veto
- Government right to override the veto.

The geology of both Finland and Sweden is mostly ancient stable low relief hard rock.

Geological search also preceded community involvement in :

France, Belgium, Switzerland*, Canada, USA.

* Switzerland to be shown later

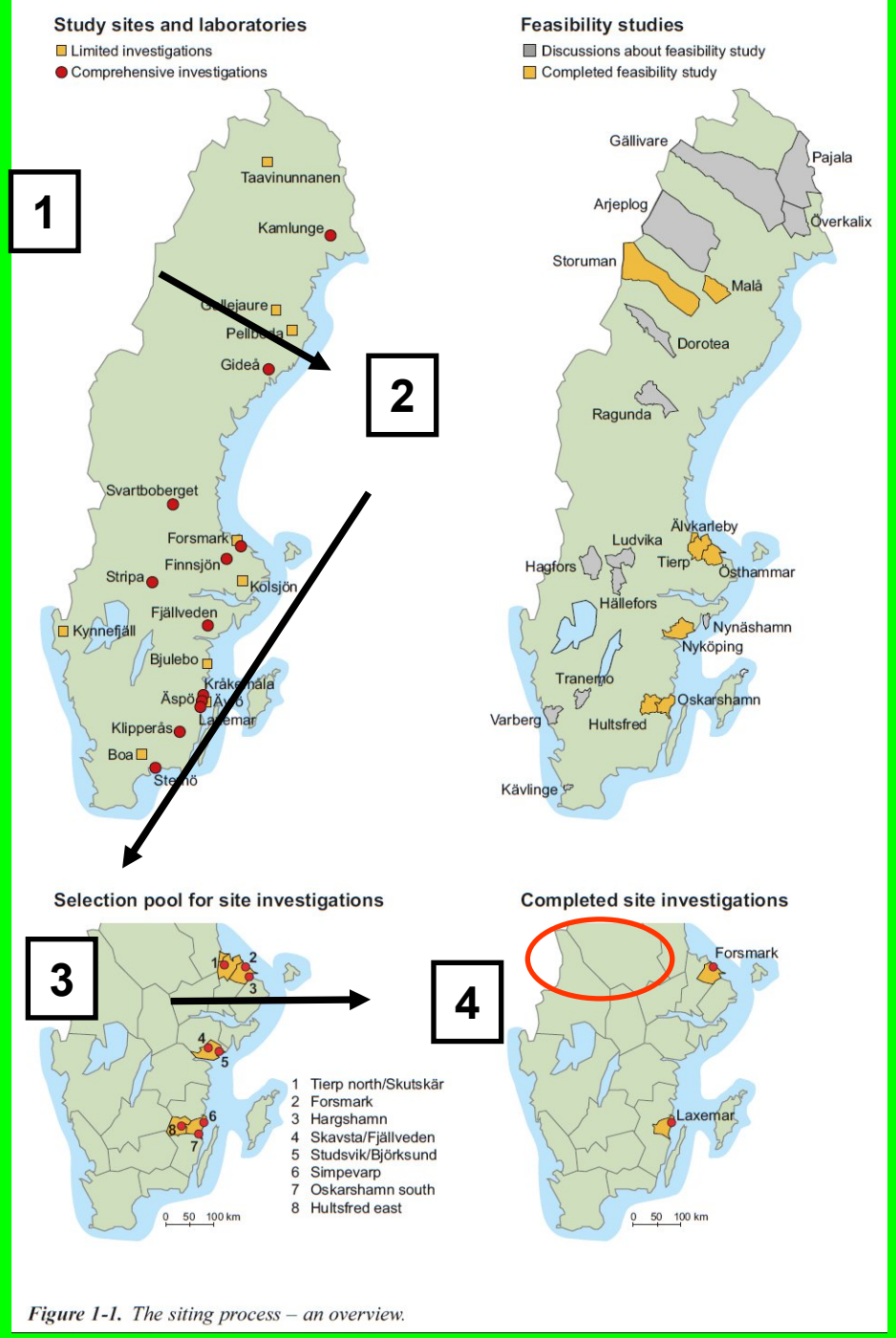


Figure 1-1. The siting process – an overview.

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.

West Cumbria has a problem with several of these.

Topographic relief

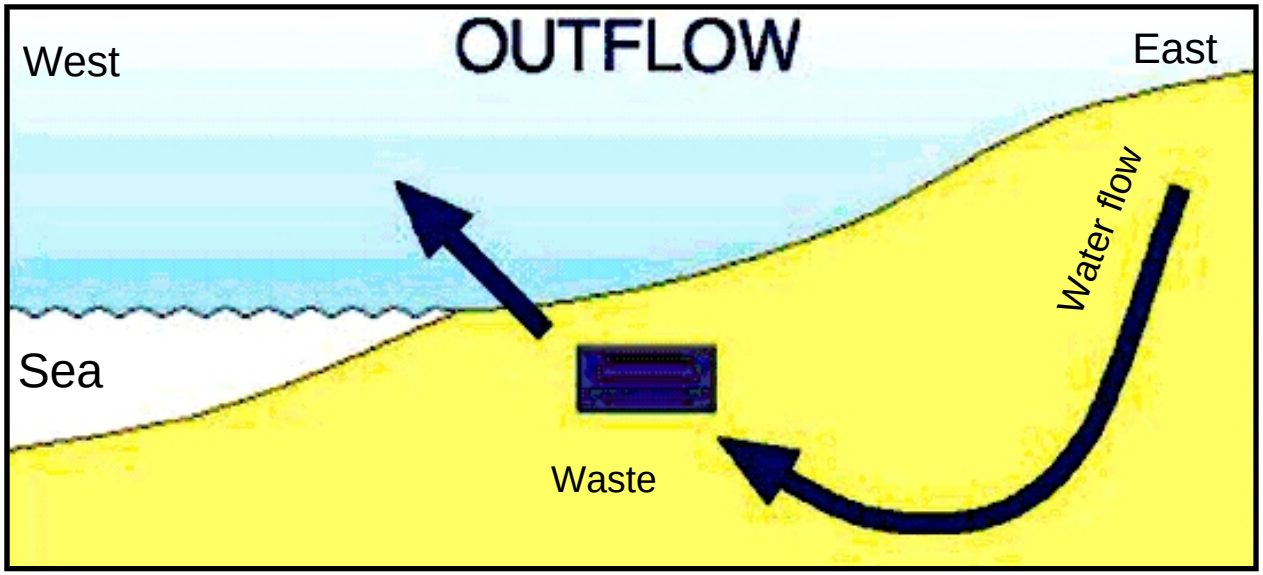
Drives the underground water flow

Why the land surface relief is crucial

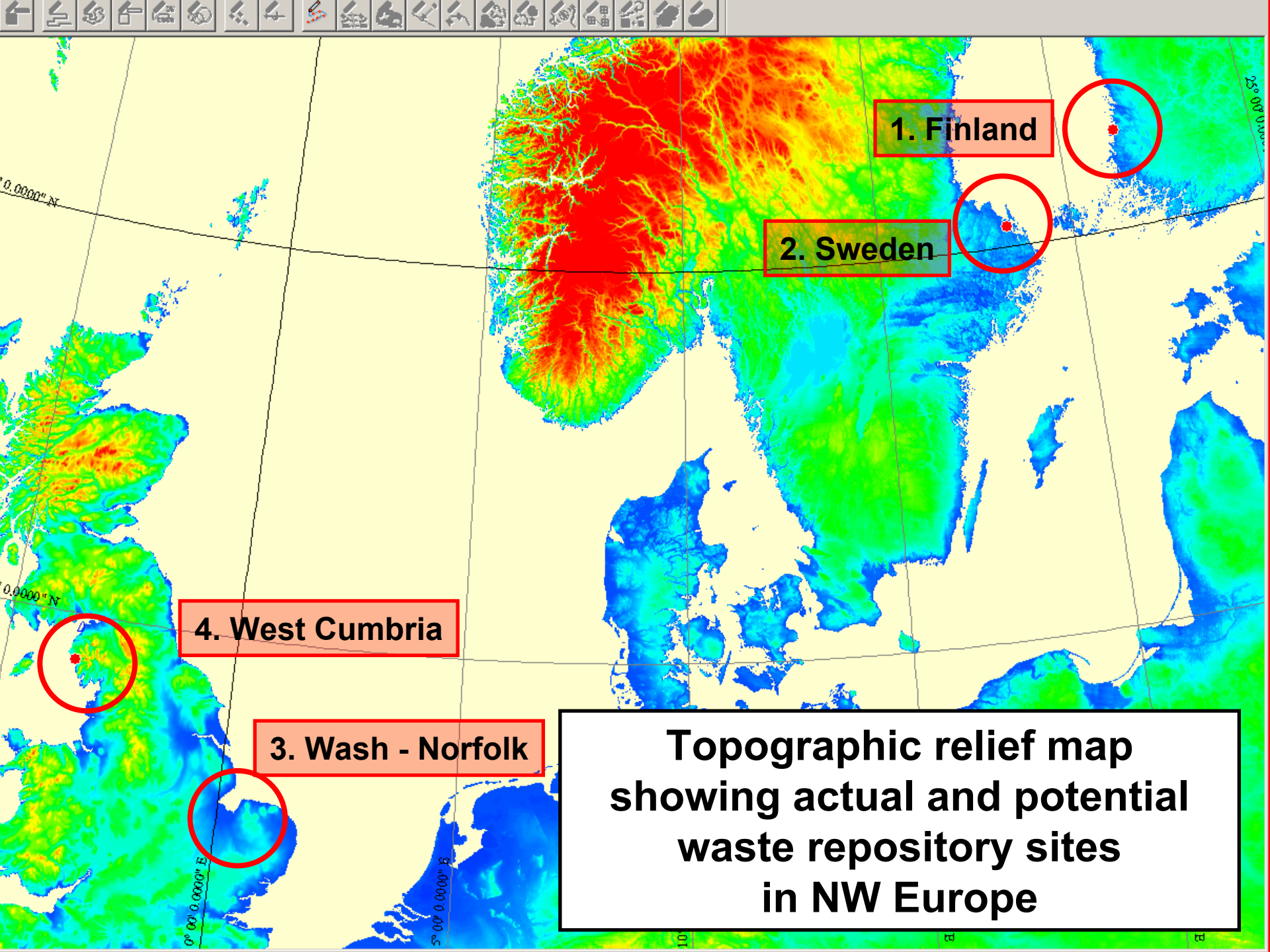
Water flow is driven by the elevation of mountains, and inevitably rises to surface as 'artesian' springs.

When toxic waste dissolves, there is no natural barrier to pollution entering drinking water and the sea.

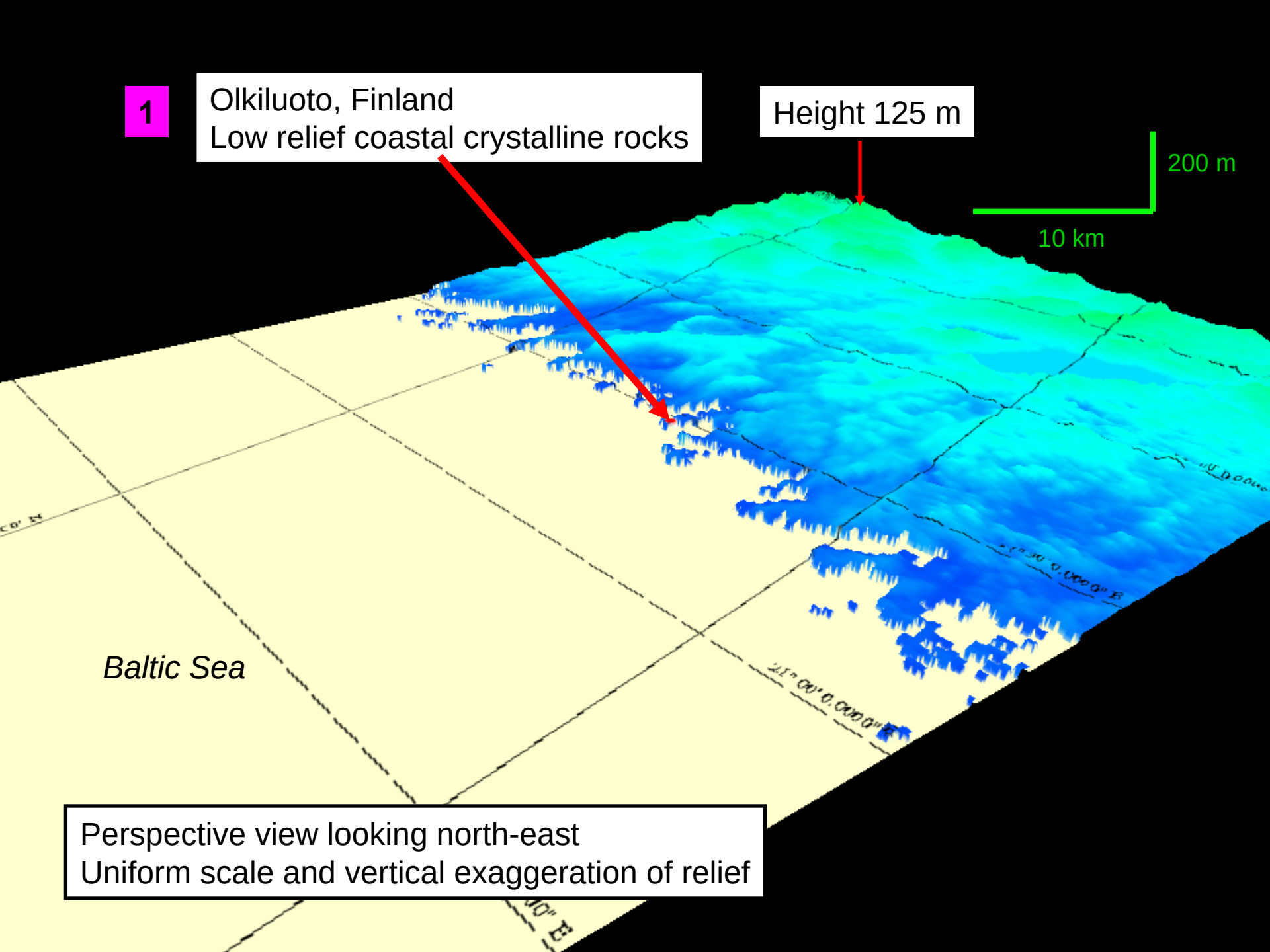
All international potential waste repository locations are in flat areas.

