Understanding the risks associated with CCS: an overview

Wolfgang Heidug

Shell International Renewables

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Capture and transport

- Risks proportional to the magnitude of potential hazard and probability that these hazards will occur

- Capture: regular health, safety, environment risks in industrial operations – no fundamental challenges

- Transport: comparable to or lower than risks of hydrocarbon pipelines

Nature of storage risks

Geological storage risks

Local

–Elevated gas-phase concentrations in the near-surface environment

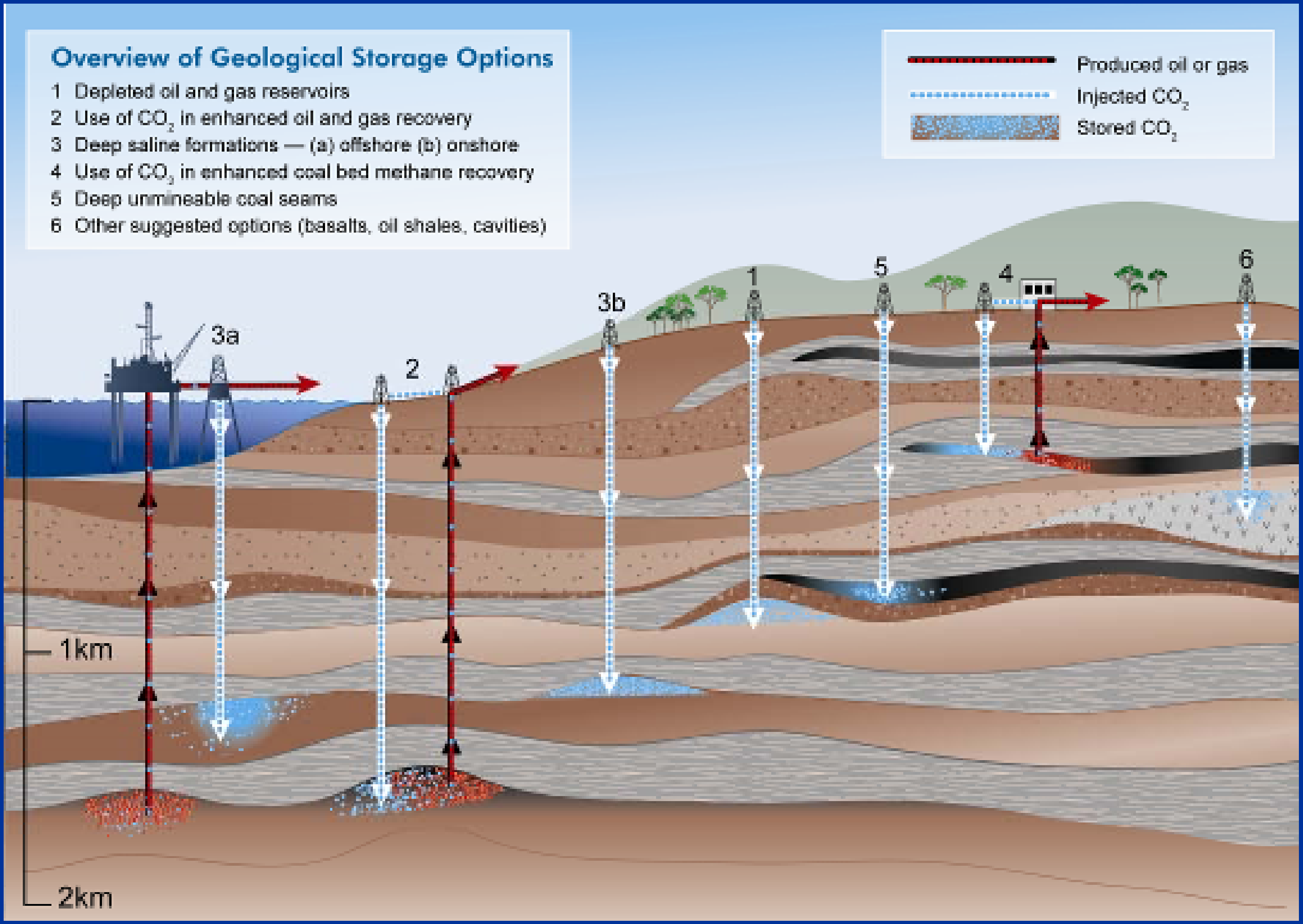
–Effects of dissolved CO_2 on groundwater chemistry

