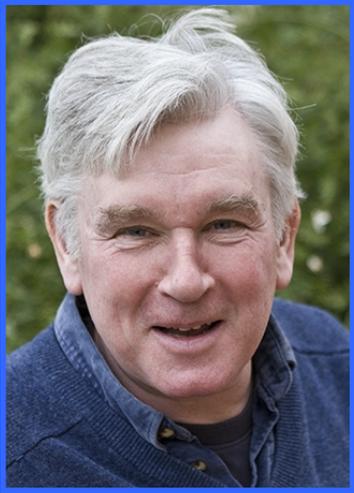


Geology:
**Why the whole of West Cumbria is
unsuitable for a nuclear waste repository**

**David Smythe
November 2010**



David Smythe: CV

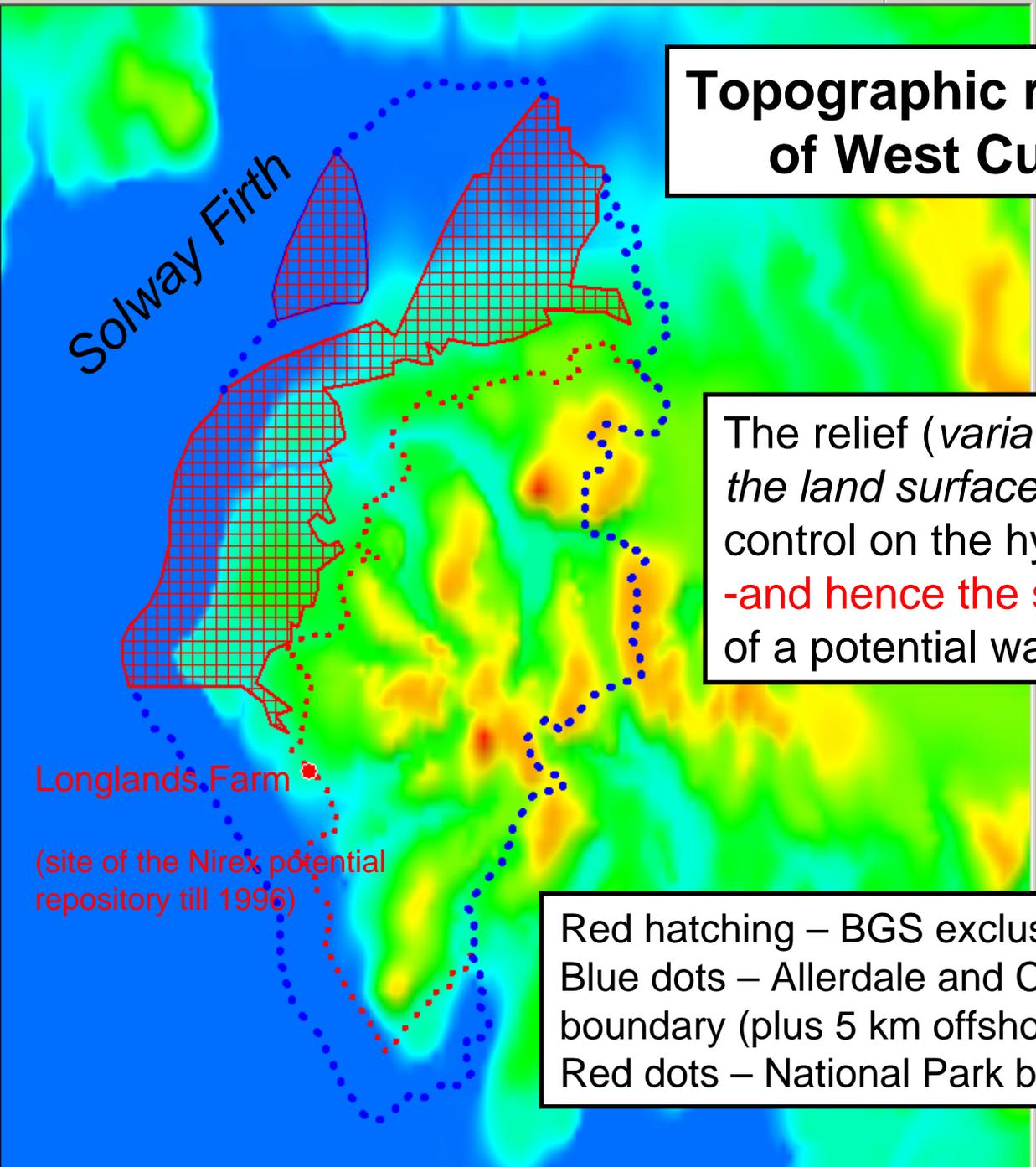
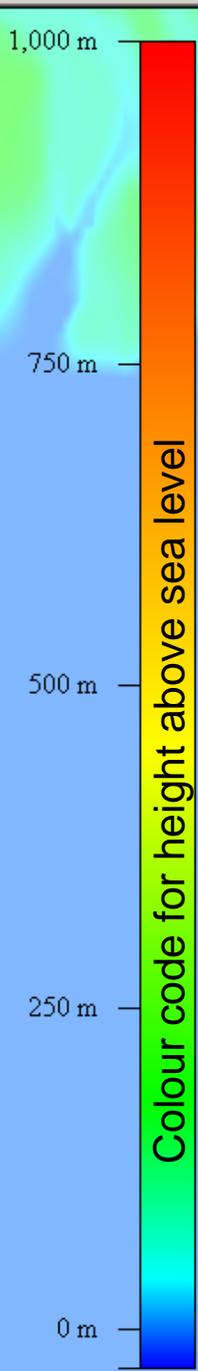
Emeritus Professor of Geophysics, University of Glasgow
BSc (Geology, 1970), PhD (Geophysics, 1987)

- Principal Scientific Officer, BGS 1973 – 1987
- Chair of Geophysics, University of Glasgow 1988 - 1998
- BNFL Geological Review Panel 1990 – 1991
- Nirex research contract 1993 - 1995:
 - Trial 3D seismic survey of potential repository zone
First-ever 3D survey of such a site
First-ever academic research 3D survey
- Expert Witness for FoE at Planning Inquiry 1995 - 1996

Topographic relief map of West Cumbria

The relief (*variation in height of the land surface*) is the primary control on the hydrogeology **-and hence the safety -** of a potential waste repository.

Red hatching – BGS exclusion zones.
Blue dots – Allerdale and Copeland district boundary (plus 5 km offshore).
Red dots – National Park boundary.