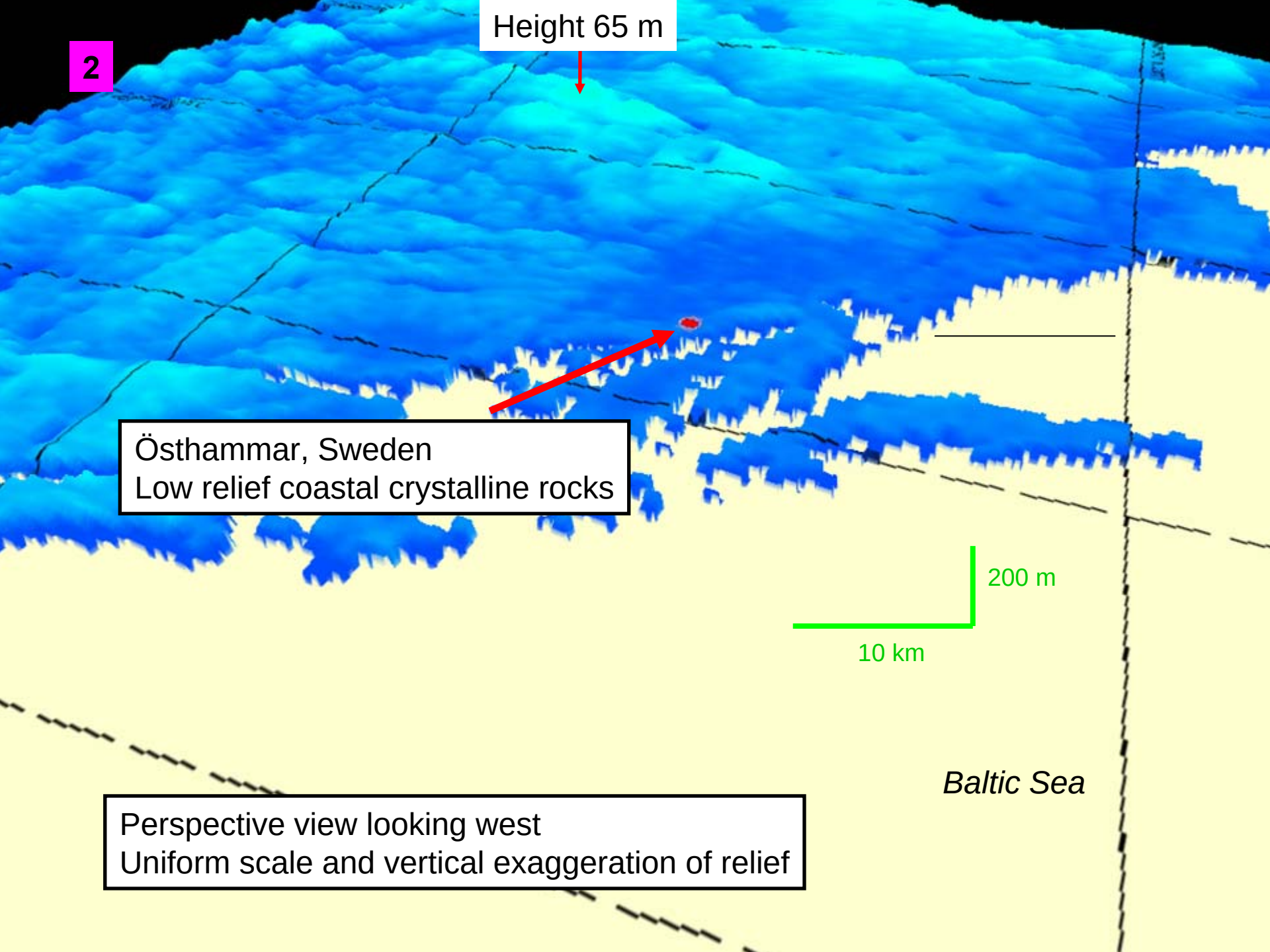


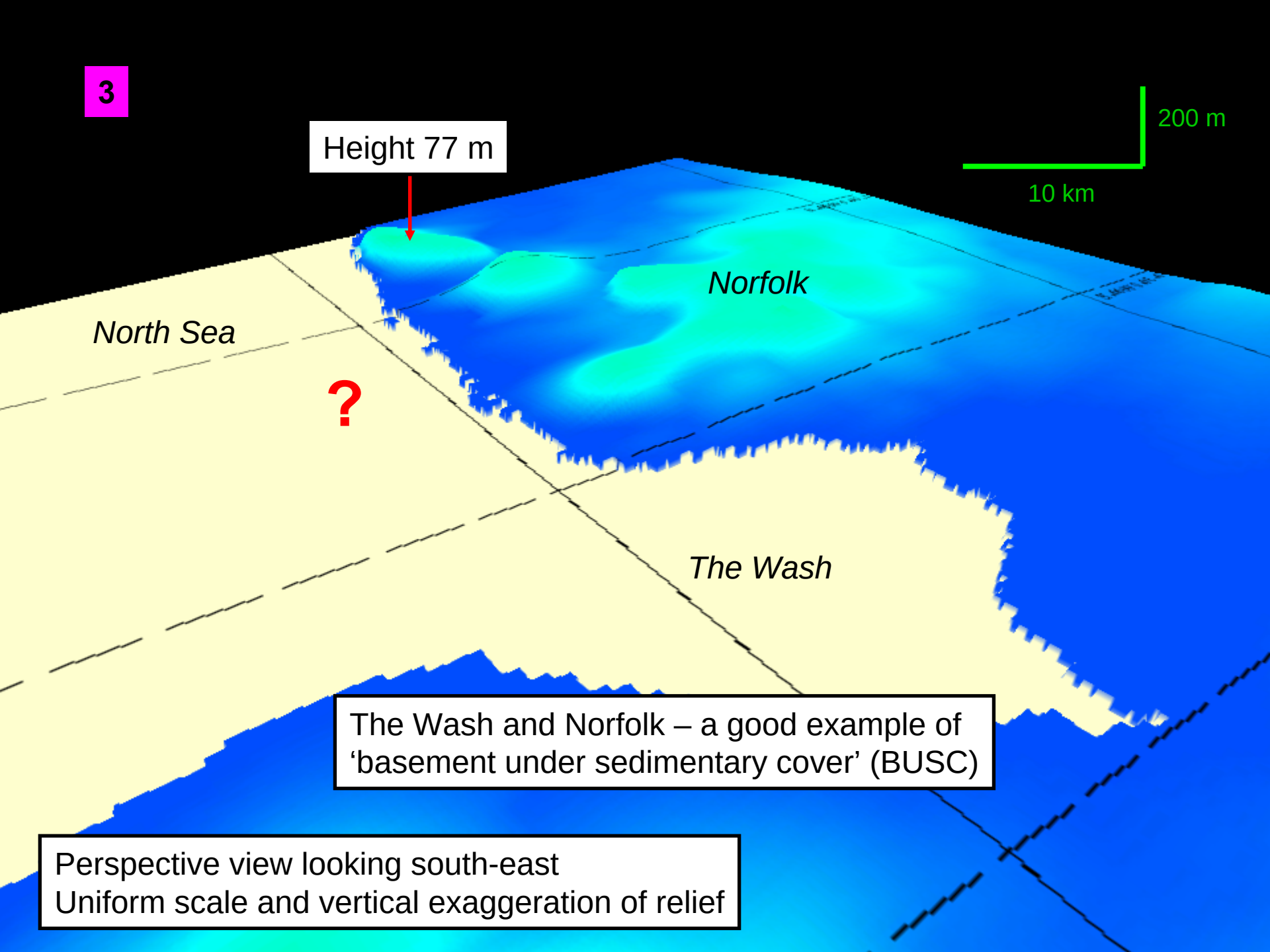
West Cumbria looks like this - it has poor site performance.

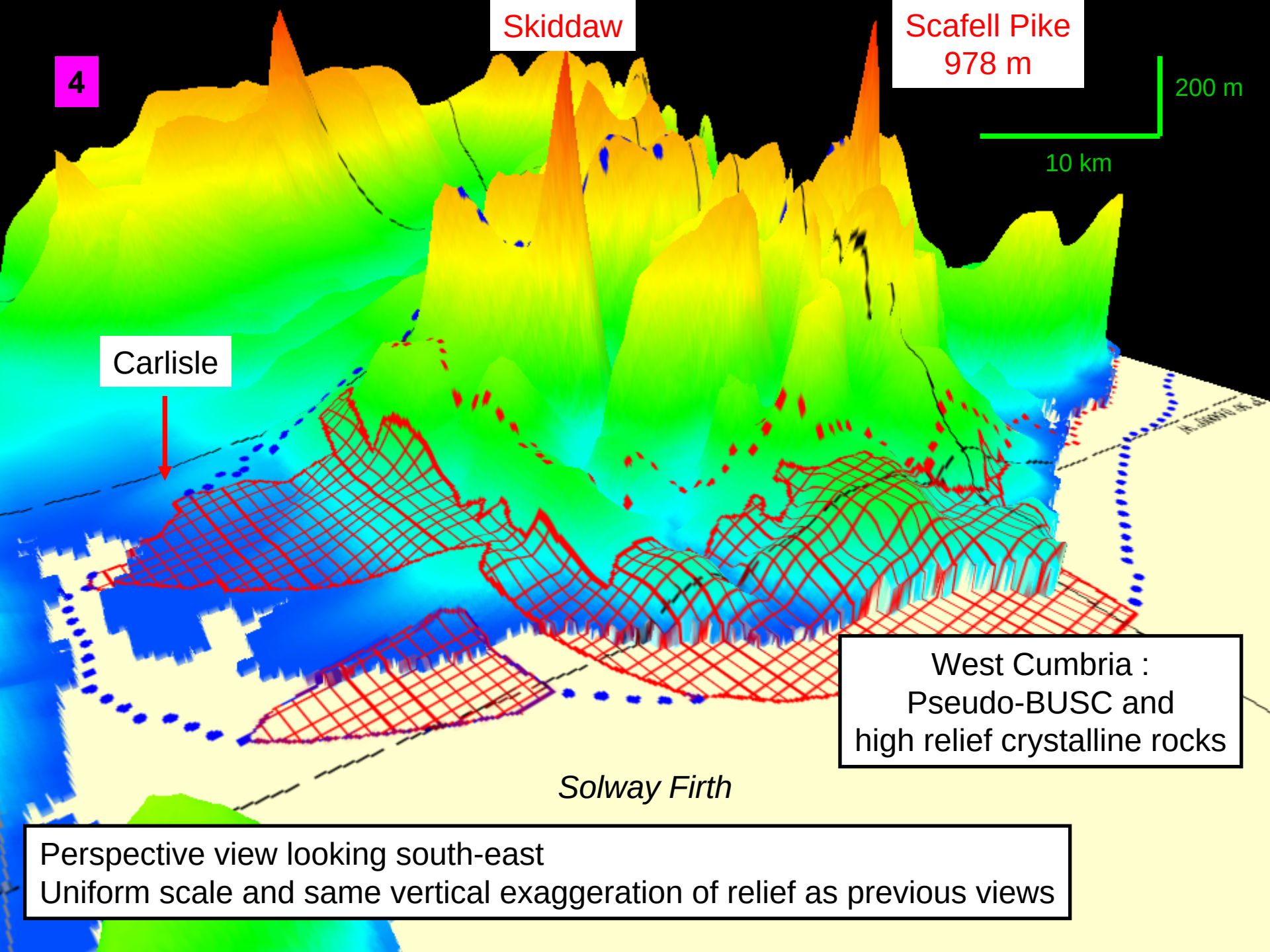


Topographic relief map showing actual and potential waste repository sites in NW Europe


1
Olkiluoto, Finland
Low relief coastal crystalline rocks
Height 125 m
200 m
10 km
Baltic Sea
Perspective view looking north-east
Uniform scale and vertical exaggeration of relief


2
Height 65 m
Östhammar, Sweden
Low relief coastal crystalline rocks
200 m
10 km
Baltic Sea
Perspective view looking west
Uniform scale and vertical exaggeration of relief


3
Height 77 m
200 m
10 km
Norfolk
North Sea
?
The Wash
The Wash and Norfolk – a good example of
‘basement under sedimentary cover’ (BUSC)
Perspective view looking south-east
Uniform scale and vertical exaggeration of relief


4
Skiddaw
Scafell Pike
978 m
200 m
10 km
Carlisle
West Cumbria :
Pseudo-BUSC and
high relief crystalline rocks
Solway Firth
Perspective view looking south-east
Uniform scale and same vertical exaggeration of relief as previous views

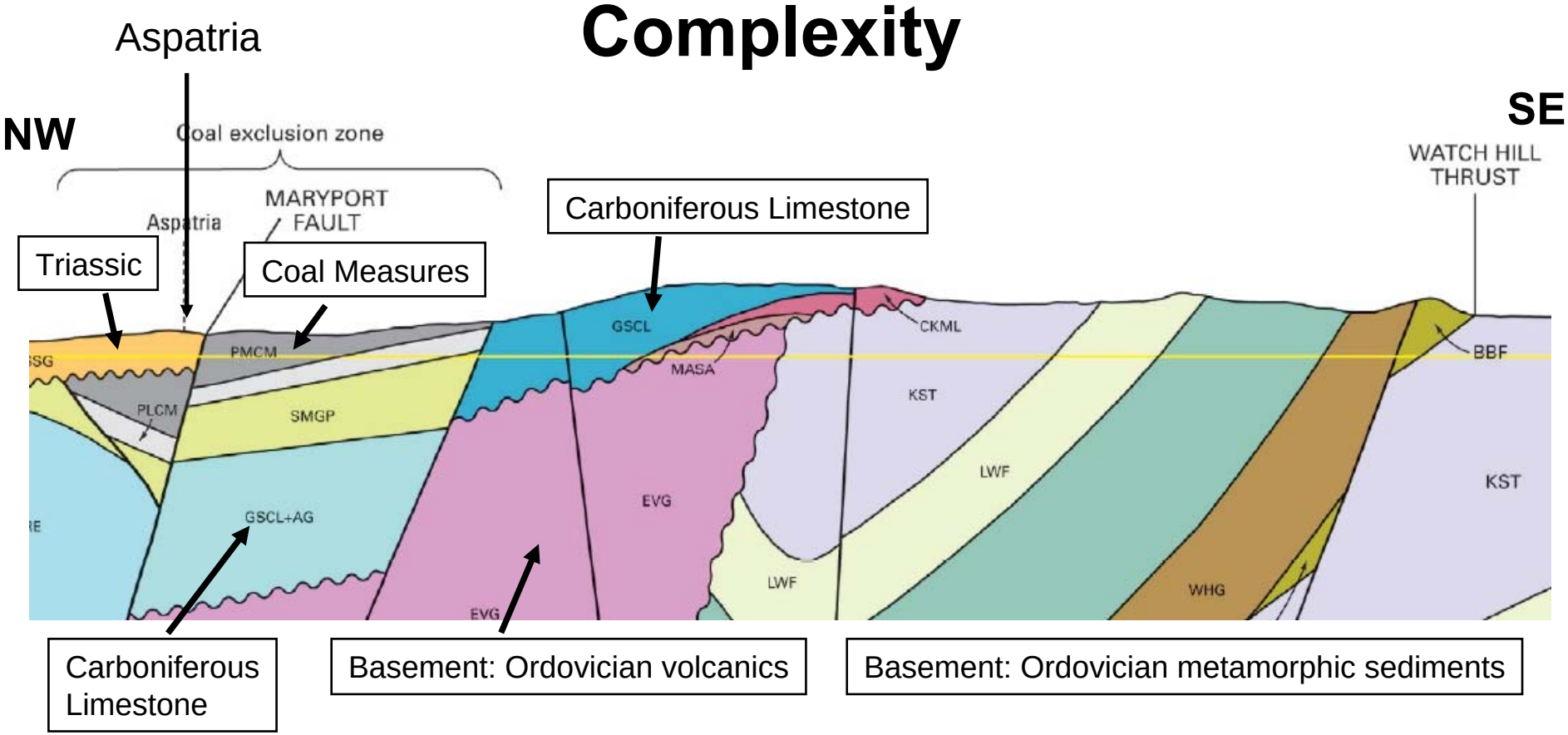
Geology

Complexity

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



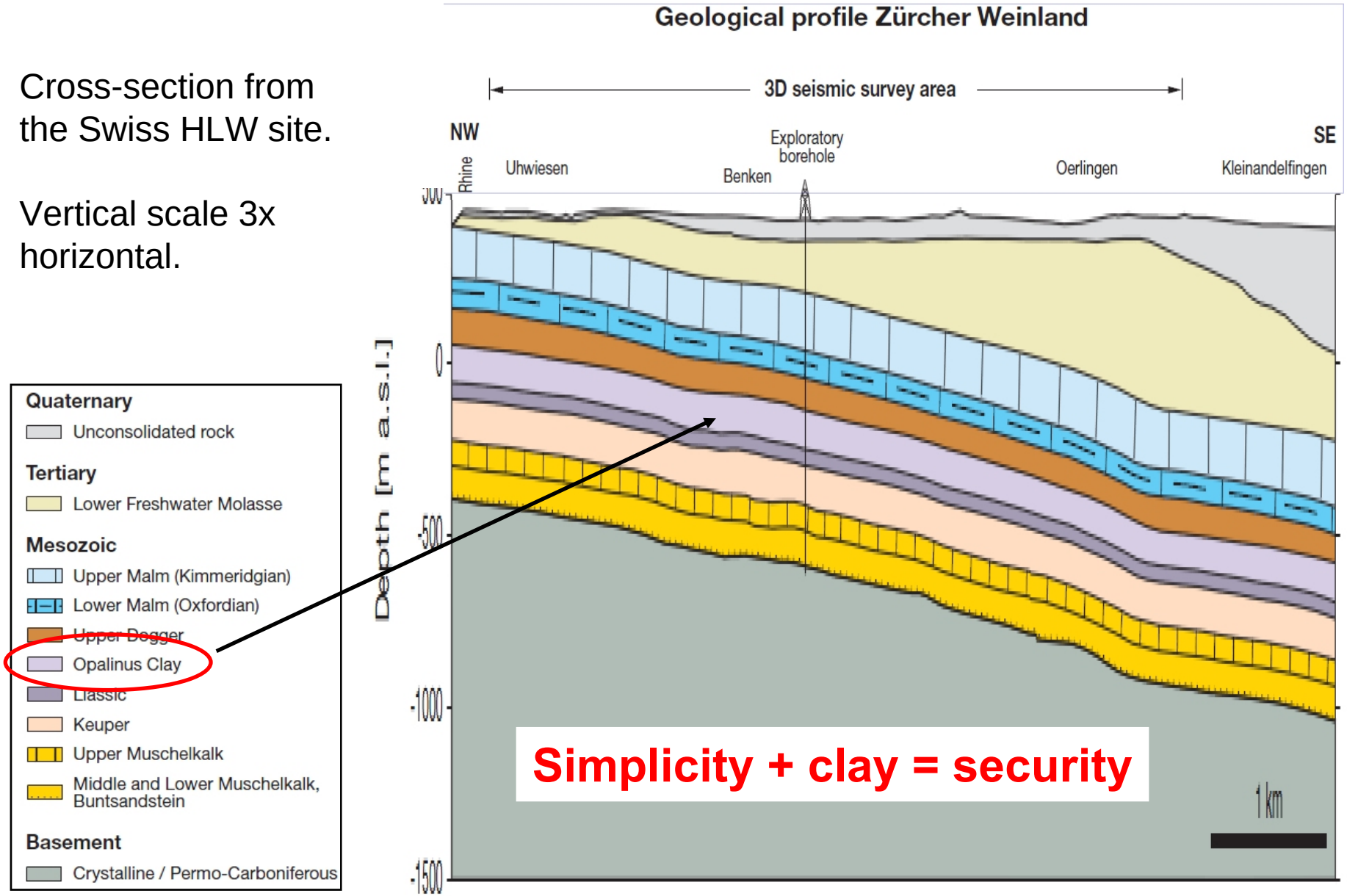
Cross-section through Allerdale from BGS screening report.
Vertical scale 3x horizontal.
Sea level – yellow line; base of section at 1500 m.
Faults are denoted by solid lines, unconformities by wavy lines.