–Effects that arise from the displacement of fluids by the injected CO_2

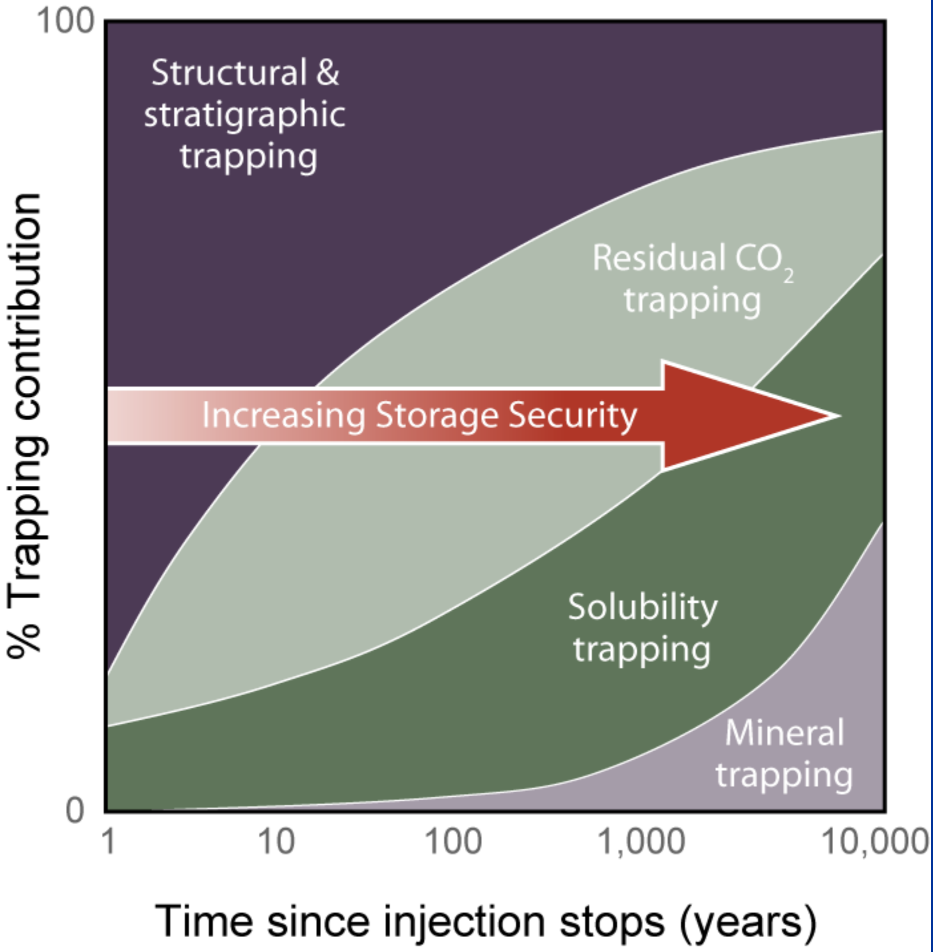
Global

CO_2 back to the atmosphere

Options for storing CO2 in deep underground geological formations



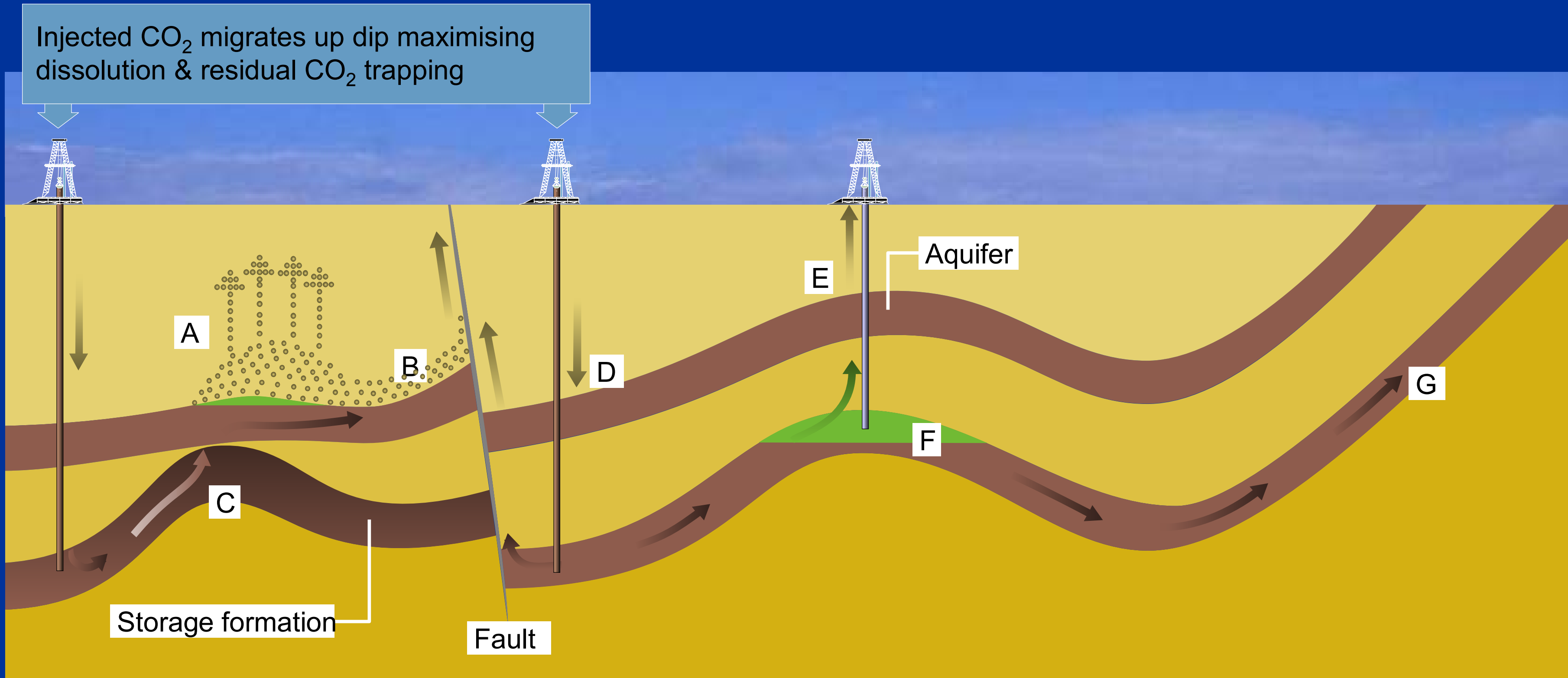
What keeps CO_2 underground?



Storage performance depends on a combination of physical and geochemical trapping.

Over time, residual CO_2 trapping, solubility trapping and mineral trapping increase.

How could it leak?



Potential escape mechanisms

- A. CO_2 gas pressure exceeds capillary pressure & passes through siltstone
- B. Free CO_2 leaks from A into upper aquifer up fault
- C. CO_2 escapes through 'gap' in cap rock into higher aquifer
- D. Injected CO_2 migrates up dip , increases reservoir pressure & permeability of fault
- E. CO_2 escapes via poorly plugged old abandoned well
- F. Natural flow dissolves CO_2 at CO_2 /water interface & transports it out of closure
- G. Dissolved C escapes to atmosphere ocean

Risk Management

1. Site Selection
2. Risk Assessment
3. Monitoring & Verification
4. Remediation Planning

- **Pre-Injection**
  - Characterization of the site
  - Long-term risk assessment
  - Monitoring
  - Remedial measures
- **Operation**
  - *S*hort-term prediction
  - Monitoring of the site to verify the predictio
- **Abandonment**
  - Update of long-term assessment
  - Decide on duration of site-specific monitori
- **Post-abandonment**
  - Update assessment & transfer of liabili
  - site-specific monitoring, if necessary

What makes a good storage site?

