Site selection for radioactive waste storage: how difficult?

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- Problem and requirements
- Approach in UK
- Fundamentals of selection
- Diverse UK site options
- Uncertainty
- Models unknown states
- Risk

What is the problem ?

Existing waste

Existing fuel and Plutonium

Future waste, fuel, Plutonium

Small volume

Highly toxic

Highly radioactive

Long time

Mixture of components

Surface storage (today)

Unsustainable - needs better stores

Requirements for performance

NOT ‘secure’
NOT “no leakage”
NOT “depth / location / size/ volume”

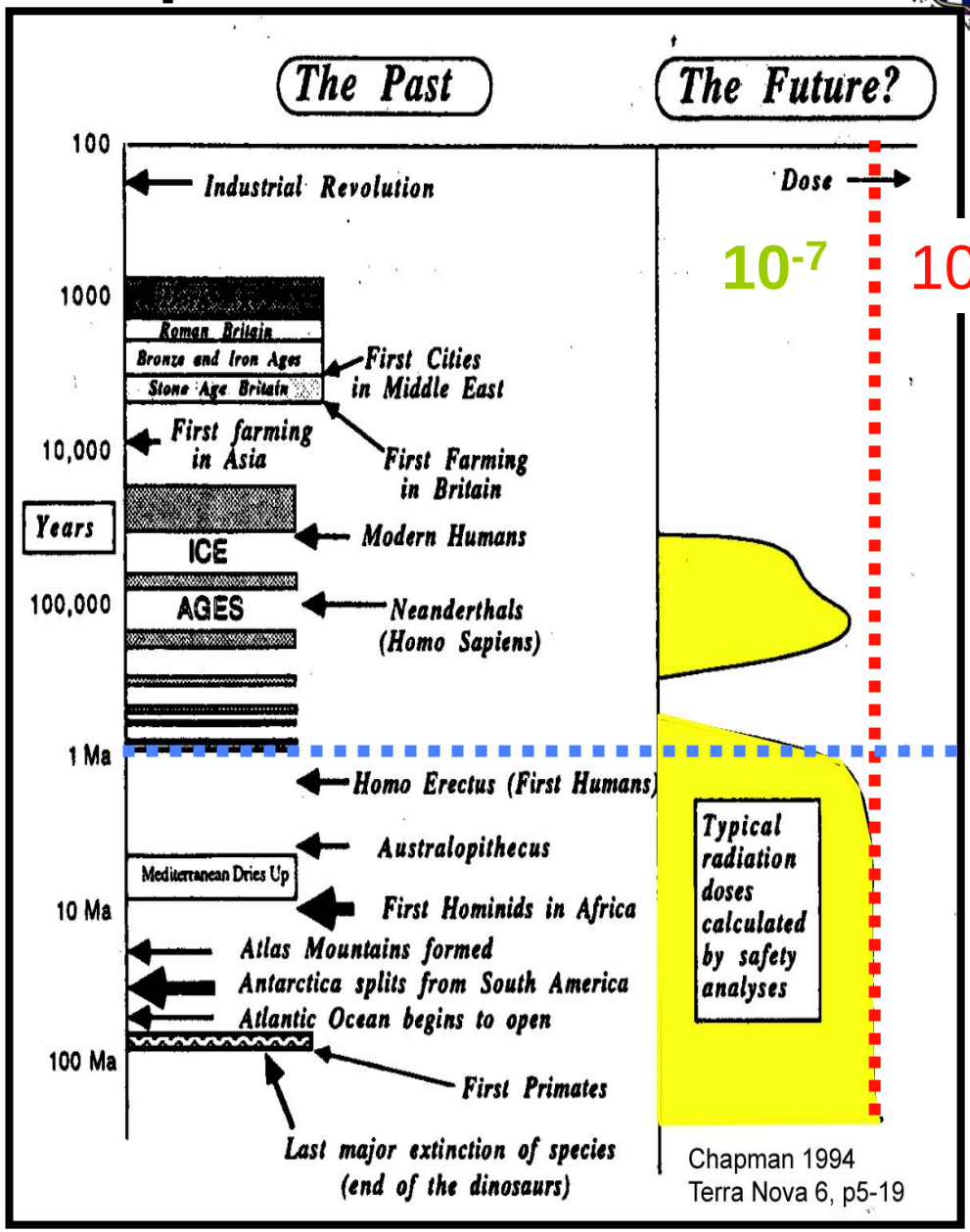
Risk of death 10^{-6}
1 in one million to affected population

Per year

Next one Million years into future

Extra dose of about 0.02mSv

ie 1% more than natural UK background
(which varies by 300%)



How did we get here?

1950' s UK first civil nuclear power
Magnox - some still operating

1960	AGR reactors
1970	=> PWR Sizewell B 1995
2022 ?	EDF PWR
1970	Exploration waste storage
1980	Slow progress ……
1990	Dounreay / Sellafield selected
1997	Sellafield rejected
1998-9	House of Lords
2001	Consultations
2003	CoRWM 1
2006	CoRWM Report
2006	NDA => evaluation, CoRWM 2
2008	**Site search ==> finish ?**
2020	Start construction
2040	Start operation

R o W

WIPP USA - **operating**

Yucca Mountain USA

=> Olkiluoto Finland -
construction underway

?? Sweden - short list

?? France, Germany

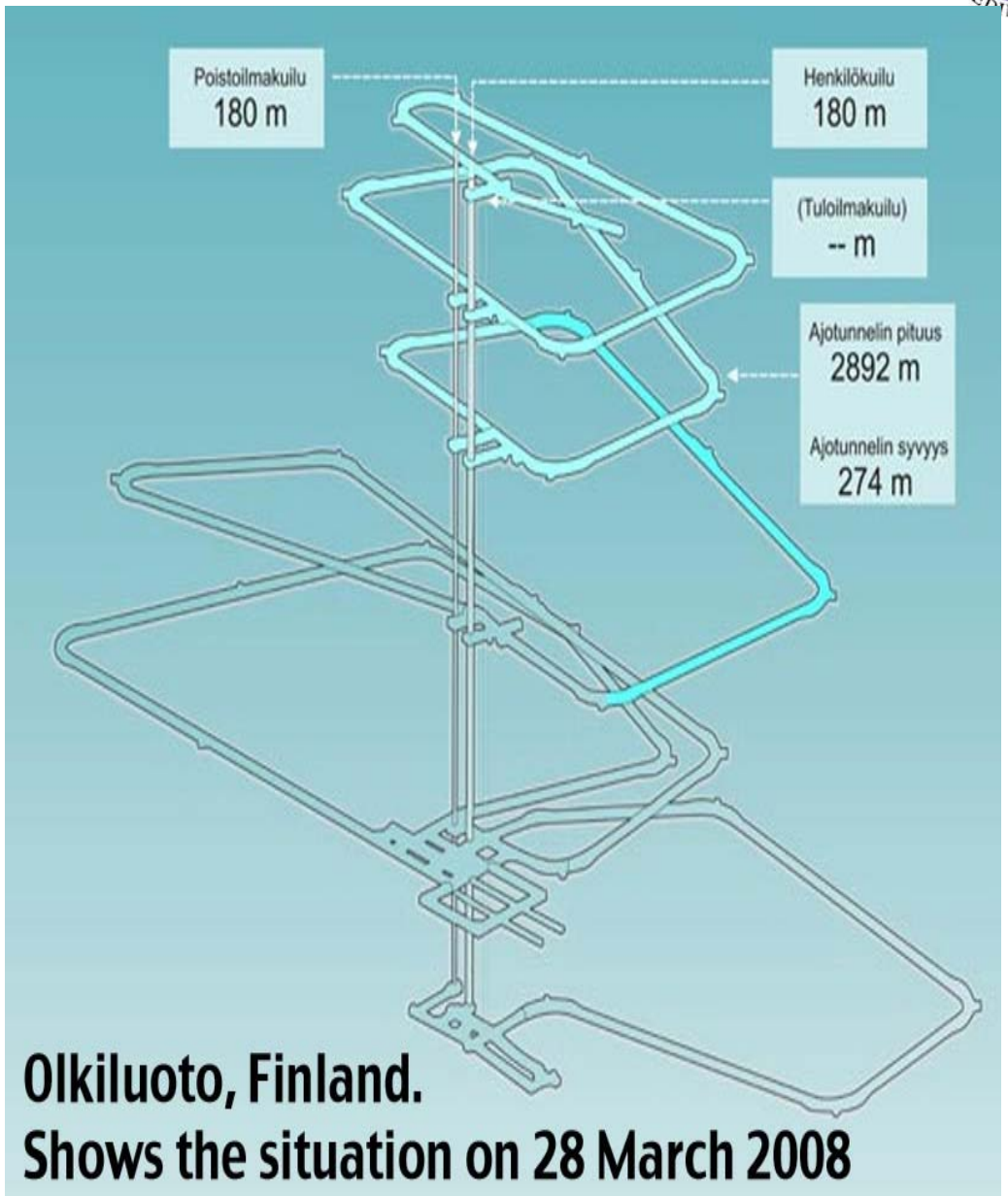
Romania - **underway**, in a mine …

UK … 2040 …..etc

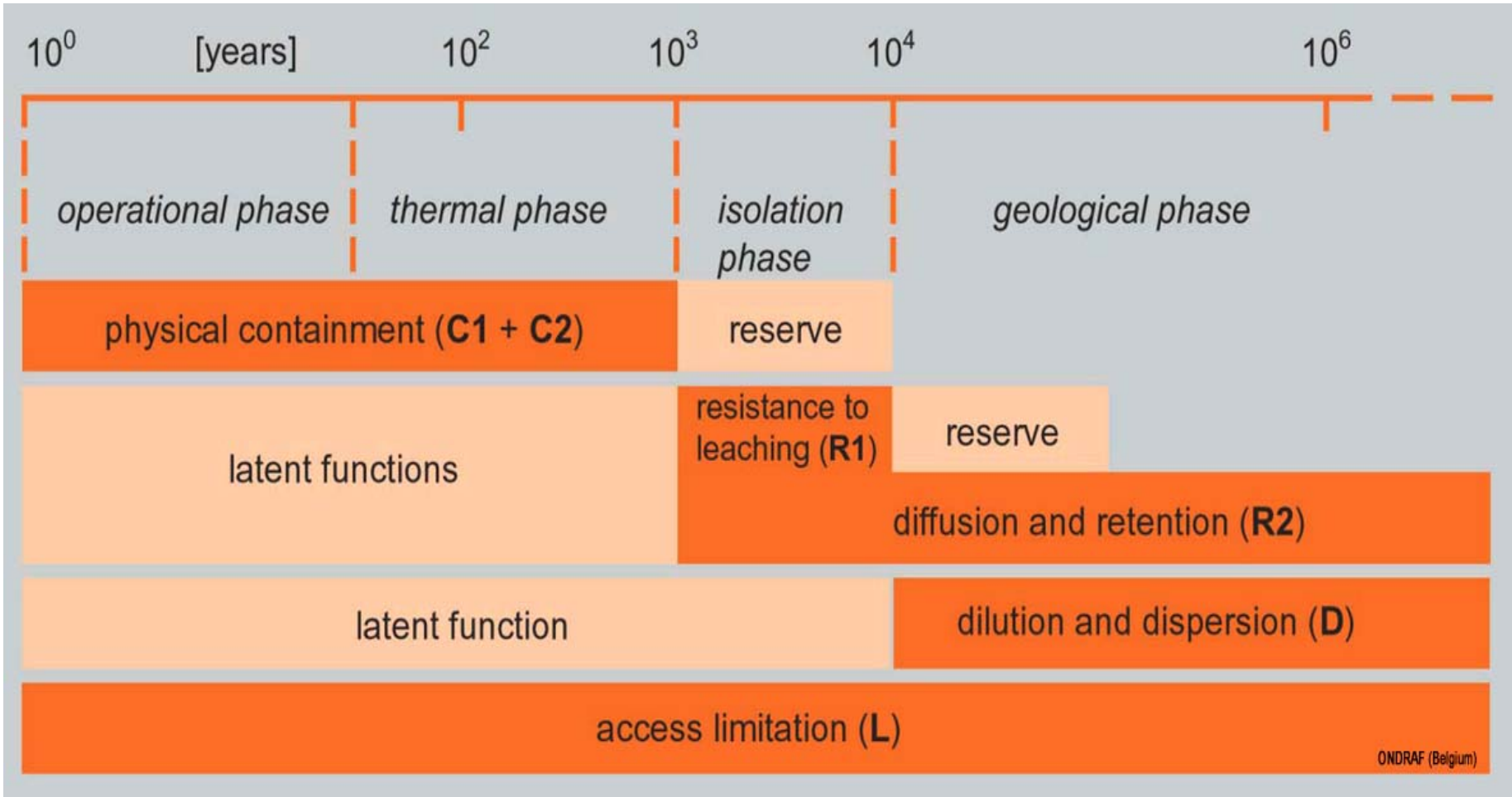
Philosophy in UK

- Find a site
- Make surface measurements
- **Engineer a cavern**
- Measure below ground
- Deposit waste retrievably
- Close after 50-100 years