- 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 district by district

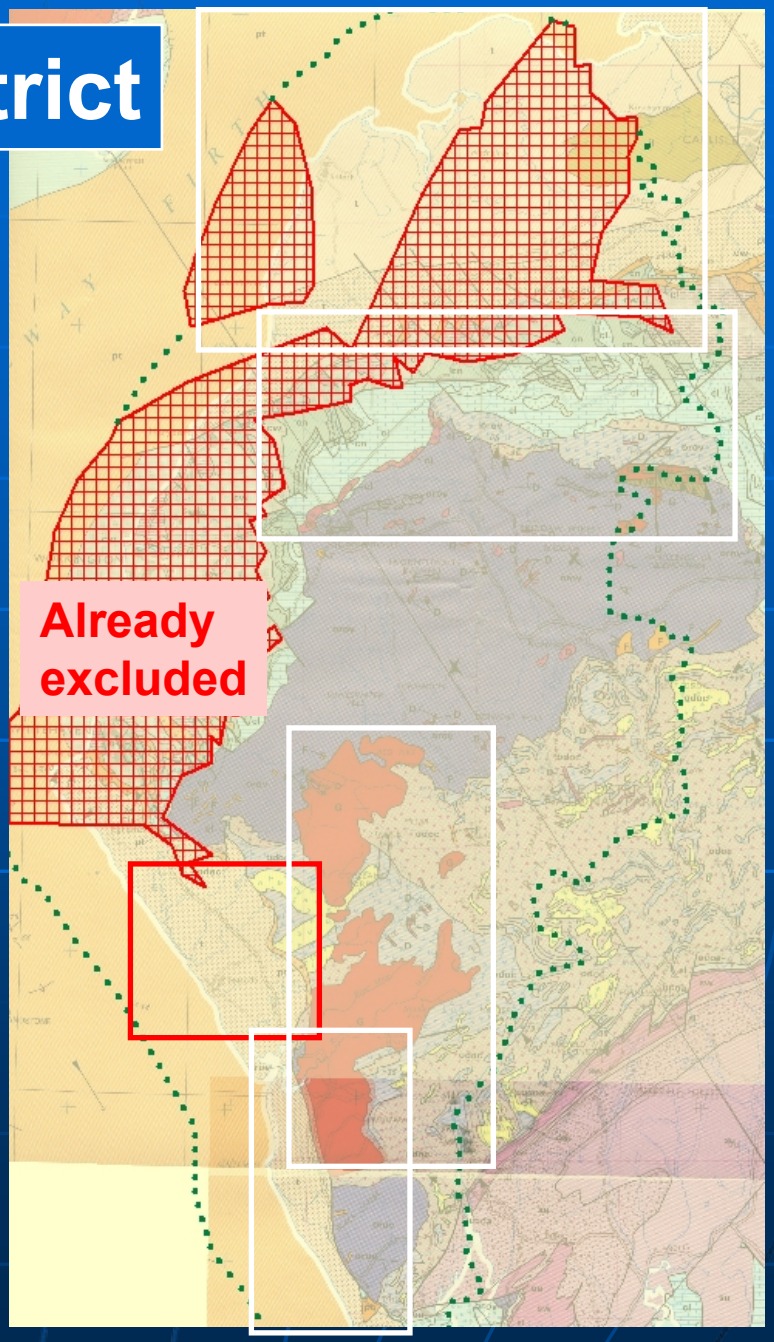
Northern Allerdale

Limestone belt

Eskdale granite

Sellafield / Longlands Farm

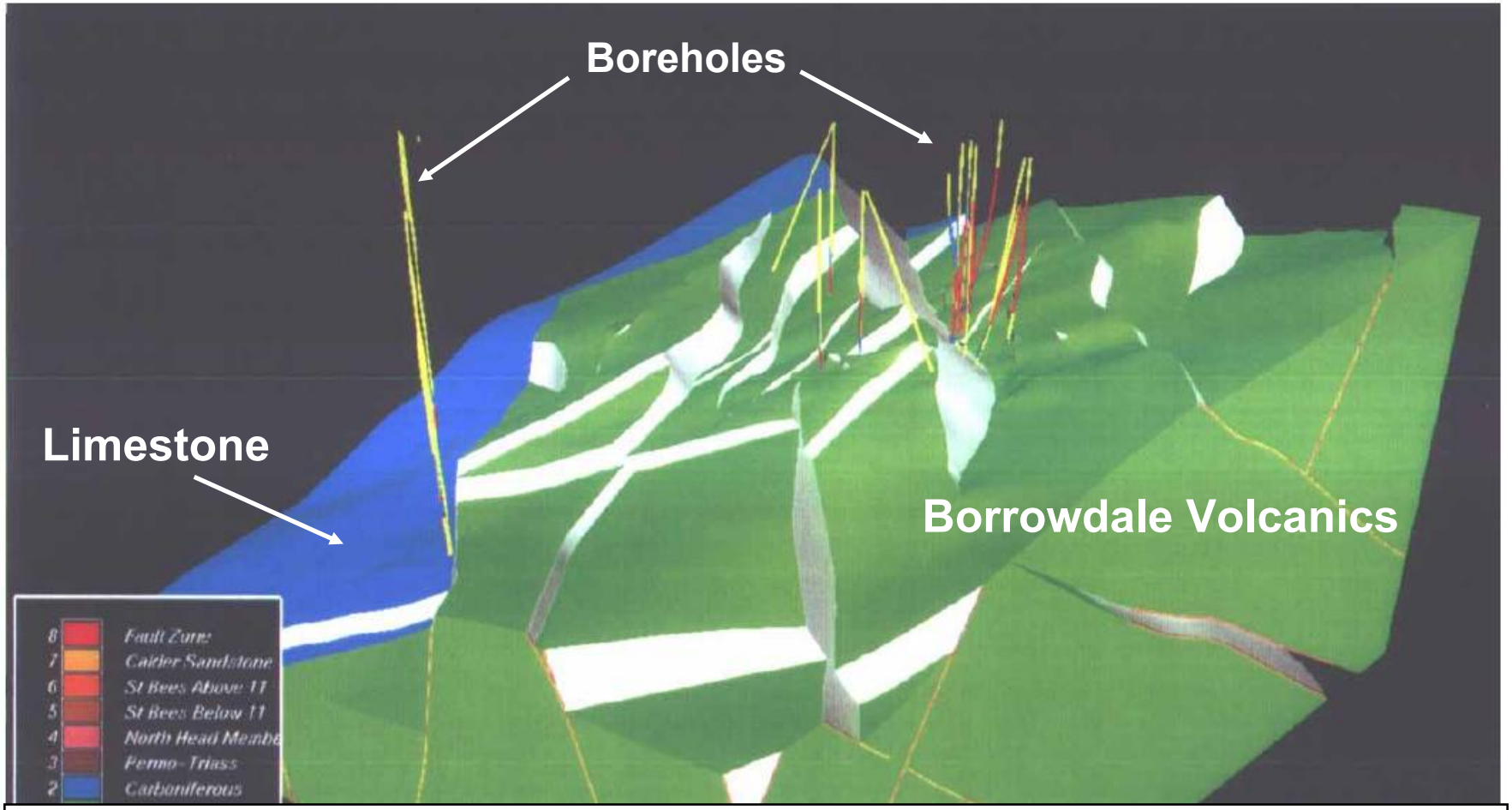
Southern coastal belt



Sellafield
Longlands Farm
Borrowdale Volcanic Group

£400M spent
Rejected by Inquiry

Can it be revived?



3D model of the structure at base of sediments, looking to the NW. No vertical exaggeration, 5 km x 5 km.

White surfaces are the faces of the faults.
This structure is modelled by computer to try to predict water flow and ultimate safety (shown later).

Geology district by district

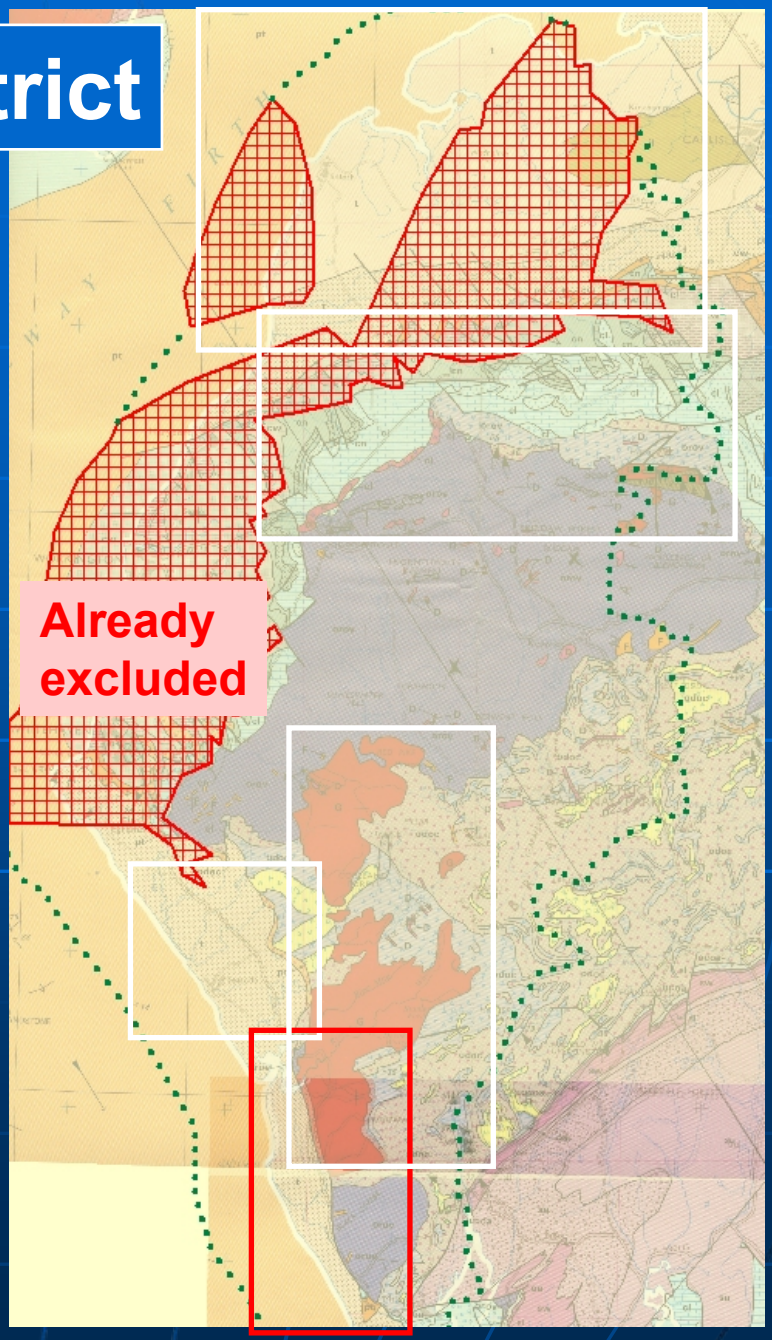
Northern Allerdale

Limestone belt

Eskdale granite

Sellafield / Longlands Farm

Southern coastal belt

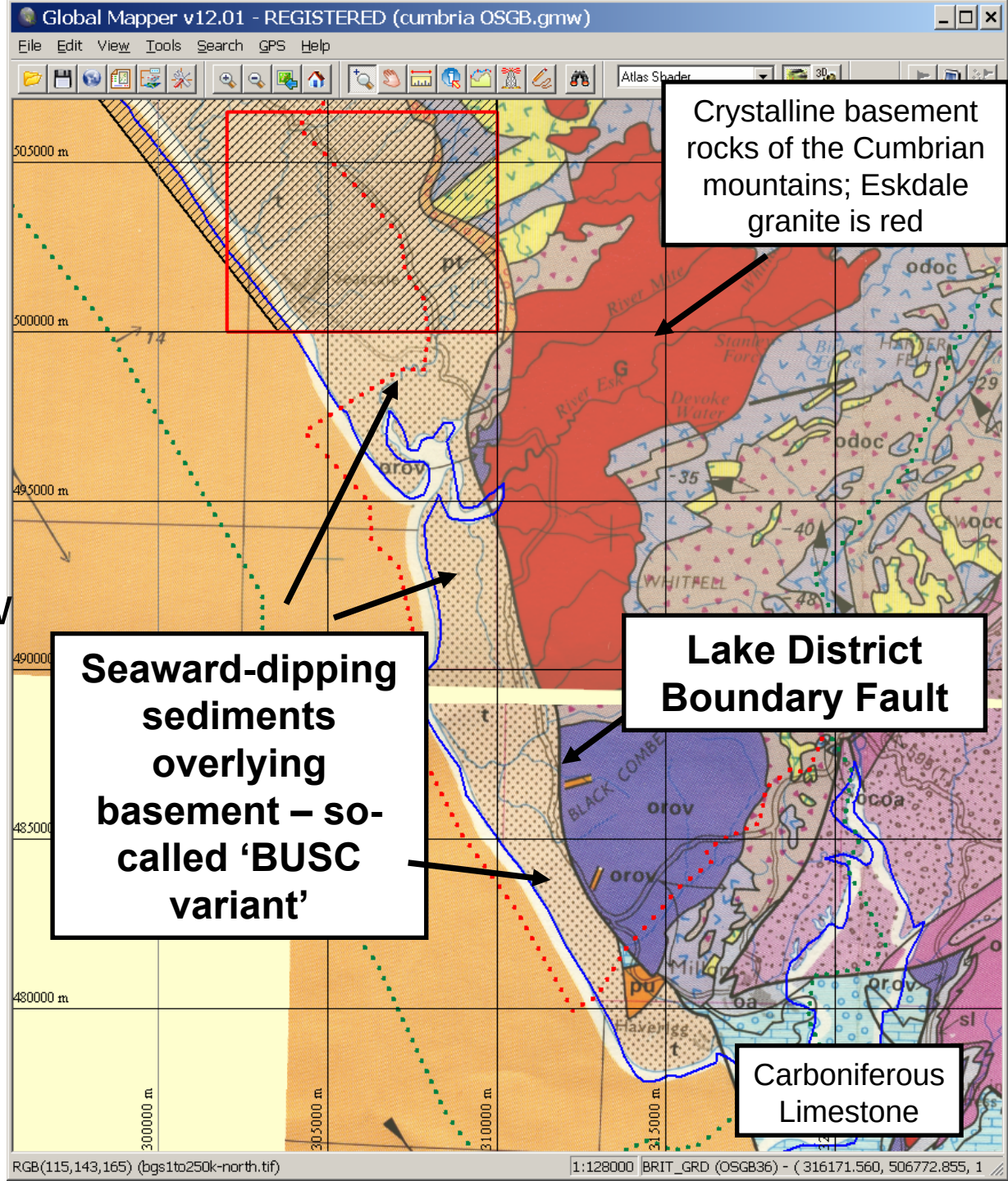


Coastal geology south of Longlands Farm

Coastal sedimentary strip problems:

- Complex, very narrow strip.
- Limestone present.
- Major fault line.

Conclusion: (even) worse than Longlands Farm.



Geology district by district

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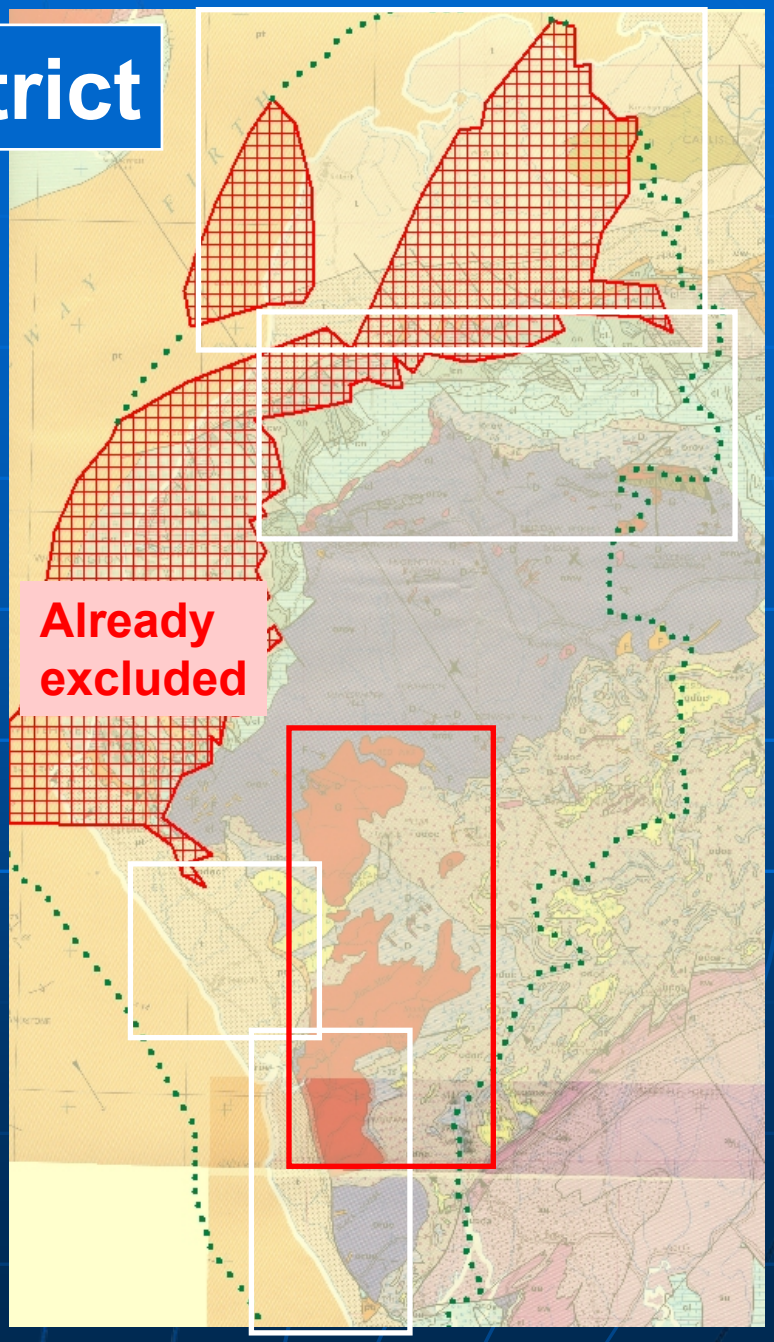


Eskdale granite: summary

Unsuitable because of:

- Extreme topography
- Adjacent to Lake District Boundary Fault
- Oxidising groundwater (old haematite mines, present-day leaching of uranium)
- Heavily faulted internally
- Complex internal structure
- Possible ‘hyperpermeable’ fracture zones (as found in granite below Weardale, Durham)

