Carbon Sequestration in Geologic Environments

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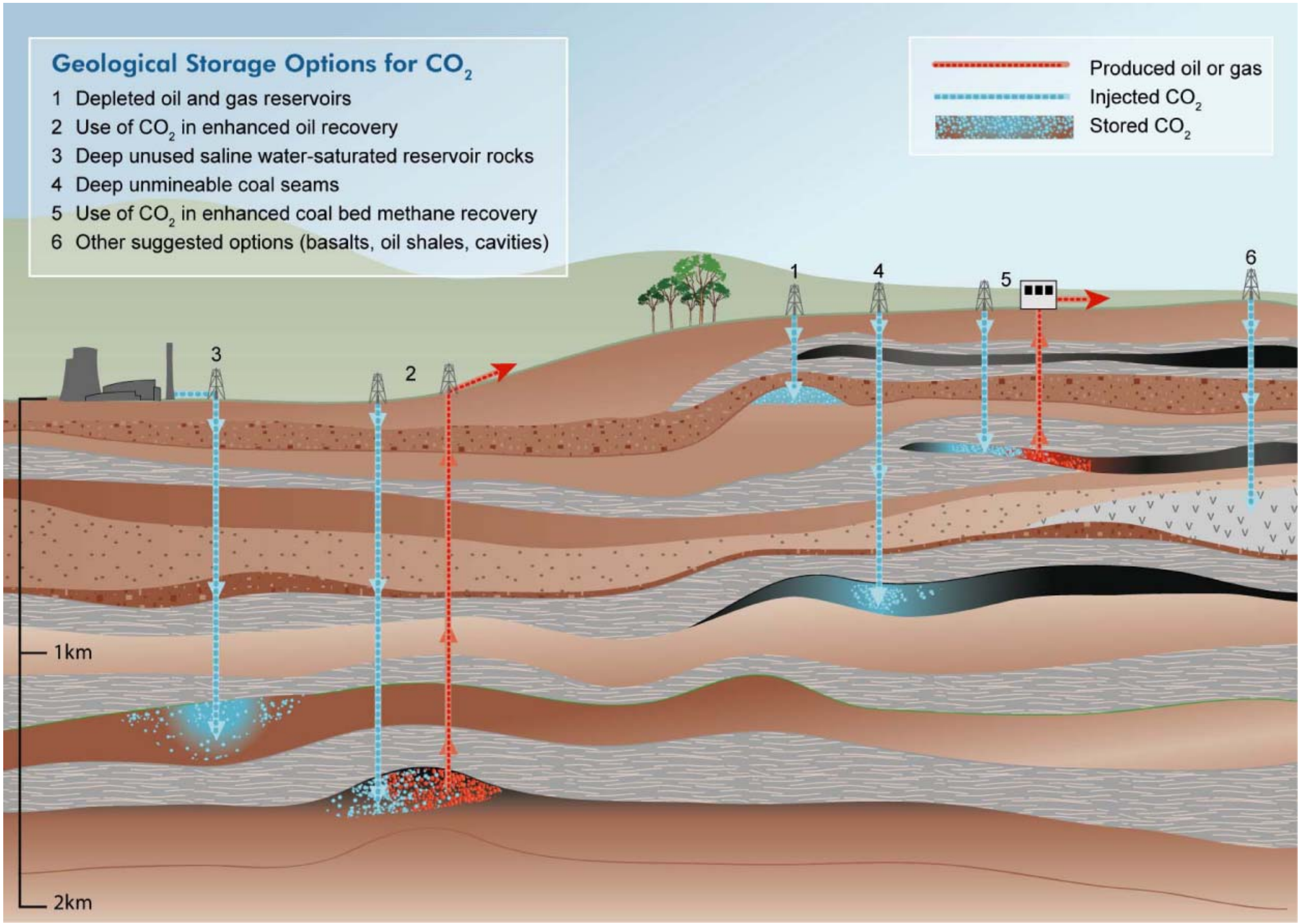
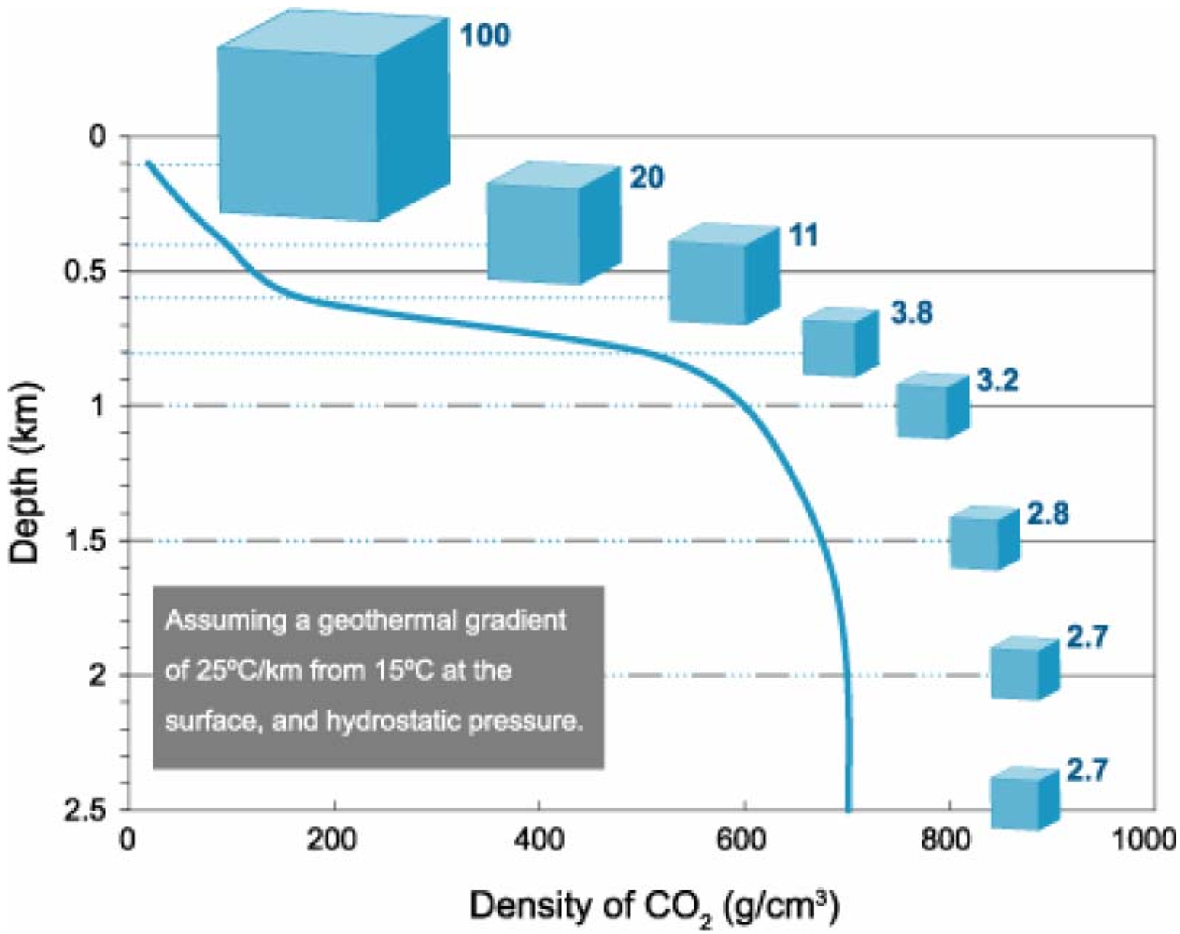
Geology and Geological Engineering

