

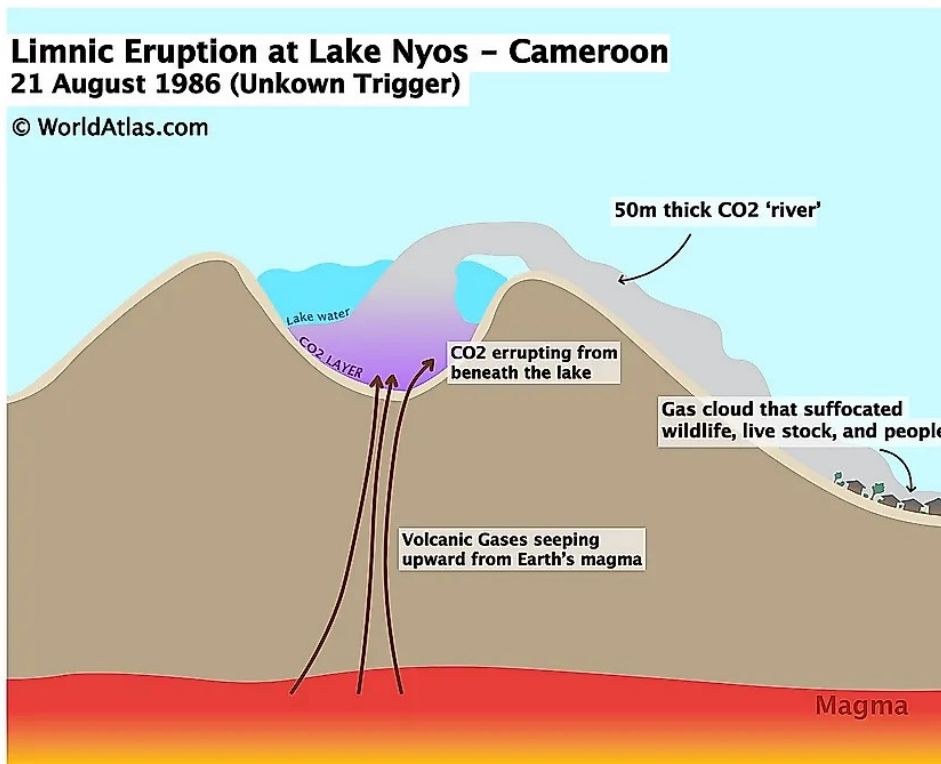
## The importance of a realistic leakage evaluation to support public awareness and acceptance for carbon capture and storage



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# Lake Nyos

**Greenpeace, 2008:** “As long as CO<sub>2</sub> is in geological sites, there is a risk of leakage....Continuous leakage, even at rates as low as 1%, could negate climate mitigation efforts....**A natural example of the danger of CO<sub>2</sub> leakage occurred at Lake Nyos, Cameroon in 1986. Following a volcanic eruption, large quantities of CO<sub>2</sub> that had accumulated on the bottom of the lake were suddenly release, killing 1700 people and thousands of cattle...**



# TV shows

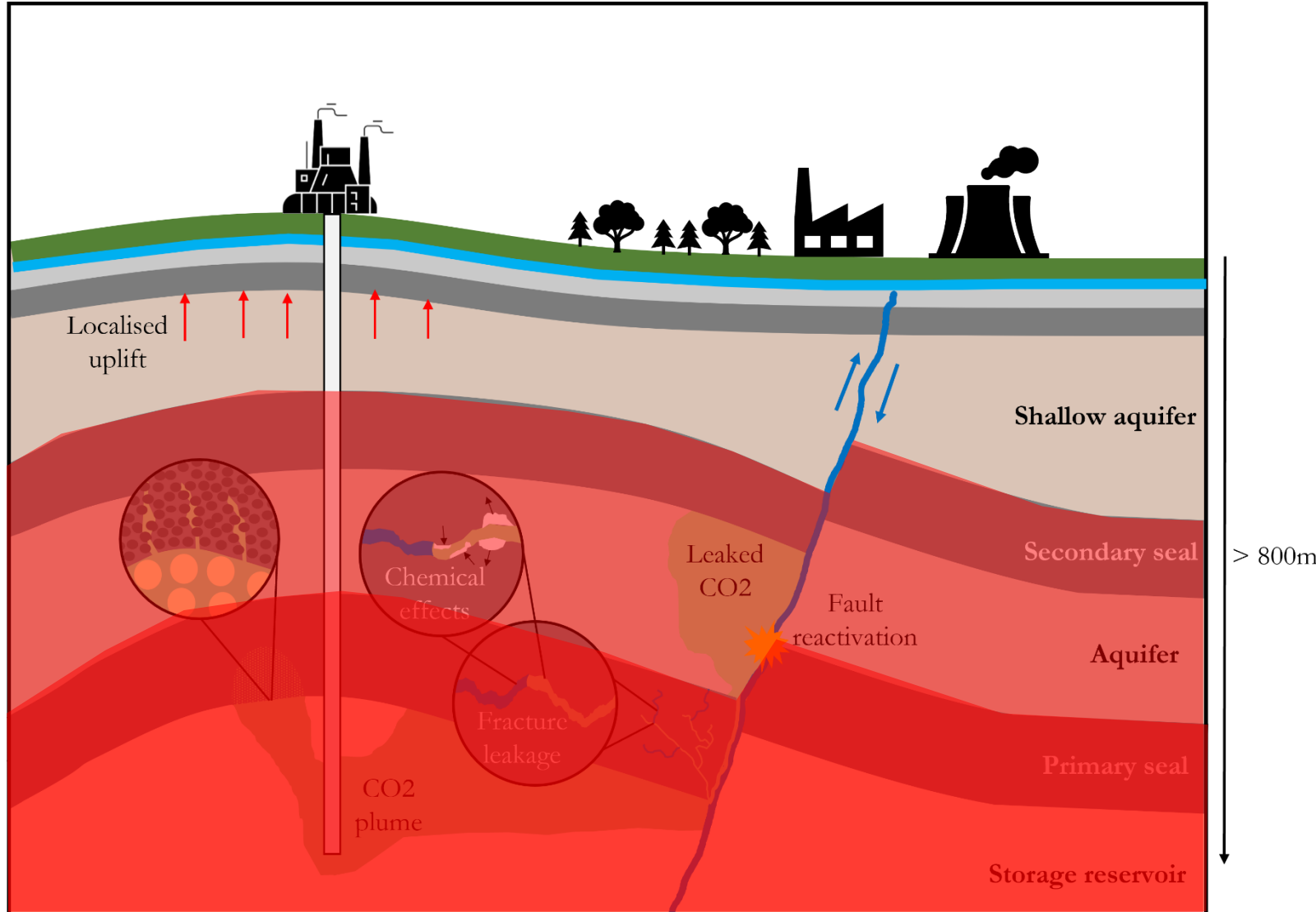
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2011