Geology district by district

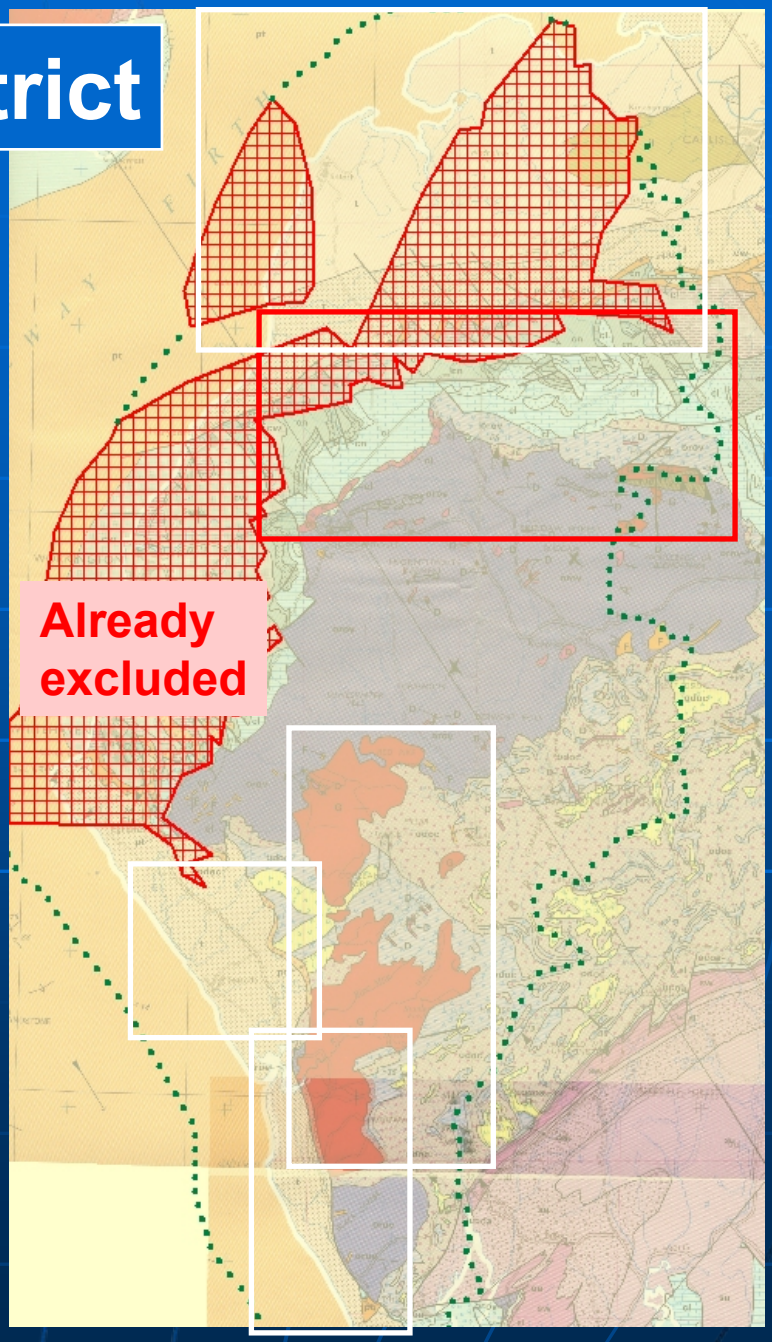
Northern Allerdale

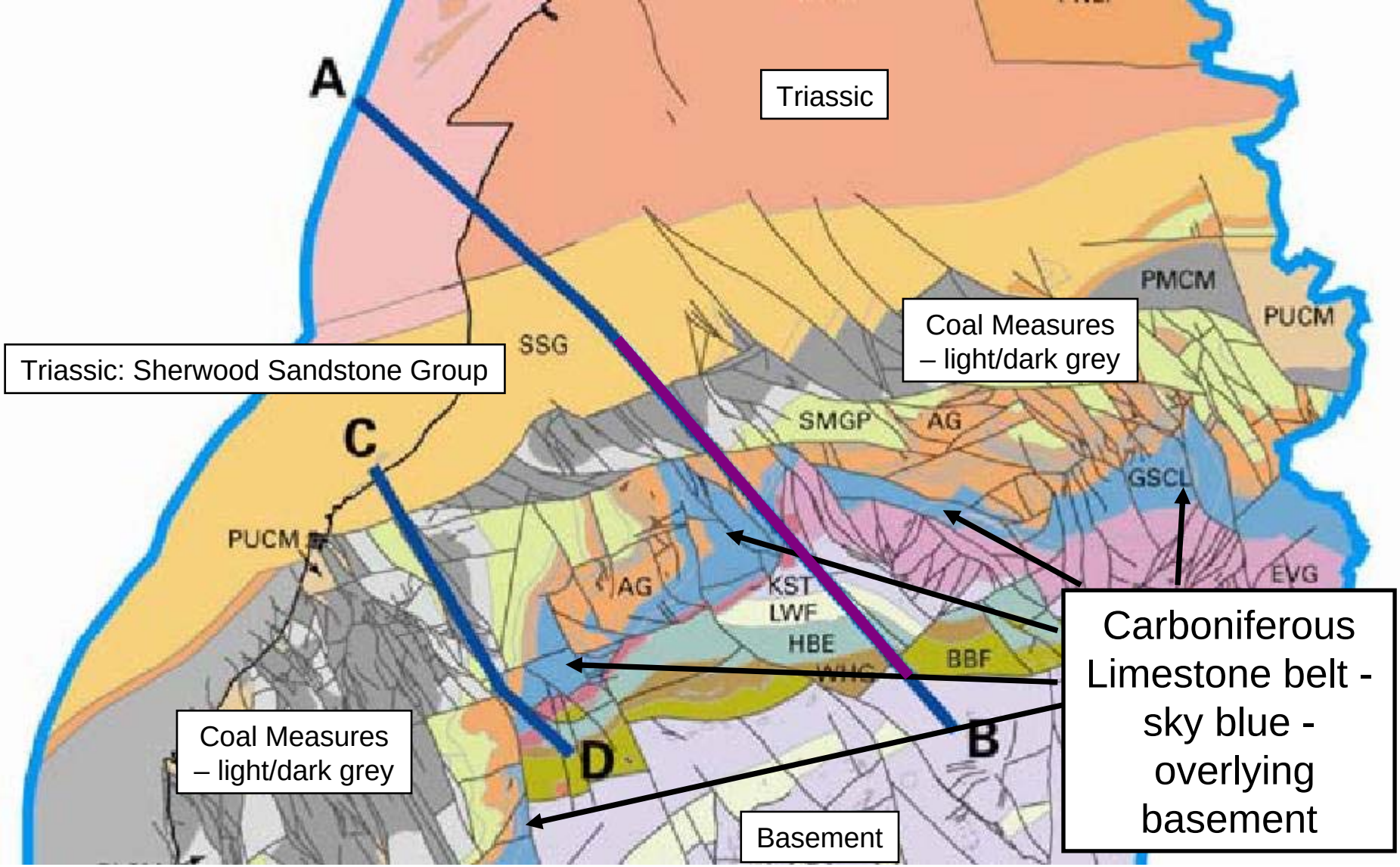
Limestone belt

Eskdale granite

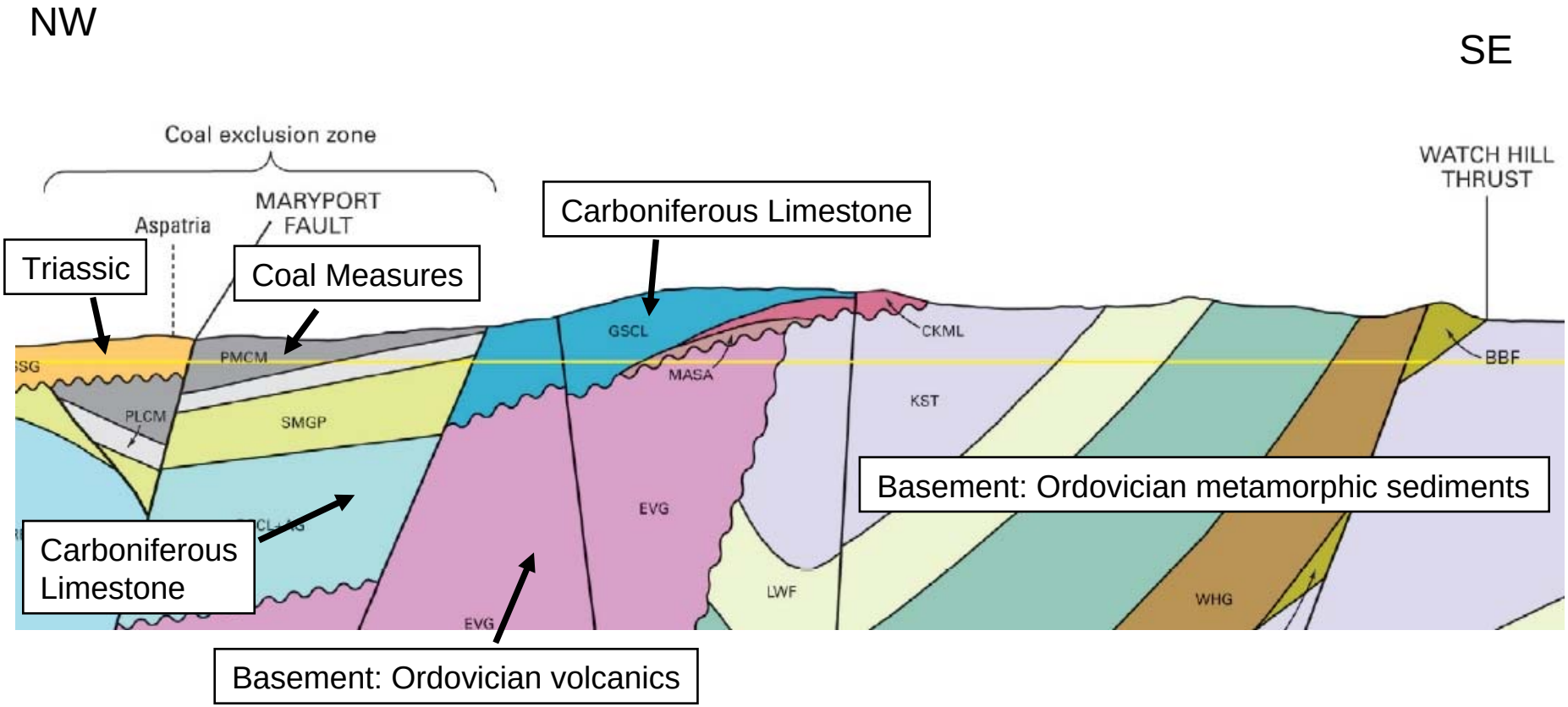
Sellafield / Longlands Farm

Southern coastal belt





A cross-section along the purple segment of line AB is shown in the next figure. Complex.



- **Complex, 3-dimensional**
- **No suitable basement-type rocks**
- **Limestone and Coal Measures present**
- **Geologically unsuitable**

Geology district by district

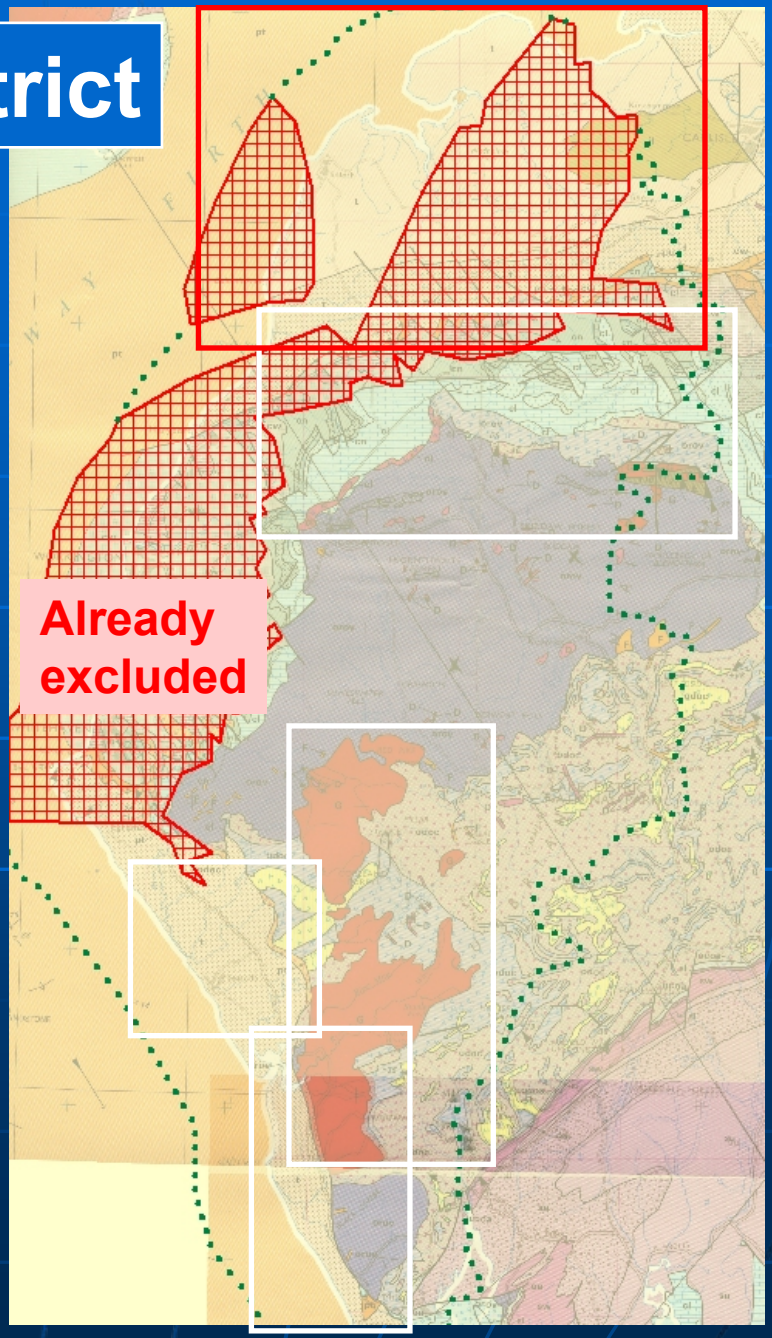
Northern Allerdale

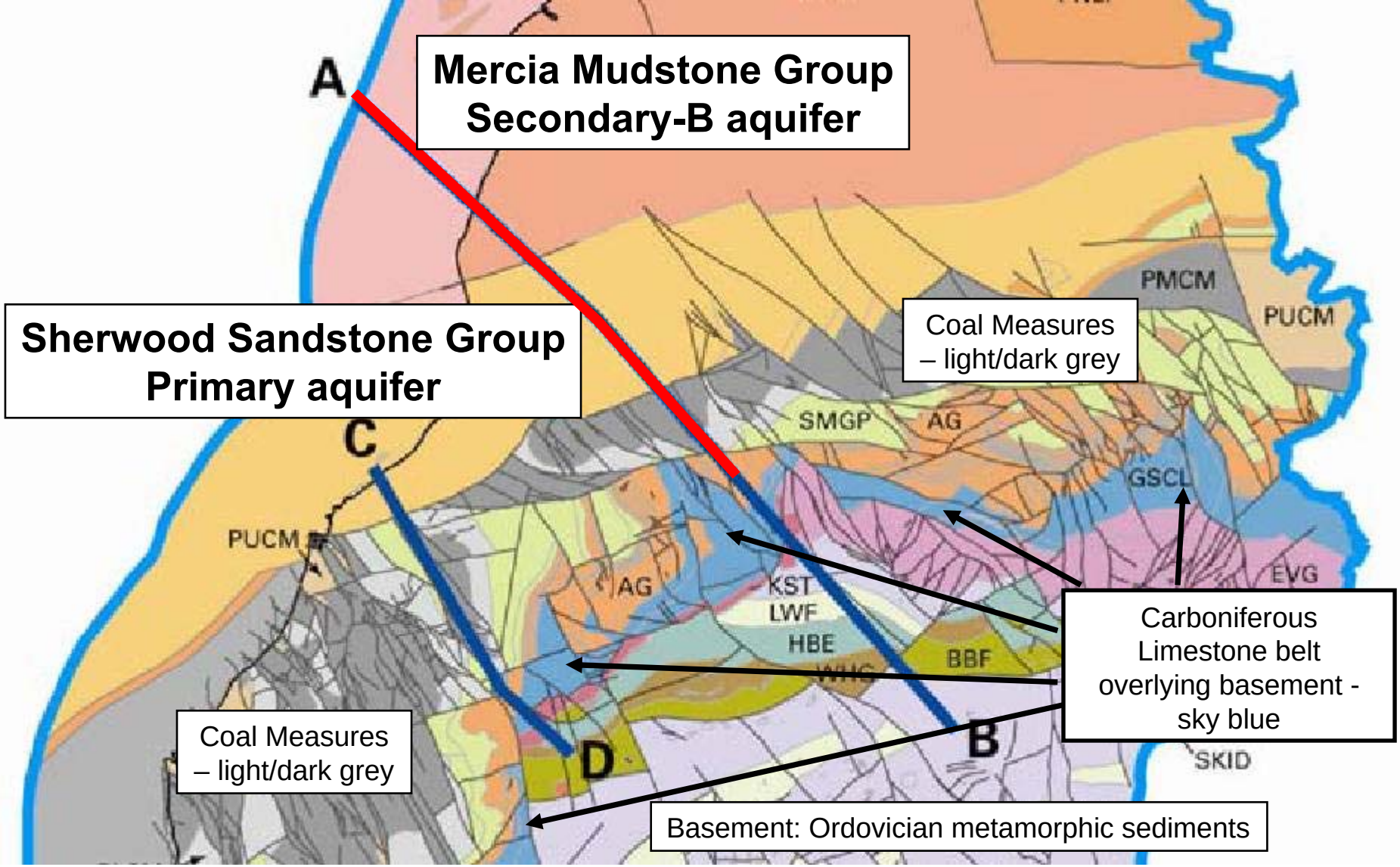
Limestone belt

Eskdale granite

Sellafield / Longlands Farm

Southern coastal belt

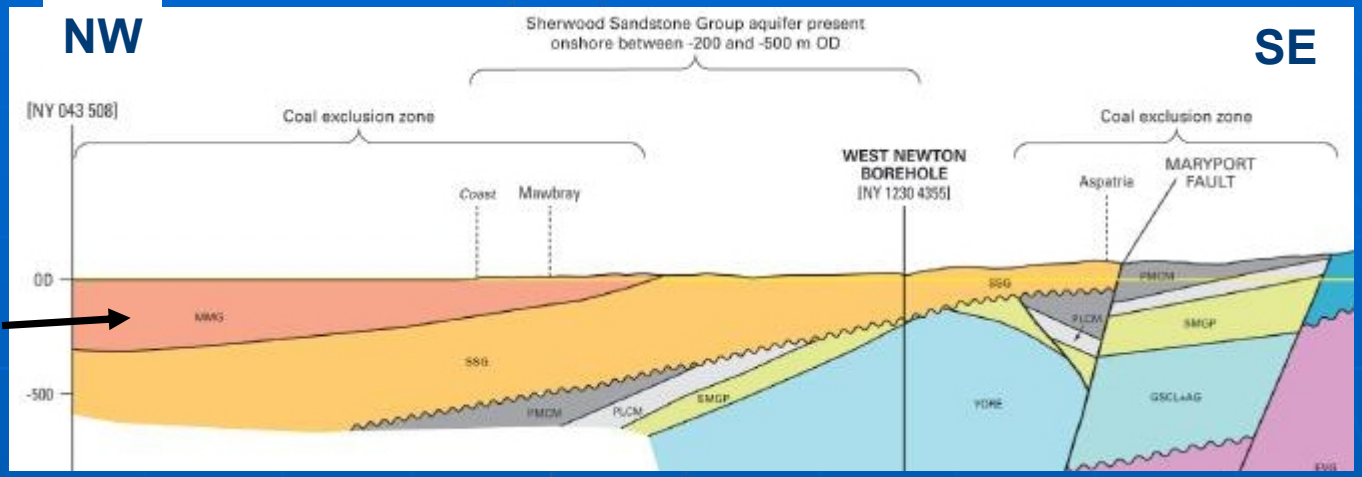




Sediments of northern Allerdale
A cross-section along the red segment of line AB is shown in the next figure.

