British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL


# Static $CO_2$ geological storage capacity estimation

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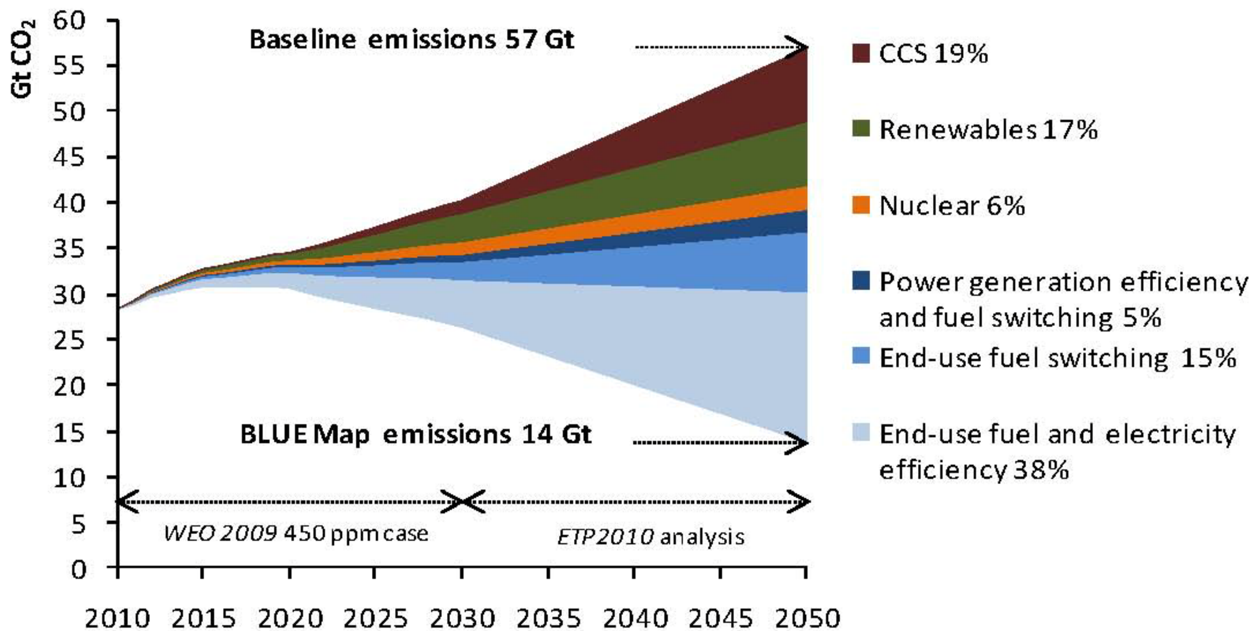
# Why would anyone want to make an estimate of potential for geological storage of $CO_2$?

- In the IEA Blue Map, CCS provides 19% $CO_2$ mitigation by 2050 (8.17 billion tonnes annually)
- add 25% additional $CO_2$ generated by capture = approx 10,000 Sleipners, 3400 large CCS projects



# What do policymakers want from an estimate?

- The answers to three questions - in order to determine the role that CCS can play in a portfolio of greenhouse gas mitigation options
- How much storage capacity can be relied on at a range of different costs?
- Where is that storage capacity?
- When will it be available?
  - Capacity
  - “Relied on” – therefore need to understand risk/ geological uncertainty
  - Need to apply cost model
    - Ideally end up being able to produce storage costs curves at different levels of risk: “we are confident that X million tonnes capacity is available at cost Y”

# $CO_2$ storage capacity estimates - understanding resources and reserves

- A resource is anything that is available and potentially useful to mankind
  - Its presence does not tell us *anything* about how much of it can be exploited economically
- Reserves are that part of a resource that can be exploited economically at present with current technology

# Comparing existing $CO_2$ storage capacity estimates

- Difficult because do not use a standard methodology
- Most estimates are resource estimates – no economic dimension
  - Different questions asked
    - Total accessible $CO_2$ storage resource
    - Resource in structural/stratigraphic traps
    - Resource in structural compartments
- IEA initiative to produce a roadmap for $CO_2$ storage capacity estimation methodologies that will answer the policymakers' questions