- Not ‘best’ site (only one)
- Must be ‘good enough”



Repository has different functions



Geoscience is considered the long-term container

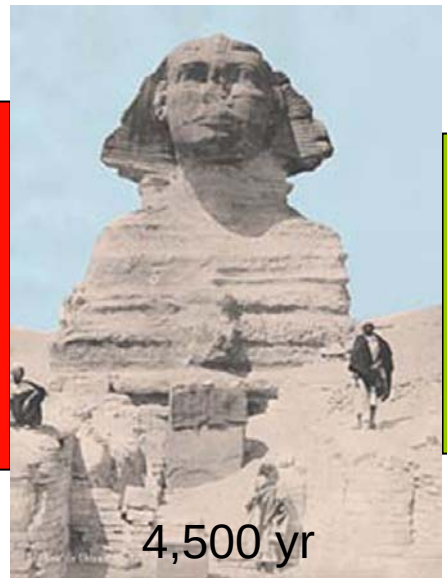
Site Selection

Fundamentals

Engineering
Not static: Site can change
Must be PREDICTABLE

Against nature

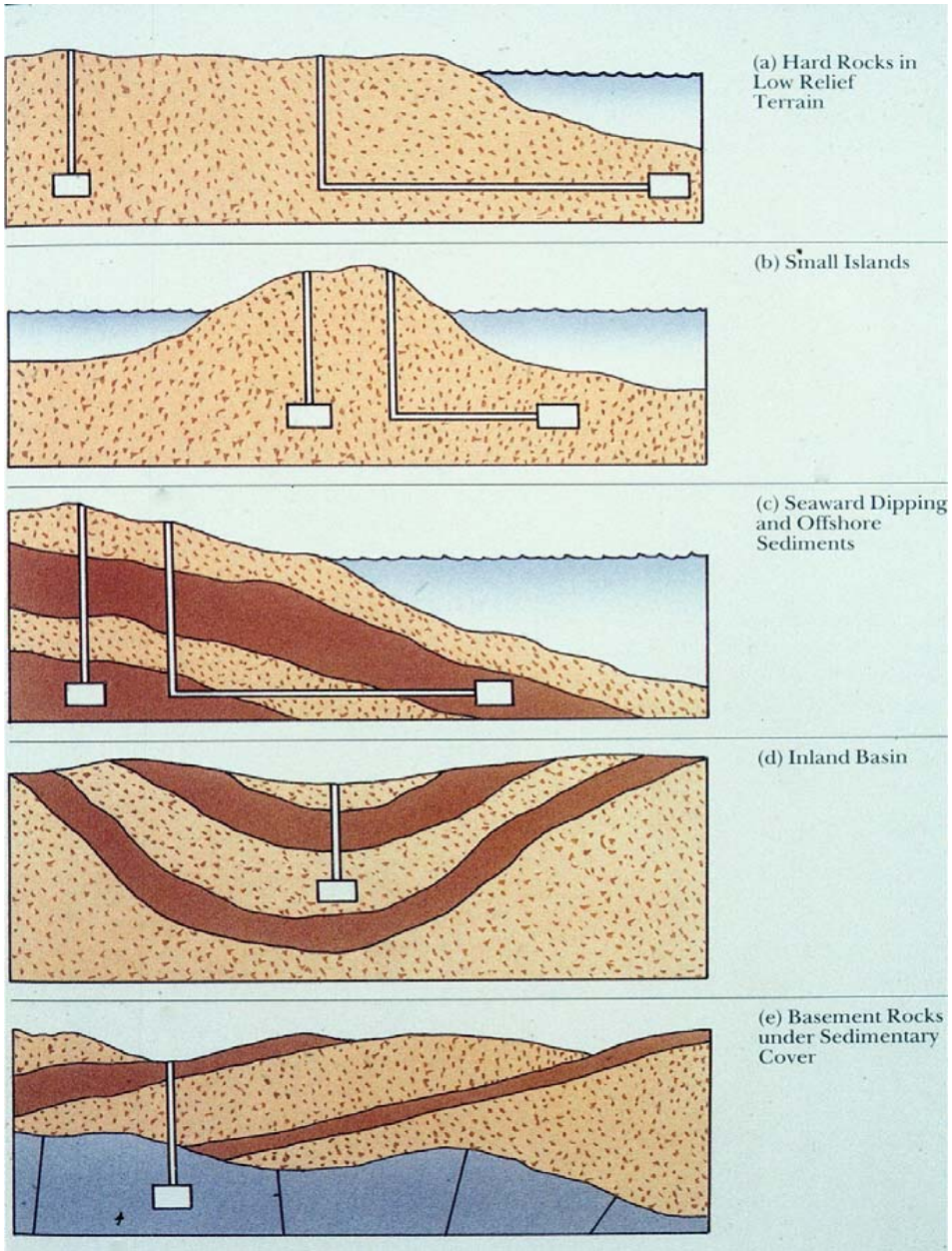
- Need **measurements** of all factors
- Need for future extrapolation, so need processes, rates, **accurate and precise coupling simulations**



With nature

- Need **direction** of process
- Need for future extrapolation, so need **approximate** rates of processes, and accurate coupling simulations

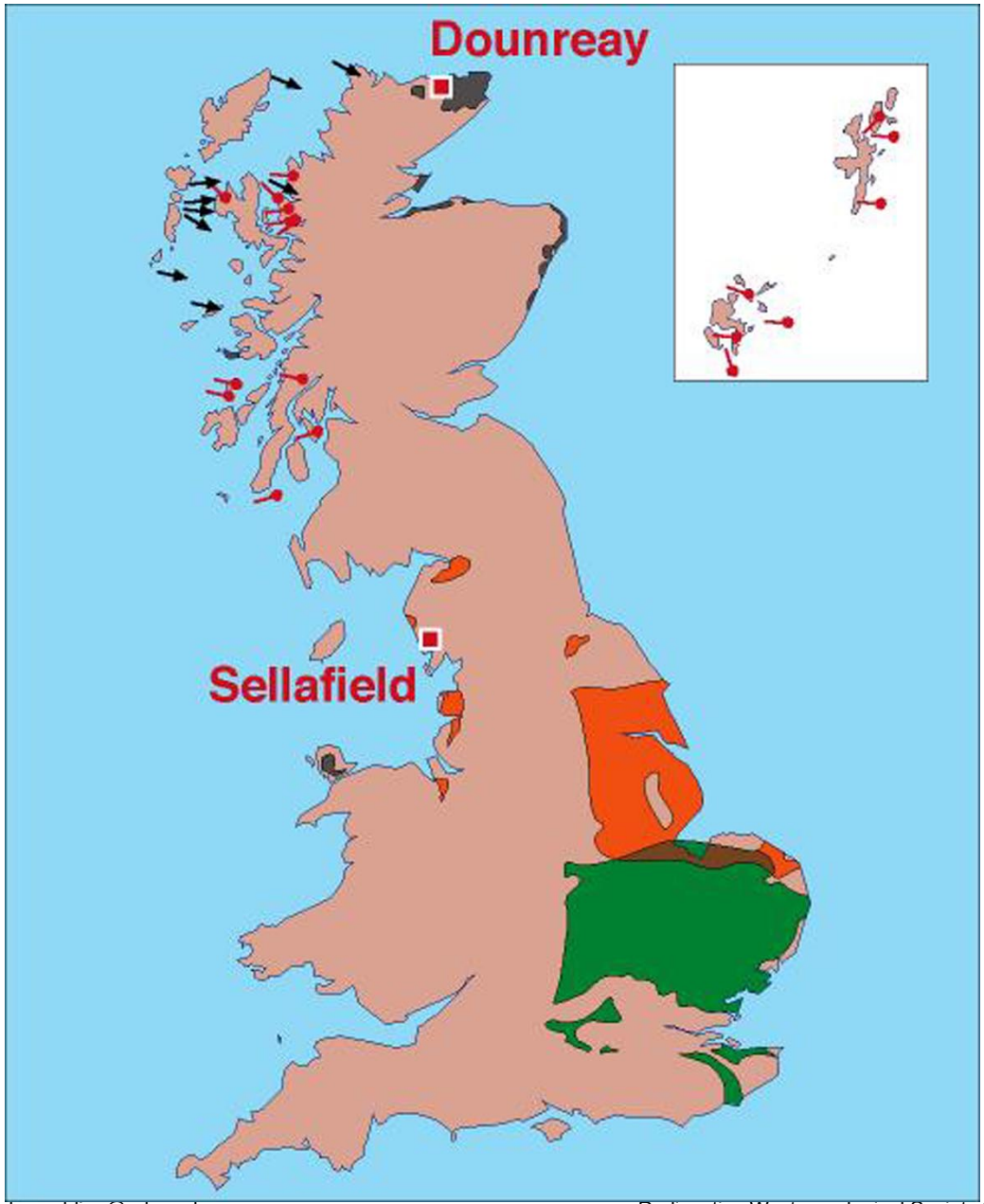
Generic site selections



These are generic explorations

The flow direction of groundwater is inherently helpful

UK onshore generic sites



Many areas of onshore UK can fit with the generic exploration criteria

Suitable sediments

Basement below sedimentary cover

Criteria for site selection

Importance of factors in Site Selection is allocated by people

- Range of options
- Future scenarios
- Weighting of importance
- Sensitivity to uncertainty
- Optimisation

Eg

- **Low weighting for geological and engineering performance**

V

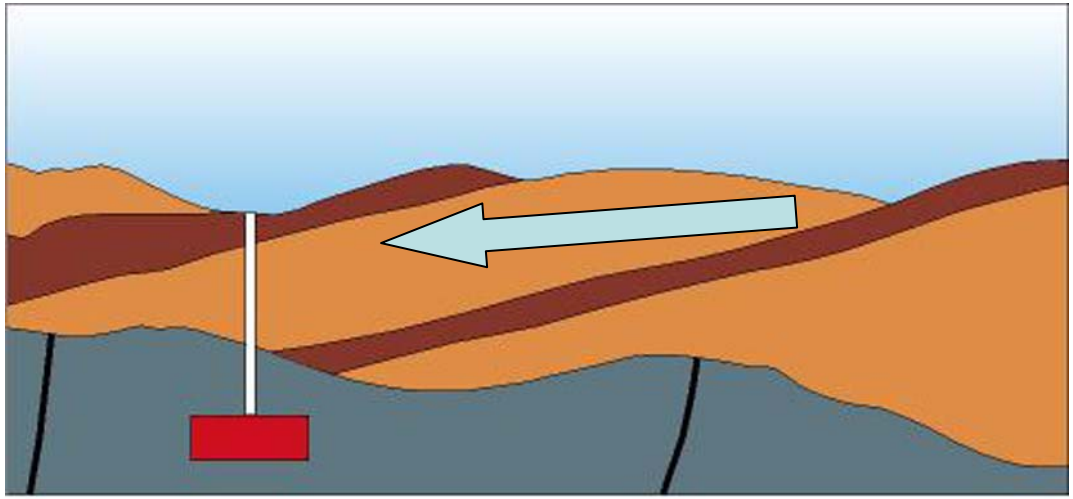
- **High weighting for local opinion**

2001 process MRWS:
"an opportunity for people to influence the decision-making process, the criteria used to evaluate potential sites and their relative weight "

Stage in EIA process	Action relating to radioactive waste management	Organisation responsible
Scoping	Consultation on the scope of the Environmental Impact Assessment, what should be assessed and how and how stakeholders should be involved.	Implementer
Assessment	The short-list of sites are assessed against the agreed criteria to identify a preferred site.	Implementer
Writing environmental report	A report (Sustainability Appraisal) of the assessments is written, including a summary report.	Implementer
Environmental impact assessment report review	A national debate to review the Sustainability Appraisal.	Government
Decision	Government will decide whether to approve implementation of the facility at the recommended site	Government
Implementation and monitoring	The implementer will construct the facility and the Government will ensure appropriate monitoring is undertaken.	Government