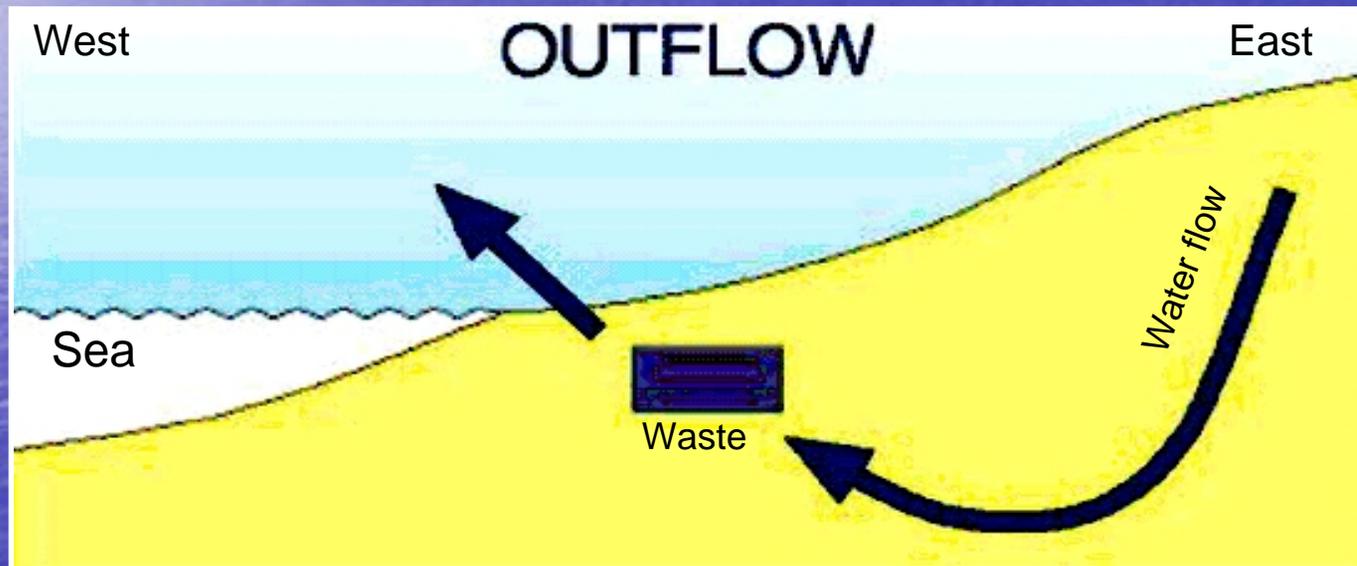


Why the land surface relief is crucial

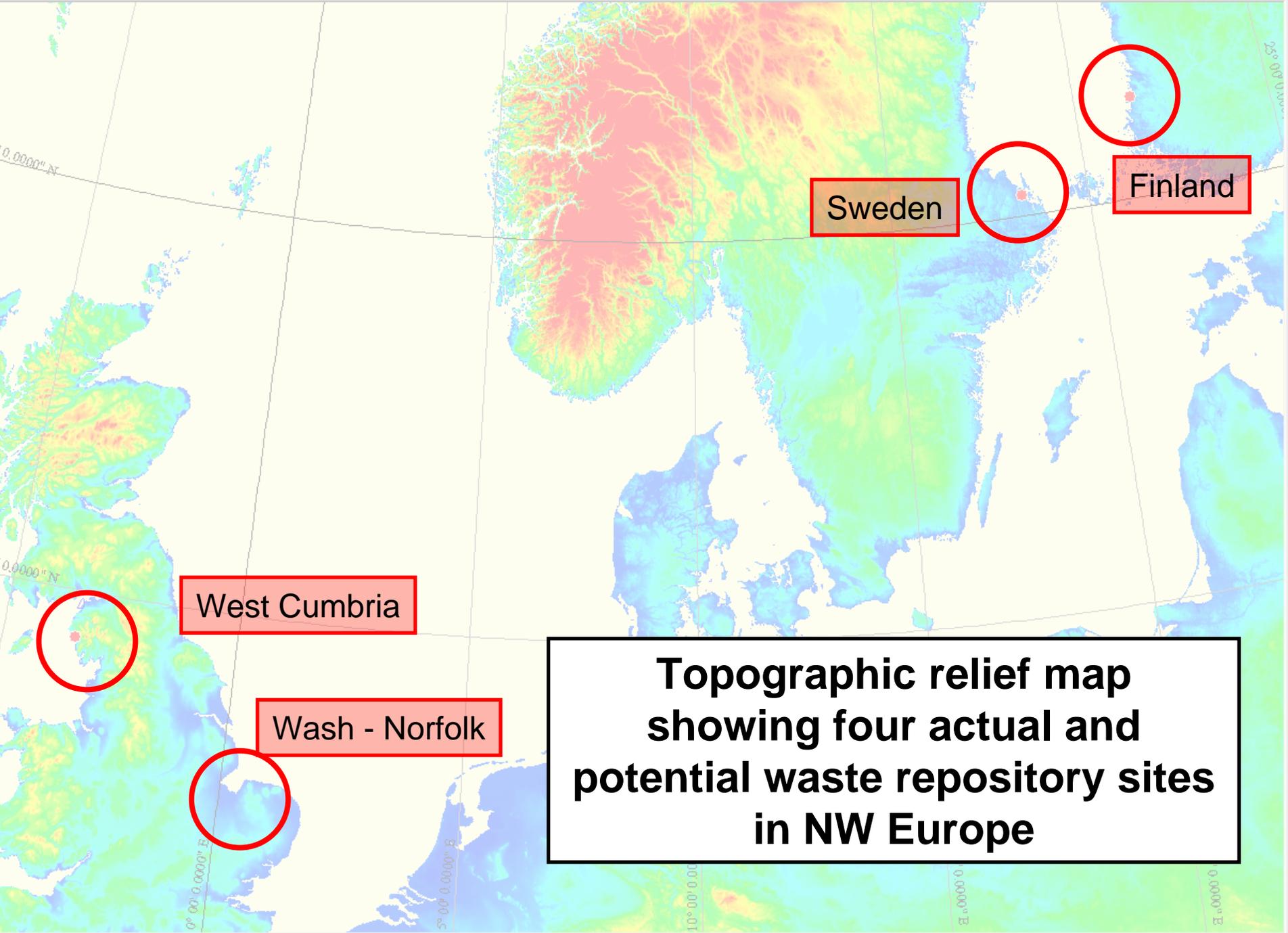
Water flow is driven by the elevation of mountains, and **inevitably** rises to surface as 'artesian' springs. The higher and nearer the mountains, the stronger the flow.

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

West Cumbria looks like the picture here - it has **poor site** performance.



This is why all international potential waste repository locations are in very flat areas. The sole exception was the now-abandoned Yucca Mountain site in the USA, where they tried to find a site **above** the water table.



