CARBON MANAGEMENT TECHNOLOGY CONFERENCE

CARIBE ROYALE HOTEL & CONVENTION CENTER
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Potential Impacts of CO_2 Storage on Groundwater Resources

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IEA Greenhouse Gas R&D Programme

Carbon Management Technology Conference
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Evaluating technology options to mitigate greenhouse gas emissions

ieaghg

Project Contractor

- Study commissioned by IEAGHG and carried out by CO_2GeoNet
- Lead by BRGM

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Content of Presentation

- Potential Overlap of Resources
- Classification of potential impacts and overlap
- Potential Leakage Mechanisms
  - Chemical Effects
  - Physical Effects
  - Analogues
  - Modelling Studies
- Regulations
- Mitigation and Remediation

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Potential Overlap of Resources

- Consideration of groundwater protection in site selection
- Global distribution - GIS based approach
- WHYMAP – world hydrological mapping and assessment programme
    - Lack of depth data
- Storage Maps - Globally, only limited data are available - Regional Approach used
    - Geocapacity
    - NatCarb
    - Other less detailed maps e.g. China

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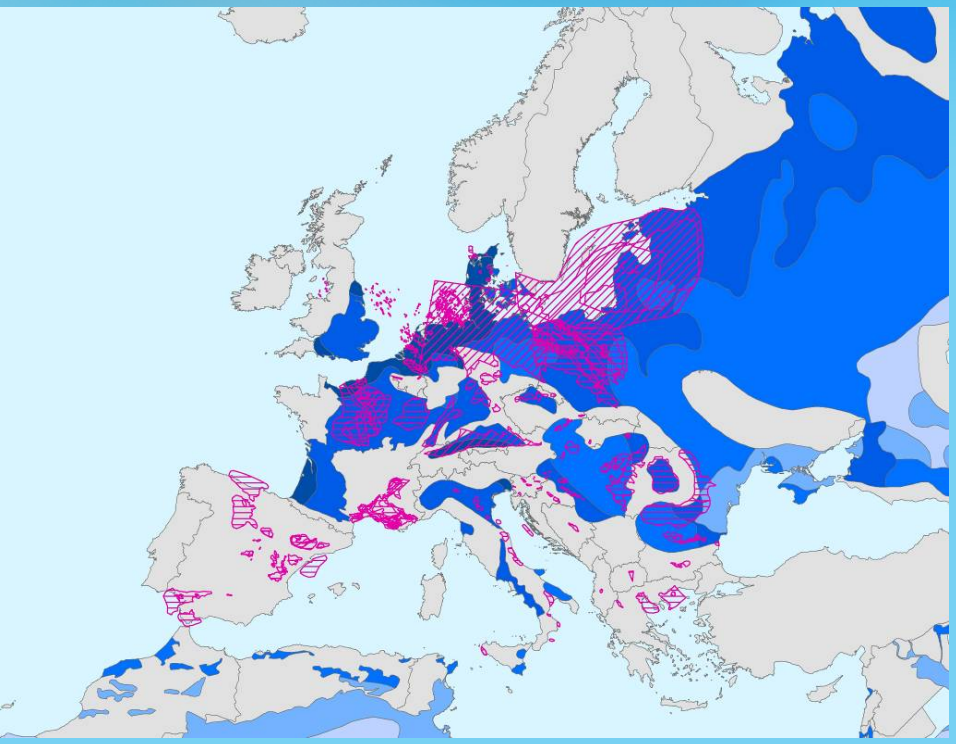
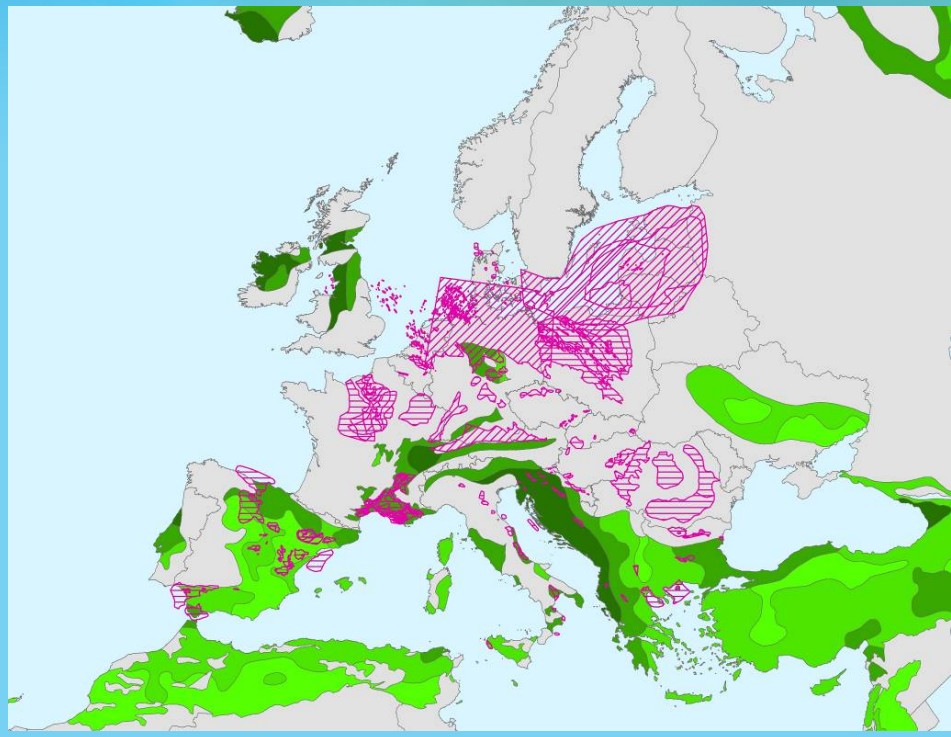
Geographical Overlap - Europe