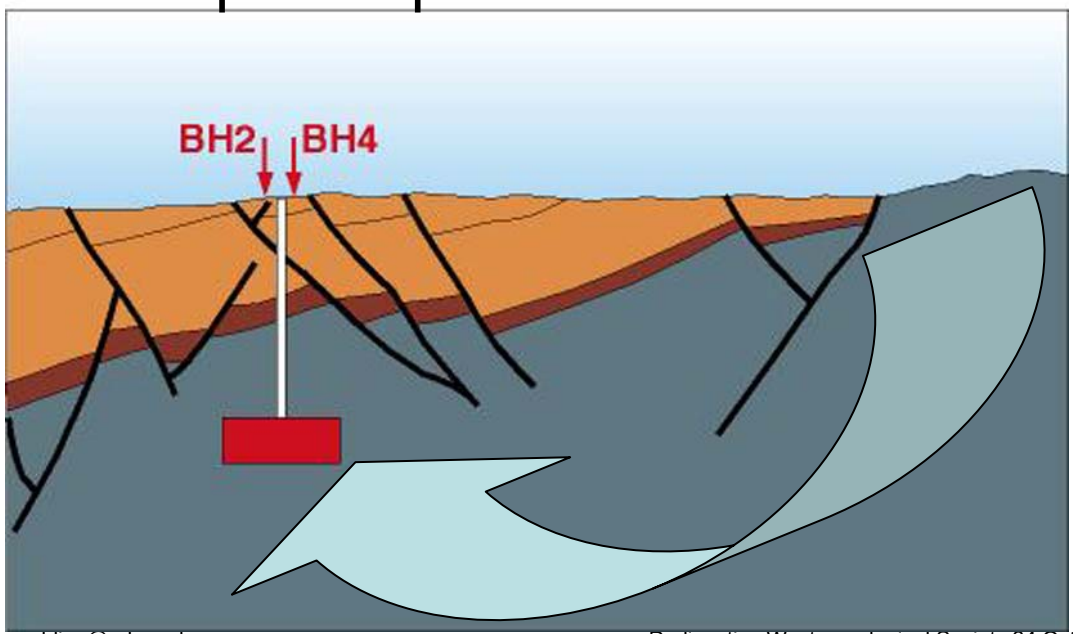
Sustainable Development Commission 2006 vol 5 www.sdc.org.uk

Adapting of criteria



Original generic site

"Adapted" specific site



Initial generic identification can become changed during the evaluation process

This can have important effects on the "fundamental" site integrity.

Here, water flow no longer passes overhead, but flows through the store

Why so much rush ?

2001 process MRWS:

"sites that were considered to be potentially suitable previously on geological grounds could be considered suitable"

"Equally, **given the developments that have occurred**, sites where the geology was viewed as less favourable previously could be included in the new site selection process"

2001 process MRWS:

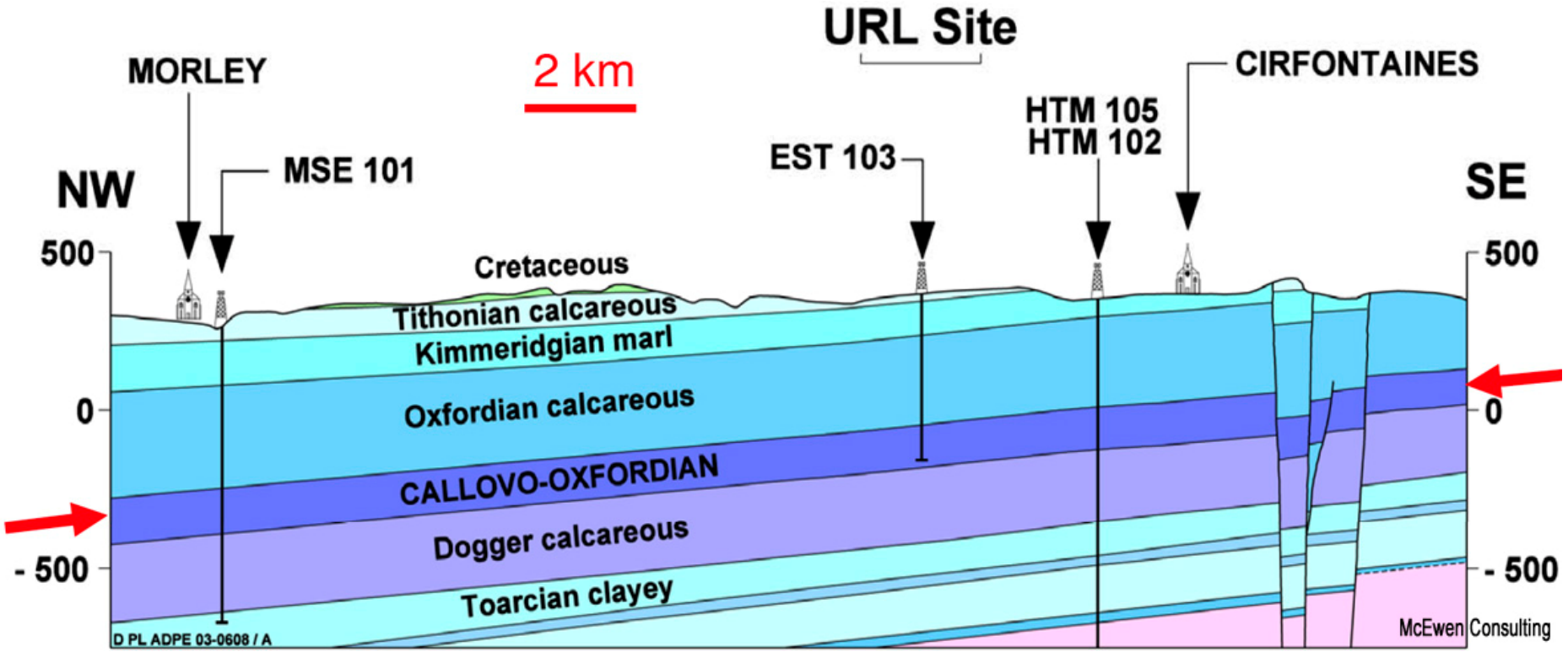
" from 537 sites sequentially to 204, 165, and on down to a shortlist of 10 and 2 generic offshore"

25 June 2008

"Copeland Borough Council has already expressed its interest to the Government"

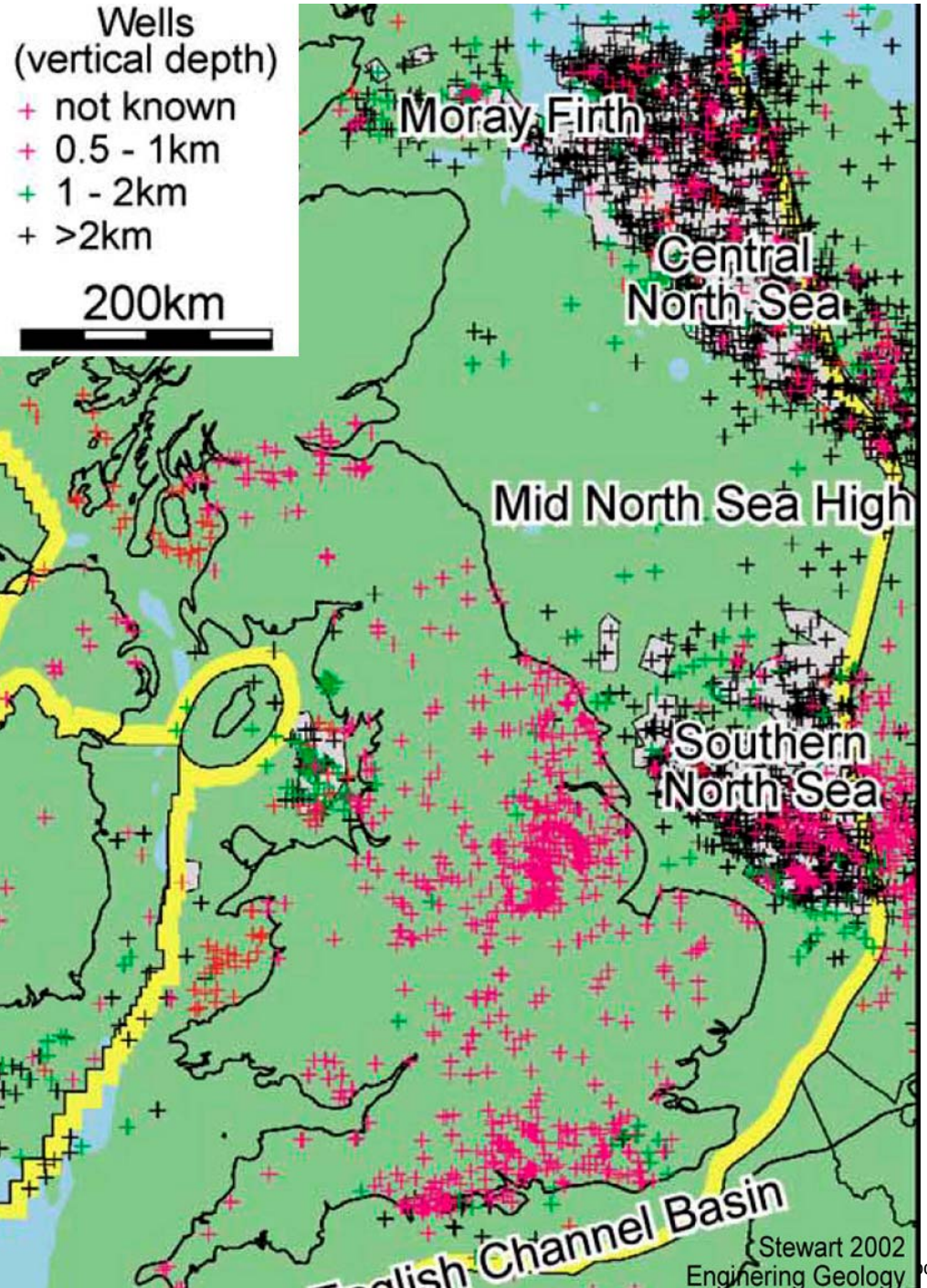
Different Types of UK Site

Why ignore sediments ?



ANDRA France (NAGRA Switzerland). Mud sediments.
Simple structure: easy to evaluate across tens km
Rock is very low-flow < 10^{-10} m/s oil and gas “seal”
Fractures are self-sealing ==> Diffusion not flow
Mineralogy adsorbs leachates