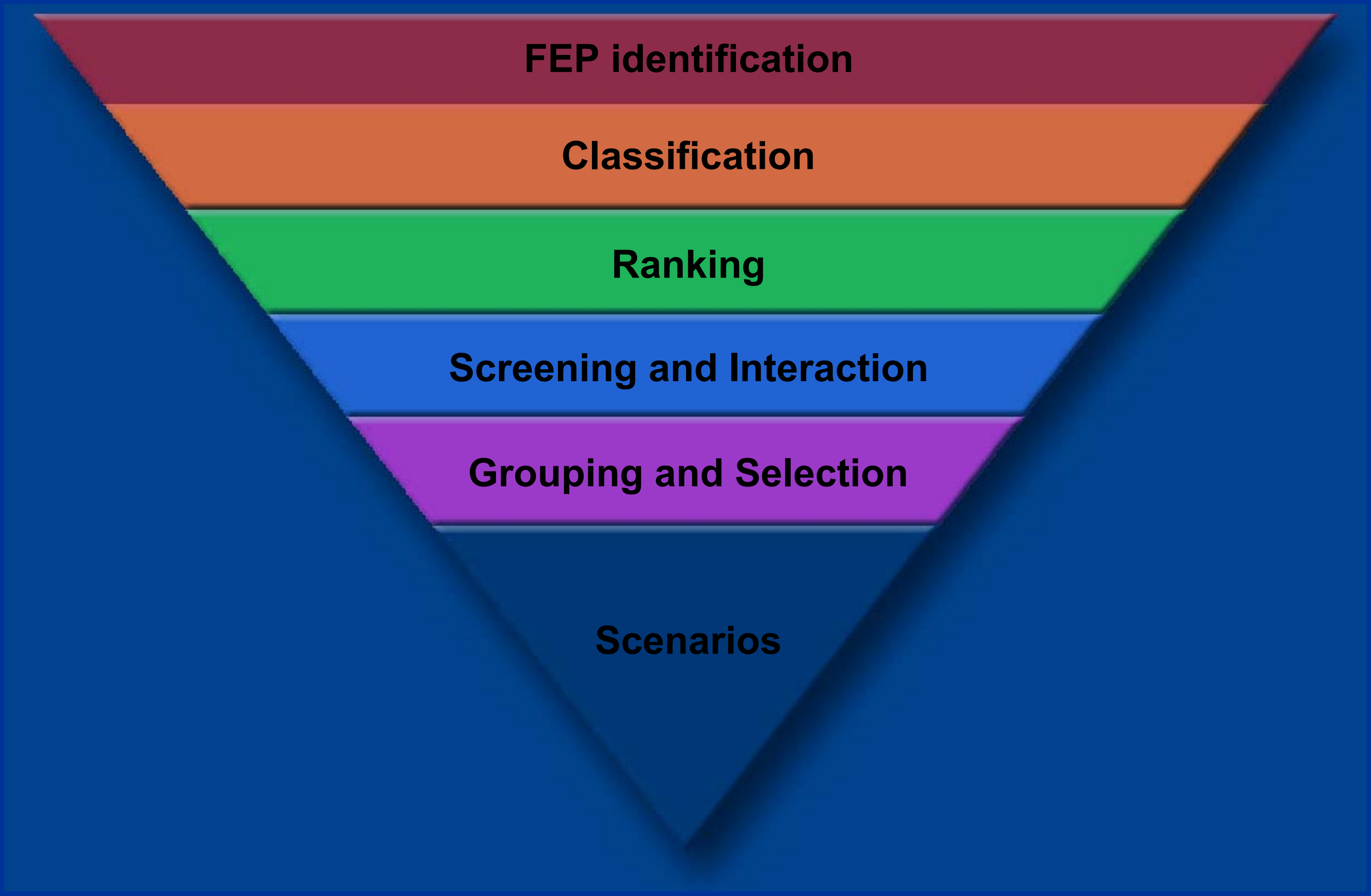
Stratigraphy	**Caprock**	**Storage formation**
	- Low permeability - Large thickness - Lateral continuity - Absence of faults	- High permeability - Large thickness - Areally extensive
Geomechanics	Tectonically stable Favorable stress conditions on faults and fractures	
Geochemistry	Mineralogies that - Buffer acidity increase - Promote trapping as an immobile solid phase	
Anthropogenic Factors	Location and conditions of abandoned wells	