Combining GEOCAPACITY data on DSF both (pink) with WHYMAP thematic layers representing **large, uniform freshwater aquifers** (blue).



Combining GEOCAPACITY data on DSF(pink) with WHYMAP thematic layers representing areas with **complex hydrogeological structure** (green)

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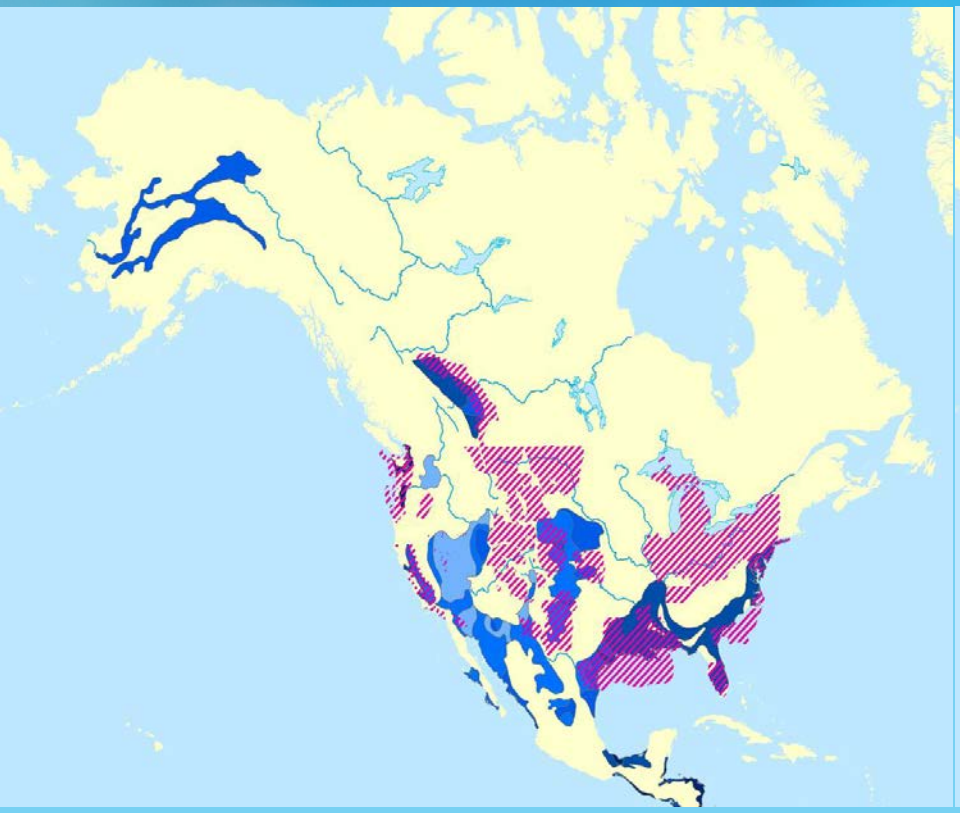
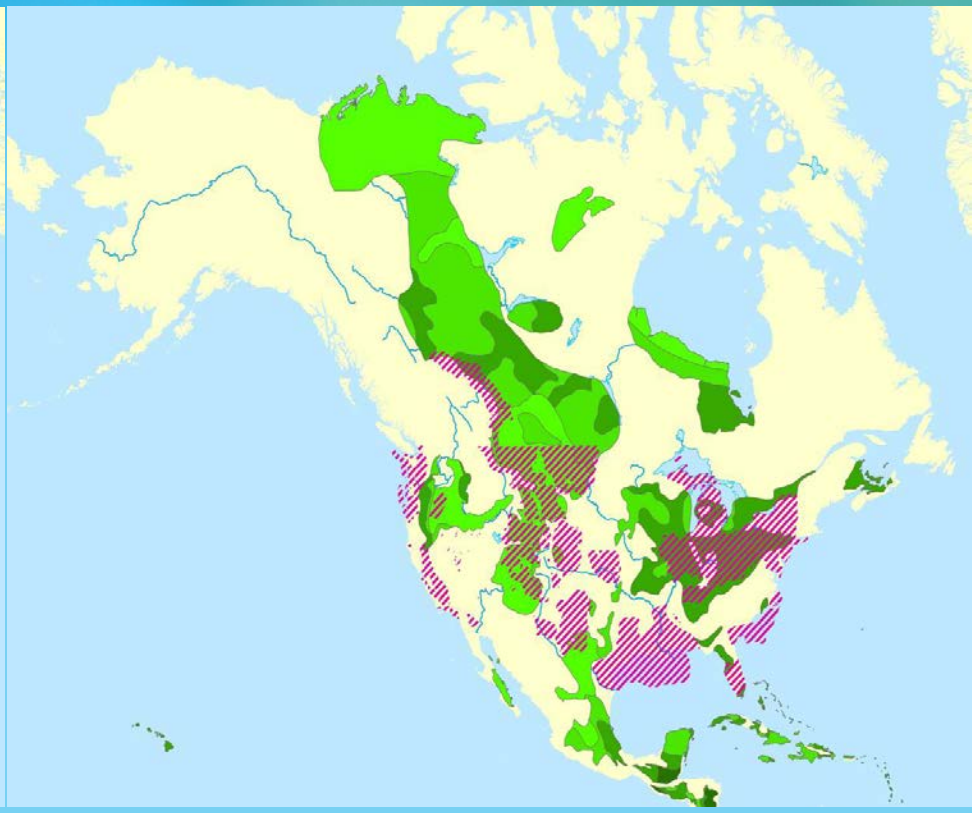
Geographical Overlap - N. America