Offshore sites

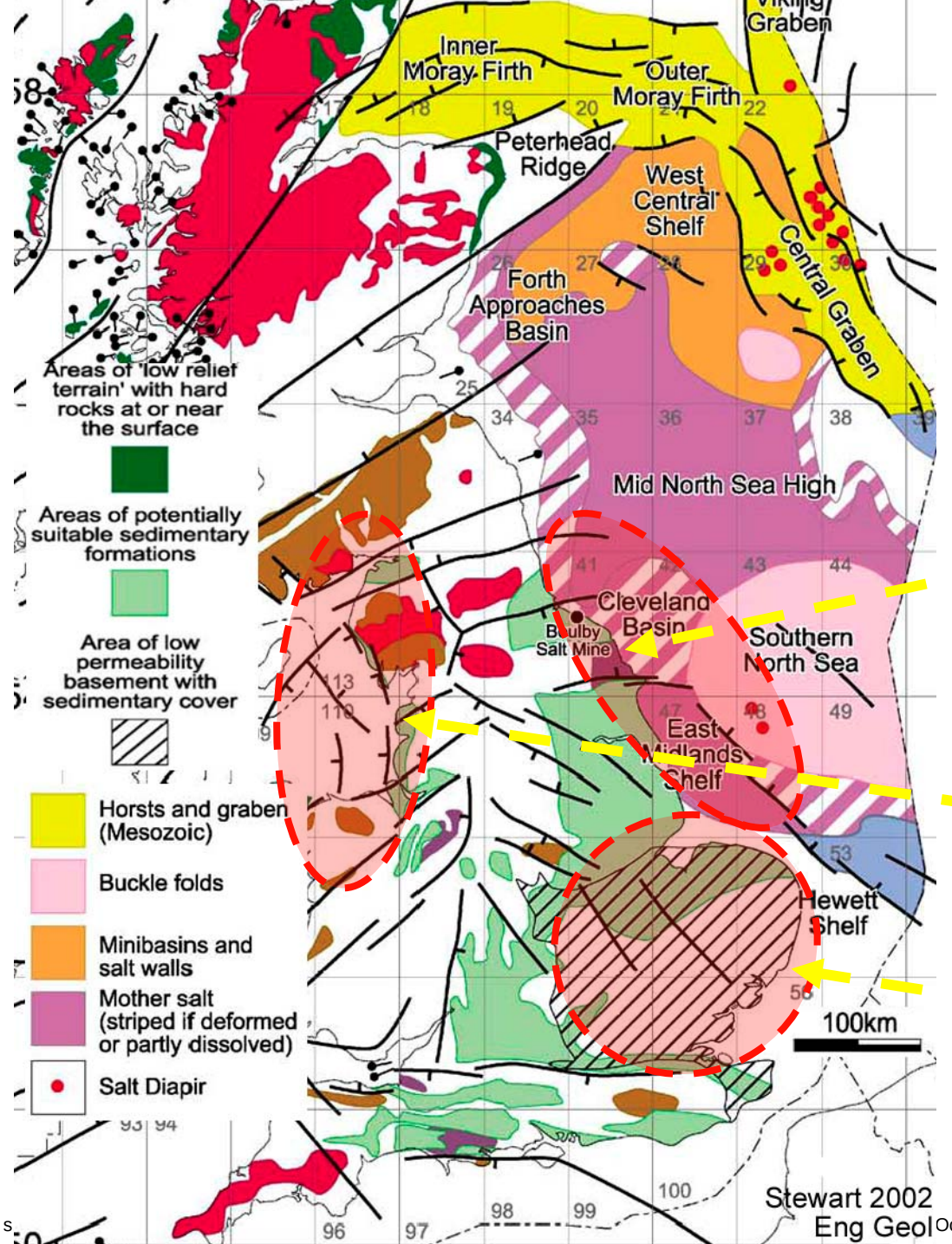


Original generic sites were defined from the late 1970's

Subsequently, more is known about offshore than all of onshore

Generic zones offshore

Channel tunnel 30km £5Bn, with 2 degree gradient, to reach the repository depth 600m



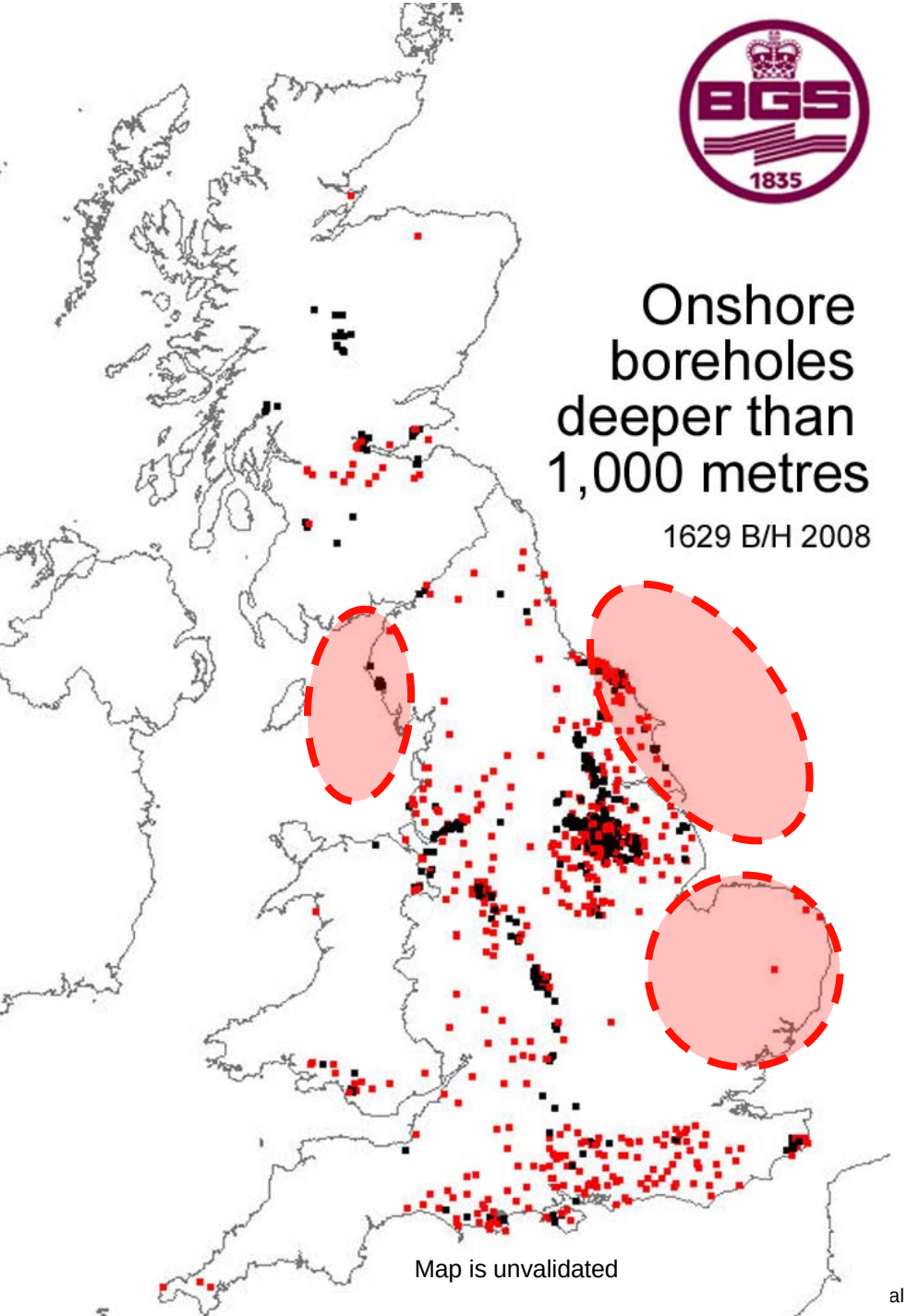
Salt over sandstone

Salt over sandstone

Deep saline granite

Sediments above basement

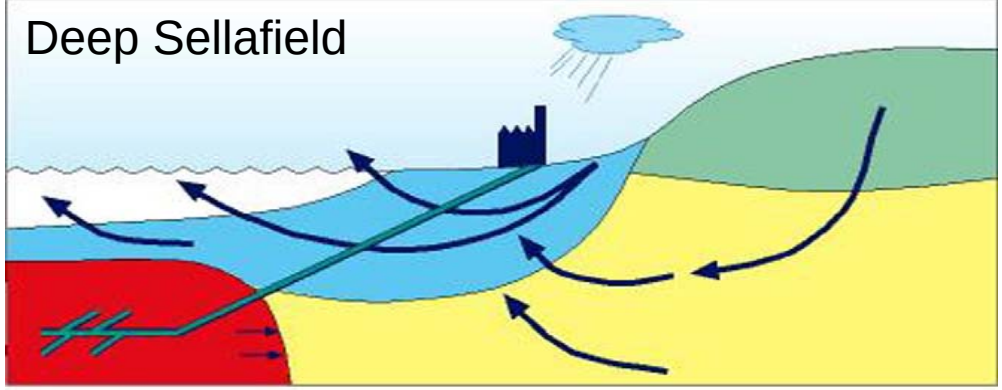
Onshore boreholes



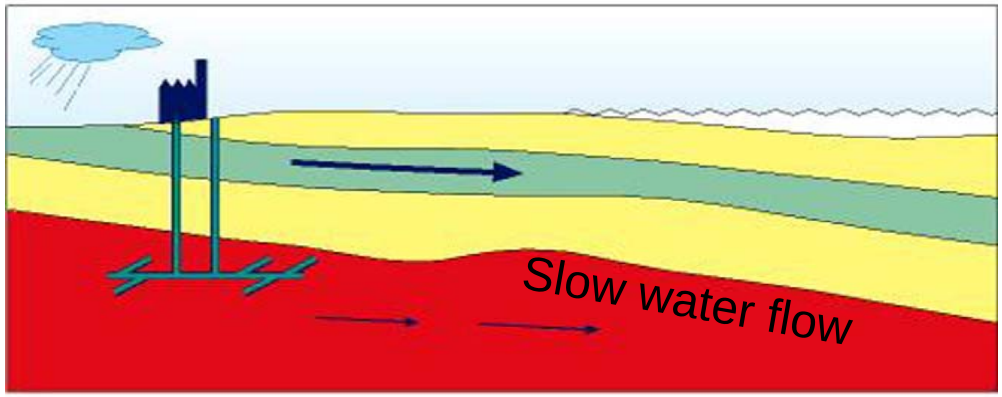
Deep boreholes are focused on coal, hydrocarbon, geothermal : all excluded as radwaste stores

How can volunteer bids be evaluated quickly / at all ?

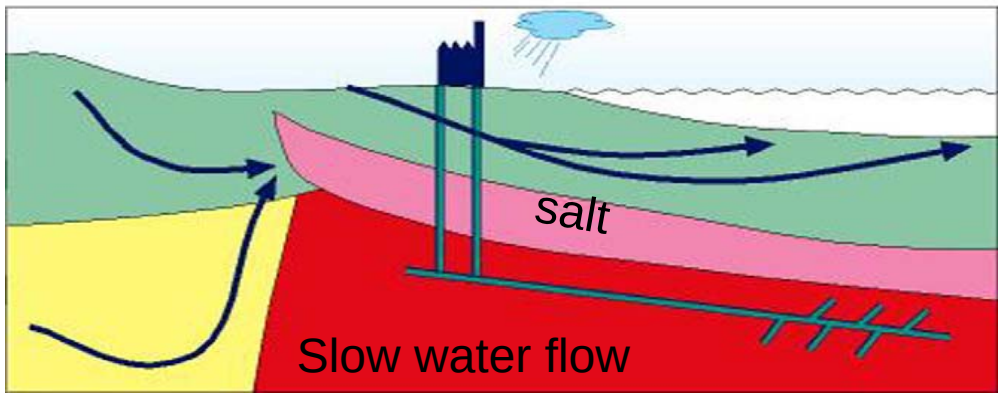
And …. generic nearshore sites



Seaward water flow



Nearshore salt



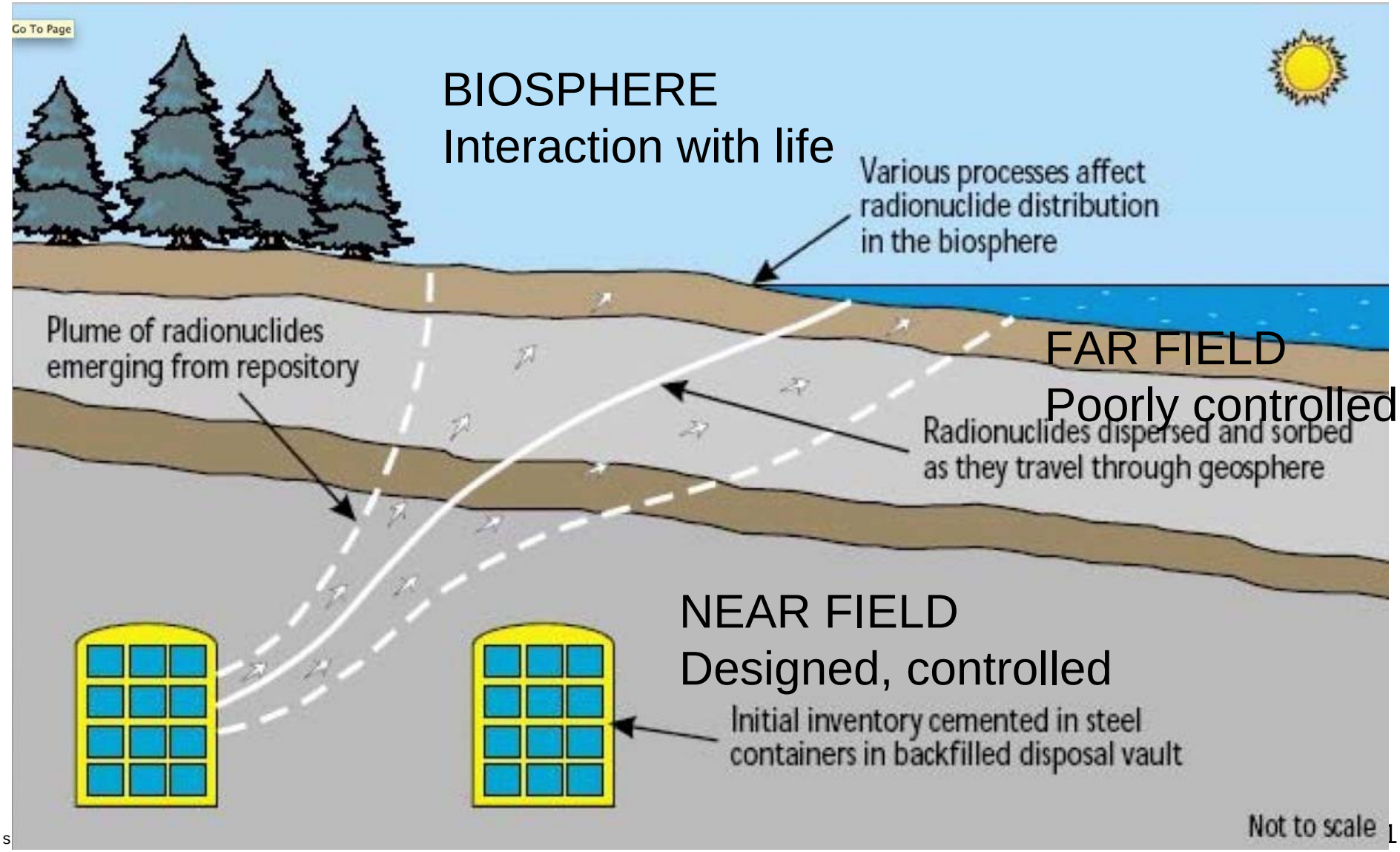
Volunteer communities are only onshore

This excludes all the new information - specific to UK, about the nearshore, and about the offshore