Cross-section: Aspatria to Solway Firth

Mercia Mudstone Group



Mercia Mudstone Group - unsuitable

- Not previously considered as a host rock by the BGS.
- Current hydrocarbon exploration - should be excluded.
- Regional hydraulic gradient is high.
- Undesirably shallow depth of between 200 and 500 m.
- Geology is well understood due to oil industry exploration.
- Haematite-bearing red beds – oxidising environment.
- The groundwater is fresh, and exploited as an aquifer.
- The hydraulic conductivity is 10,000 - 1,000,000 times too high.
- Not a seal for hydrocarbons if less than at least 600 m thick.
- Cut by large faults which may act as water conduits.

The MMG was probably introduced as a debating tactic by MRWS.

The current process

Misinformation

Inquiry Inspector ?

But the government has airbrushed out the history of the 1995-96 Planning Inquiry.

- to put Sellafield back in the frame.

Since 1997 successive governments have:

- Hidden details of 1995-96 Inquiry.
- Done no research to find other potential sites.
- Removed right of Public Planning Inquiry.
- Elevated ‘voluntarism’ as the main selection criterion.

And is now:

- Misrepresenting Inquiry conclusions.
- Presenting Sellafield as ‘potentially suitable’.
- Implying that other countries use voluntarism.
- Inviting volunteer ‘communities’ to come forward.
- Presenting the ‘initial unsuitability screening’ as a pass mark for West Cumbrian geology.

In denial

Nirex discussed Sellafield in 2005, asserting:

"*It has been argued that the rejection of the RCF planning application indicates that Sellafield was unsuitable as a repository site.*

***However, we believe that this was never a conclusion from the RCF Local Planning Inquiry Inspector's report*."**

Really ?

"– and can we now add in High Level Wastes as well ?"

Letter from Chris McDonald (Inquiry Inspector) : *The Guardian*, 2007

“The relevant geology in west Cumbria is apparently now claimed to be "stable, although imperfect". But 10 years ago the nuclear industry had not found a way of maintaining the stability of that geology when physically exploring the underground site.

… the imperfection consists of simply **failing to meet the internationally agreed criteria** on the suitability of rocks for nuclear waste deposit.

The **site should be in a region of low groundwater flow**,
and the **geology should be readily characterisable and predictable**,
whereas the **rocks there are actually of a complex volcanic nature**,
with **significant faulting**.

…the industry was relying on an overlying
layer of sedimentary strata to dilute and disperse any groundwater leakage,
when the **international criteria require such a layer to act instead as a barrier**.

The site is not suitable and investigations should be moved elsewhere.

The site selection process was flawed, not treating safety as the most important factor, and irrationally affected by a strong desire to locate close to Sellafield.”

Fibbing

The NDA (Nirex, 2005) claimed support from the BGS for Sellafield:

"*Based on the results of this work, *we believe that Sellafield is a potentially suitable site for a repository. This view is shared by the British Geological Survey (BGS) and many other specialist consultants*."**

Really ?

*** The Nirex 97 set of documents**

I asked for evidence …

Freedom of Information request (1)

NDA response, January 2012:

"the assertion … was based on verbal evidence, as a result of the …Director of the BGS, Dr David Falvey,

responding in the affirmative to the (paraphrased) question,

"Does the BGS consider that Sellafield might be a suitable site?" …"

Freedom of Information request (2)

BGS response, January 2012:

[on correspondence] "*our radioactive waste expert, Richard Shaw has searched through all relevant material within our archive and confirmed that there is no correspondence between BGS and Nirex … relating to the suitability of the Sellafield site for a radioactive waste repository …*"

[on publications] *"we have only published factual reports that relate to the Sellafield site and these will not contain the sort of statement you require for your research*."

Flaws in the BGS screening report

1. The screening report
2. Water
3. Oil and gas

Initial Geological Unsuitability Screening of West Cumbria

Why was a full review not done before the screening-out (as specified in the new IAEA guidelines) ?

Next: Potable groundwater

Former Designation	Environmental Agency (EA) Designation (from April 2010)
Major Aquifer	*Principal Aquifer (e.g. Sherwood Sandstone Group)*
Minor Aquifer	*Secondary A Aquifer (e.g. Carboniferous strata)*
Non-aquifer	***Secondary B Aquifer* (e.g. Borrowdale Volcanic Group)**
	Unproductive strata (e.g. halite in the Permo-Triassic strata)

From BGS screening report

"***The EA aquifer designation shown in Table 4 post-dates the CPG/CRP report which does not provide guidance on which of these categories would be excluded. In this study only Principal and Secondary A aquifers are regarded as exploitable groundwater resources***."

In effect – we are sticking to the old classification

Why not Secondary B aquifers ?

The […] and Mercia Mudstone groups are classified as a Secondary B Aquifer (formerly non-aquifers).

These rock units do not represent major exploitable groundwater resources as defined both in the Exclusion Criteria (Defra, 2007) and within the spirit of the EU Water Framework directives.

Really ?

[… City of Leicester 'Waterstones']

BGS screening report:

"Some, but not all, of the rock volume in areas where aquifers and shallow permeable formations are present in the Partnership area are excluded.

However, nowhere does the exploitable aquifer rock volume extend over the whole of the depth range between 200 m and 1000 m below ground level and, consequently, the total area is not excluded at this stage."

(illogical)

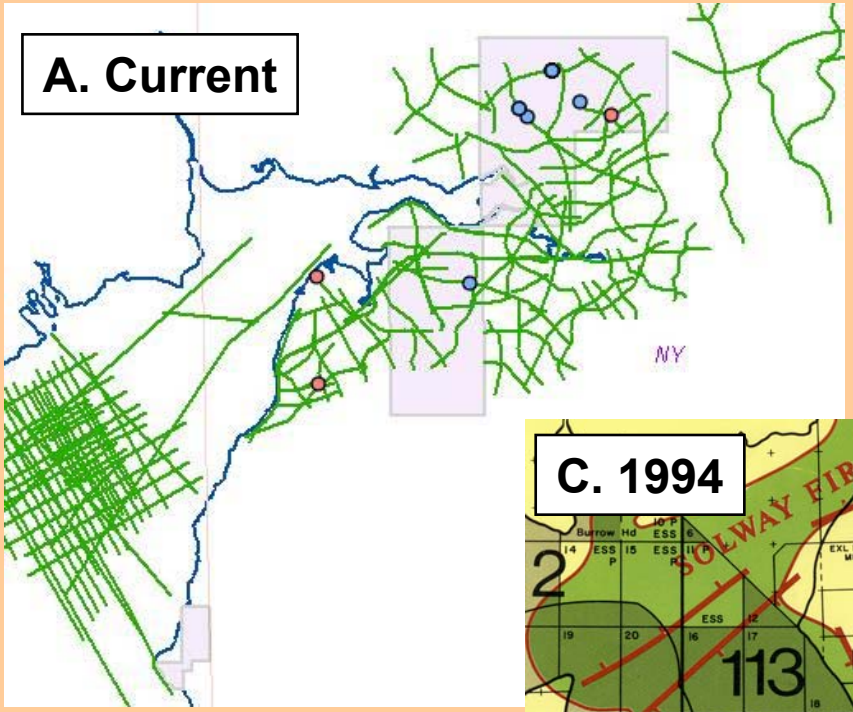
So they are asking for the highly improbable – 800 m thick aquifers.

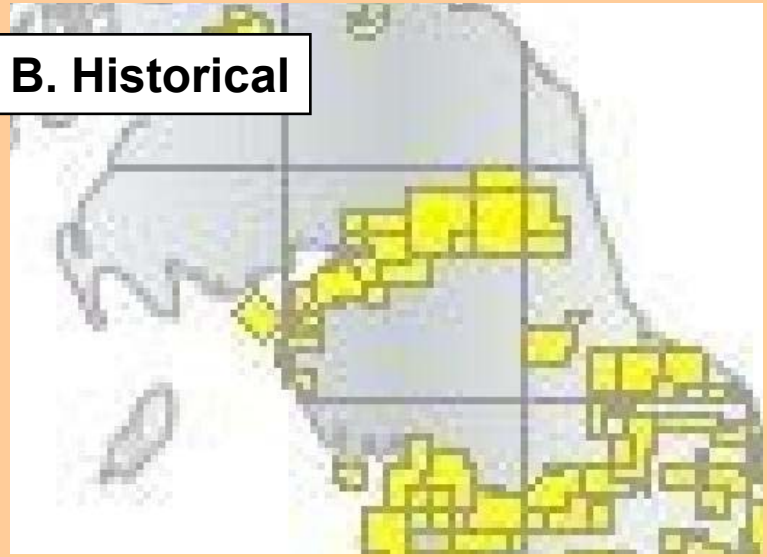
Why ?

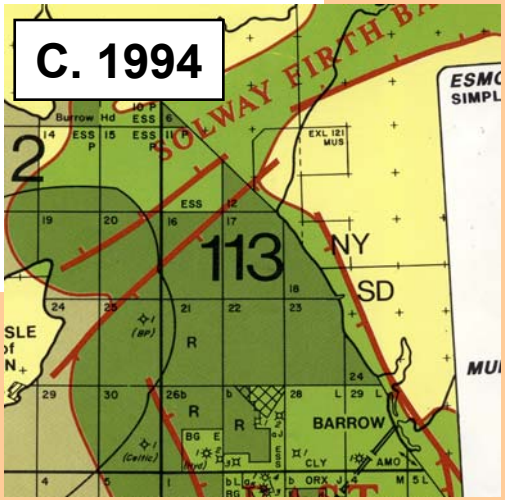
… because if the groundwater exclusion had been applied in a rational way …

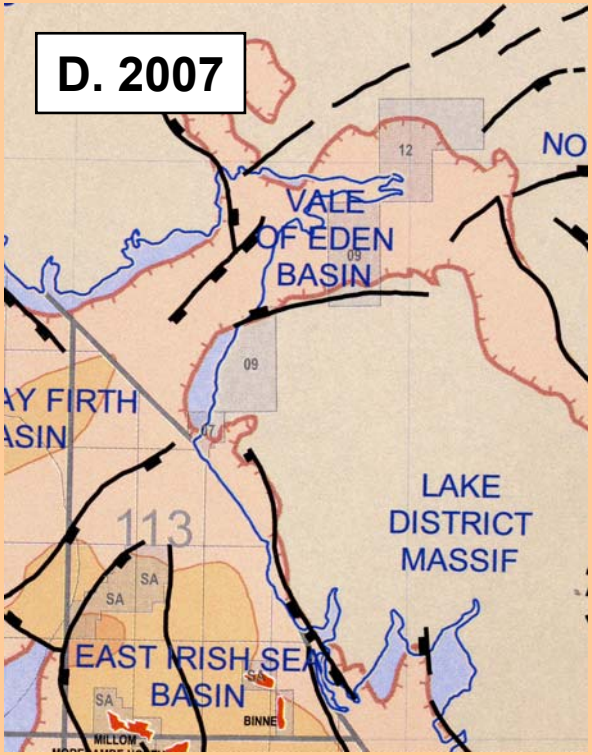
the whole of northern Allerdale would have been screened out.

Next: Oil and gas exploration





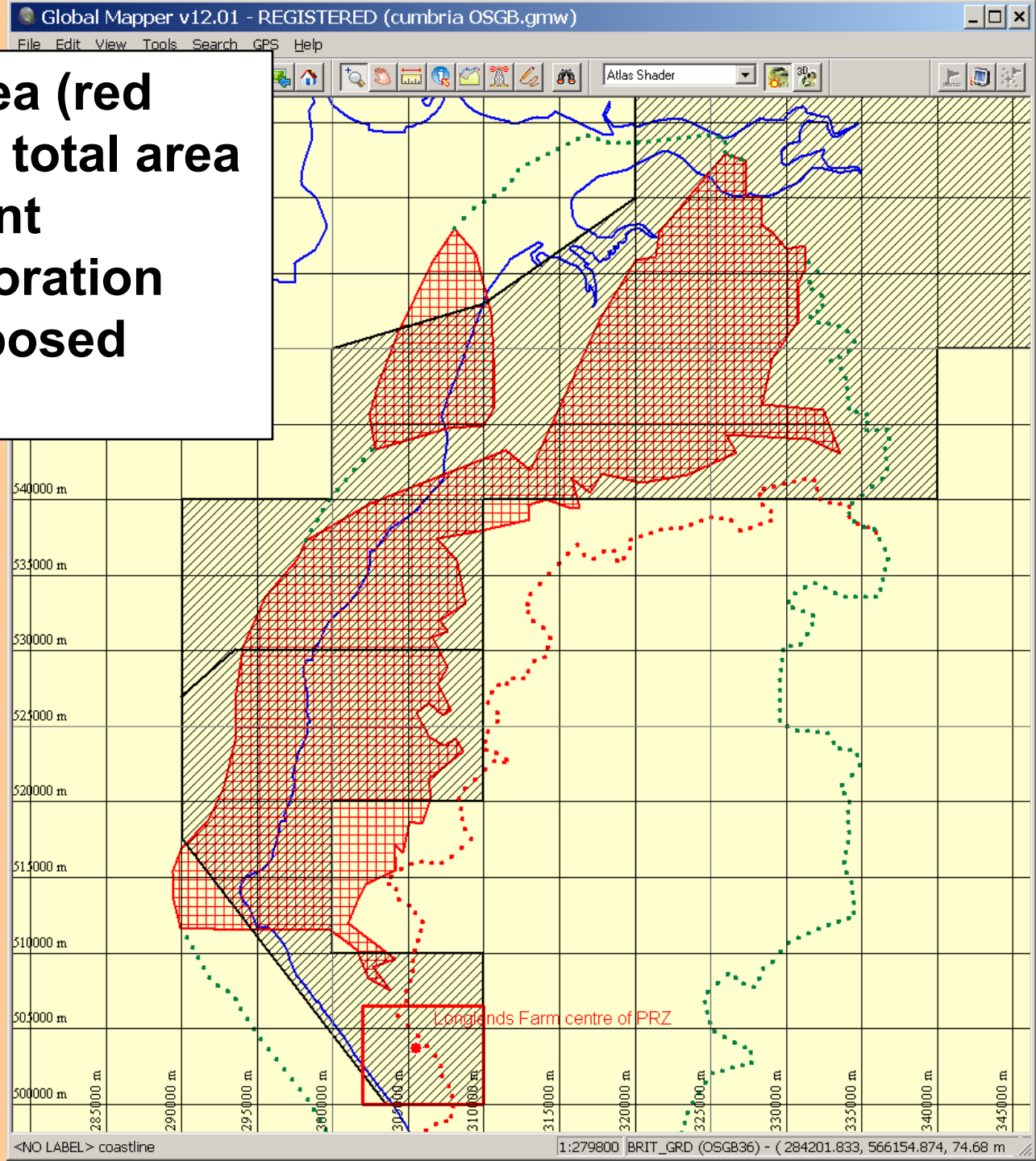




Medley of maps showing exploration activity at different epochs in Allerdale.

A. DECC map (2011) showing available seismic profiles (green), exploration wells (red and blue dots) and current licensed areas (grey).
B. Historically licensed areas in the north of England (yellow).
C. PESGB map (1994) showing Mustang Resources exploration licence. extending south from Workington into the Sellafield Site quadrant.
D. PESGB map (2007) showing licences (grey).

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?

Making a safety assessment in complex geology

Analysis of ‘Nirex 97’

– the set of documents that allegedly changes everything.

Trying to make a ‘safety assessment’ to prove that a dump will be safe for n years
(the number n varies and is not consistently applied).

Crucial data include **Permeability**

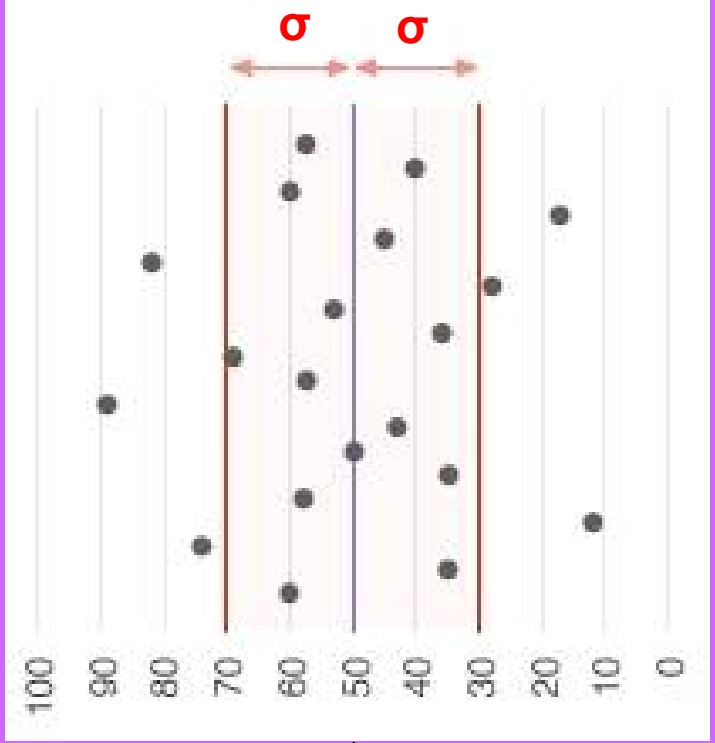
-How fast fluids can flow through the rocks

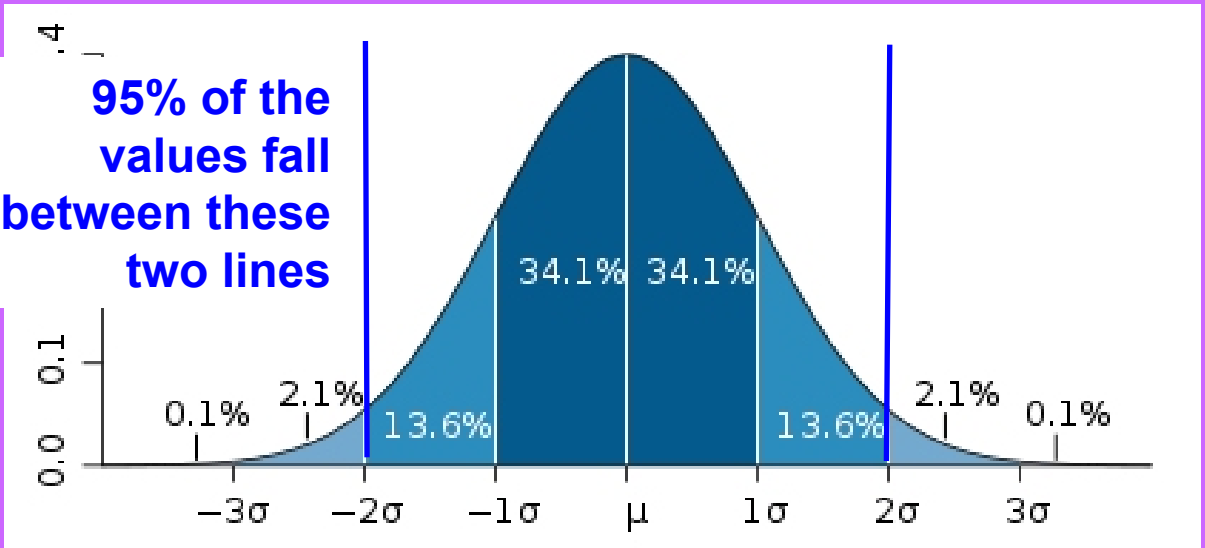
-First, what about **uncertainty** ?