Combining data on DSF from the Carbon Sequestration Atlas (pink) with WHYMAP thematic layer representing **large, uniform freshwater aquifers** (blue)



Combining data on DSF from the Carbon Sequestration Atlas (pink) with WHYMAP thematic layer representing areas with **complex hydrogeological structures** (green)

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Typologies/Mapping Scenarios

- Areas with potential DSF storage overlain by:
  - Large, uniform freshwater aquifers
  - Complex hydrogeological structures where productive potable aquifers (including karst) may occur in close vicinity to non-aquifers
  - Localised/ very shallow aquifers
  - Formations containing saline groundwater
  - Over-exploited groundwater resources
- Areas with no DSF suitable or identified for CO_2 storage

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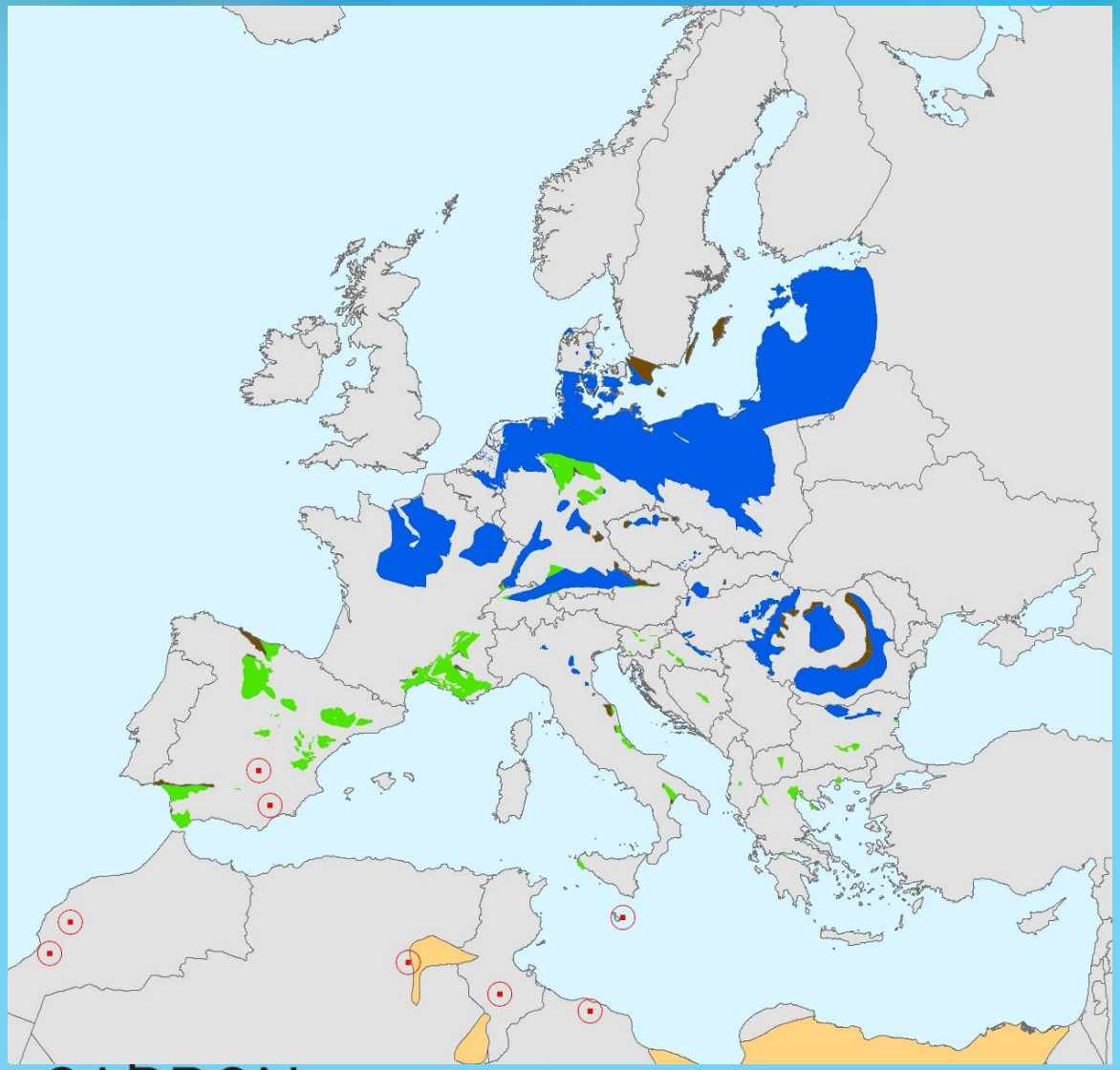
Typology Map



Blue: large and uniform freshwater aquifers (Type a).

Green: complex hydrogeological structures (Type b).

Brown: areas with local/shallow aquifers (Type c).