Groundwater flow

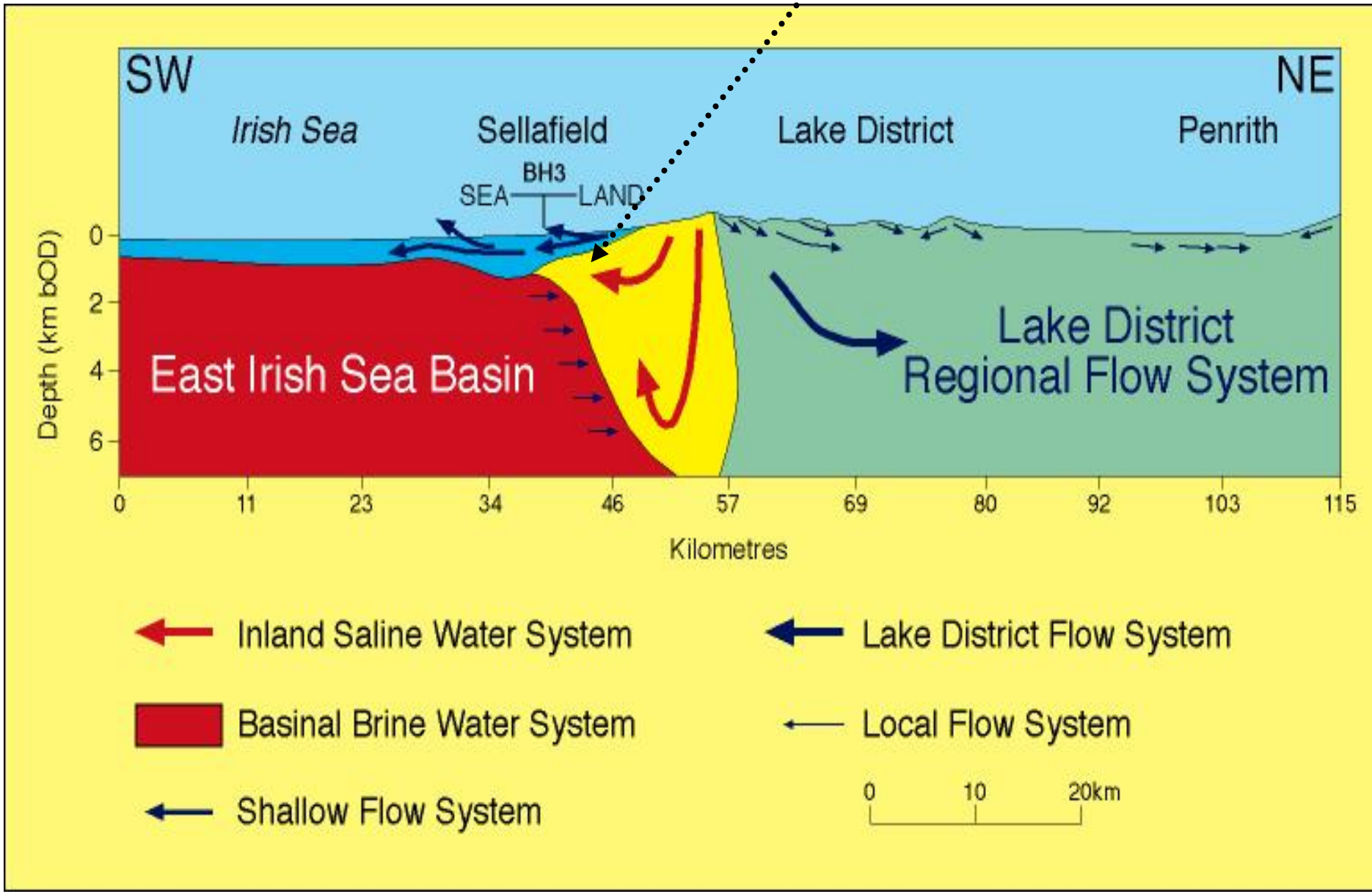
Leakage

Inevitable that a Repository will leak.
Leaks can go: Down - long path
Up - dilute , disperse