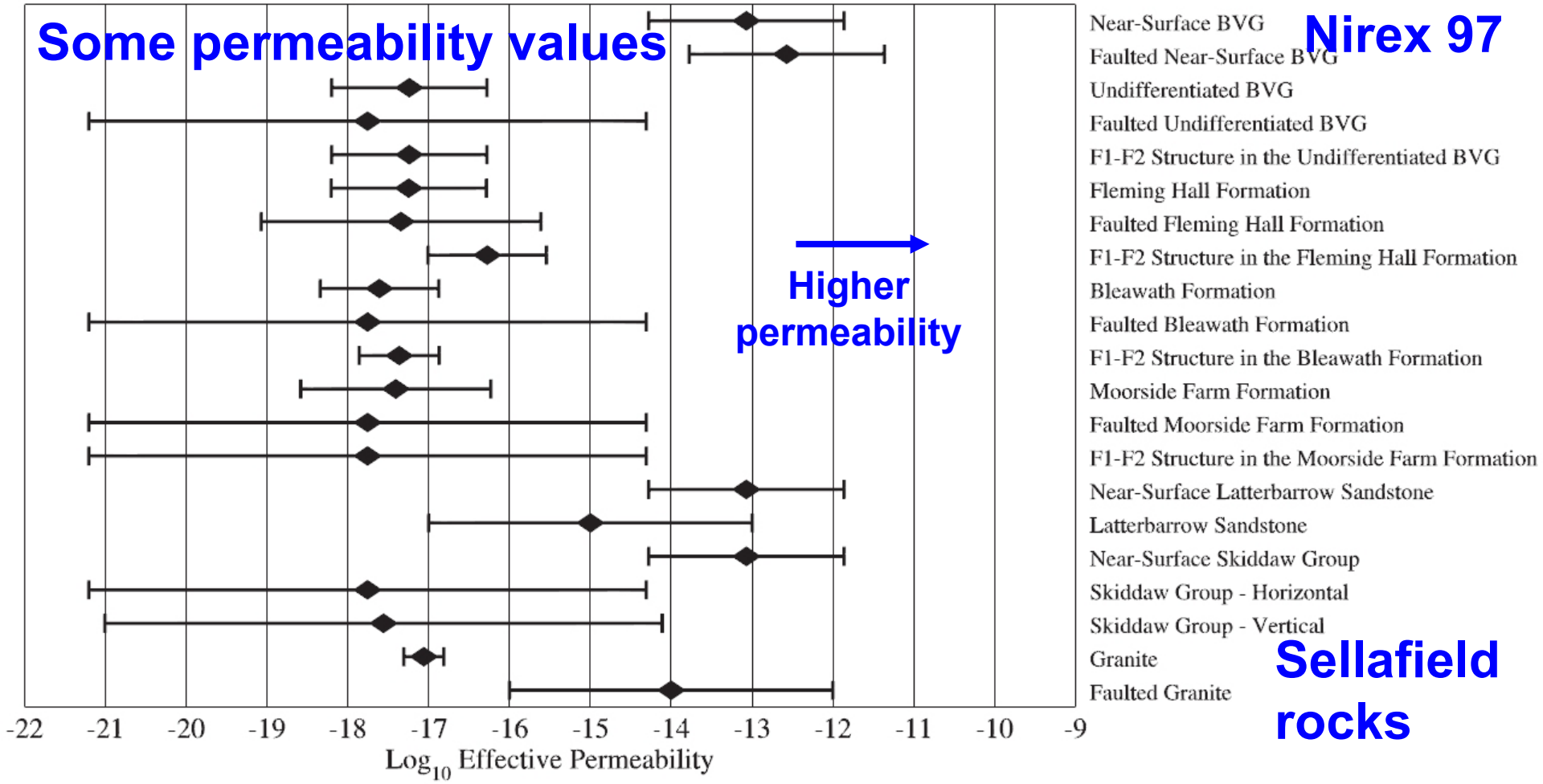
Nirex 97

Estimating the uncertainty in data:

We use
Standard deviation (σ)
or
95% confidence limit







This bar through the preferred value of permeability (diamond) shows the 95% confidence limit on either side.

But what if we have no data …

Never fear !

…. We make it up !

Nirex 97

Expert elicitation

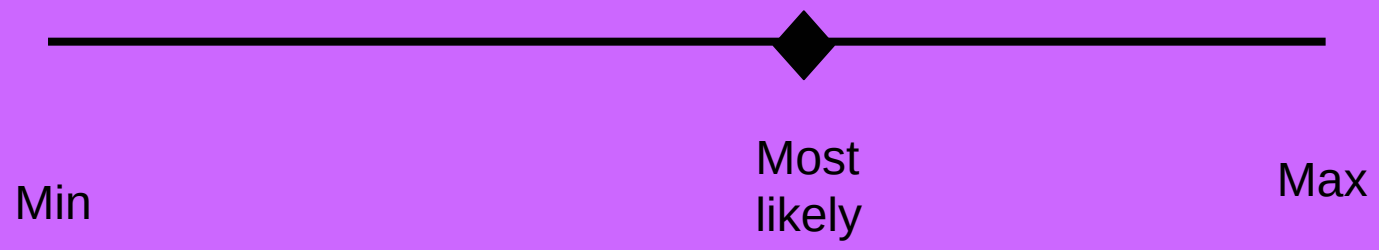
From Wikipedia, the free encyclopedia

In science, engineering, and research, **expert elicitation** is the synthesis of opinions of experts of a subject where there is uncertainty due to insufficient data or when such data is unattainable because of physical constraints or lack of resources. Expert elicitation is essentially a scientific consensus methodology. It is often used in the study of rare events. Expert elicitation allows for parameterization, an "educated guess", for the respective topic under study. Expert elicitation generally quantifies uncertainty.

Expert elicitation tends to be multidisciplinary as well as interdisciplinary, with practically universal applicability, and is used in a broad range of fields. Prominent recent expert elicitation applications are to climate change, modeling seismic hazard and damage, association of tornado damage to wind speed in developing the Enhanced Fujita Scale, and risk analysis for nuclear waste storage.

Data elicitation example:

What is the life expectancy of Adele Adkins?



Think of relevant data …..

Nirex 97













Amy Winehouse 27

Janis Joplin 27

Cass Elliot 32

Eva Cassidy 33

Billie Holiday 44

Edith Piaf 47

Sarah Vaughan 66

Adele 23+ ??

Joni Mitchell 68+

Nina Simone 70

Etta James 73

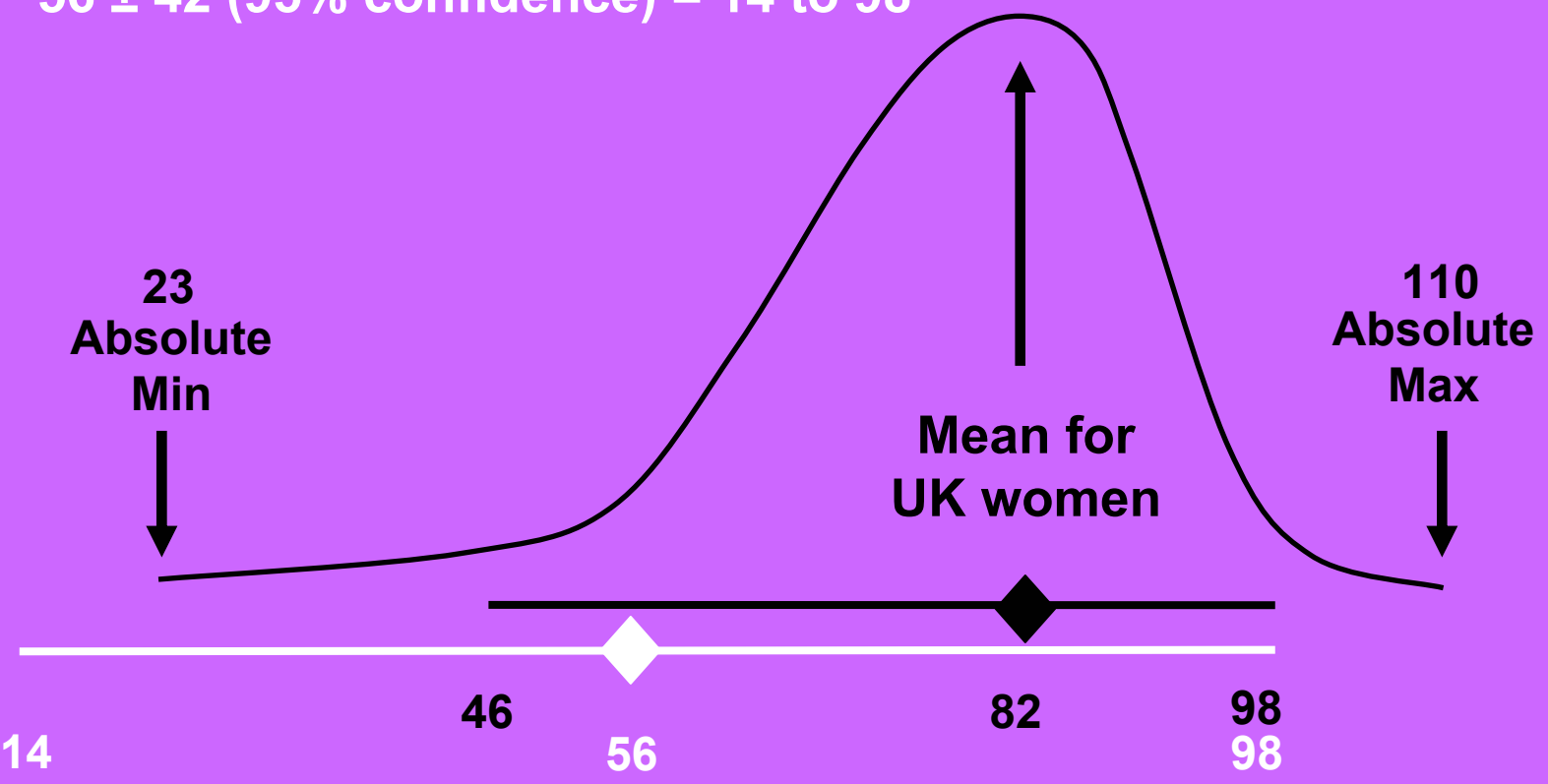
Ella Fitzgerald 79

Peggy Lee 81

Juliette Greco 84+

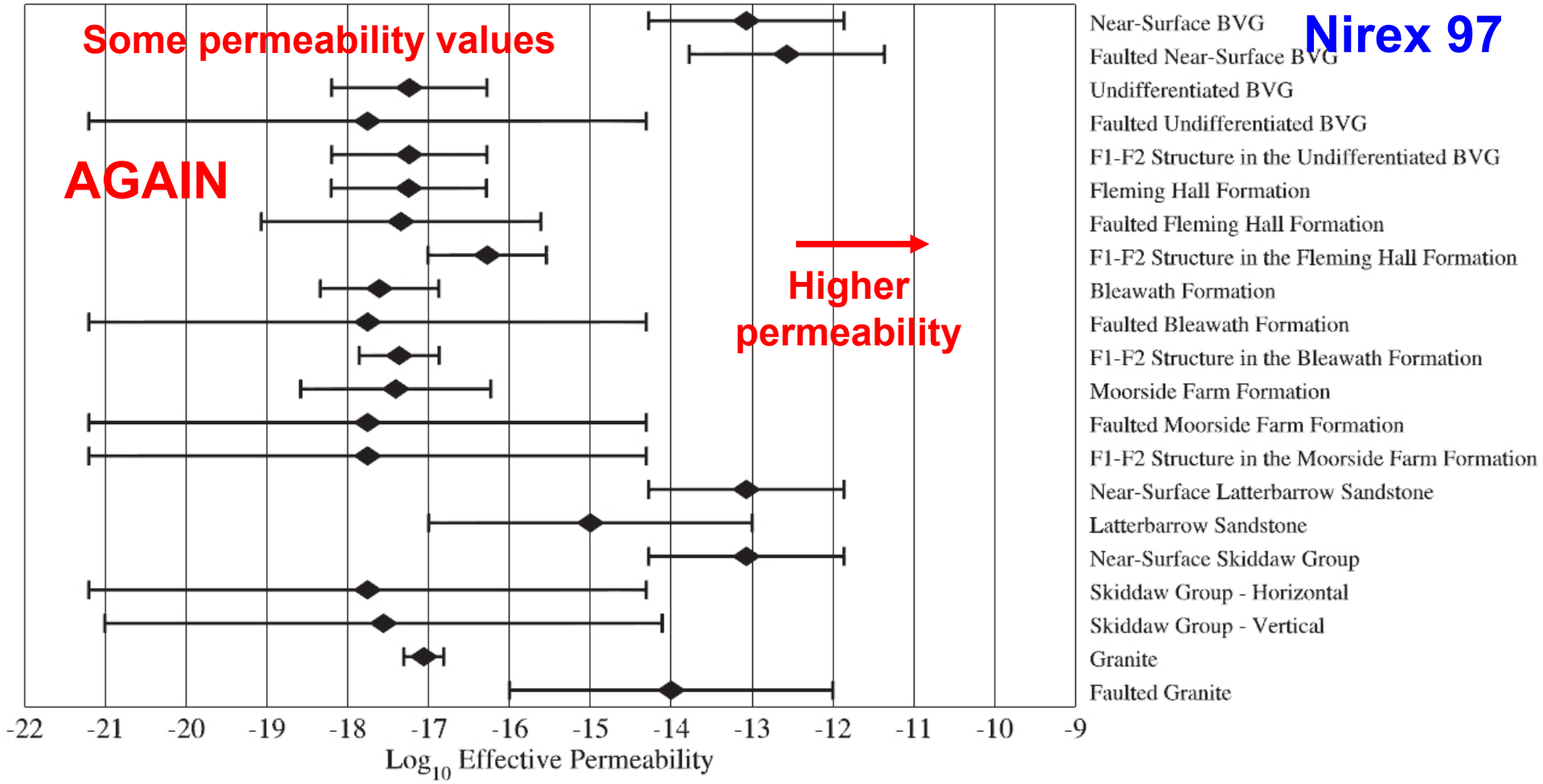
Life expectancy of Adele – quantified in two ways Nirex 97

(1) From singer sample we get mean of 56 ± 21 (s.d.)
56 ± 42 (95% confidence) = 14 to 98

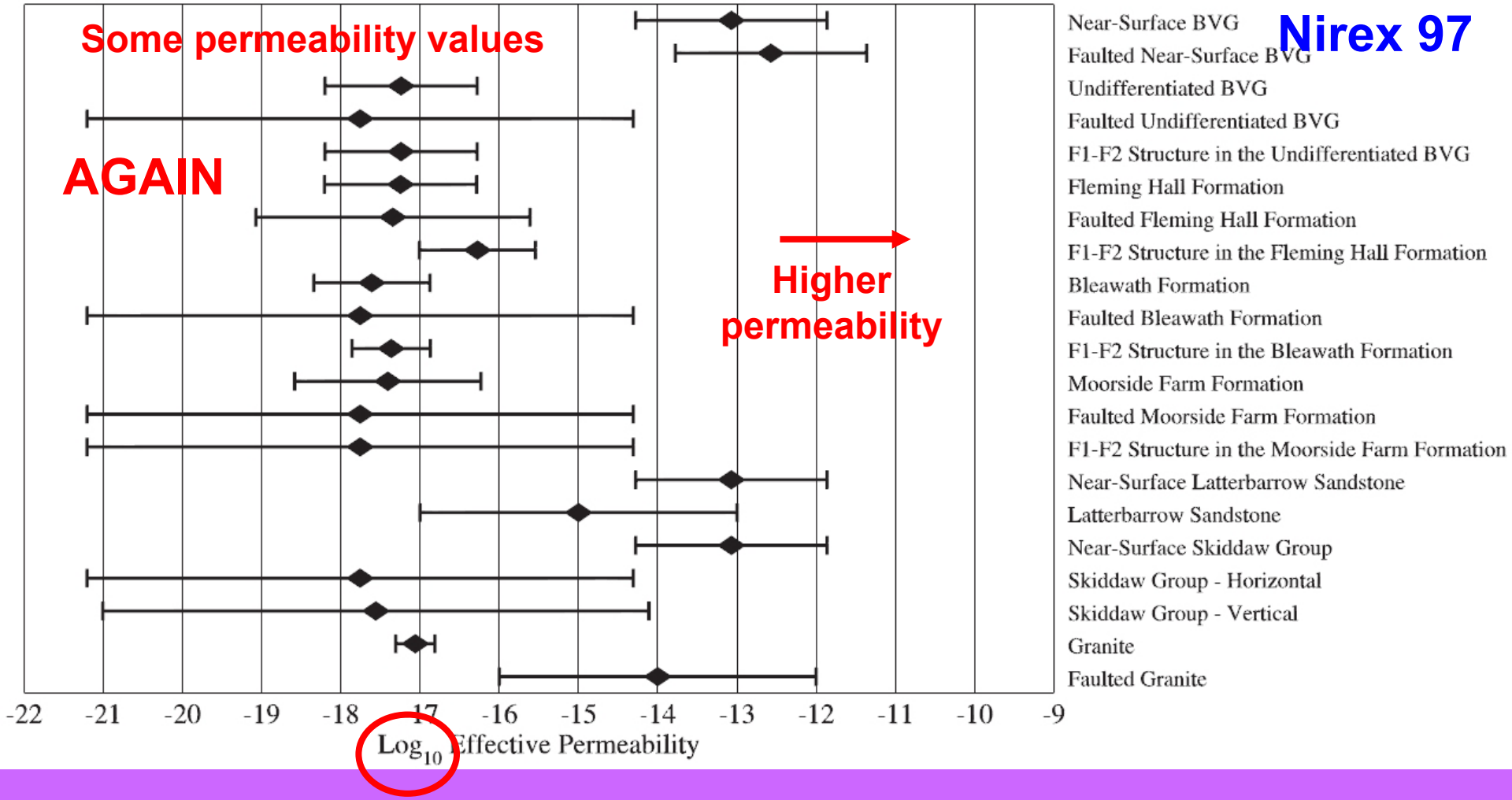


(2) From graph above - all women + Adele's current age:
82 +16 / -36 (95% confidence)