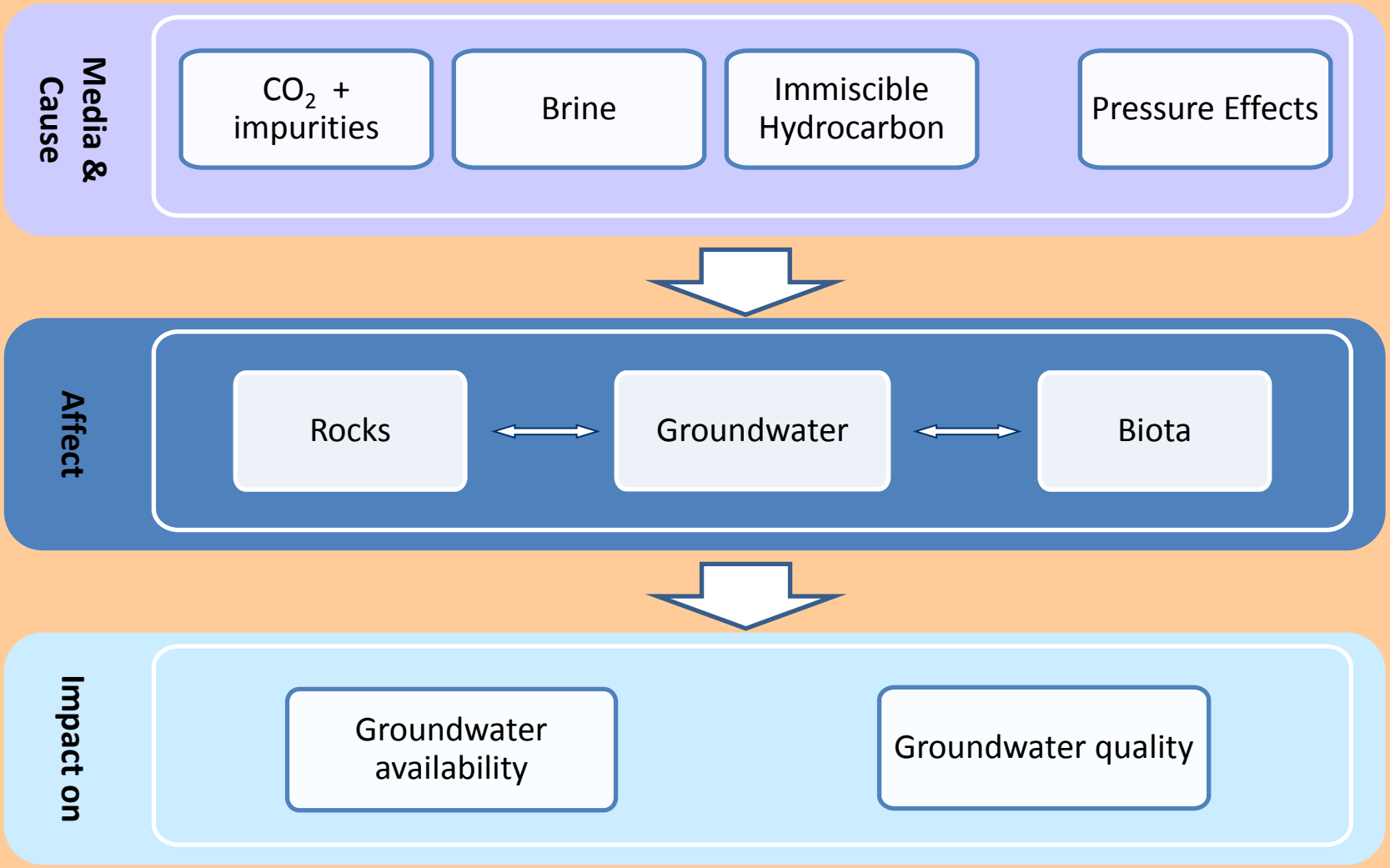
Grey: areas with no deep saline formations suitable for CO_2 storage (Type f).