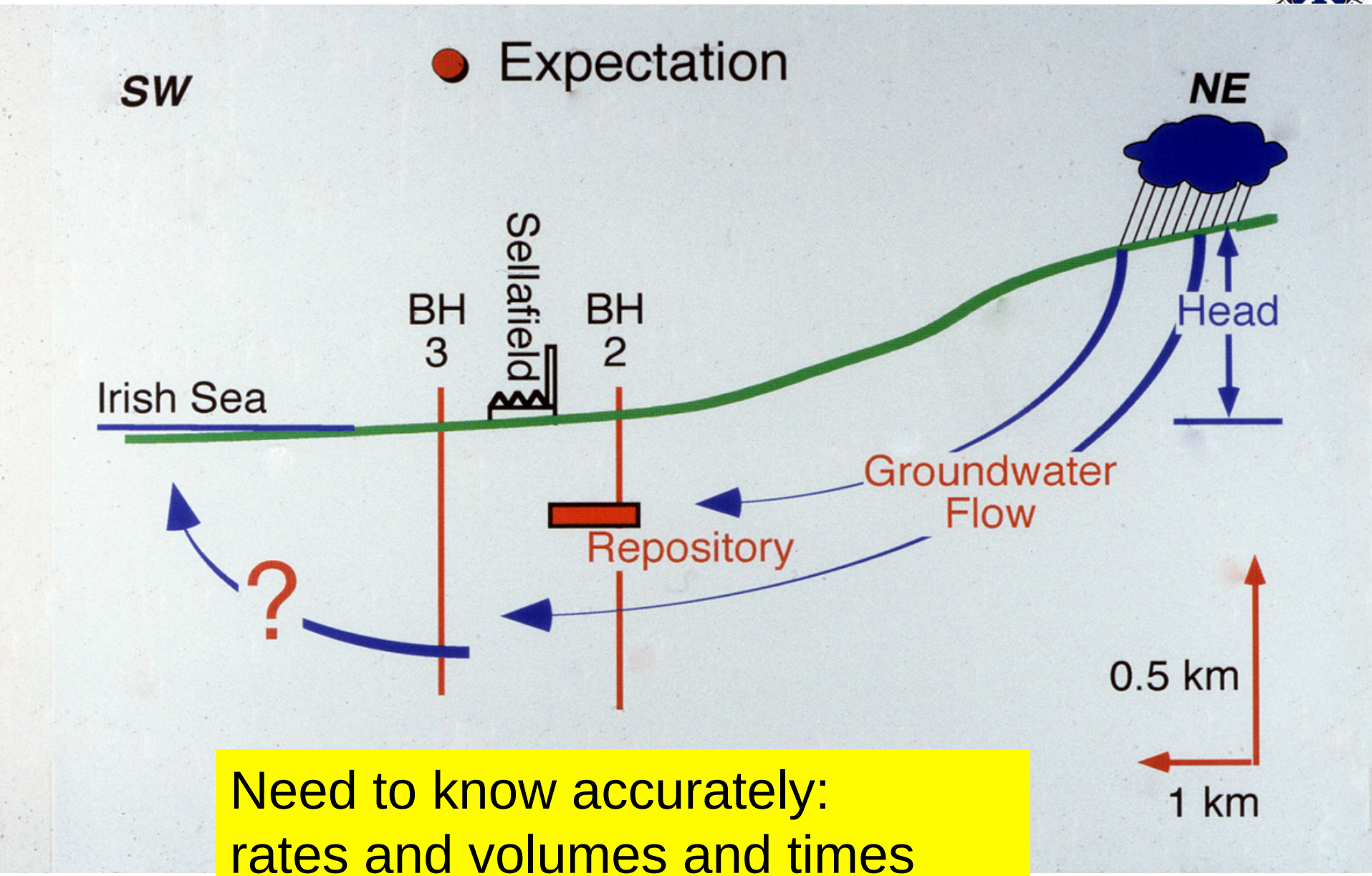


Topography of proposed site

Choose simple, or complex site



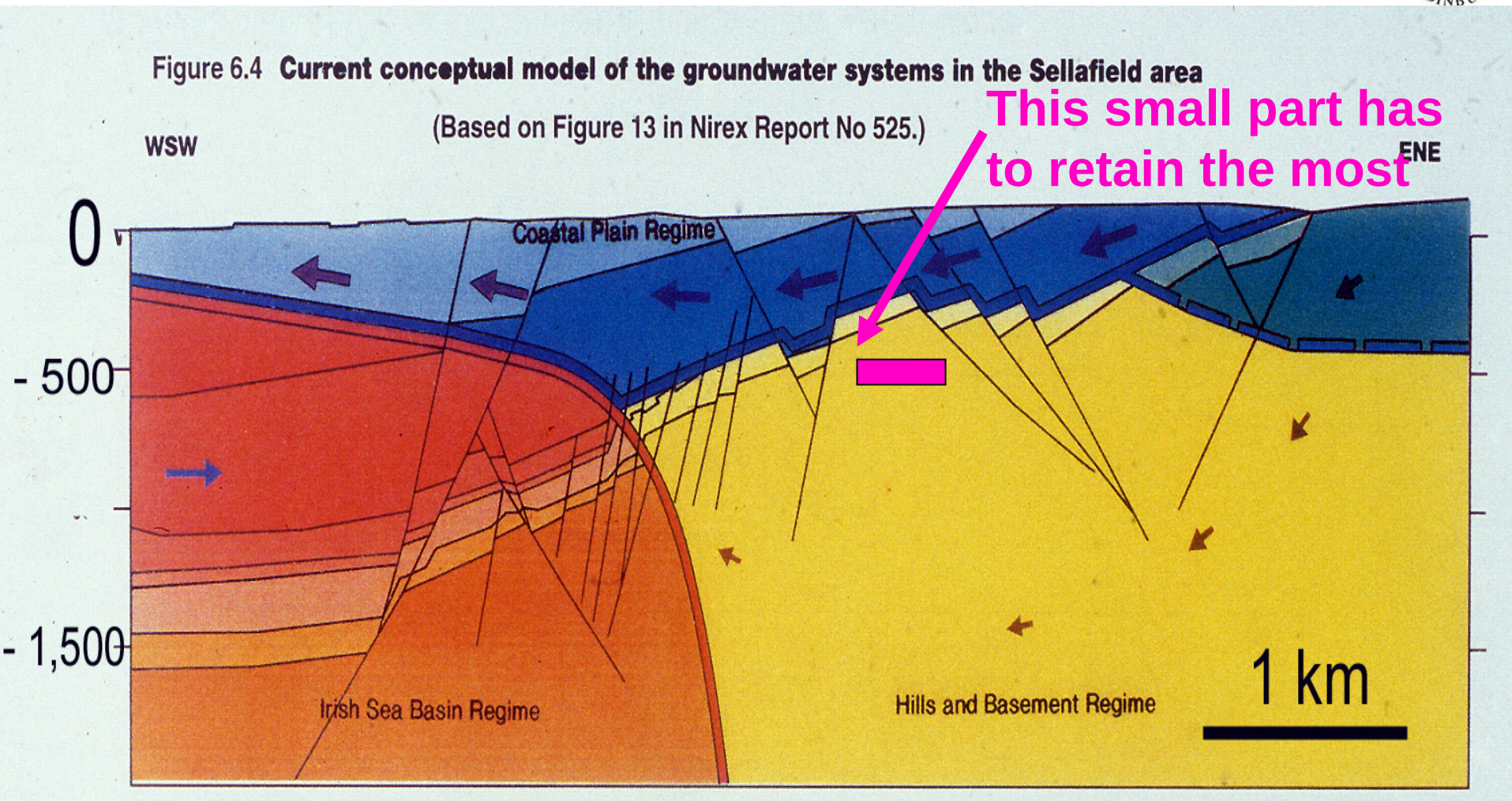
Fundamental: outflow difficult



Need to know accurately:
rates and volumes and times

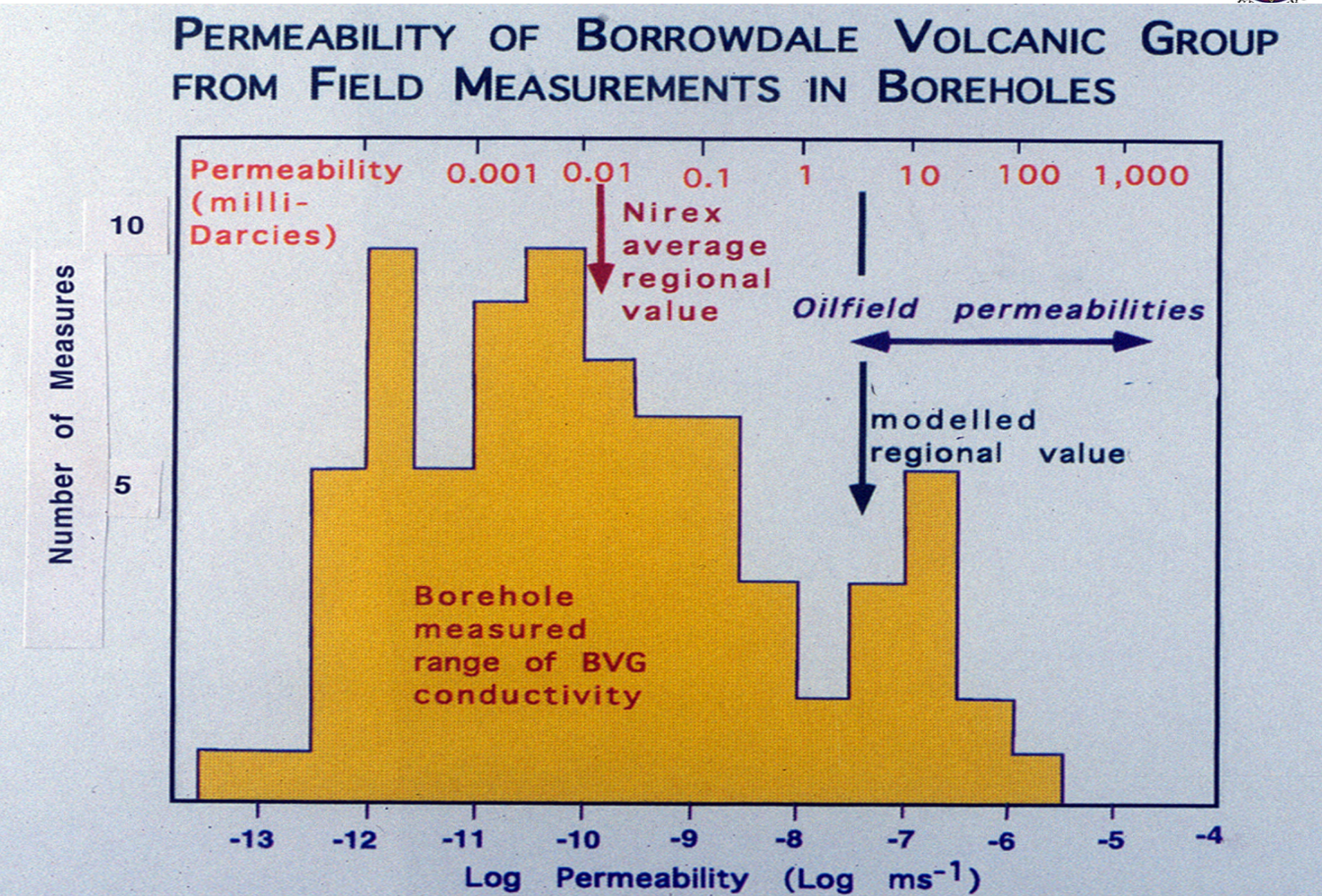
Non-average values

Flow **below** repository



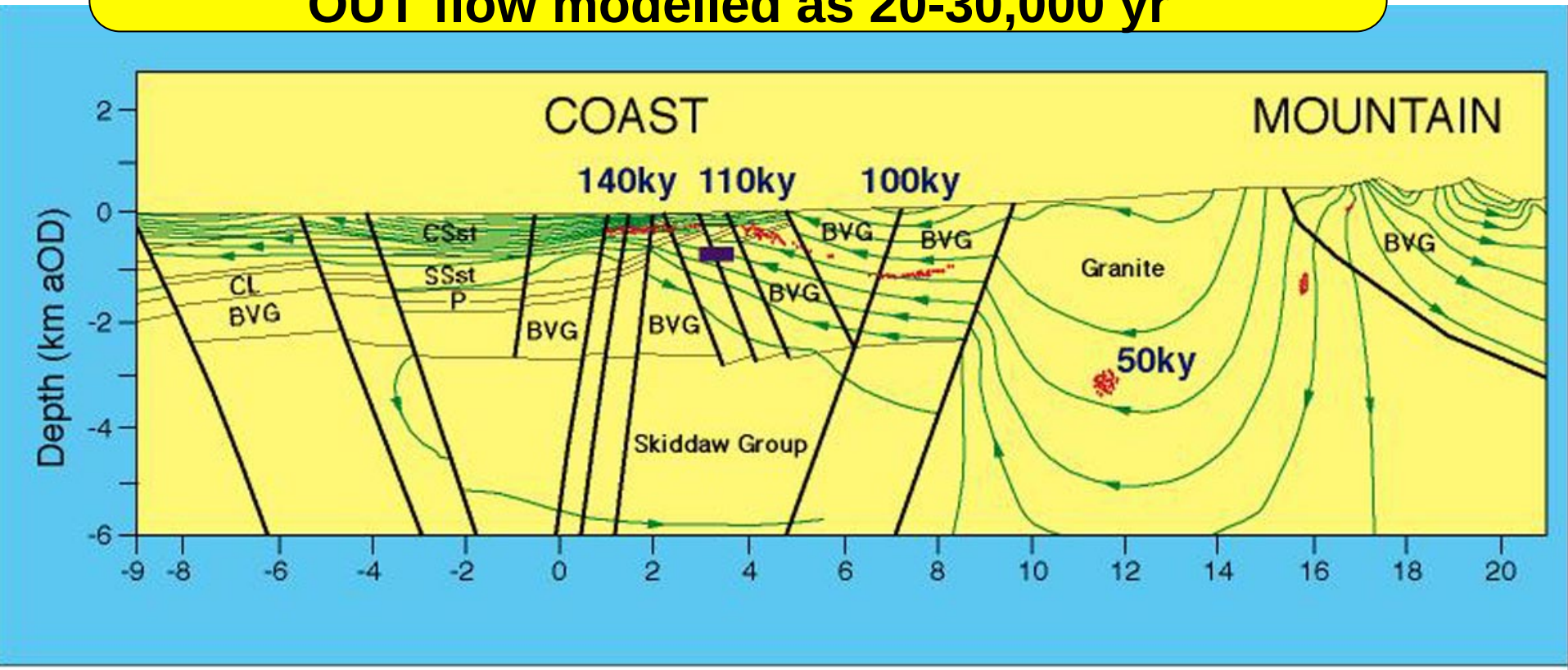
Groundwater moves, and can ascend from beneath
Best performance at IN-flow, not OUT -flow

Extremes control performance



Against, or with flow paths?

IN flow water age - modelled as 120,000 yr
measured as 100,000 - 1,000,000 yr.
OUT flow modelled as 20-30,000 yr



Flow Line

Fault

CSst Calder Sandstone

CL Carboniferous Limestone

SSst St Bees Sandstone

BVG Borrowdale Volcanic Group

P Permian

PRZ Proposed Repository Site

Singular features
Unusual events
Risk

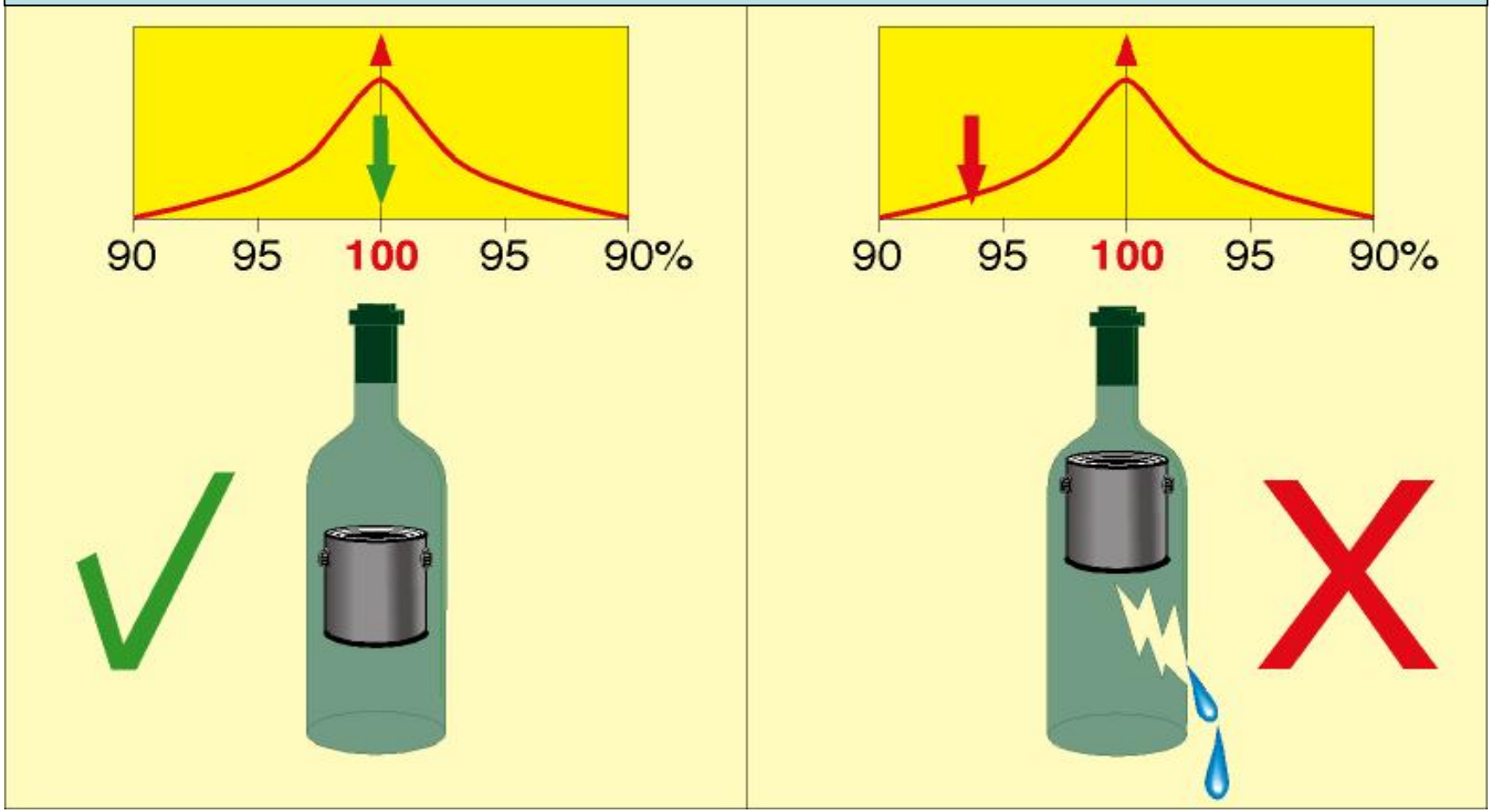
Fractures and water flow

Approaches:

- Measure everything - very difficult
- Statistically simulated - but what about the rogue 0.01%?