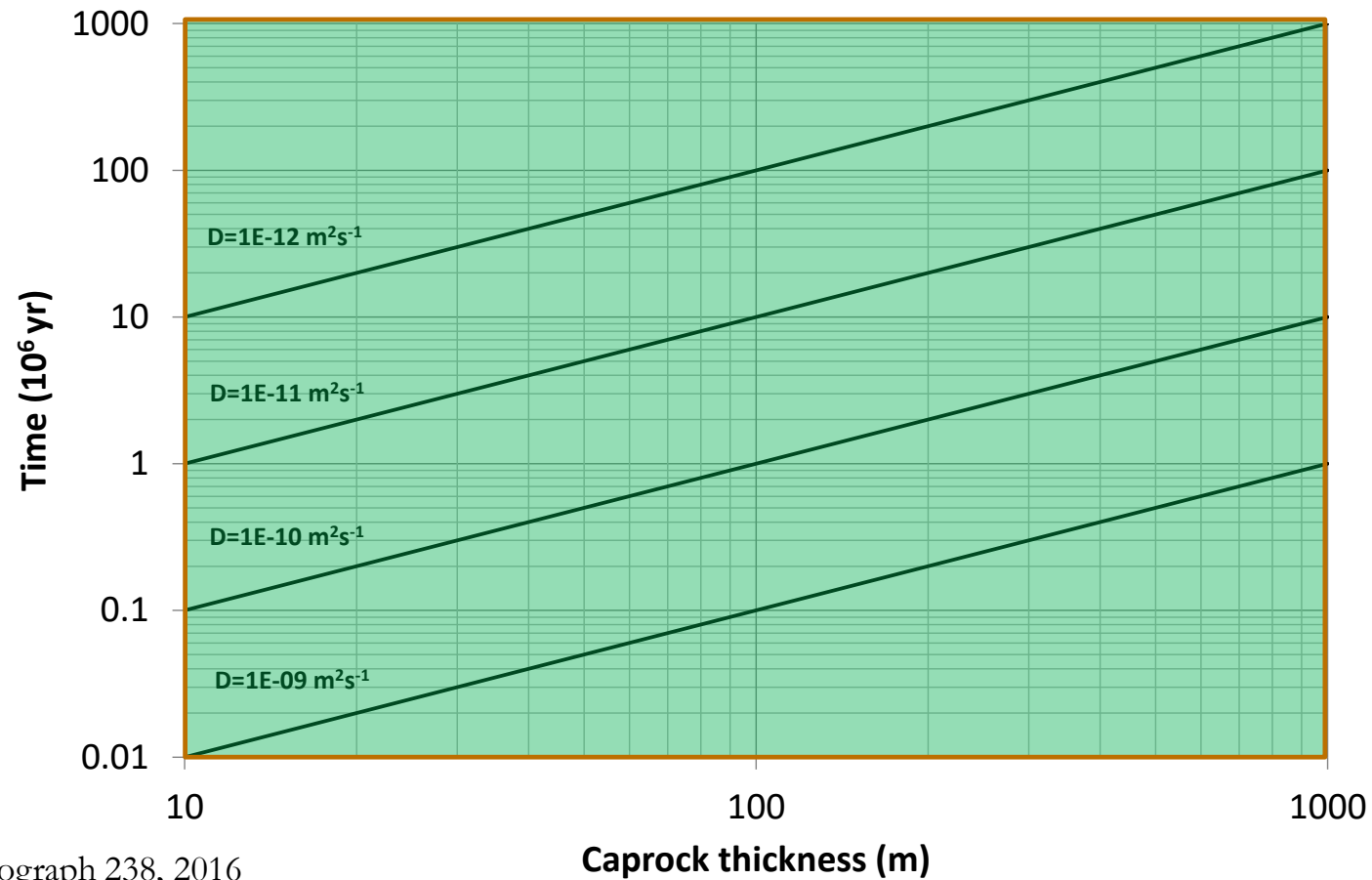
# Geological CO<sub>2</sub> Leakage



- Define the storage complex
  - Primary/secondary seals
- Faults/fractures
  - Seismic/sub-seismic?
- Advective/diffusive flow in matrix
  - Slow, irrelevant?
- Geochemical reactions?
  - Diffusion-driven; very slow?
- Induced seismicity
  - Stay away from faults
  - Manage pressures