The answer you get depends on your assumptions



This bar through the preferred value (diamond) shows the 95% confidence limit on either side

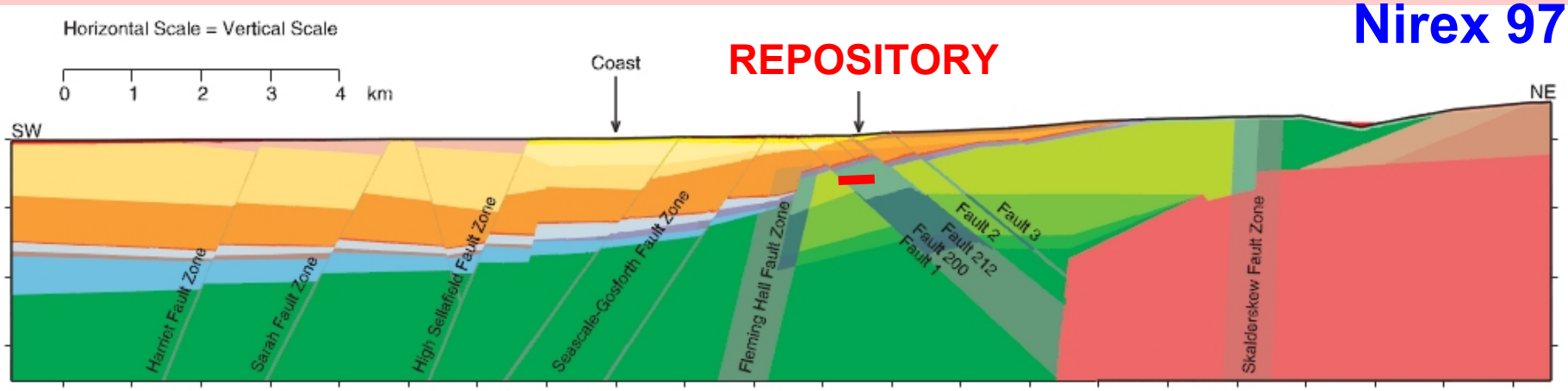


This bar through the preferred value (diamond) shows the 95% confidence limit on either side

Always read the small print

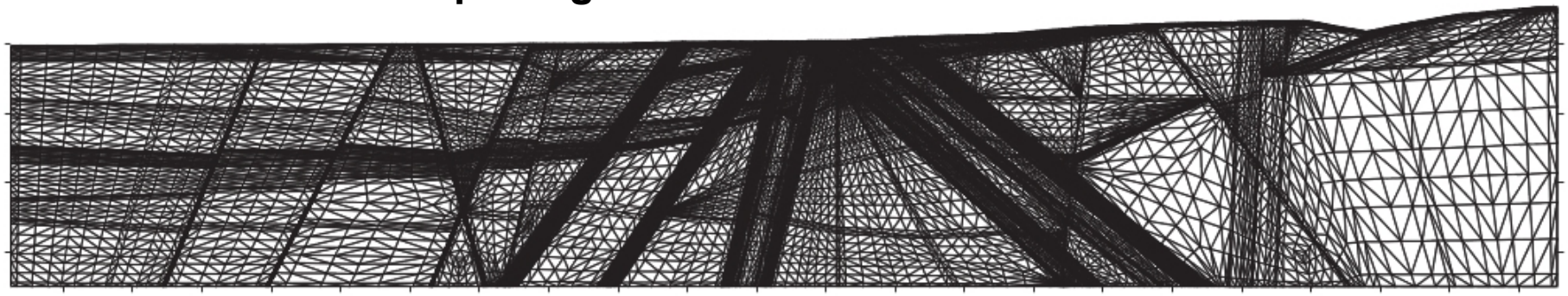
Plugging the permeability values into a computer model to predict the flow of toxic waste through the rocks.

NB The ‘engineered barriers’ are temporary. The final, most important barrier is the geology.



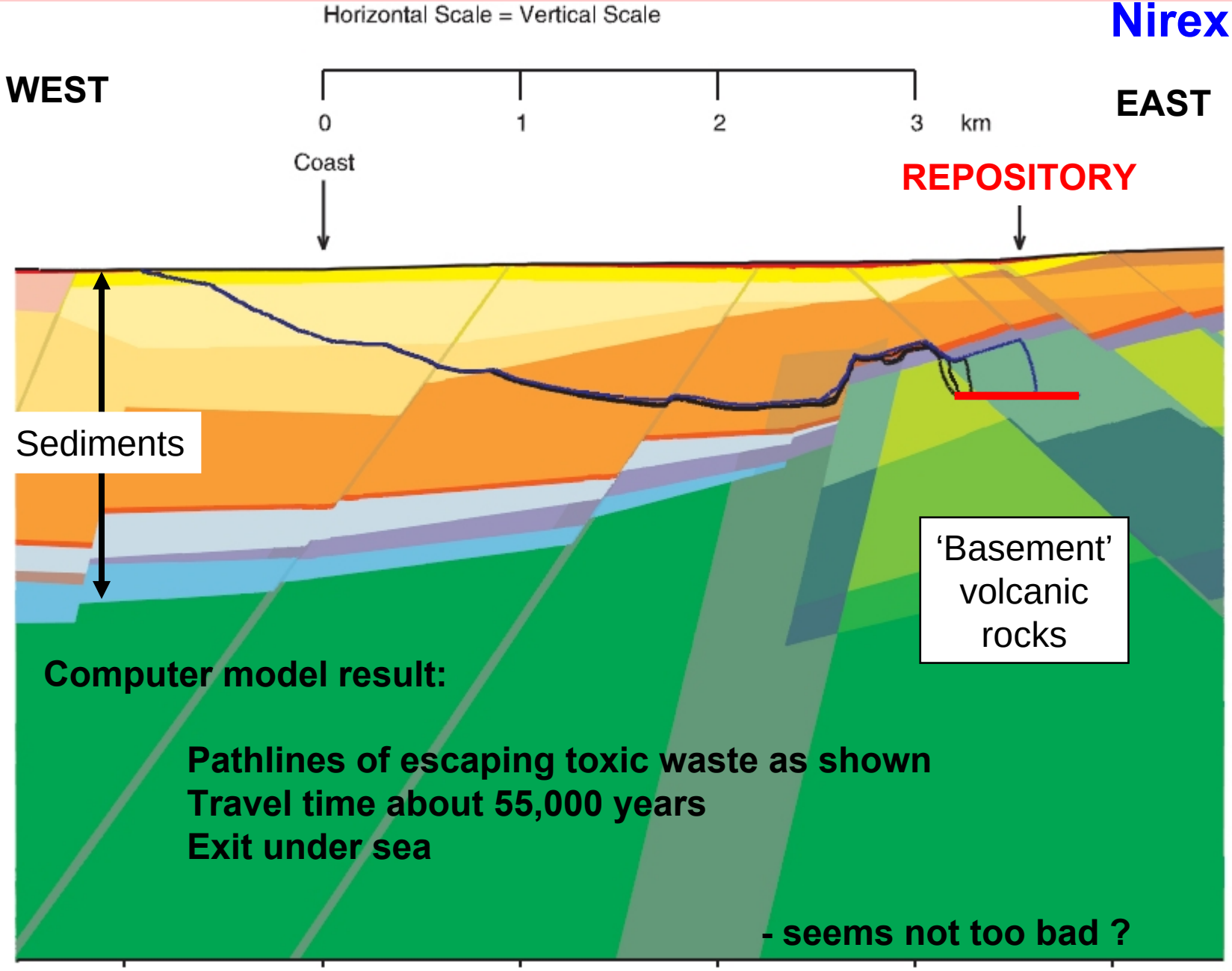
Geology coloured according to hydrogeological properties

Computer grid for calculations



How the flow is calculated – the regional 2D model

Nirex 97

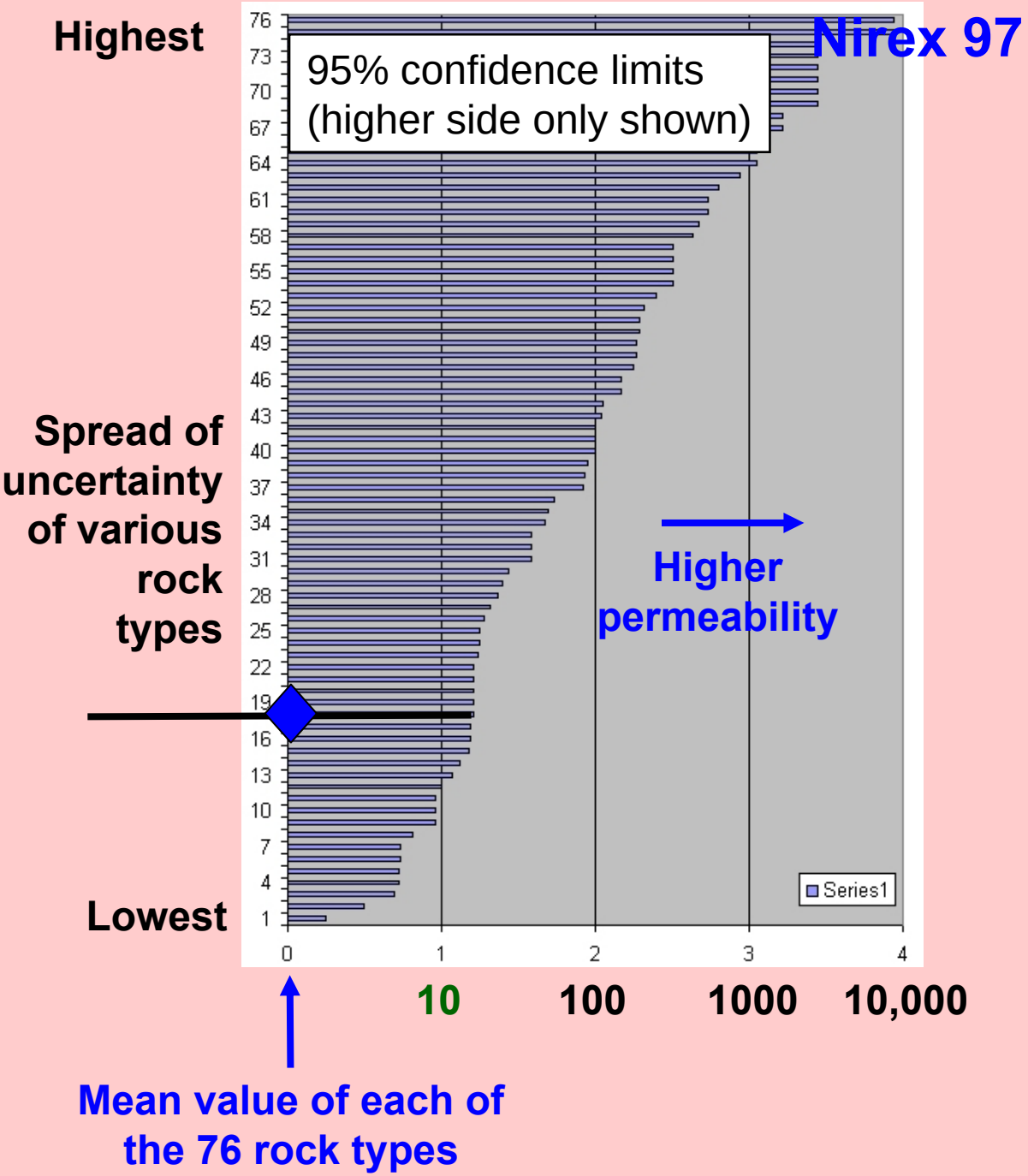

Horizontal Scale = Vertical Scale
WEST
EAST
0
1
2
3
km
Coast
REPOSITORY
Sediments
'Basement' volcanic rocks
Computer model result:
Pathlines of escaping toxic waste as shown
Travel time about 55,000 years
Exit under sea
- seems not too bad ?

BUT

Travel time is calculated using mean values of permeability for each rock type.

10 times higher permeability means 10 times faster travel time.

So 55,000 years could be just 5500 years, still at 95% confidence.



Nirex 97

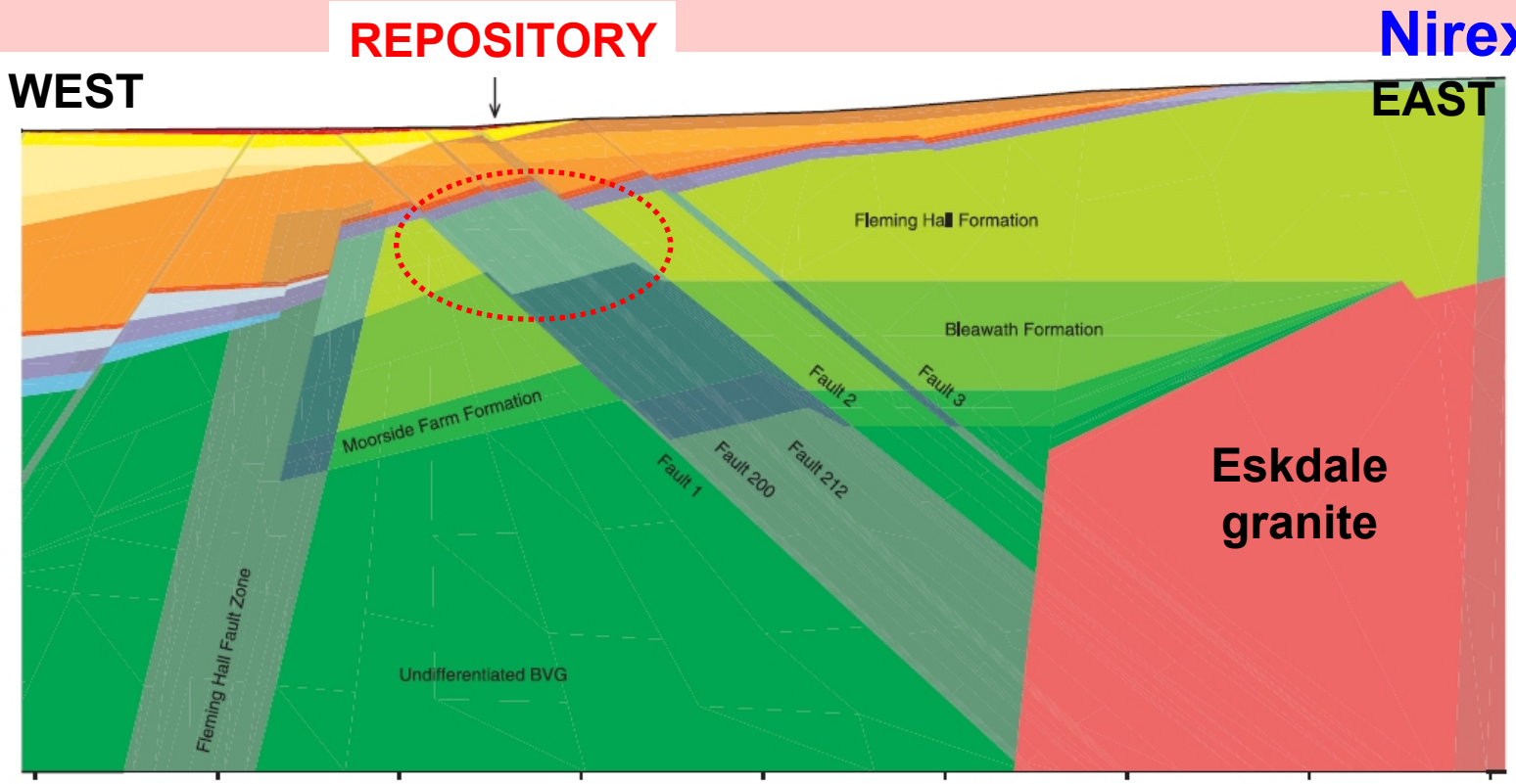
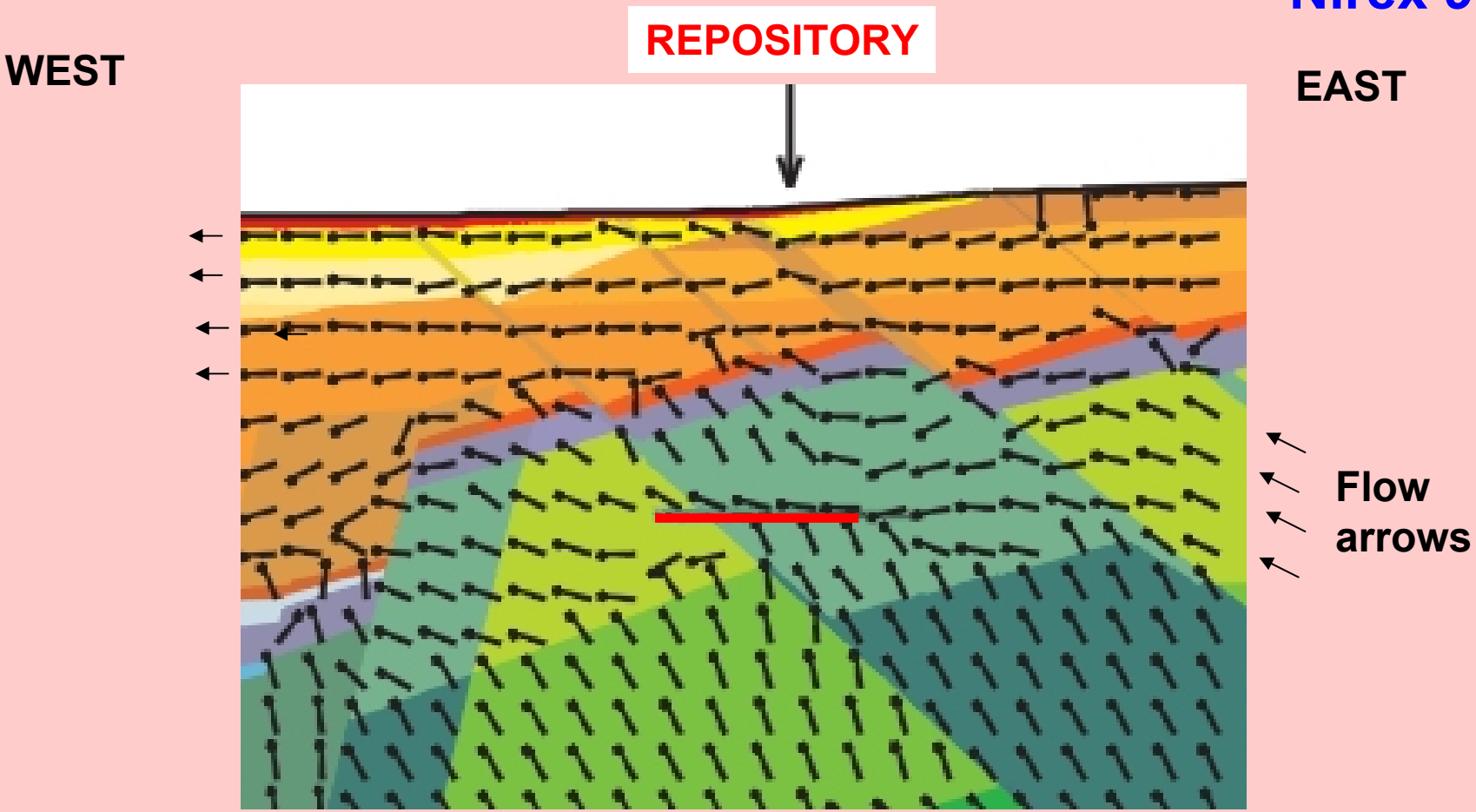