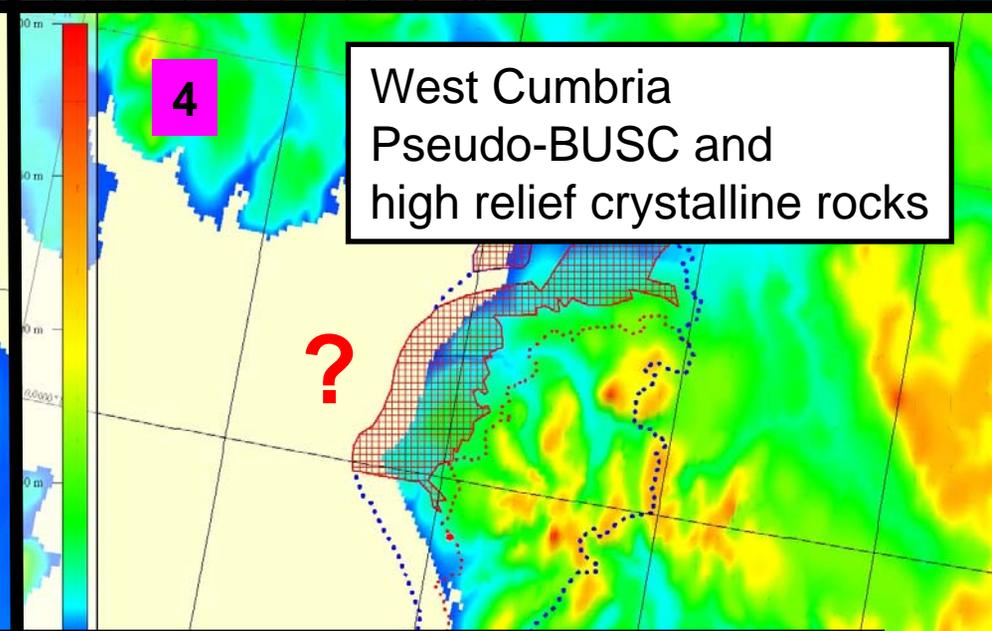
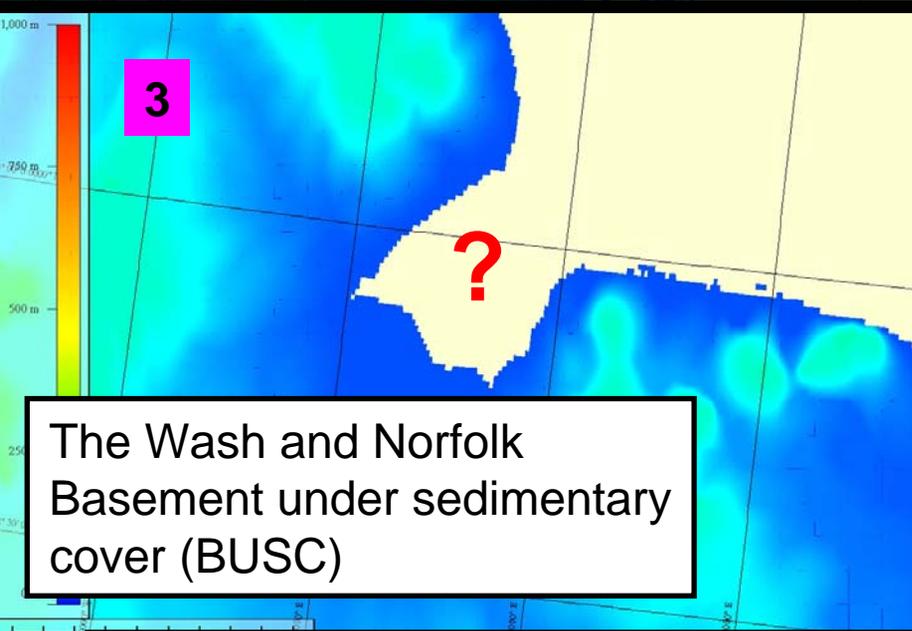
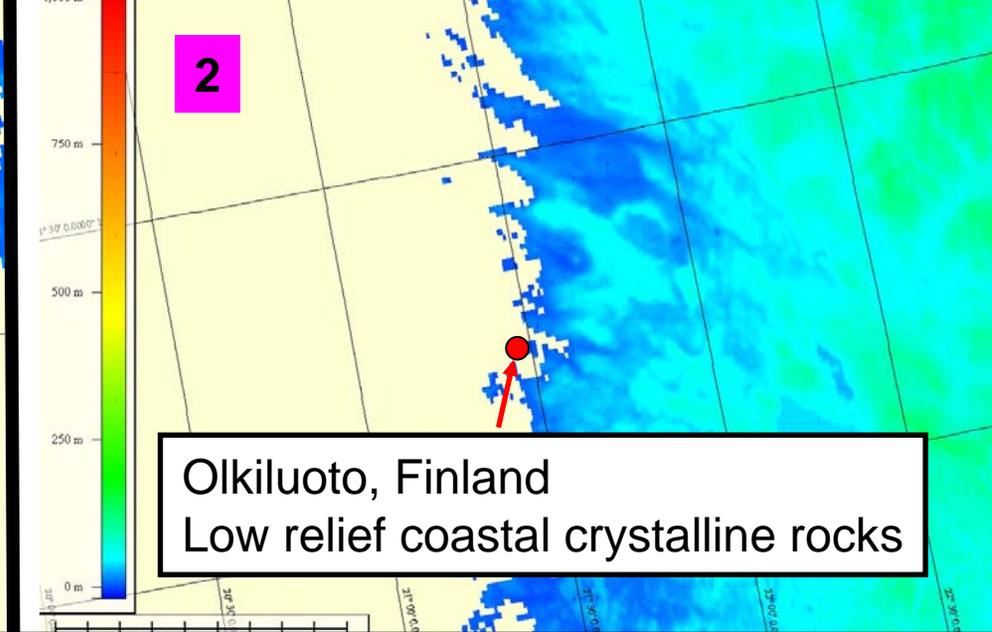
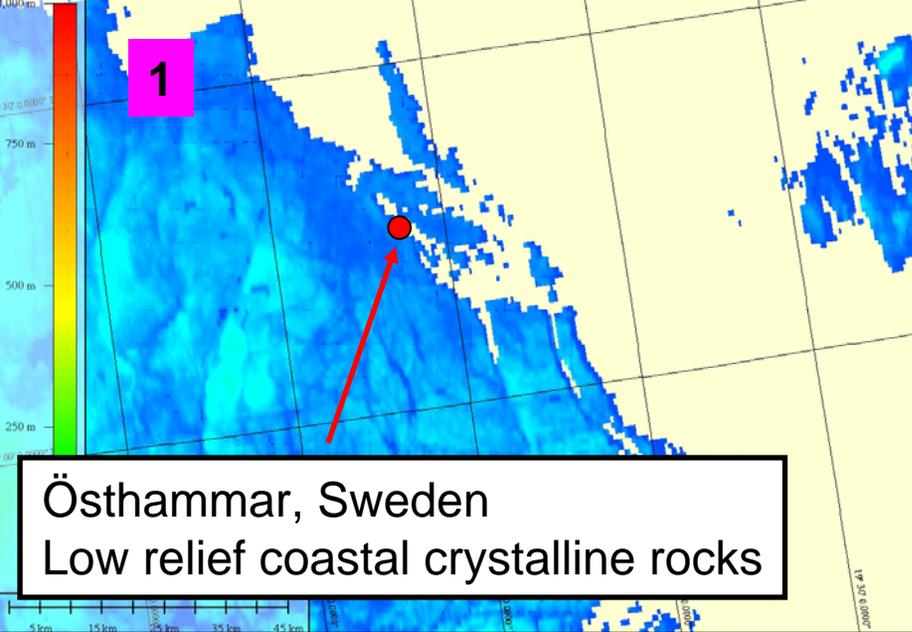
West Cumbria

Wash - Norfolk

Sweden

Finland

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

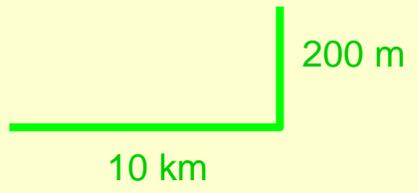


Topographic relief of four actual and potential waste localities. The maps are at the same scale, and use the same colour code for height