# What is a static capacity estimate?

- An estimate of storage capacity that:
  - does not take into account the movement of $CO_2$ in the reservoir/ involve any dynamic simulation of $CO_2$ injection?
  - does not take account of the time it might take to fill a potential storage reservoir?
  - does not require much in the way of resources "cheap and cheerful"?
- Static estimates may be probabilistic or deterministic

# Which trapping mechanisms are important over injection timescales?

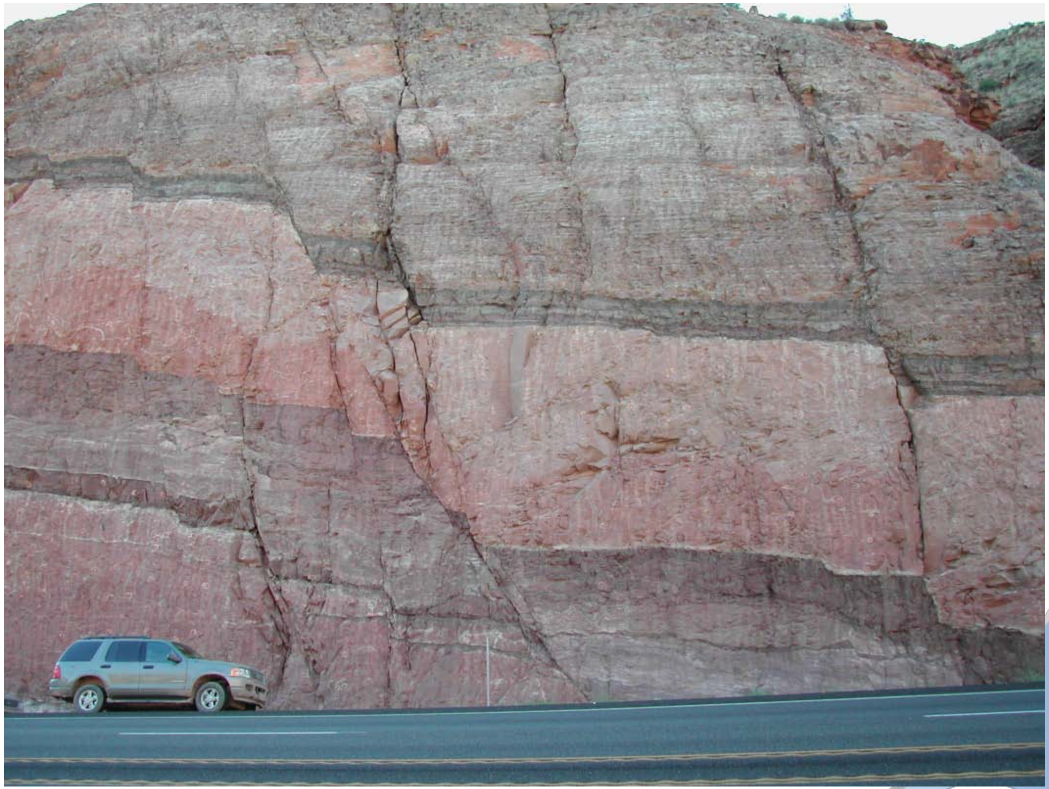
- Structural and stratigraphic trapping of free supercritical $CO_2$
- Trapping as a residual saturation
- Dissolution?
- Chemical reaction?
- Adsorption?
- Simplify problem by ignoring geochemical reaction and adsorption, ?dissolution
- Remaining problem then one of residual saturation trapping and structural/stratigraphic trapping

# Methodology

- Identify all reservoir formations
- Determine which fractions of each reservoir formation meet basic criteria for storage
  - Sealed above, depth >800 m, ?minimum reservoir quality
  - Reject parts that don't
- Divide remainder into units of assessment
- Characterise units of assessment
  - Reservoir characteristics, boundaries, risks
- Determine their pore volume
- Apply simple formulae to estimate their storage capacity
  - Different formulae for units with closed boundaries, open boundaries, traps