Geological Sequestration Options



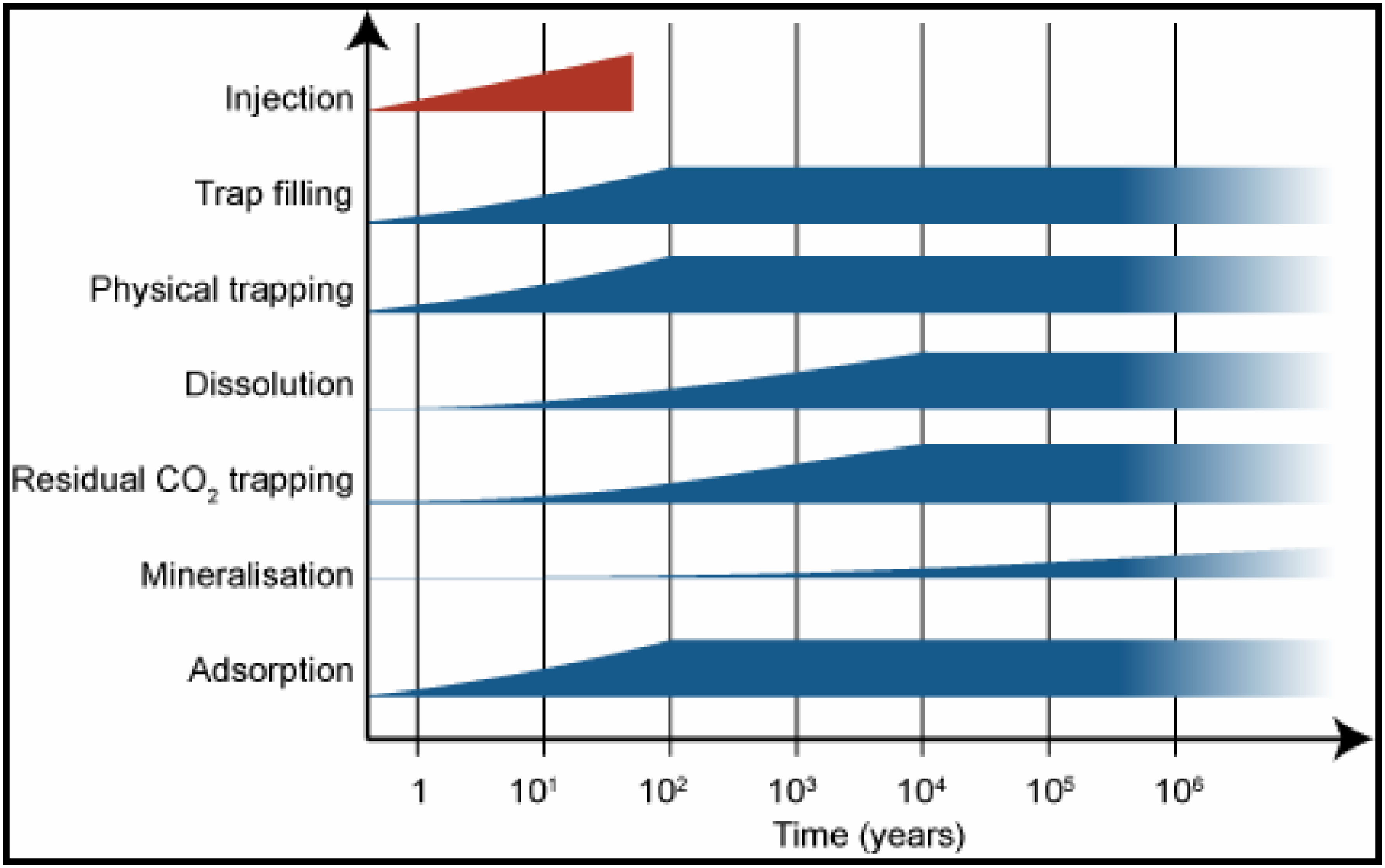
CO_2 Volume Reduces With Deeper Sequestration