1

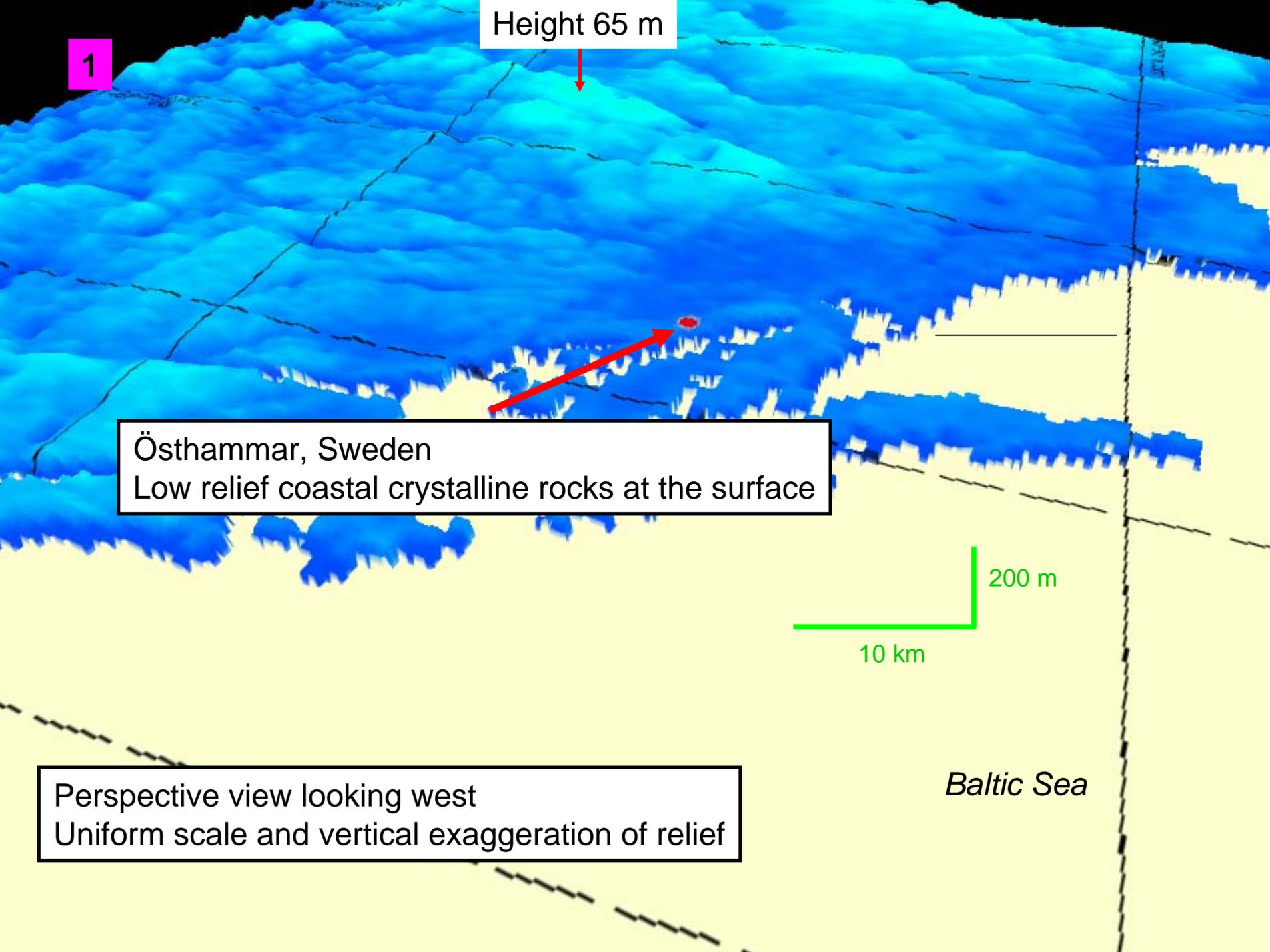
Height 65 m

Östhammar, Sweden
Low relief coastal crystalline rocks at the surface



Perspective view looking west
Uniform scale and vertical exaggeration of relief

Baltic Sea



2

Olkiluoto, Finland
Low relief coastal crystalline rocks
at the surface

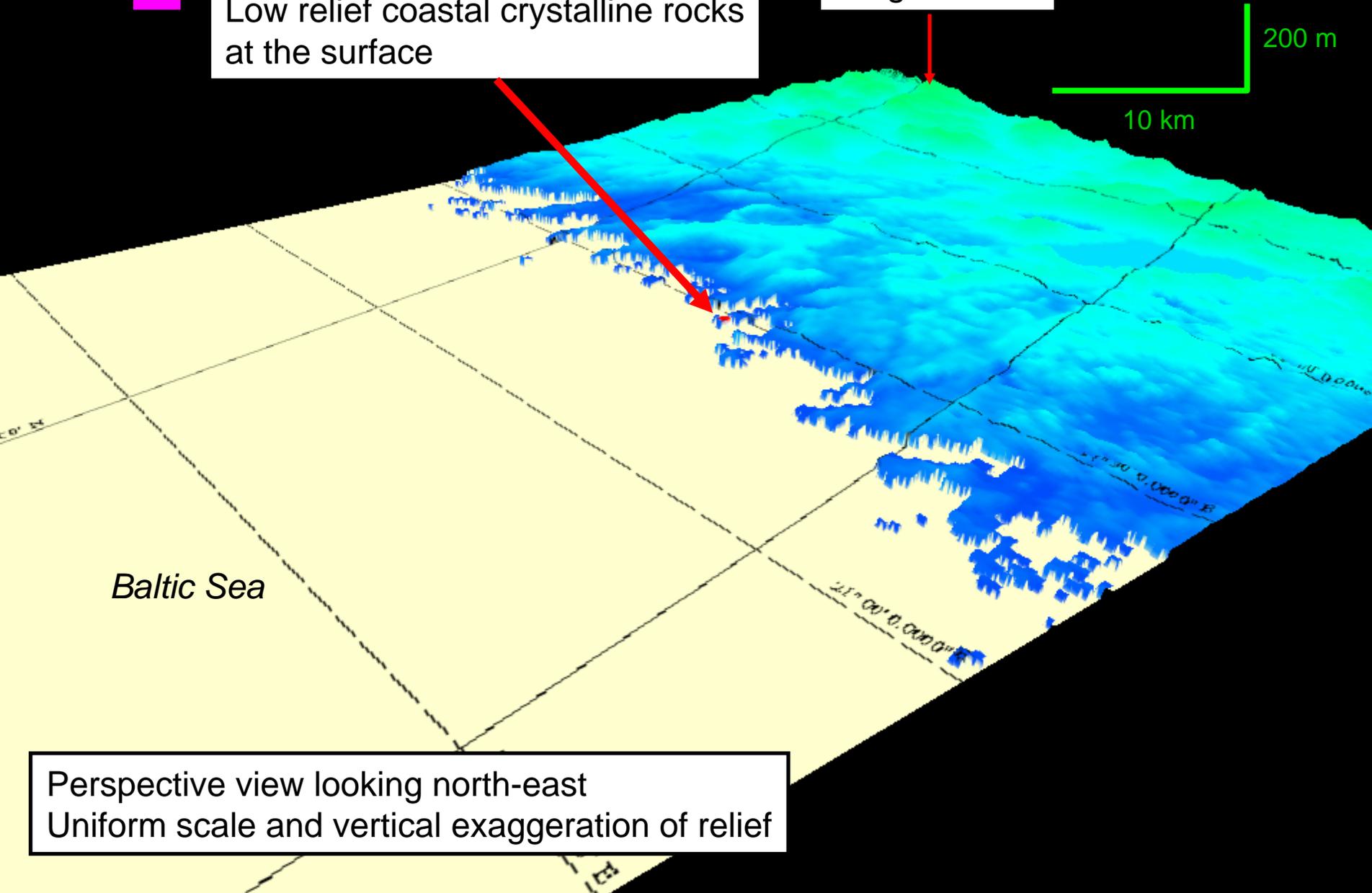
Height 125 m

200 m

10 km

Baltic Sea

Perspective view looking north-east
Uniform scale and vertical exaggeration of relief