# Boundary Conditions

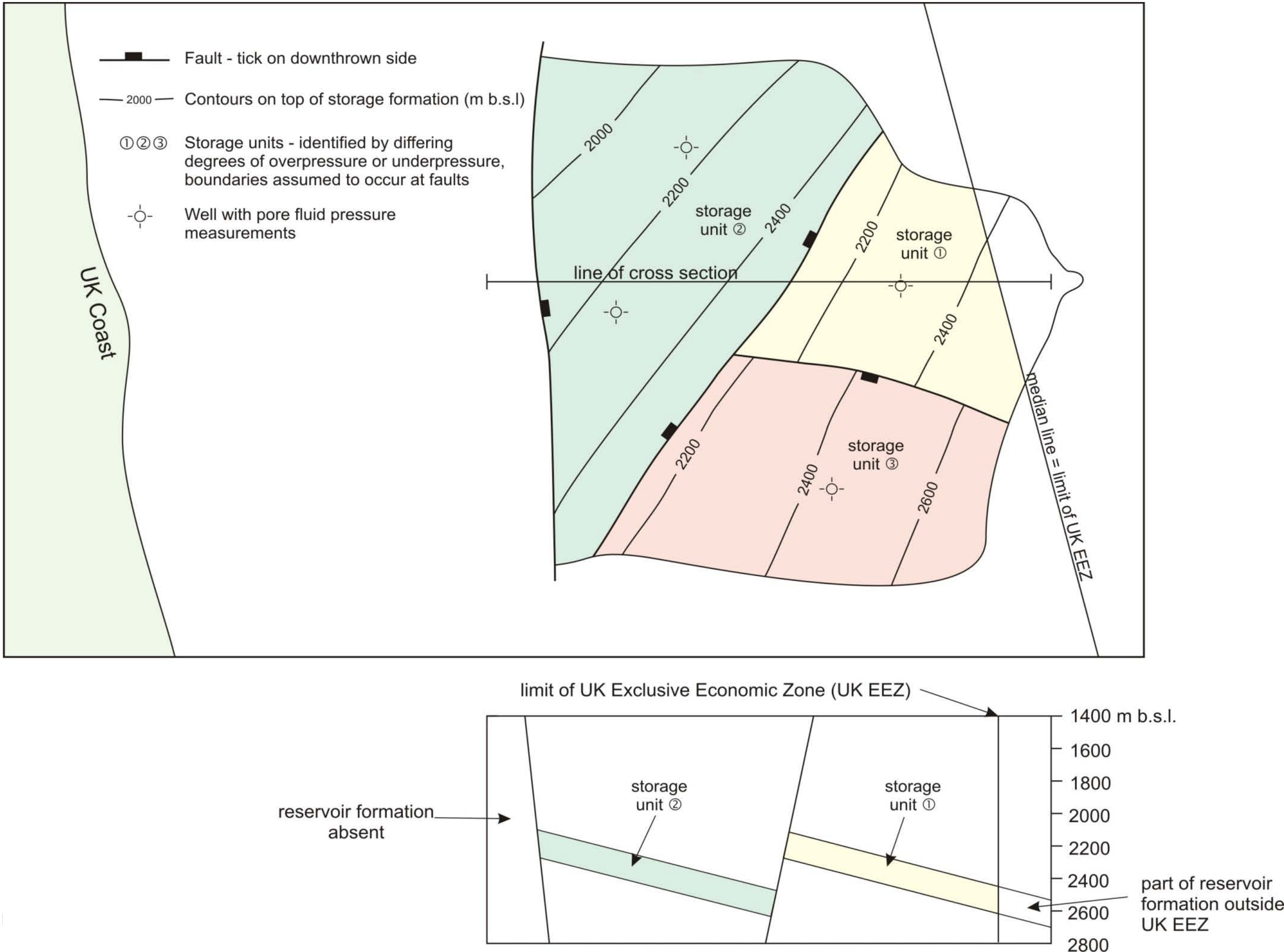
- The boundaries of an aquifer storage unit are the overburden, the underlying strata and the lateral margins of the unit (faults, pinchouts, etc.)
- The boundary conditions control brine displacement and pressure build-up, and hence $CO_2$ storage capacity