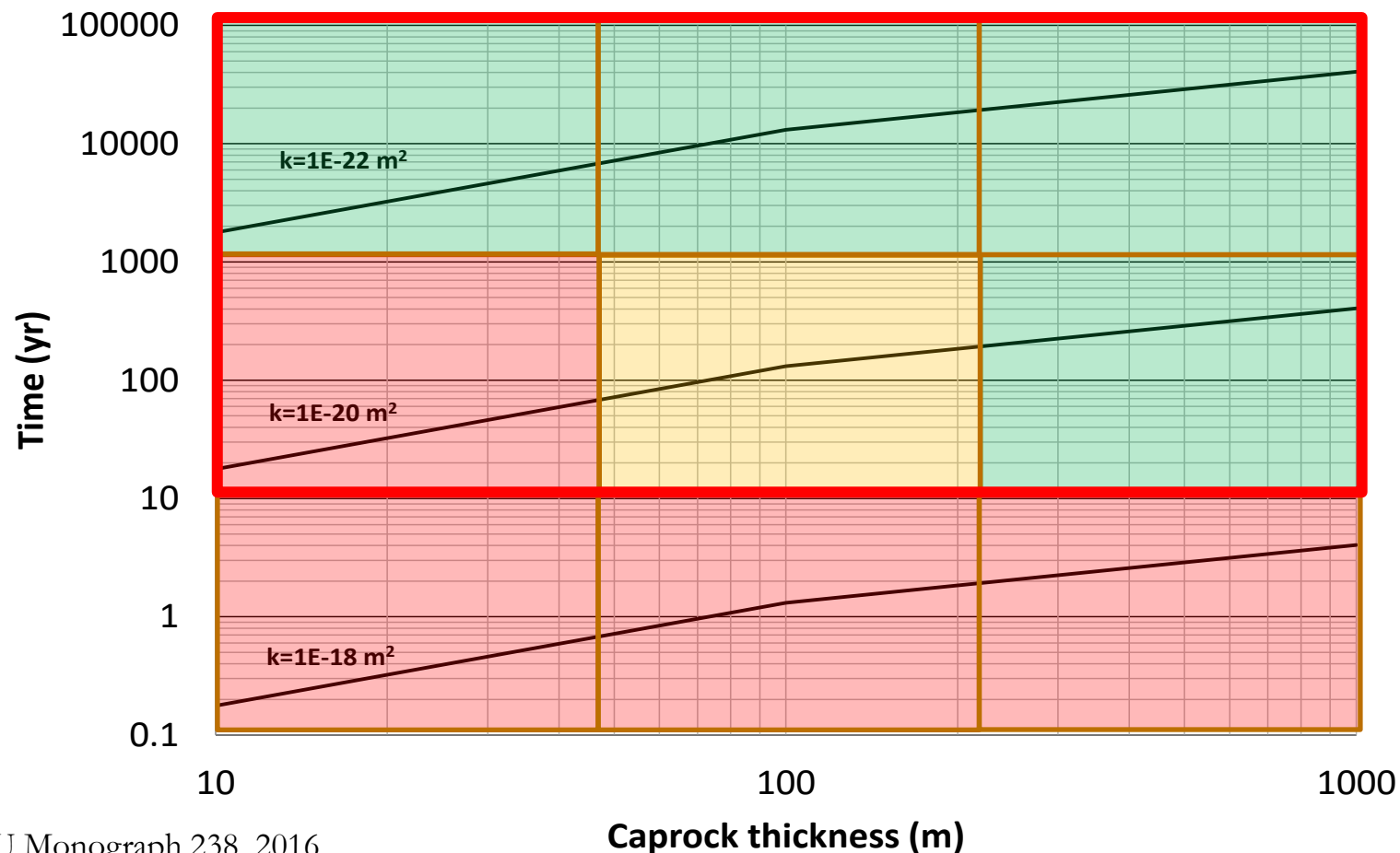
# Diffusive flow through matrix

- Diffusion occurs over geological time scales and is further reduced by geochemical reactions in the caprock