3

Height 77 m

200 m

10 km

North Sea

Norfolk

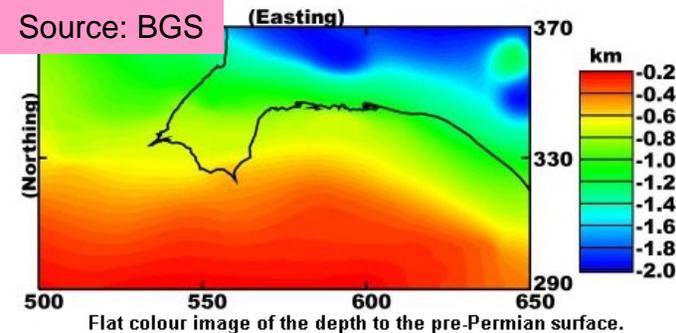


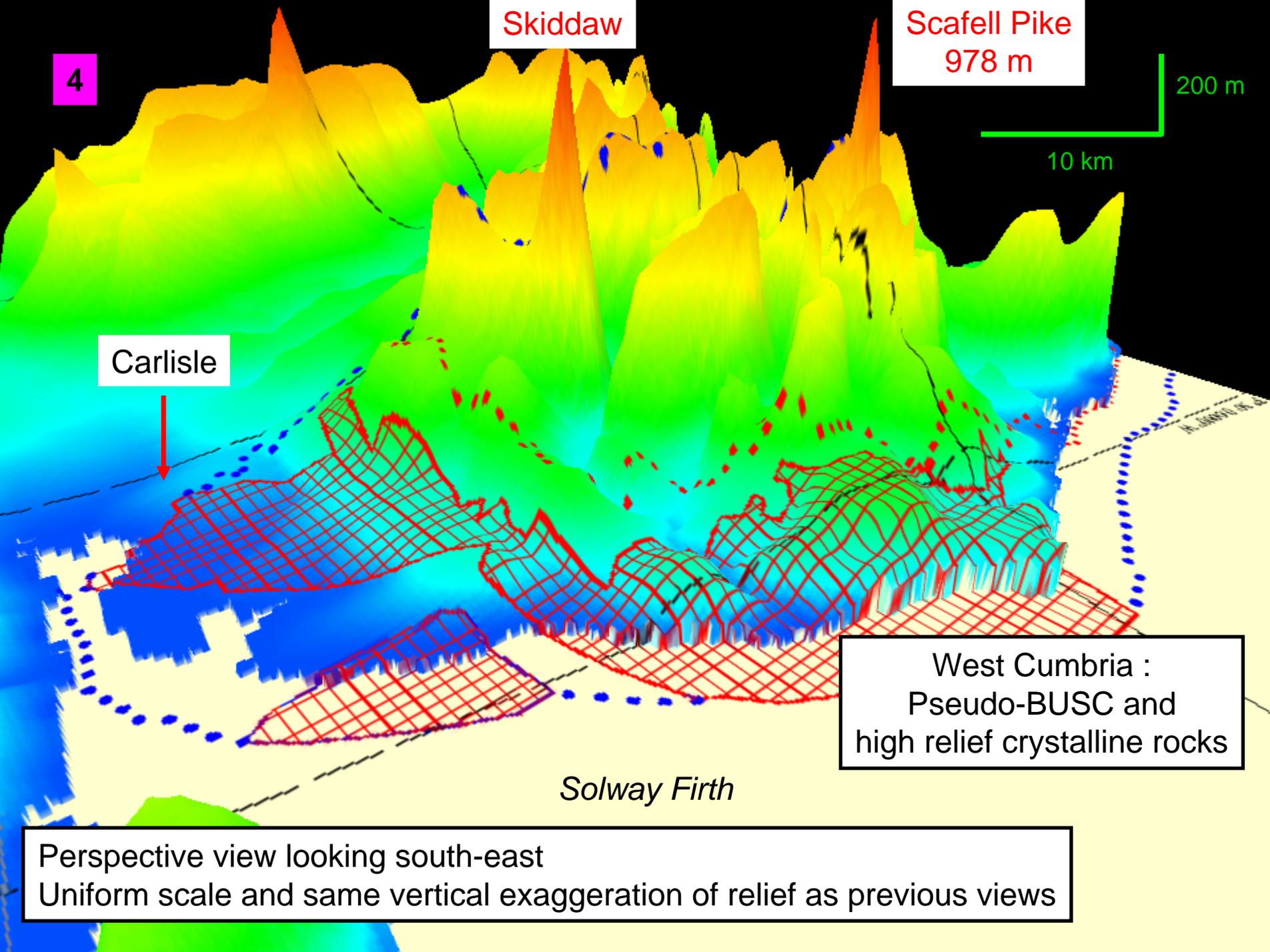
The Wash

The Wash and Norfolk – a good example of ‘basement under sedimentary cover’ (BUSC). The inset colour map shows that the top surface of the hard-rock basement along an east-west line through the southern Wash is about 700 m deep. The surface is shallower to the south and deepens to the north.

Perspective view looking south-east
Uniform scale and vertical exaggeration of relief

Source: BGS





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

Conclusions

The extreme topographic relief means that nowhere in **onshore** West Cumbria can ever conform to either of these international standard models:

- Low relief coastal crystalline rocks
- Basement under sedimentary cover (BUSC)

In addition, placing a repository in the **offshore** sediments is completely out of the question. It was considered in the past, and rejected by various BGS, BNFL and Nirex studies. There are simply no suitable host rocks, and the surrounding rocks are far too porous and permeable.

For those who want to read on, some extra slides, just slightly more technical, on the hydrogeology and geology come next.

Extra slides

Hydrogeology :

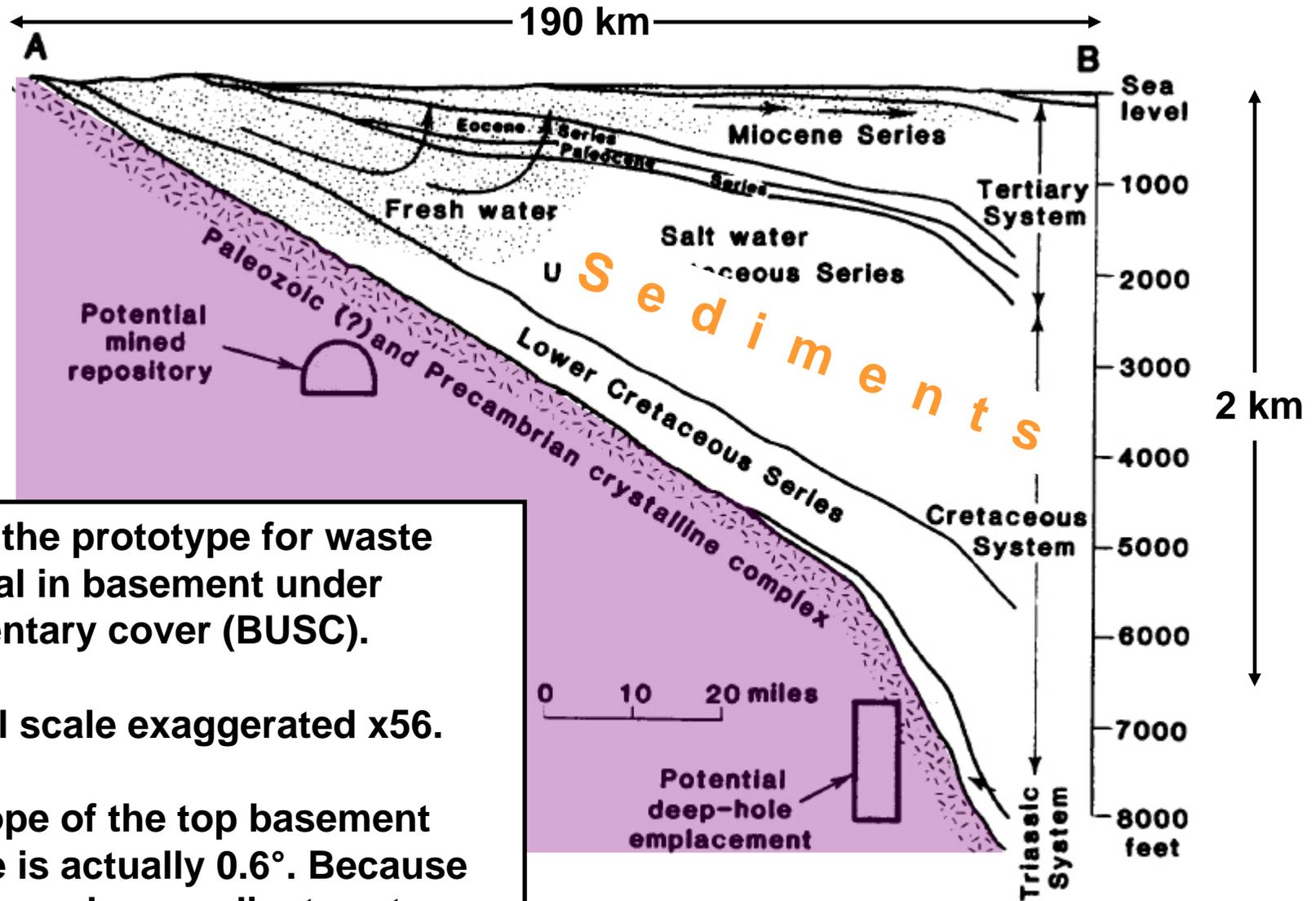
The Basement under Sedimentary Cover (BUSC) model

Starting in the late 1980s, Nirex claimed that the Longlands Farm potential repository site conformed to a 'modified BUSC' model. This view was comprehensively refuted at the Planning Inquiry.

The two slides which follow show firstly the classic BUSC site model, developed for the USA in 1981, and secondly a comparison of this model with West Cumbria.

The overall appeal of BUSC is the simplicity and predictability of the underground water flow (the hydrogeology). In contrast, the Sellafield hydrogeological environment is highly complex and unpredictable.