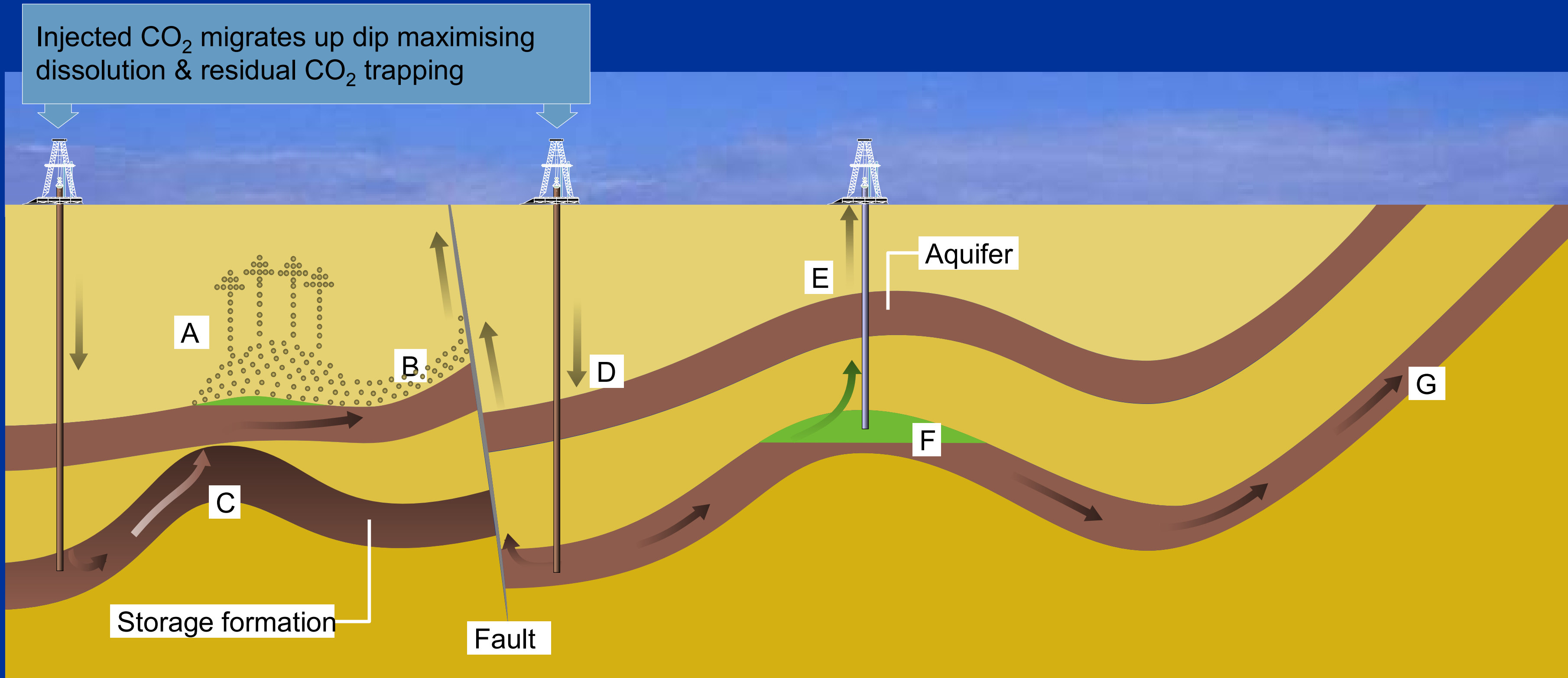
Long-term risk assessment: how to do it?

- **Feature:** **characteristic of system components**
  boreholes, lithography, nearby communities, . . .
- **Event:** **a particular happening**
  pipe fracture, nearby earthquake, meteorite impact . . .
- **Process:** **natural phenomenon**
  corrosion of casing, dissolution of packing material, convection of groundwater . . .