Figure 5.13 Detailed view of the subdivision of the BVG in the PRZ for the reference two-dimensional model. The faulted region in the BVG between Fault 1 and Fault 2 is known as the F1-F2 Structure.

The whole complex of faulted Borrowdale Volcanics at repository level (circled) is assigned just one value of permeability

- tantamount to admission of failure.

Nirex 97



Close-up view
None of the faults appear to affect the flow – very suspicious.

Can faults be known ?

Nirex 97

R. Lunn and colleagues (mathematical experts, 2008):

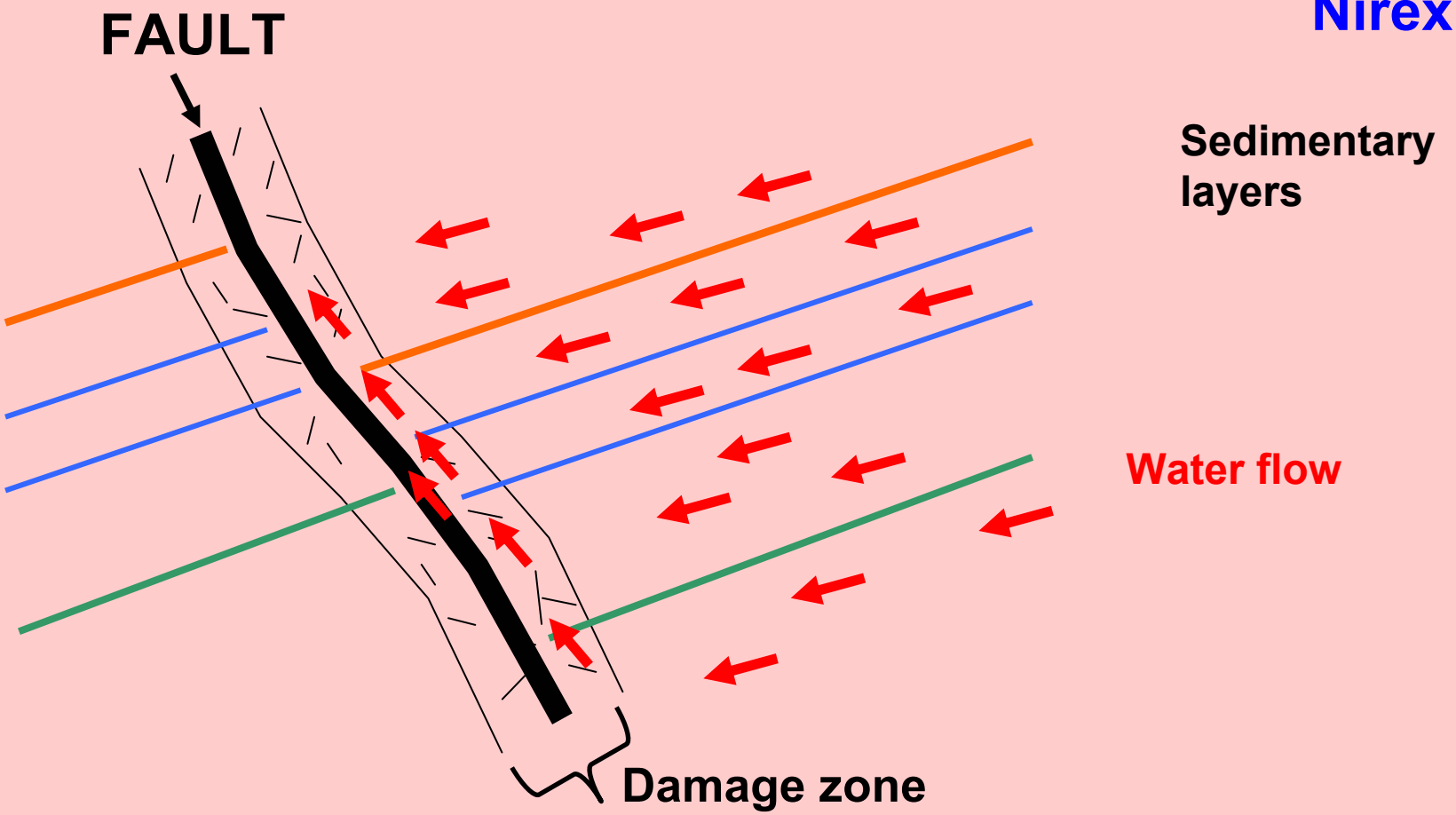
"*Faults can be barriers to flow, conduits, or combinations of the two, and their hydraulic properties vary considerably over both space and time*"

They say:

- **The *micro* properties as opposed to the *average* hydraulic properties in a fault zone are crucial.**
- **But these properties are *unmeasurable at depth.***

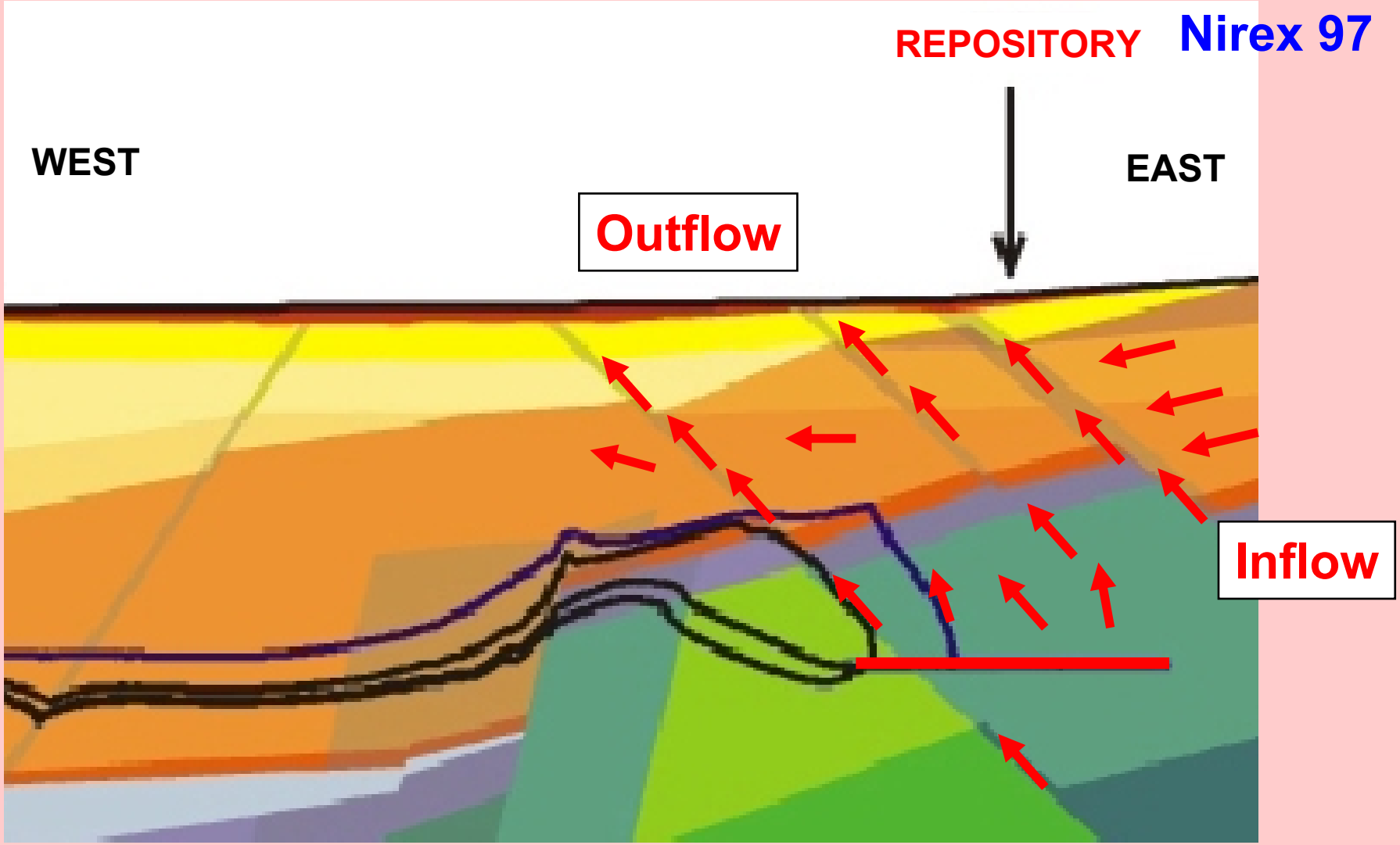
They conclude that we can never know …

Nirex 97



Fault core – could be a barrier; could be a conduit.
Damage zone – a conduit.

But fault zones have been assigned permeabilities similar to, or the same as, the unfaulted rock.



Red arrows show more realistic flow directions.
In case you find this hard to believe …

Nirex 97

United Utilities

Pay Your Bill
About your bill, water meters, moving house...

Emergencies
Details of supply disruptions & service issues

My Account | About United Utilities | Our Services | Environment & Community | News | Jobs | Investor

Drilling for water in west Cumbria

- Pay Your Bill
- Emergencies
- My Account
- About United Utilities
- Our Services

Drilling for water in west Cumbria

03 February 2011

We are using drilling
Cumbria's most prec

Our specialist teams
120m deep in fields
for a potential new g

It's all part of a uniqu
help us maintain wat
protecting the enviro

Phil Merrin, groundw
most people in White
drink water that com

"The European Habi
the amount of water
protect important pro
River Ehen which ha
of Conservation," he

People in Whitehave
their drinking water f

"However, this is the start of a long-term project to re-evaluate the way we del
Cumbria so that we maintain excellent services to our customers while minimis

United Utilities, 2011

"Our specialist teams have plunged four boreholes up to 120m deep in fields south of Egremont …

The boreholes have been sited to target geological faults to give the best access to the yields."

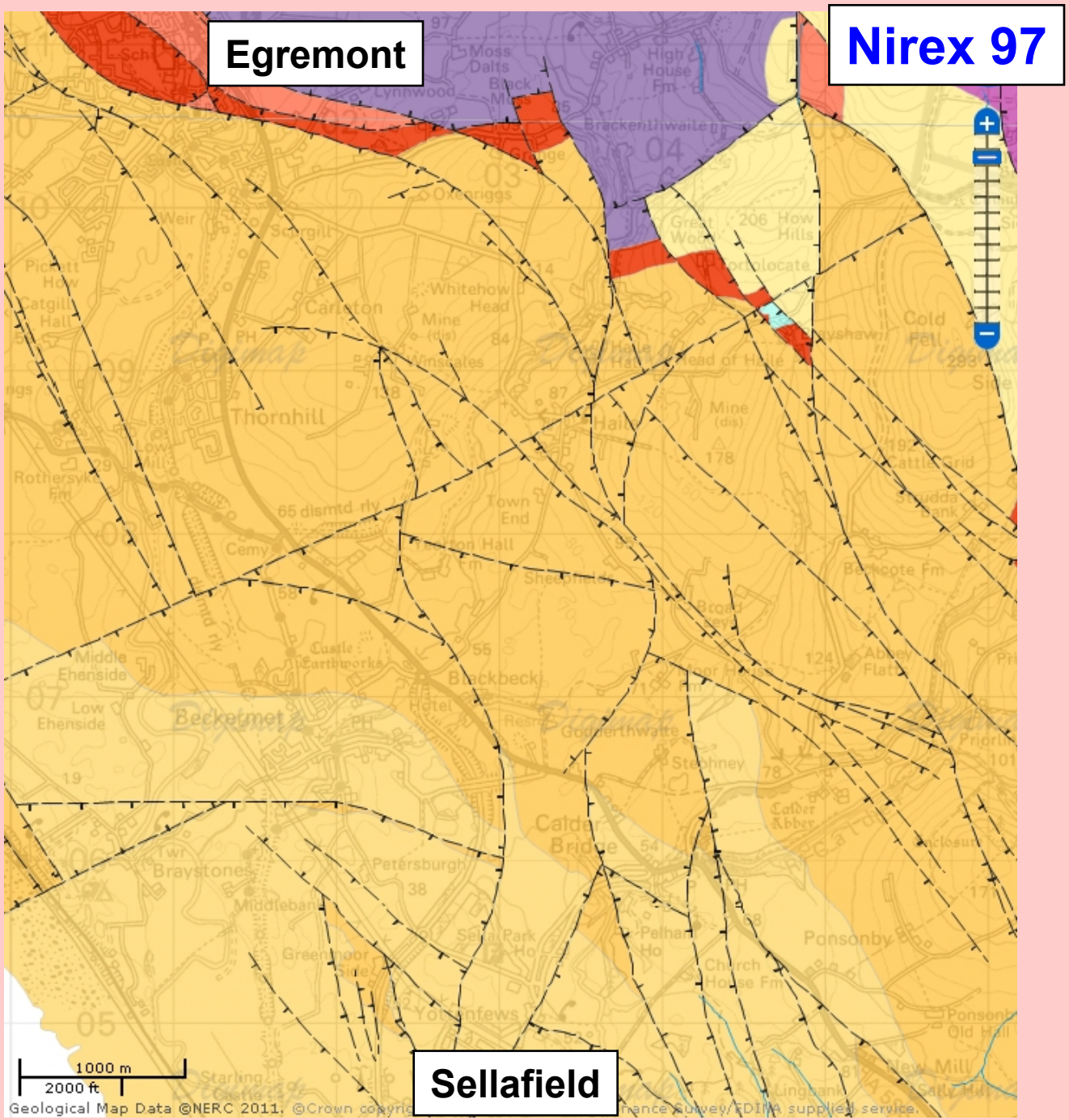
Geology map

Red / orange / buff colours are sediments

NB locations of water wells are secret …

-Possibility of terrorist contamination

- (ironic?)



Conclusions

on Nirex 97 hydrogeological modelling:

- Values fiddled to keep flow lines underground.
- Many values are just made up ('data elicitation').
- Mean values picked – not the worst case.
- Faults airbrushed out of the model.

- We should not pretend to know something just because the computer models tells us.

- Faster computers since 1996 will simply make the same mistakes faster.

- Go where the geology and hydrogeology is simple and predictable.

Committee on Radioactive Waste Management (CoRWM)

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

-**A good example of agnotology in operation.**

It 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**

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?

So ... are we REALLY managing radioactive waste safely?

NO

- History of search ignored
- International guidelines ignored
- International practice ignored
- ‘Voluntarism’ the driver
- No independent, funded scientific criticism (e.g. Sweden, Canada)
- No robust independent nuclear safety agency (e.g. France)

- why?

Why?

- The govt. (DECC) wants ‘new build’ ASAP.
- Needs to ‘sign off’ waste disposal problem.
- Agenda – re-start the failed and flawed search at/near Sellafield.
- Using a nuclear-compliant population.

Legal setbacks await if West Cumbria is not dropped.

The solutions ...

Solutions (over 20 years):

- Run down existing reactor fleet
- No new build
- Replace by renewables / efficiencies
- Search for some REALLY safe repository sites
  - (learn from the French / Swiss)
- THEN get the population onside

Reminder of what the Inquiry Inspector concluded:

"investigations should now be moved to one of the more promising sites elsewhere."

-and he did <u>not</u> mean anywhere else in Cumbria

Thank-you !