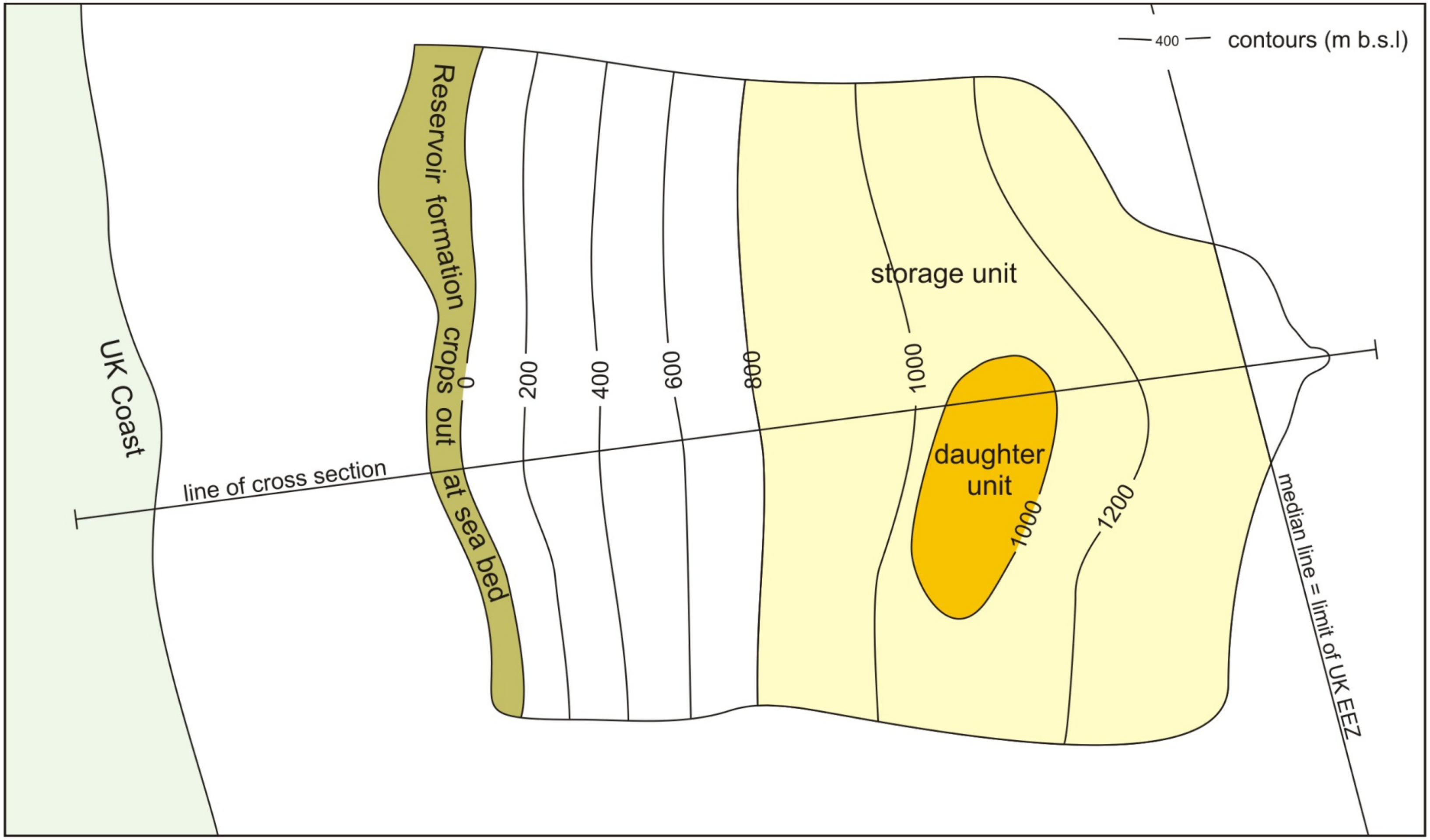
# End-member boundary conditions, UK examples