Orange: Areas with saline surface waters

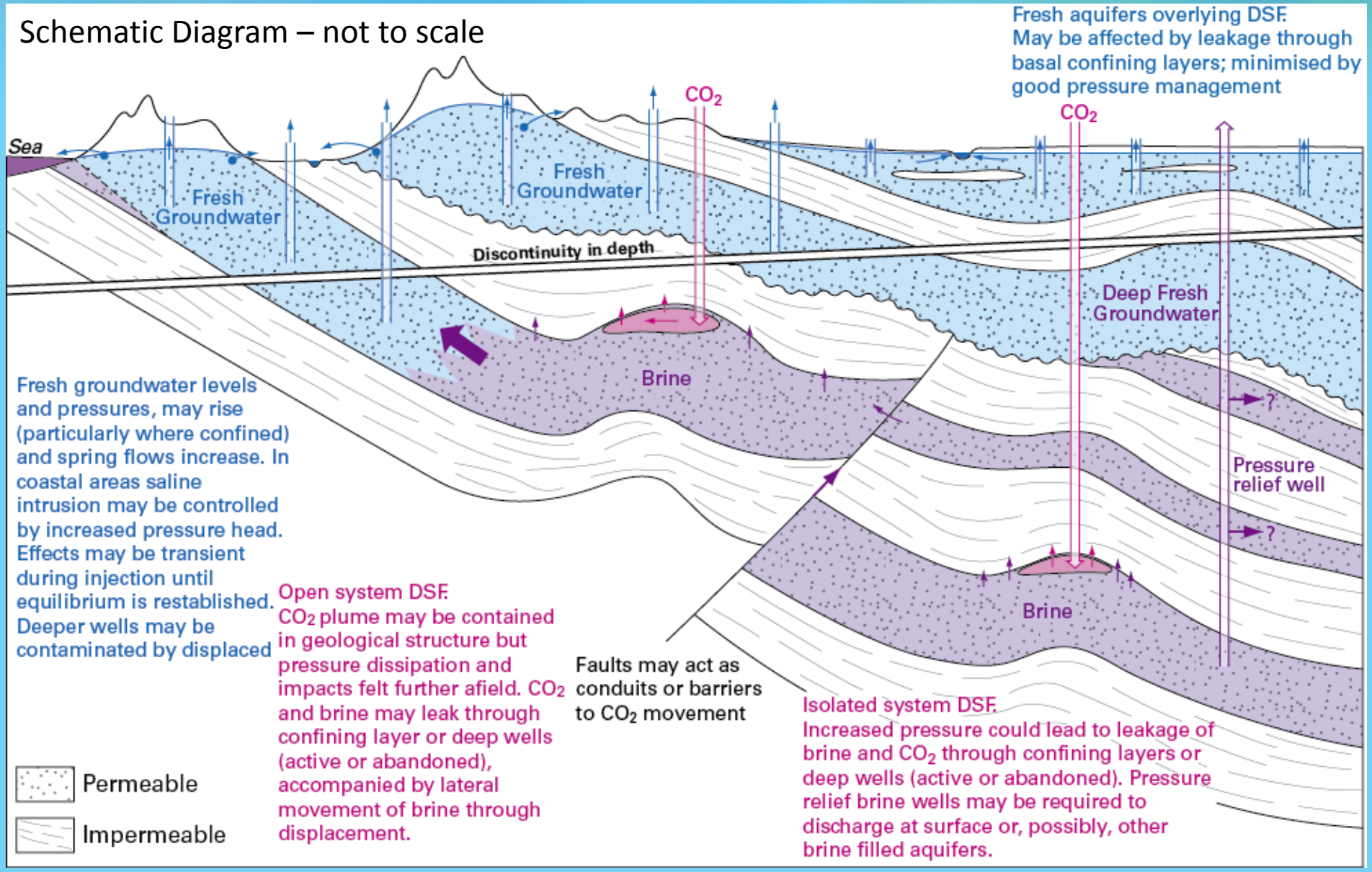
Red symbols - areas of heavy groundwater abstraction with overexploitation.