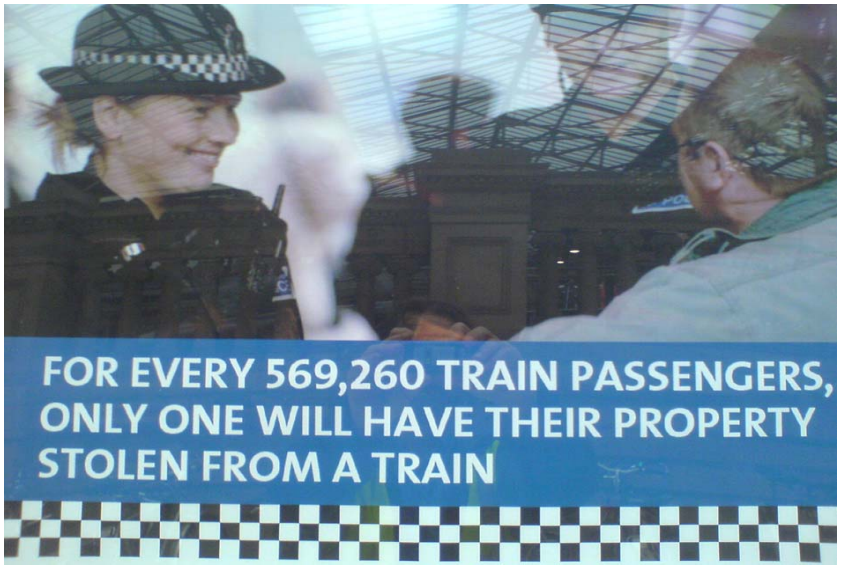
“Leakage” singular features

Statistics are a guide, not certainty



Gas will emerge from Repository from bacteria and by radiolysis - will this pressure make fractures ?

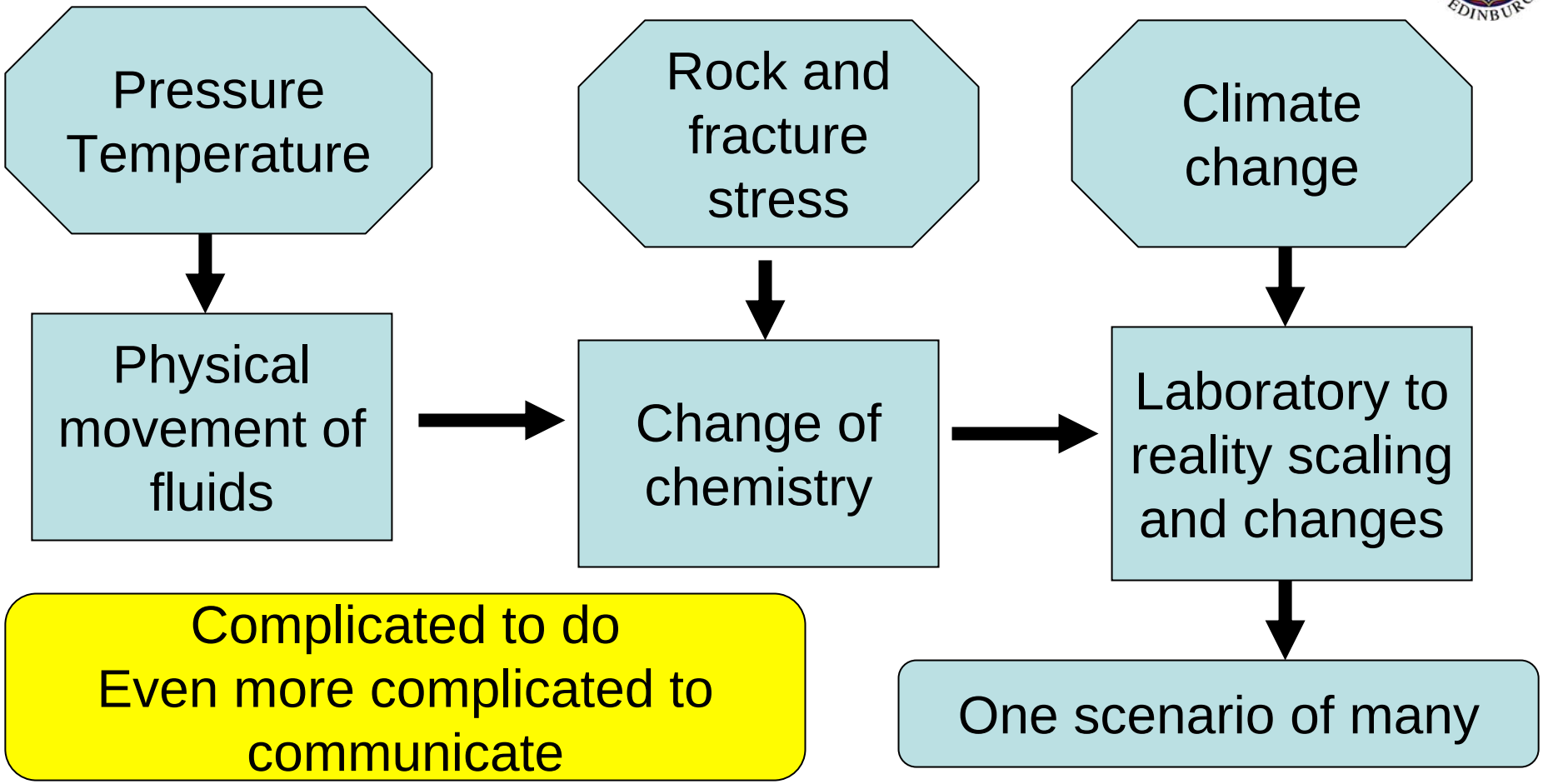
Perception of risk



Very improbable events
0.005% to 10^{-6} risk
Can be high IMPACT

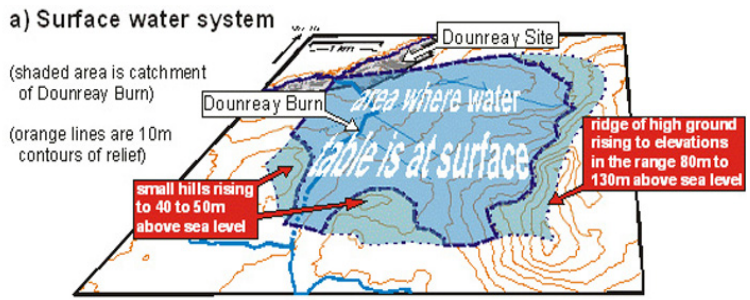
Models and unknowns

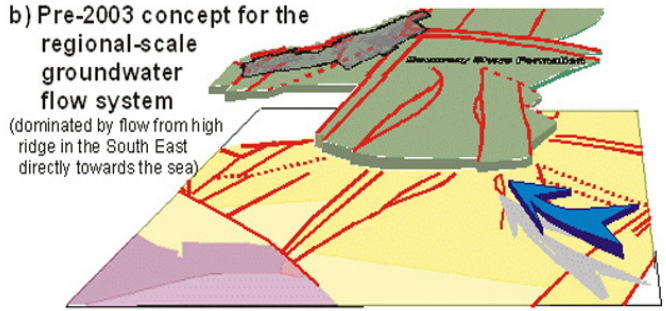
Using models - principle

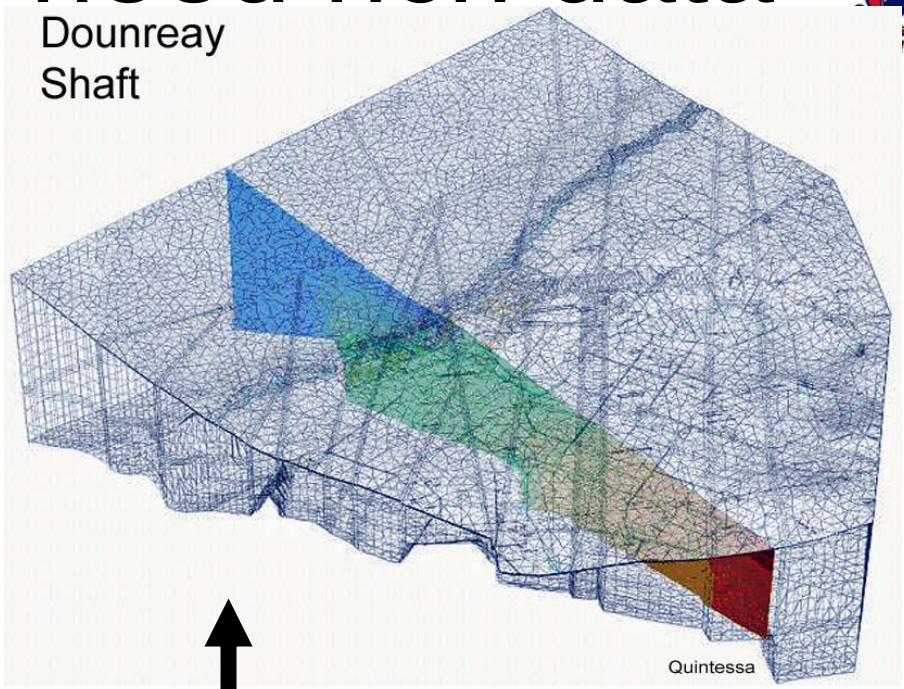


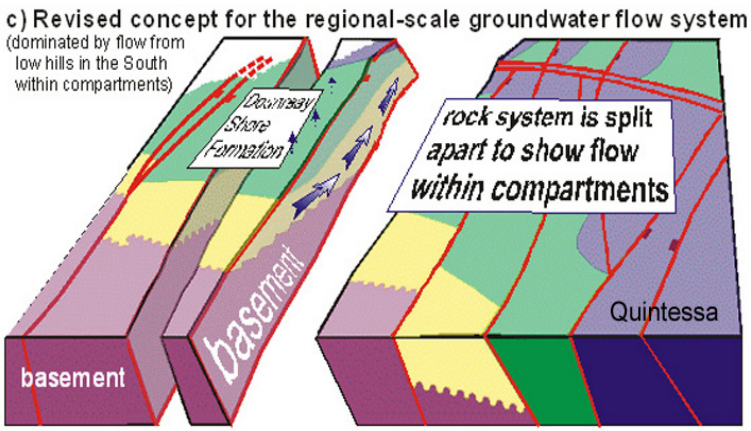
Simulations inevitable to make predictions
Need: calibration, then validation, rival models, range of barriers, several indicators of performance