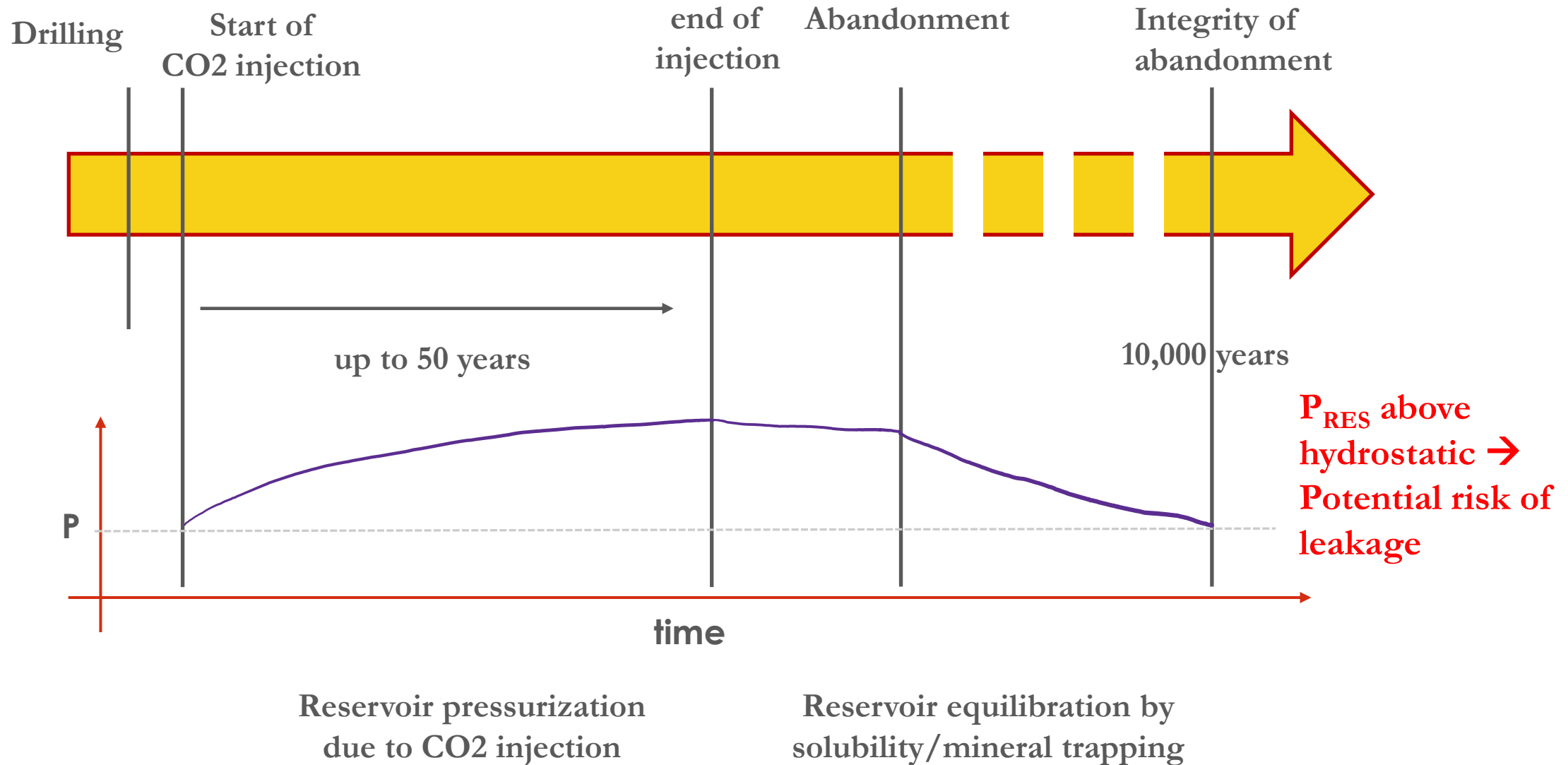


# Advective flow through matrix

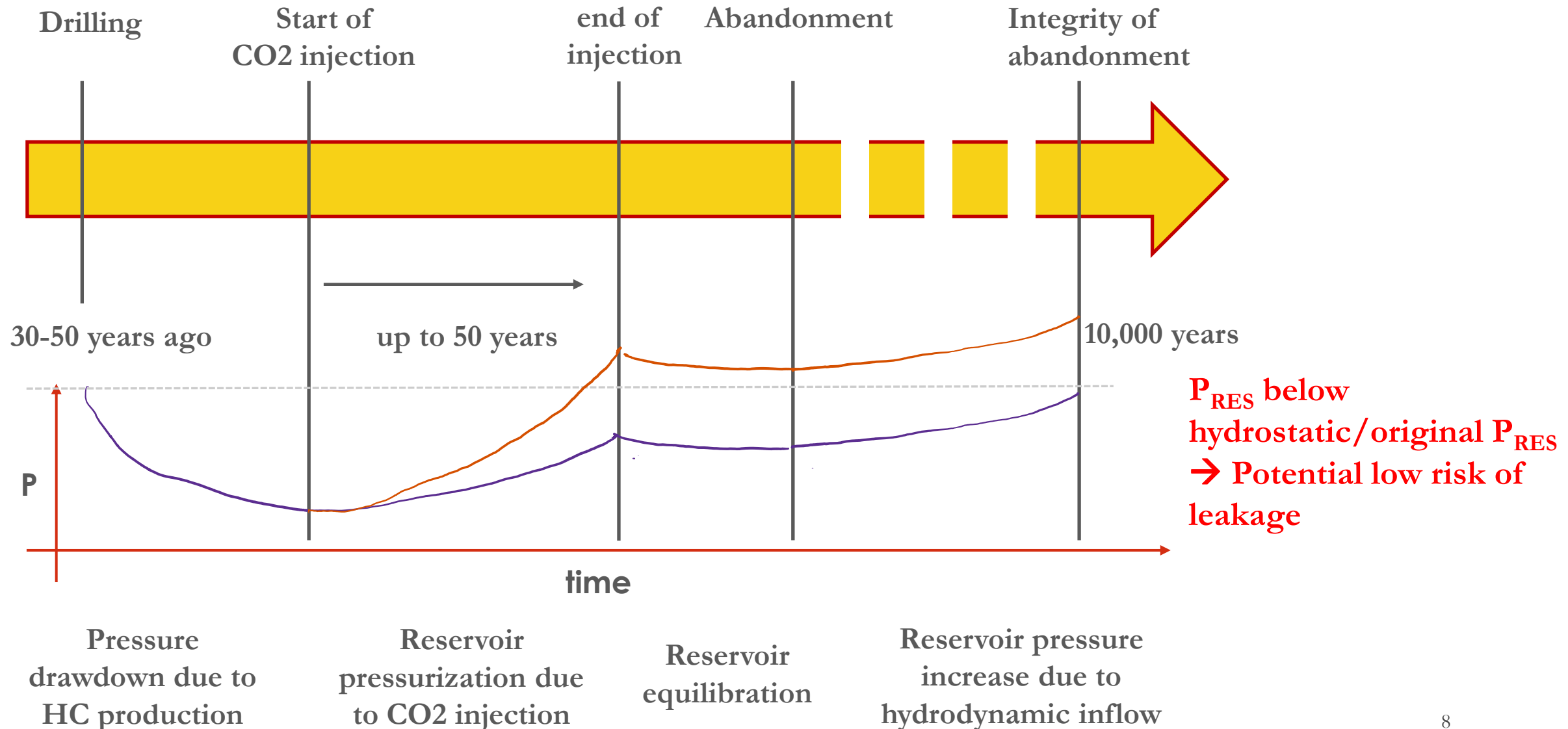
- Onset of capillary leakage at gas column heights  $>100$  m
- Gas flow occurs at low saturations resulting in low rates.