Impact Mechanisms

Potential Impacts of CO_2 Storage on Shallow Groundwater



Potential Leakage Pathways



Natural Analogues

- Pressure effects
  - Natural gas storage
- Chemical effects
  - Lab experiments
    - limited use. Reaction rates several orders of magnitude higher compared to field conditions
  - Industrial Analogues
    - Acid-gas injection, CO_2-EOR, brine injection
  - Natural Analogues – CO_2 accumulations
    - Mostly volcanic and fractured - not good CO_2 storage analogue, but potential analogue for leakage into groundwater

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Modelling Studies

- Review of modelling studies
- Basin Scale modelling Hydrodynamics
  - Single phase approach
  - Reservoir Flow Simulator
  - Analytical Modelling
- Geochemical models take into account
  - initial mineralogy
  - possible thermochemical reactions
  - kinetic rate of the reactions and surface complexation.
- Chemical impacts considered
  - Acidification and release of solutes
- Limited number of studies - effect on groundwater

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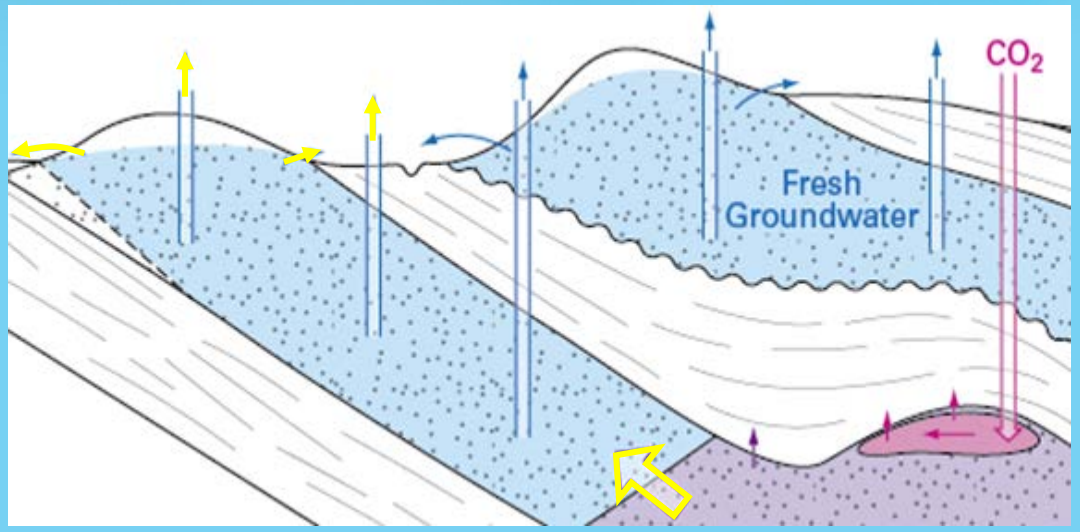
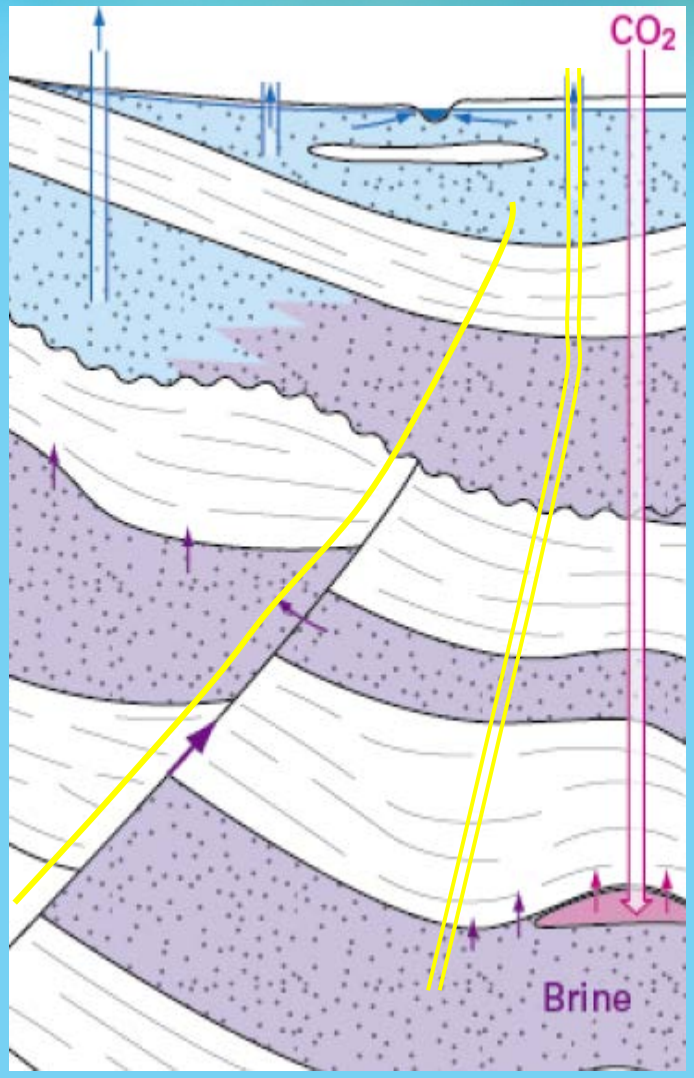
Pressure effects

displacement of brine in ‘open’ aquifers





- faults, abandoned wells
  - characterization and monitoring of pathways

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Pressure Effects

- Hydrodynamic models show effect of pressurisation over much larger area than associated CO_2 plume
- **Pressure pulse** will rapidly attain a large extent (up to 100 or 200 km) **within the storage formation.**
- Pressure pulse is largely controlled by the **amount of injected CO_2** and the **permeability of the sealing rock**.
- Pressure in the vicinity of the injection well can reach values of several tens of bars, while the **impact on the head pressure in surface outcrops is much less**.