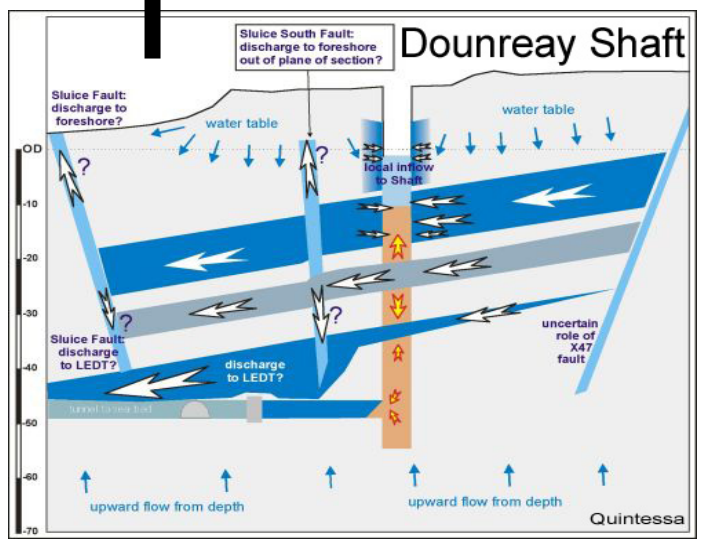
Complex models need rich data







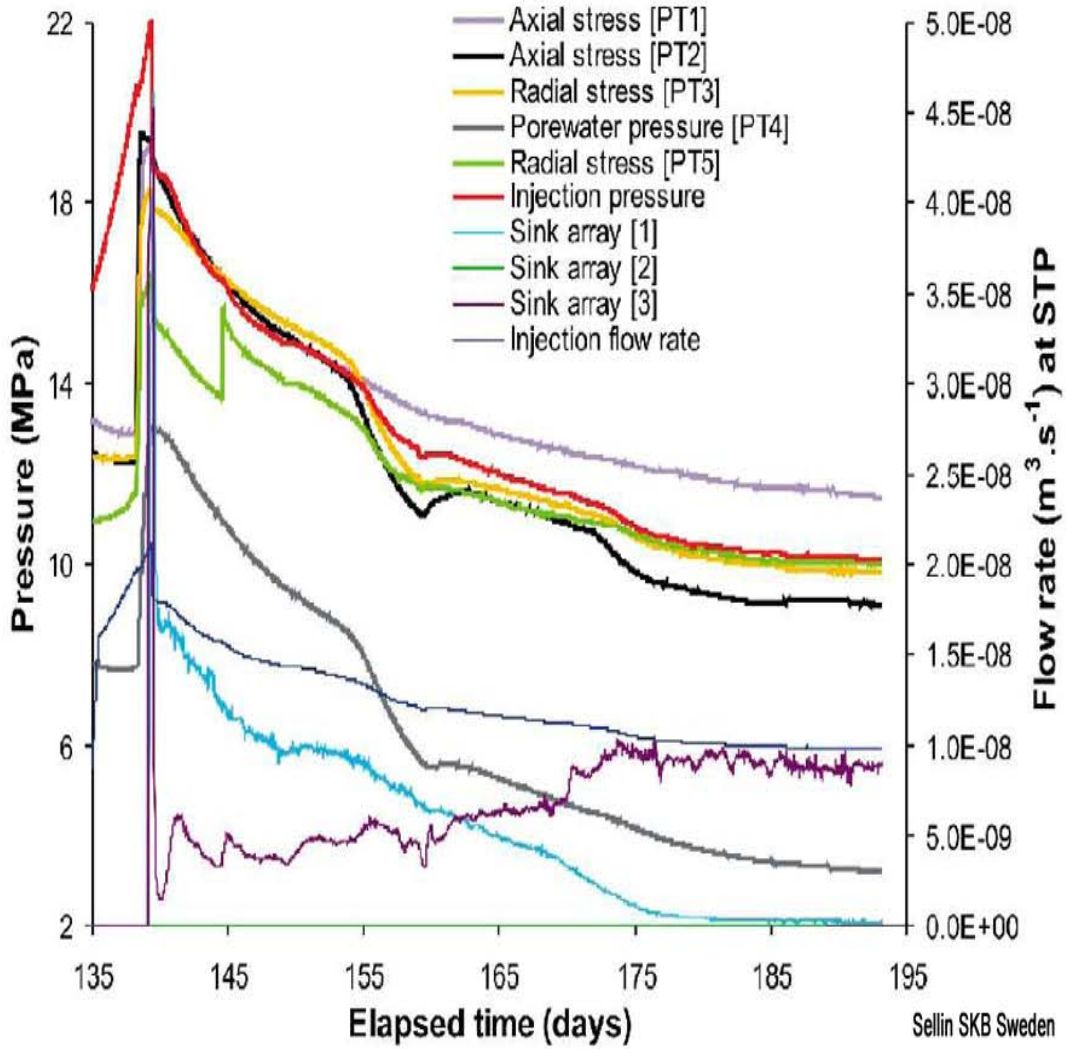




Can all the data exist ?

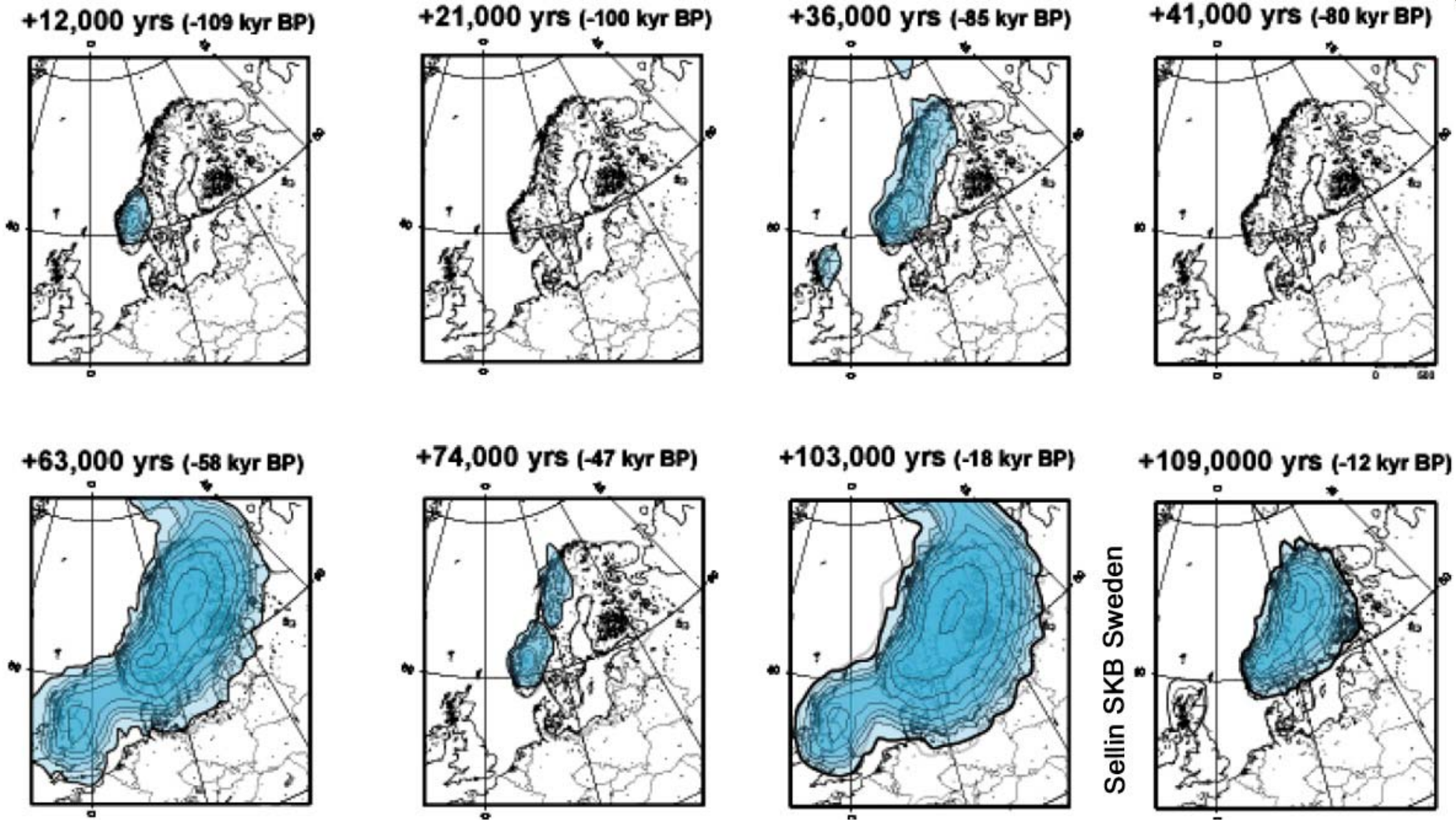
Gas pressures

- Carbon steel will generate hydrogen gas
- The gas may affect the performance of the repository
- Formation of permanent fractures:
  - Loss of diffusional barrier
- De-saturation
  - (Loss of diffusional barrier)
- High gas pressure
  - Mechanical damage to repository



Hydrogen from radiolysis - will this pressure make fractures ?
Permeability need to permit escape, whilst limiting water fow

Future climates



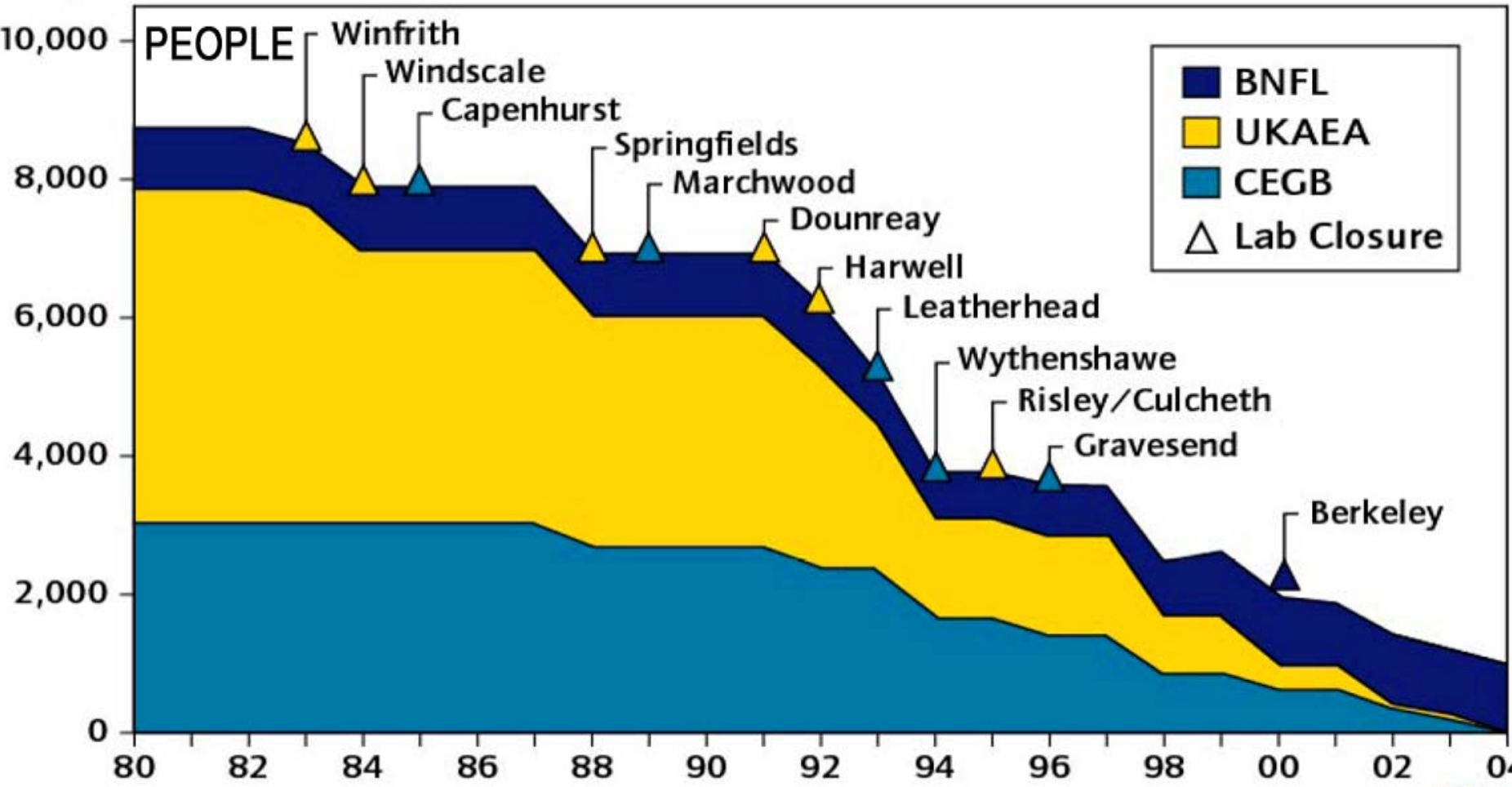
Glaciation predicted : effect on fluid pressure, stress, fluid circulation rate and depth and pathway, geochemistry …..

Who referees ?

- Environment Agency
- CoRWM
- RCUK
- NGO
- Replication by academics (how to be ‘independent”?)
- (International) peer review

- Is there a co-ordinated R&D overview ?
- Is the information public enough ?
- How can support be independent?

Skills shortages



Geoscience too has rival employers:
Hydrogeology, engineering, geophysics, environment, oil, carbon, City….

Summary

- UK has diverse geology - potentially suitable sites
- Initial choices vital - one or **several sites**?
- Hard rock caverns (again), or **offshore sediments** ?
- Working **with nature** or engineering against it ?
- Volunteer communities solve politics, may create technical problems. Site choice much **too quick** ==> one site (again)
- **Uncertainty** is not understood. **Risk** can be emotional
- Who are the **referees** to NDA and Government ?

From 1996 Sellafield

@ Univ Edinburgh