Geological cross-section through the coastal plain of Maryland, USA



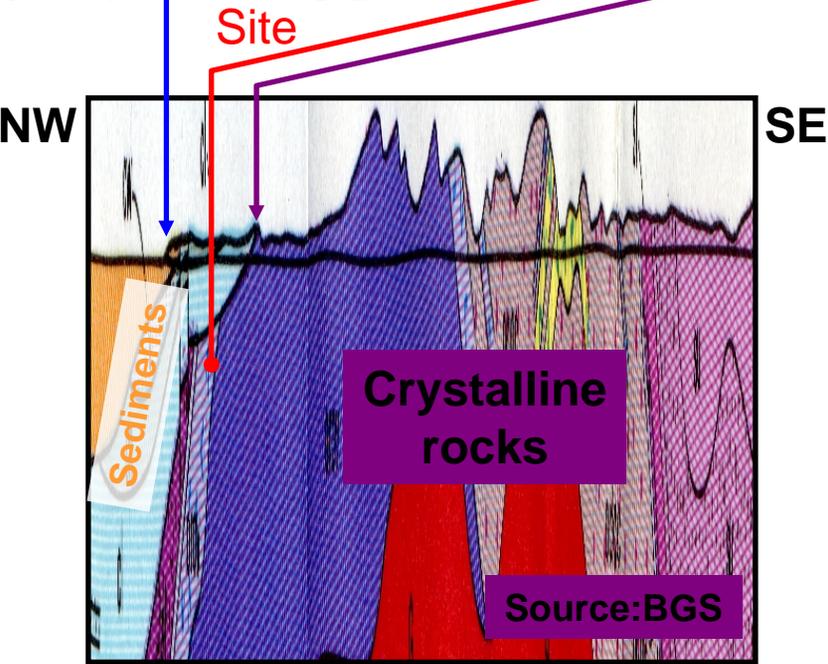
This is the prototype for waste disposal in basement under sedimentary cover (BUSC).

Vertical scale exaggerated x56.

The slope of the top basement surface is actually 0.6° . Because of this very low gradient, water flow within it is almost stagnant.

Vertical exaggeration 56x

True BUSC cross-section mirrored (sea now on left) at V.E. x 10



Geological cross-section from Windermere to the Solway. Same scales as the BUSC cross-section above.

Flaws in the Cumbrian model compared to the true BUSC type:

- Horizontal scale compressed by x 20.
- Height of terrain within zone of interest higher by x 20.
- Dip (tilt) of the sedimentary layers higher by x 40.

So the relative proportions of BUSC are distorted by $20 \times 20 = 400$.

Result: the water flow patterns within West Cumbria are far too vigorous and complex – it is **not** a BUSC environment.

Extra slides

Geology

In view of the extreme topographic relief in West Cumbria, further consideration of the region, in the search for a deep geological disposal site, is really superfluous.

However, just to make it quite certain that there is no loophole or escape hatch which might bring the region into play again, I attach a few slides looking in more detail at the geology of the localities *not* excluded by the BGS preliminary screening report.