# Pressure evolution in saline aquifers

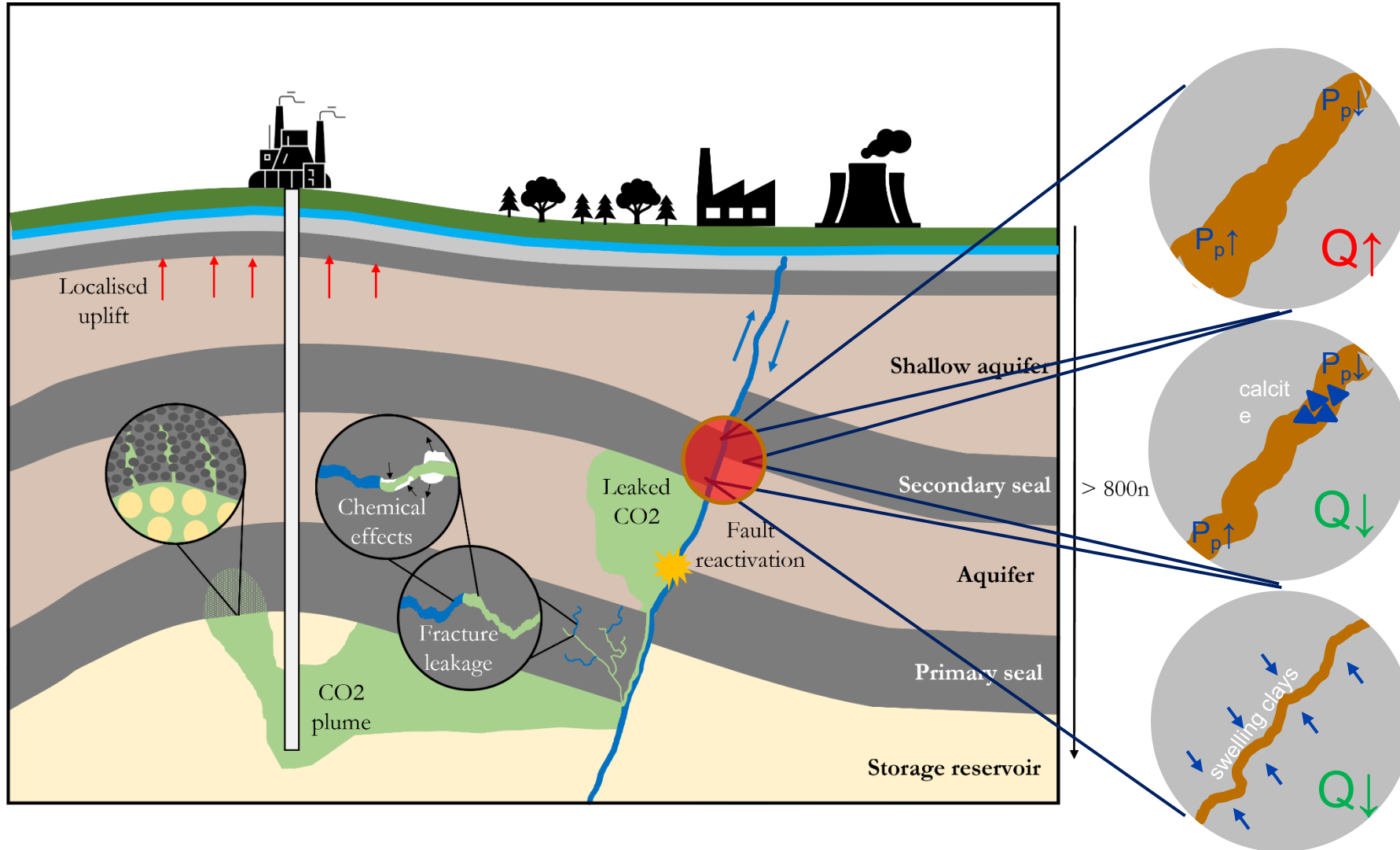


# Pressure evolution in depleted reservoirs



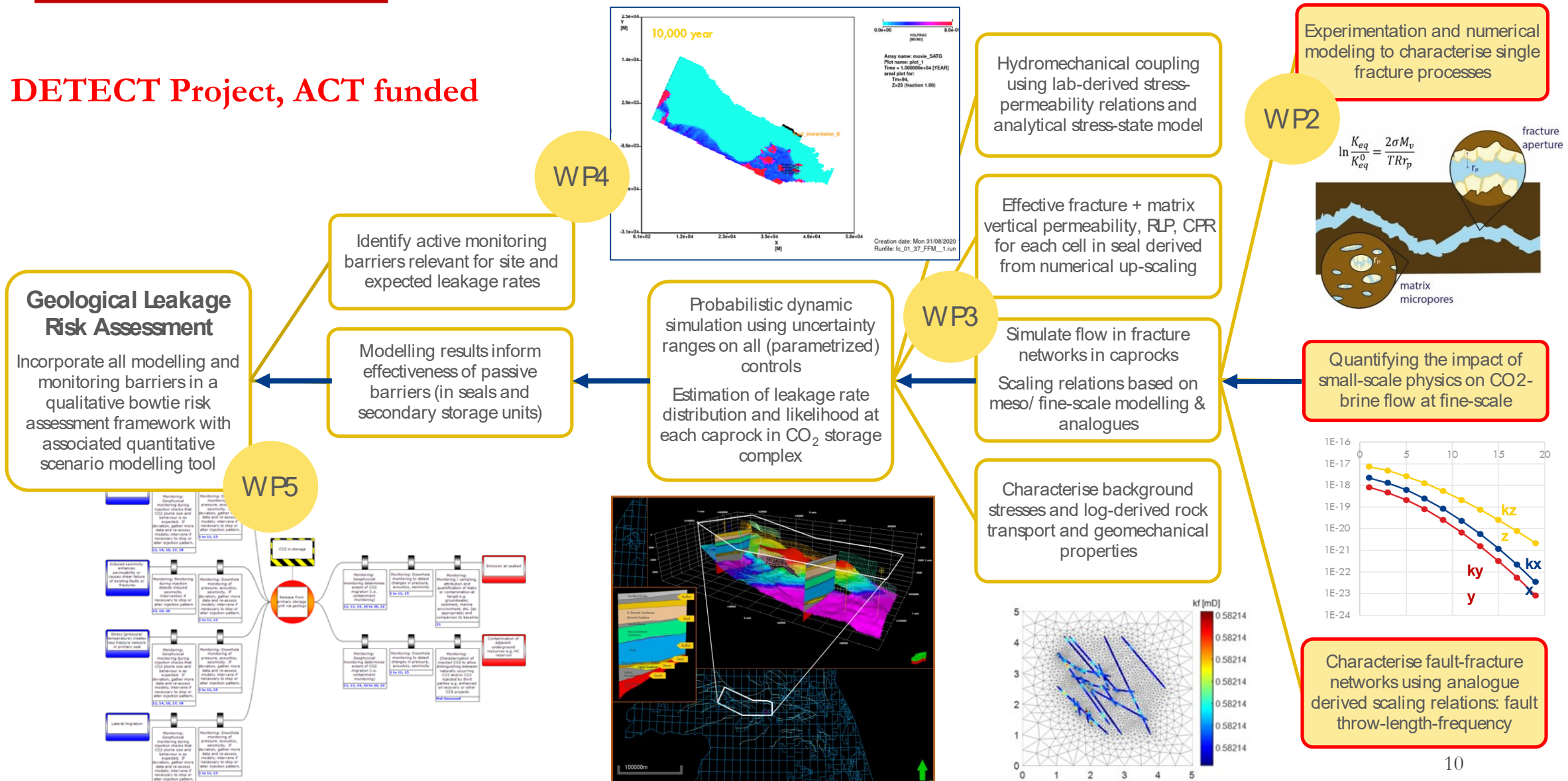


# Fault/Fracture leakage



# Workflow to assess fault leakage potential

DETECT Project, ACT funded

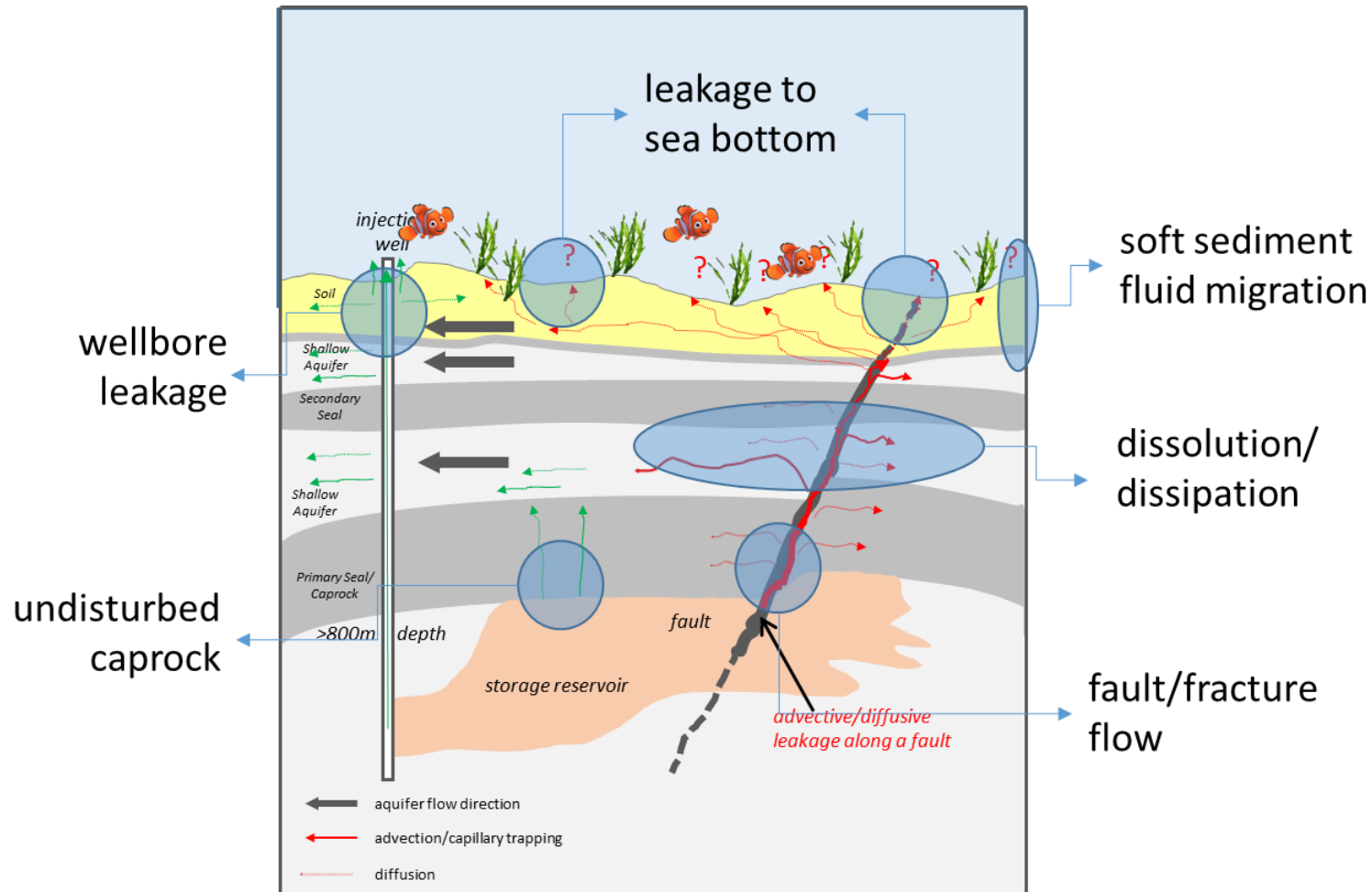


# Can we utilise the subsurface safely?

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- What leakage mechanisms are relevant?
  - **Wells** – but localised!
  - **Faults and Fracture Networks** → subject to future research
  - **(Induced Seismicity** → major area of research)
  - **Capillary Leakage**, only when seal of limited thickness and high permeability
  - **Diffusive Leakage** only over geol. time scales
- **Reservoir geology is key:** Know your playground, aquifer dynamics, regional seal distribution and thickness
- Standard and updated industry practice and risk assessment, especially when storage in depleted reservoirs
- Support by academia is key to better understand the ***unknown*** for every specific case study

# What is happening in the shallow overburden?



- Need for targeted **monitoring systems** focusing on the reservoir, top of caprock and shallow subsurface
- Need for case-specific, (semi)-quantitative **risk assessment** to identify key threats and barriers