Scenario

Scenario Development





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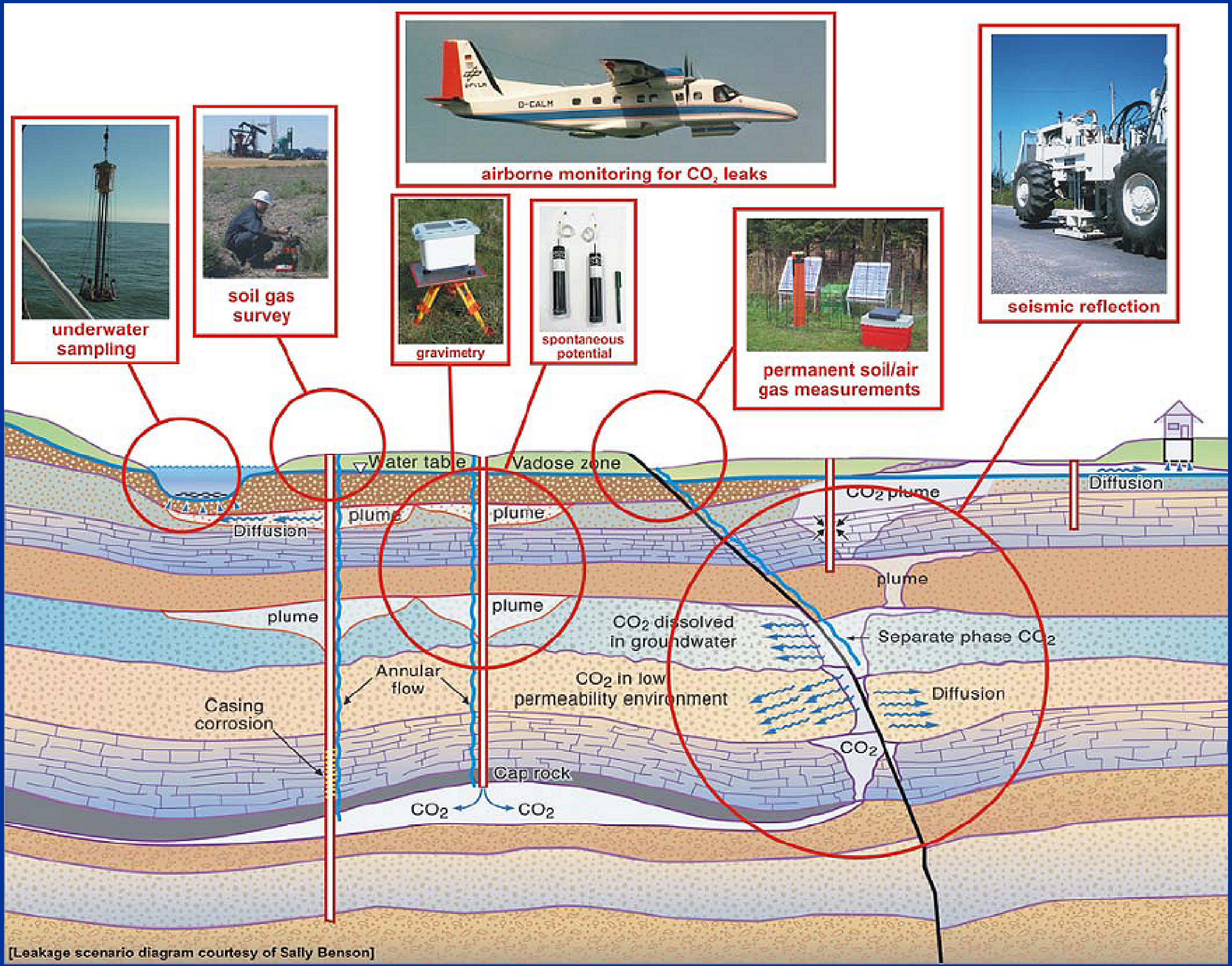
Remedial measures

A. Extract & purify ground water	**B**. Extract & purify ground water	**C**. Remove CO2 & re-inject elsware	**D**. Lower injection rates or pressures	E. Re-plug well with cement	**F**. Intercept & re-inject CO2	**G**. Intercept re-inj CO2

Monitoring

- Monitoring should be tailored to specific conditions and risks at storage site
- Monitoring techniques include:
  - Sensors for measurement of CO_2 in air
  - Geochemical downhole sampling
  - Well logs
  - Geophysical techniques
    - Seismic
    - Electromagnetic
    - gravity

Monitoring and Scenarios



Courtesy British Geological Service

What can be achieved?

According to IPCC SRCCS fraction retained in appropriately selected and managed geological reservoirs is

- very likely to exceed 99% over 100 years, and
- is likely to exceed 99% over 1,000 years.

"Likely" is a probability between 66 and 90%,"very likely" of 90 to 99%

Local risk of geological storage can be comparable to risks of current activities

- Natural gas storage, EOR