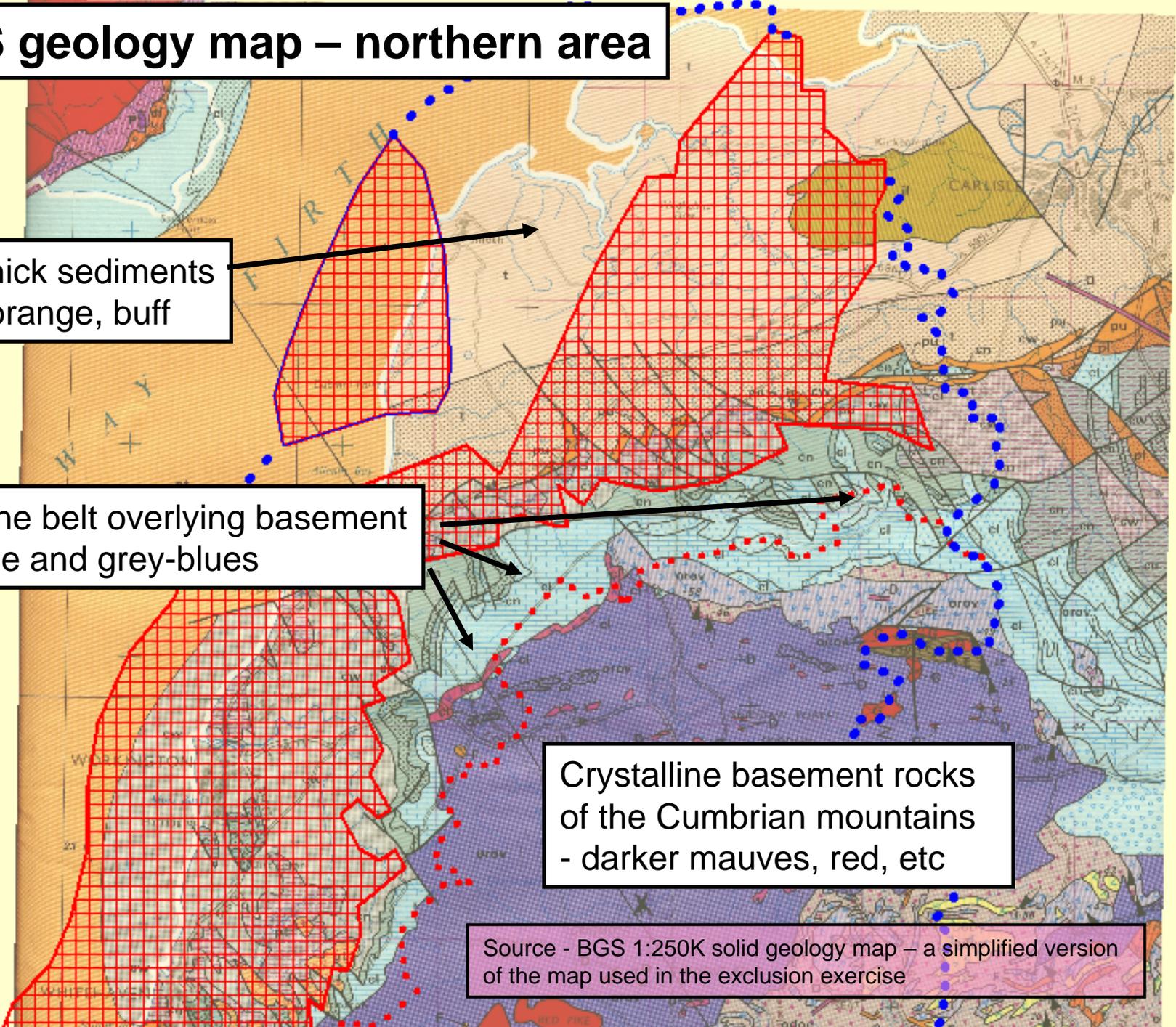
BGS geology map – northern area

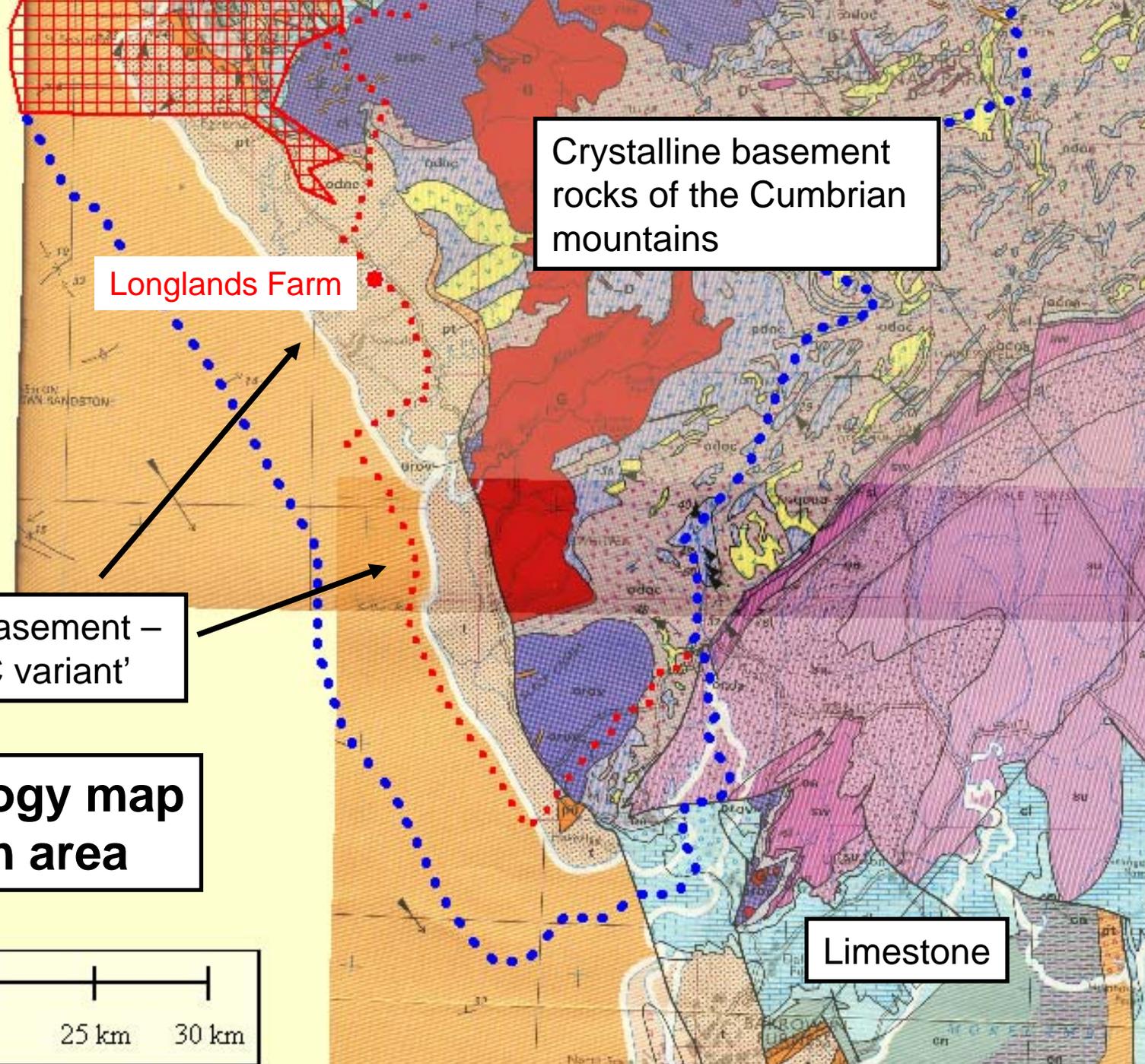
Thick sediments
- orange, buff

Limestone belt overlying basement
- sky blue and grey-blues

Crystalline basement rocks
of the Cumbrian mountains
- darker mauves, red, etc

Source - BGS 1:250K solid geology map – a simplified version of the map used in the exclusion exercise





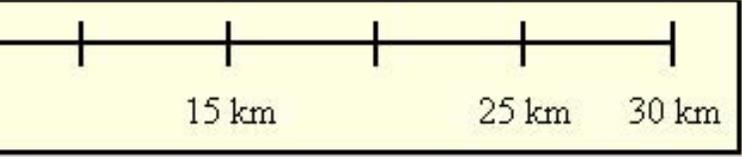
Crystalline basement rocks of the Cumbrian mountains

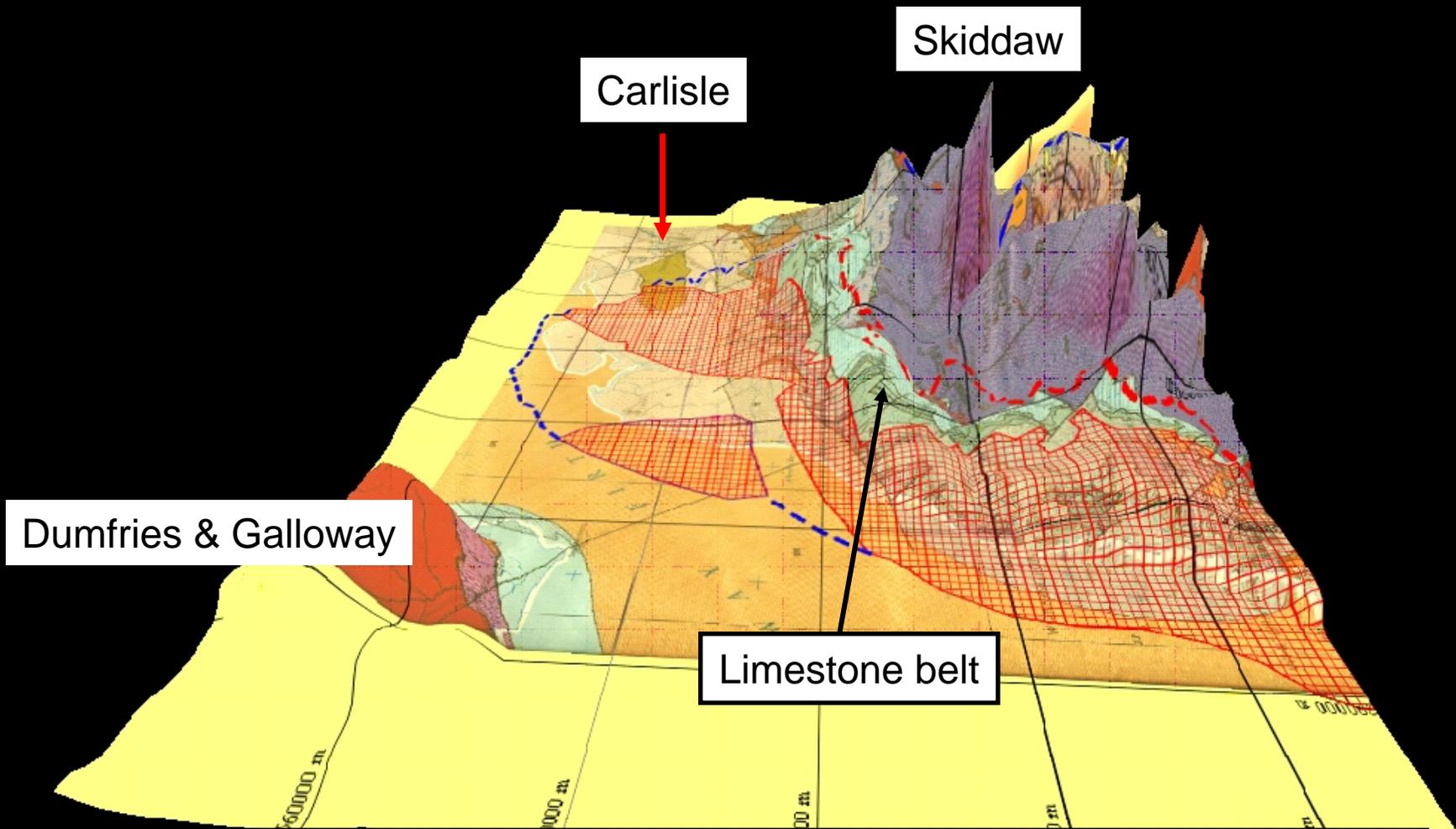
Longlands Farm

Sediments on basement – so-called 'BUSC variant'