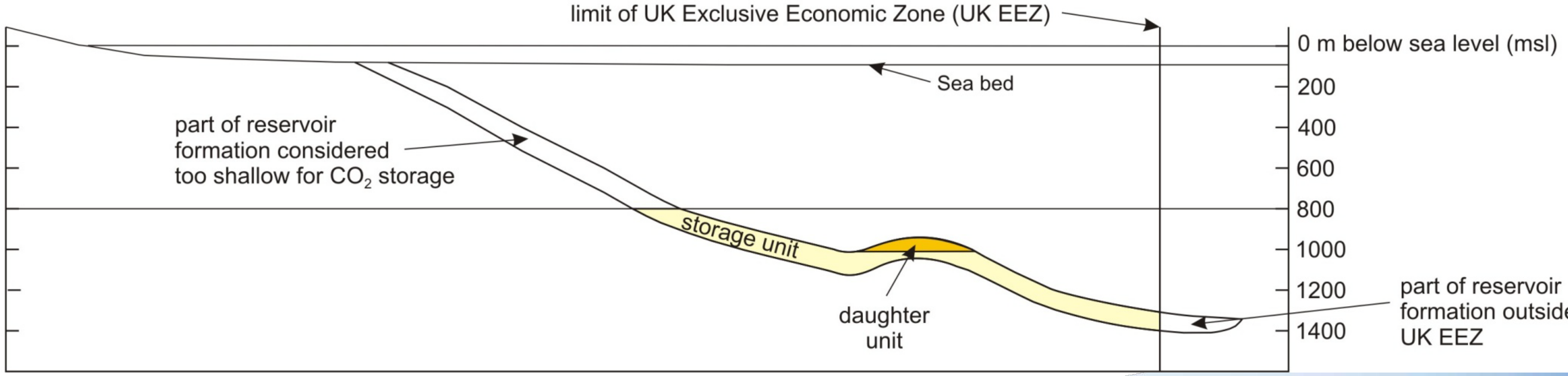
- To all intents and purposes totally closed
  - E.g. Fulmar compartments in Central Graben known from varying degrees of overpressure
- Open formation outcropping at sea bed with inferred good internal communication
  - E.g. Forties Sandstone Member, Utsira Sand

- In reality probably many intermediates
  - ?Leman Sst compartments – may break down when sufficient pressure difference across their boundaries
  - these treated as closed in UKSAP study


Fault - tick on downthrown side
2000 Contours on top of storage formation (m b.s.l)
①②③ Storage units - identified by differing degrees of overpressure or underpressure, boundaries assumed to occur at faults
Well with pore fluid pressure measurements
UK Coast
line of cross section
storage unit ②
storage unit ①
storage unit ③
2000
2200
2400
2600
median line = limit of UK EEZ
limit of UK Exclusive Economic Zone (UK EEZ)
1400 m b.s.l.
1600
1800
2000
2200
2400
2600
2800
reservoir formation absent
storage unit ②
storage unit ①
part of reservoir formation outside UK EEZ

©


400 contours (m b.s.l)
Reservoir formation crops out at sea bed
UK Coast
line of cross section
storage unit
0
200
400
600
800
1000
1000
1200
daughter unit
median line = limit of UK EEZ


limit of UK Exclusive Economic Zone (UK EEZ)
0 m below sea level (msl)
Sea bed
200
400
600
800
1000
1200
1400
part of reservoir formation considered too shallow for $CO_2$ storage
storage unit
daughter unit
part of reservoir formation outside UK EEZ