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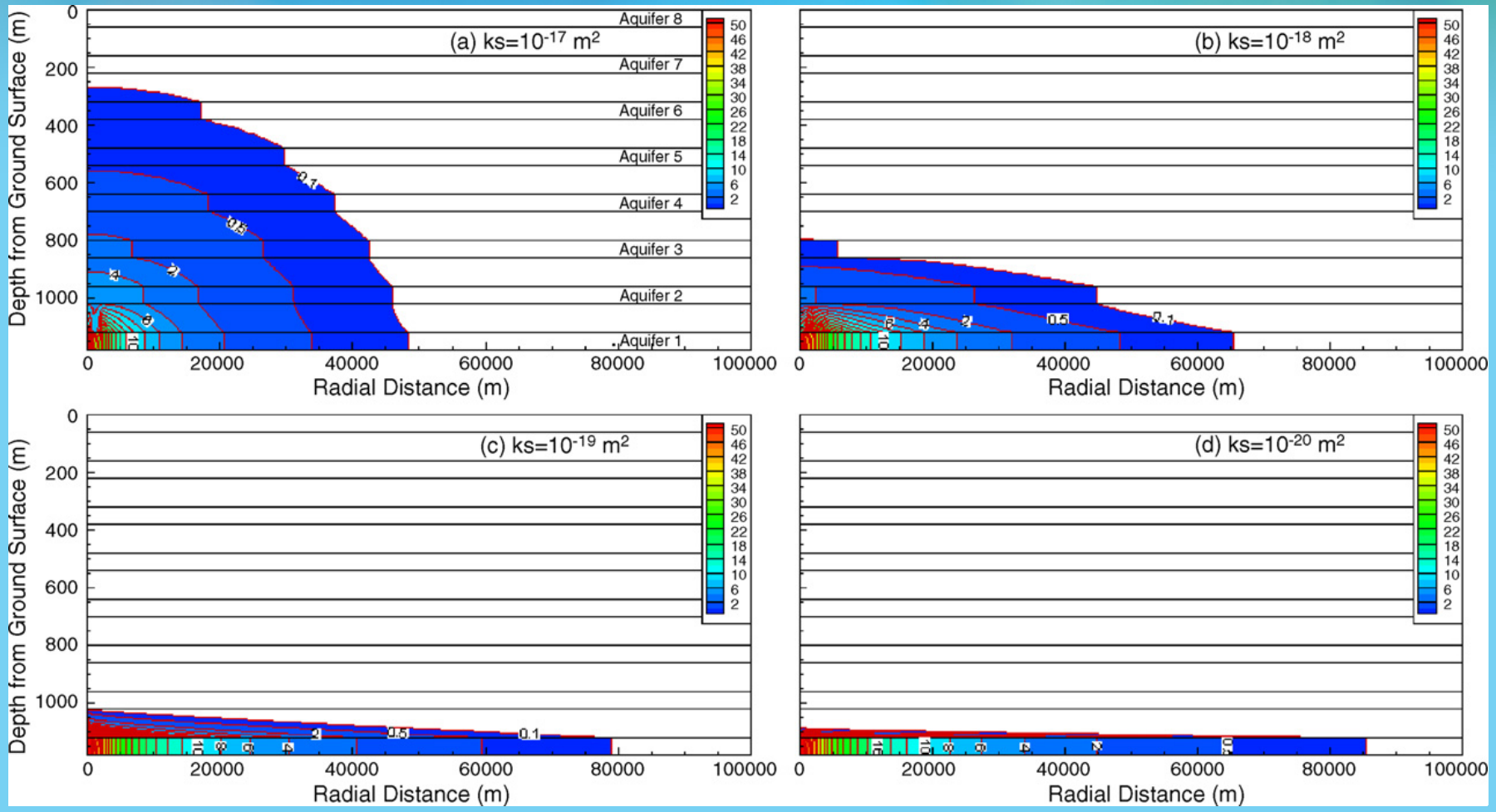
Effect of Seal Permeability



Pressure build-up after 30 years of injection for different seal permeabilities – adapted from Birkholzer et al, 2009

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Potential Chemical Processes

- Modifications in flow
- Migration of dissolved organic compounds
- Mineral dissolution
- Precipitation of carbonates / other secondary minerals resulting from rock alteration
- Co-precipitation and sorption of metals
- Changes in microbiological activity
- Aqueous complexation of cations that can promote solubility

Regulations

- Regulations from different countries reviewed
- Some measures particular to groundwater protection
- Existing groundwater protection rules
  - could be some legal barriers against the storage of CO_2 in deep saline aquifers.
  - Amendments needed to allow injection of CO_2 such as in the European Directive for CO_2 storage. Or injection likely to depend on authorisation/ permit by authorities in charge of the protection of groundwater.

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Mitigation

- Reduction of pressure in the storage reservoir – Brine/ CO_2 extraction
- Interception and extraction of CO_2 plume followed by reinjection
- Increase of pressure in the formation into which leakage is occurring.
- Isolation (shut-off) of CO_2 leaks in identified and accessible locations

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Summary

- Areas of geographical overlap between potential DSF CO_2 storage and overlying potable aquifers identified – WHYMAP and regional storage maps.
- Classification scheme developed for various geological settings in which conflicts could occur - tested for Europe
- Two approaches have been used to address potential impact mechanisms of CO_2 storage projects on the hydrodynamics and chemistry of shallow groundwater.
  - natural or industrial analogues; laboratory experiments.
  - hydrodynamic and geochemical models,
- Possible mitigation options assessed include
  - Extraction of CO_2 / brine from the storage/ overlying formations

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Thank You / Questions

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