BGS geology map – southern area

Limestone

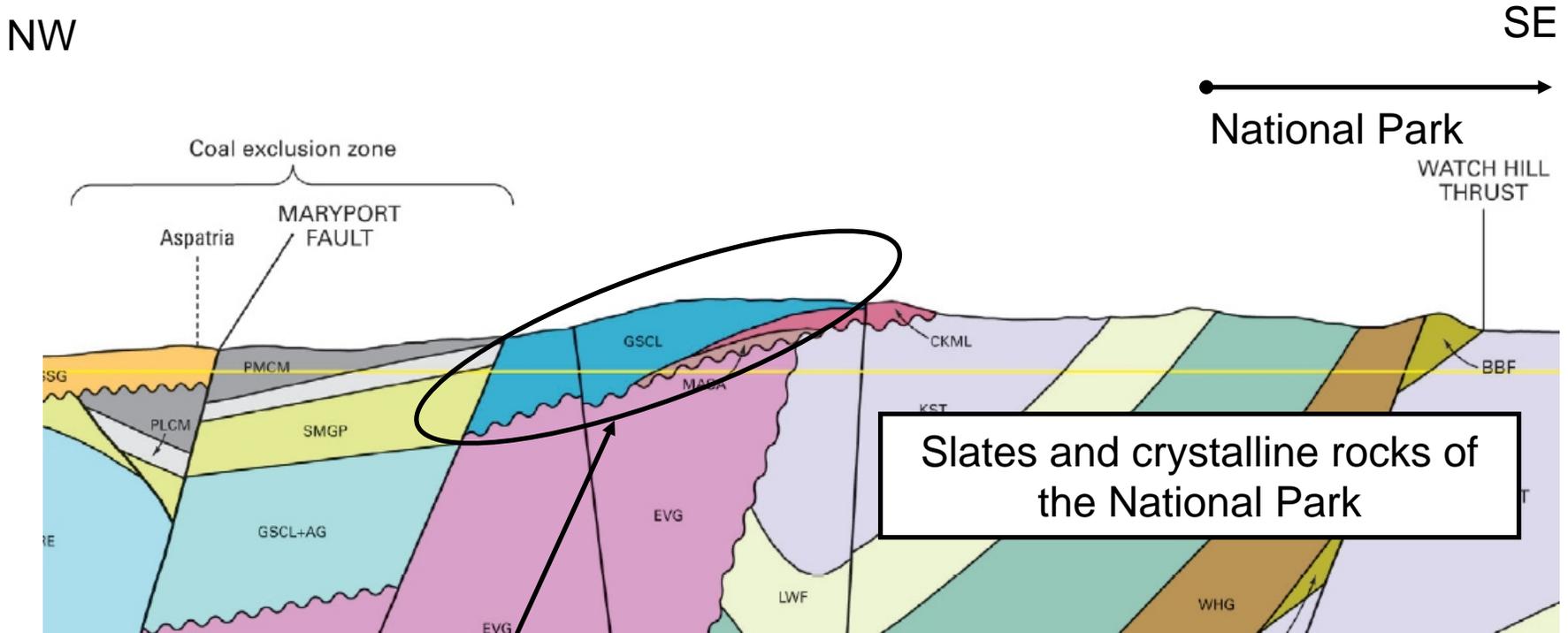




**BGS geology map draped over the terrain. Perspective view looking east.
Next we examine the limestone belt between the exclusion zone and the National Park.**

The limestone belt around the northern flanks of the National Park

Part of BGS geological cross-section AB (Fig. 9)



The *Great Scar Limestone Group*:

Question: could this belt of rock around the edge of the National Park be considered for cover rock above a repository in the volcanic rocks (lilac) ?

The limestone belt around the northern flanks of the National Park

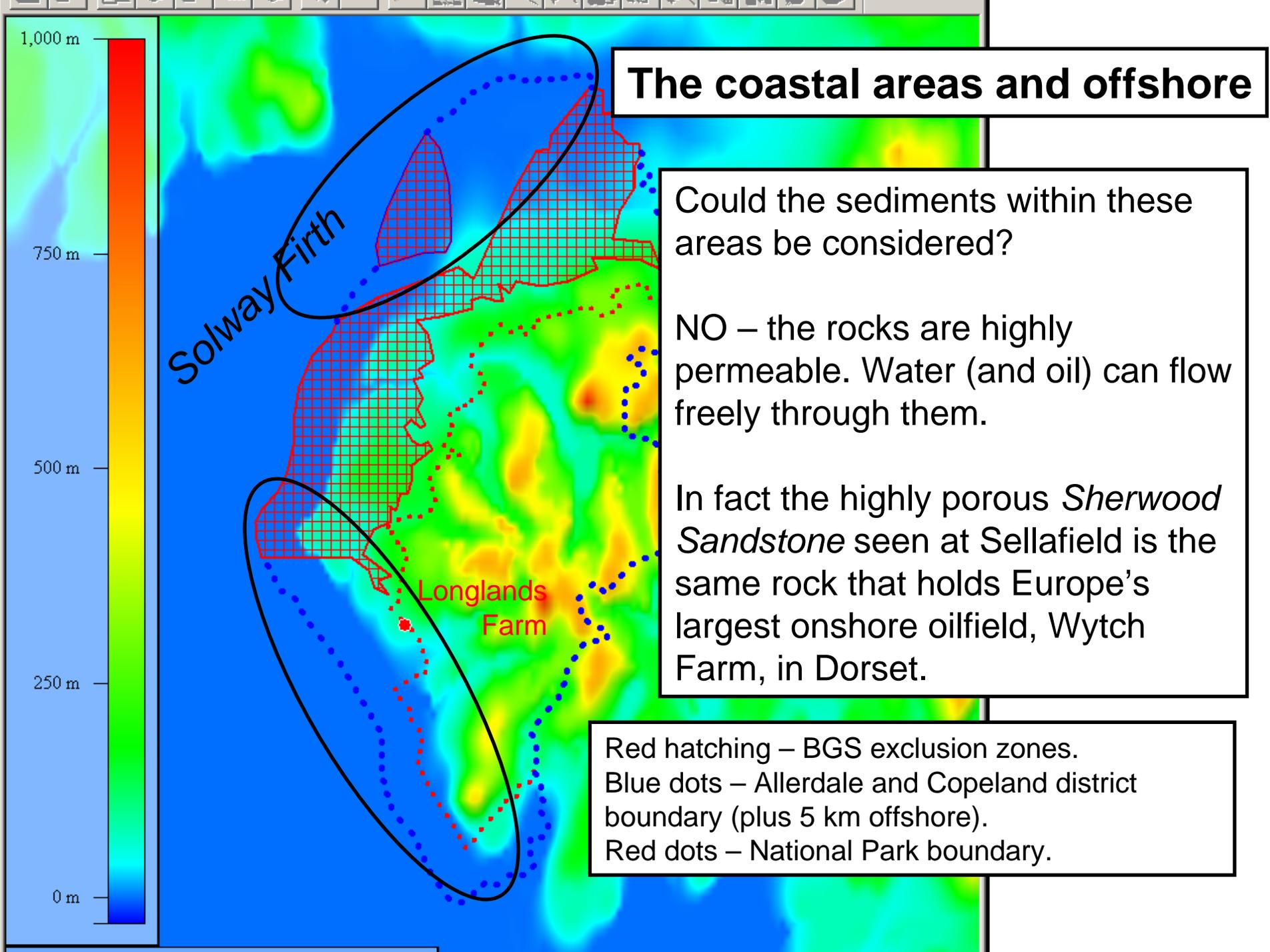
Answer : NO !

“Groundwater (hydrogeology)

*The Carboniferous rocks are **structurally complex** with **fault zones** offering either conduit flow conditions or acting as groundwater flow barriers. Near the surface, the Great Scar Limestone Group and thin limestone beds in the Yoredale Group may exhibit **karstic fracture-flow** in the near surface, while the mudstone beds are poorly permeable and inhibit vertical groundwater movement. There are no known deep karstic formations.”*

- From the BGS screening report, p. 19

- The geology of both the cover rocks and the volcanic host rock is even more complex than at Sellafield.
- The presence of limestone cover rocks was previously ruled by the BGS to exclude a potential site.
- Such an environment would fail completely to conform to international norms.



The coastal areas and offshore

Could the sediments within these areas be considered?

NO – the rocks are highly permeable. Water (and oil) can flow freely through them.

In fact the highly porous *Sherwood Sandstone* seen at Sellafield is the same rock that holds Europe's largest onshore oilfield, Wytch Farm, in Dorset.

Red hatching – BGS exclusion zones.
Blue dots – Allerdale and Copeland district boundary (plus 5 km offshore).
Red dots – National Park boundary.