# Storage efficiency factors for open formations

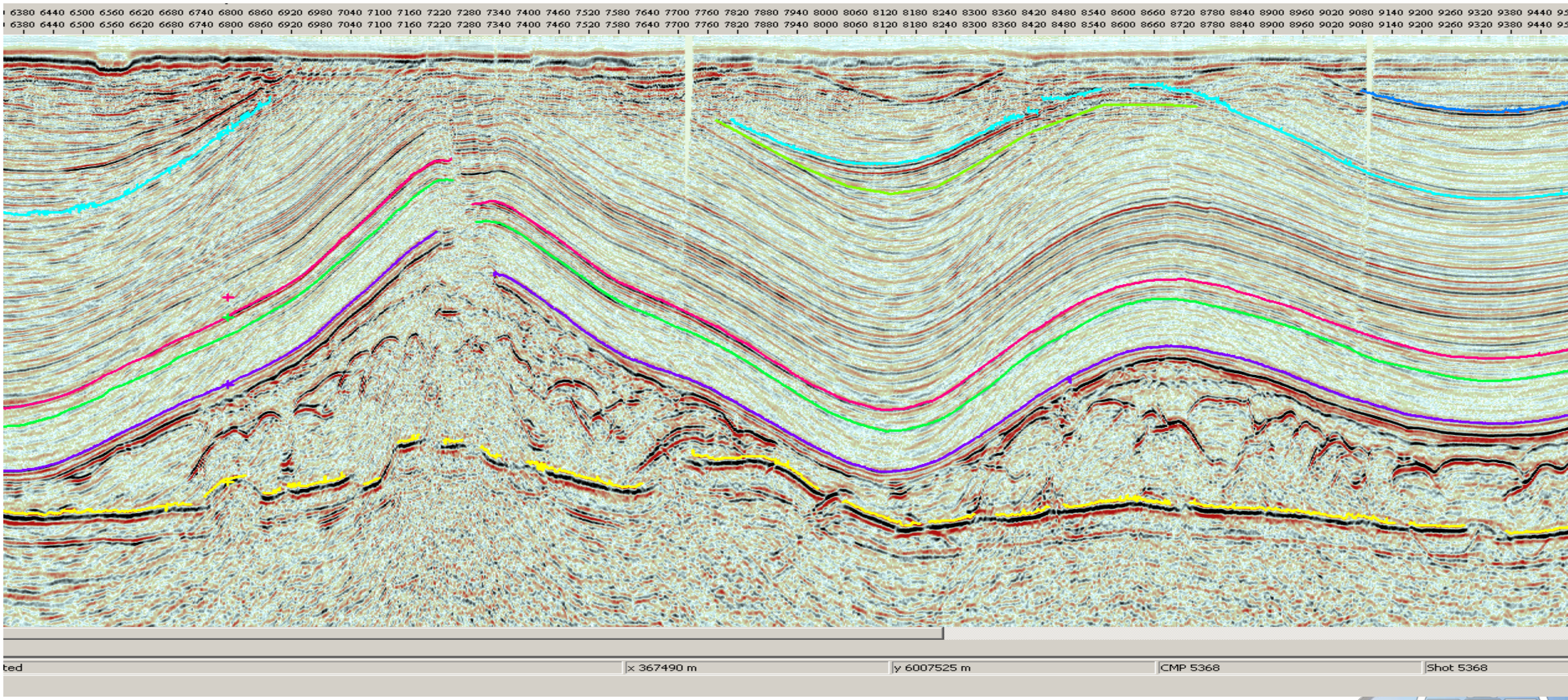
- Great uncertainty – in reality possibly quite site-specific
- Storage efficiency factors used in UKSAP discussed in next presentation
- Some previous estimates use IEAGHG 2009 study
- Factors used commonly around 2% of pore volume or less (range 0.1- >6%)
- Significantly higher than pressure cells – as might be expected because fluid can escape through seabed, creating space for $CO_2$.

# Hydrocarbon fields and other traps

- Can achieve higher $CO_2$ saturations than in other parts of formations
- Potential calculated separately but
  - Where parent unit is a pressure cell, take into account pressure effect on other (saline water-bearing) parts of the formation
  - Where parent unit is an open unit, subtract volume from parent unit before estimating its capacity

# Risk and geological uncertainty

Leakage a risk for buoyant storage – can be expressed as a distribution of the likelihood of the pore volume that acts as a trap. Basically a judgement by the assessor




Seismic data courtesy of WesternGeco

# Done that, what have I got?

- An estimate of the "$CO_2$ storage resource"
- How do I compare resource estimates across different countries?
  - If I consider pressure build-up can be managed and therefore it is solely an economic matter I could call this the "Technically Accessible $CO_2$ Storage Resource" © USGS, useful in laissez-faire economies
  - In the UKSAP project, the estimate assumes pressure mgmt wells will not be used (subset of TASR - Netherlands estimate makes same assumption)
  - Some estimates only consider storage in traps

# Economic dimension

- How to answer the policymakers question: “How much $CO_2$ storage capacity can be relied on a particular cost?”
  - Need to construct marginal storage cost curve
  - Needs good cost model
  - Advantage of assessment unit concept is that it provides a manageable basis for estimating costs
  - Dependent to some degree on concepts used to define transport and storage,
    - e.g. straight line transport from nearest gas import terminal to storage site

# Improving static capacity estimates

- In the next presentation you will find out how to convert these simple estimates into a sophisticated analysis
  - Storage efficiency factors
  - Injectivity
  - $CO_2$ migration
  - Accounting for rate of filling