# Time, rates and depth matters

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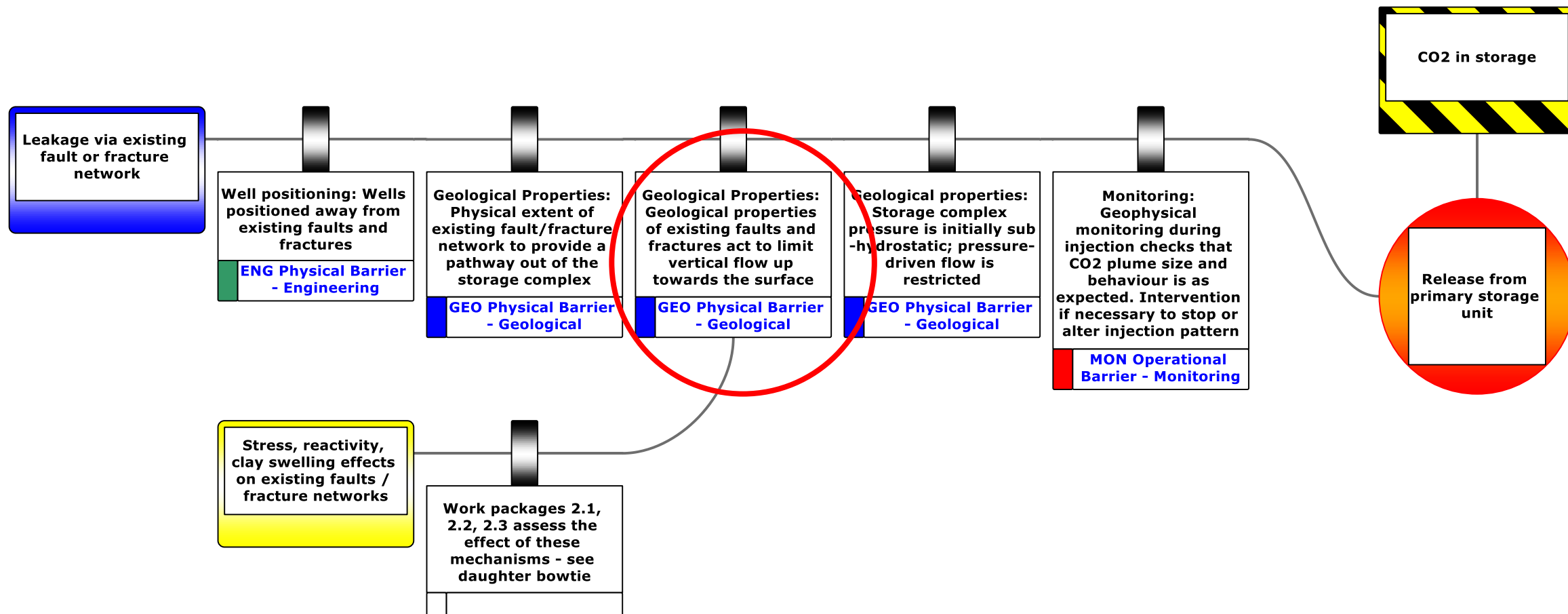
- Understand geological versus engineered time scales!
  - In CCS we care about short times scales (thousand's of years) compared to natural fluid flow occurring over millions of years
- CO<sub>2</sub> stores are at large depth and overlain by hundreds of meters of sediments!
- If leakage occurs, what rates are acceptable
  - For regulators?: any!
  - For public?: do we know or is the topic too complex?
  - For environment?: do we know or is the topic too complex?

**MANY THANKS!**

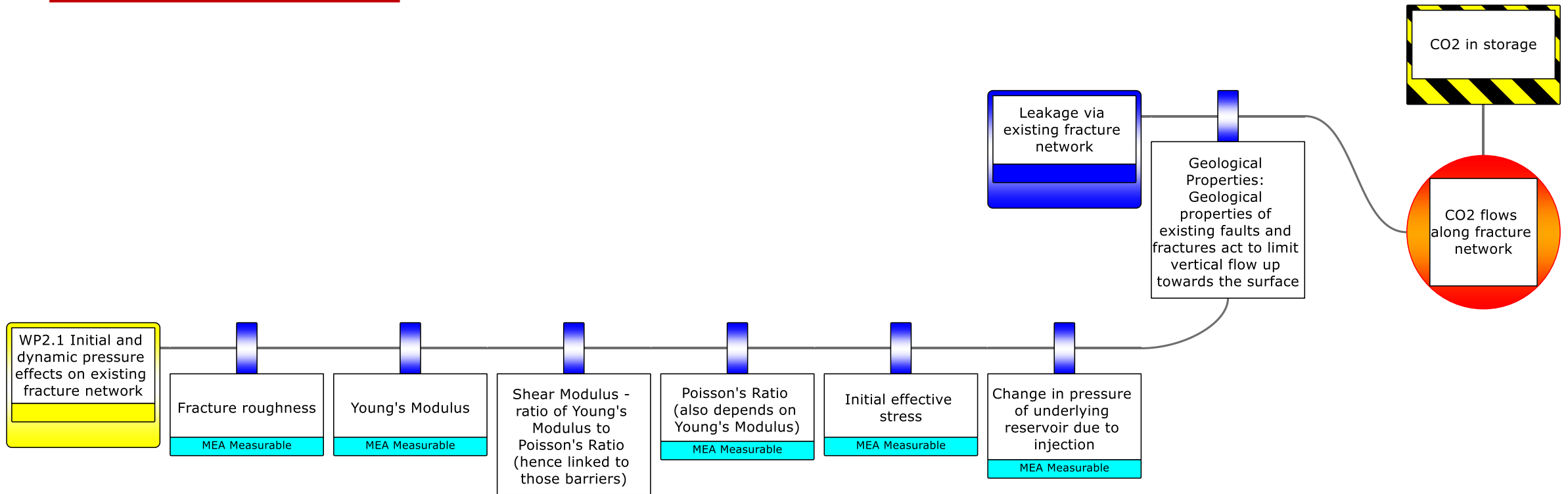


**BACKUP**

# Bowtie RA: Fracture/fault leakage



# Reservoir pressure changes



# Geochemical effects