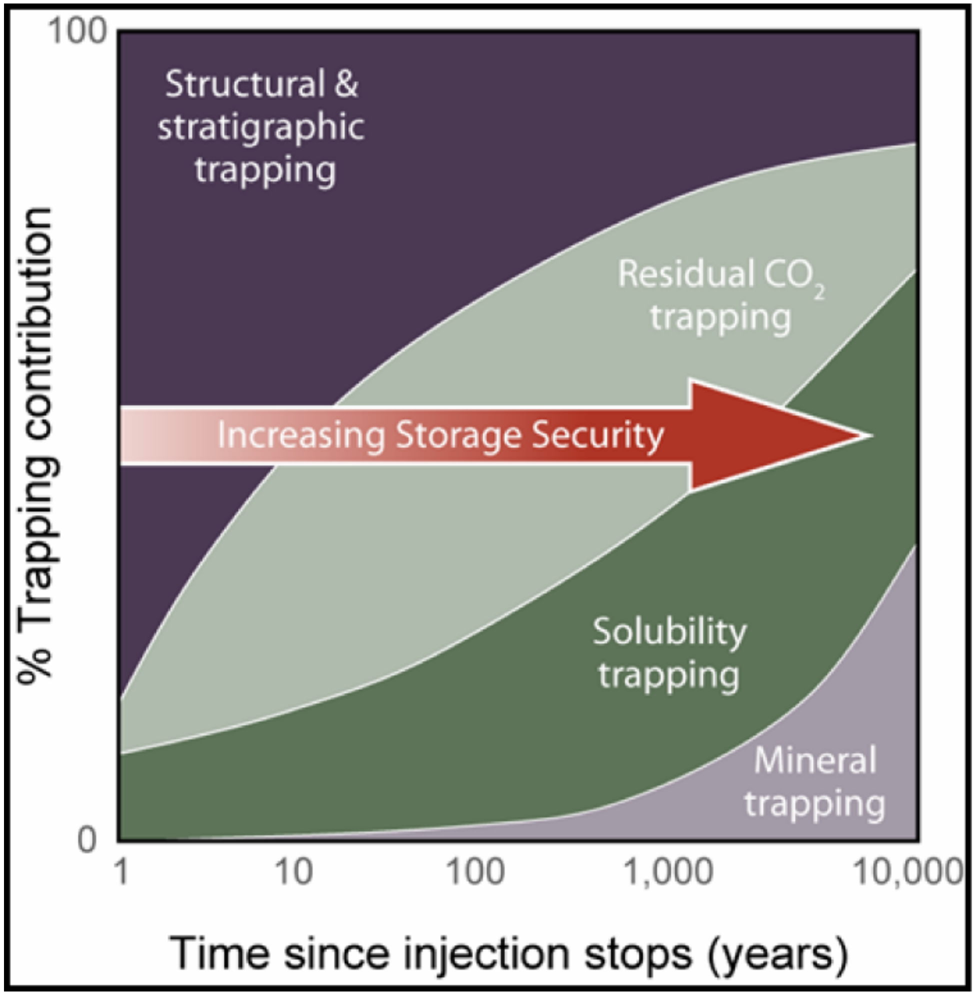
CO_2 Trapping Mechanisms

- Structural and Stratigraphic Trapping
  - Capillary Barriers
  - Permeability Barrier
- Solubility Trapping
  - CO_2 Forms carbonic acid by mixing with in situ fluids
- Residual Saturation Trapping
  - CO_2 trapped in large pores
- Mineral Trapping
  - CO_2 binds with minerals (adsorption)
  - CO_2 precipitates as minerals

Timing for CO_2 Storage Mechanisms



Security of Trapped CO_2 Varies with Mechanism

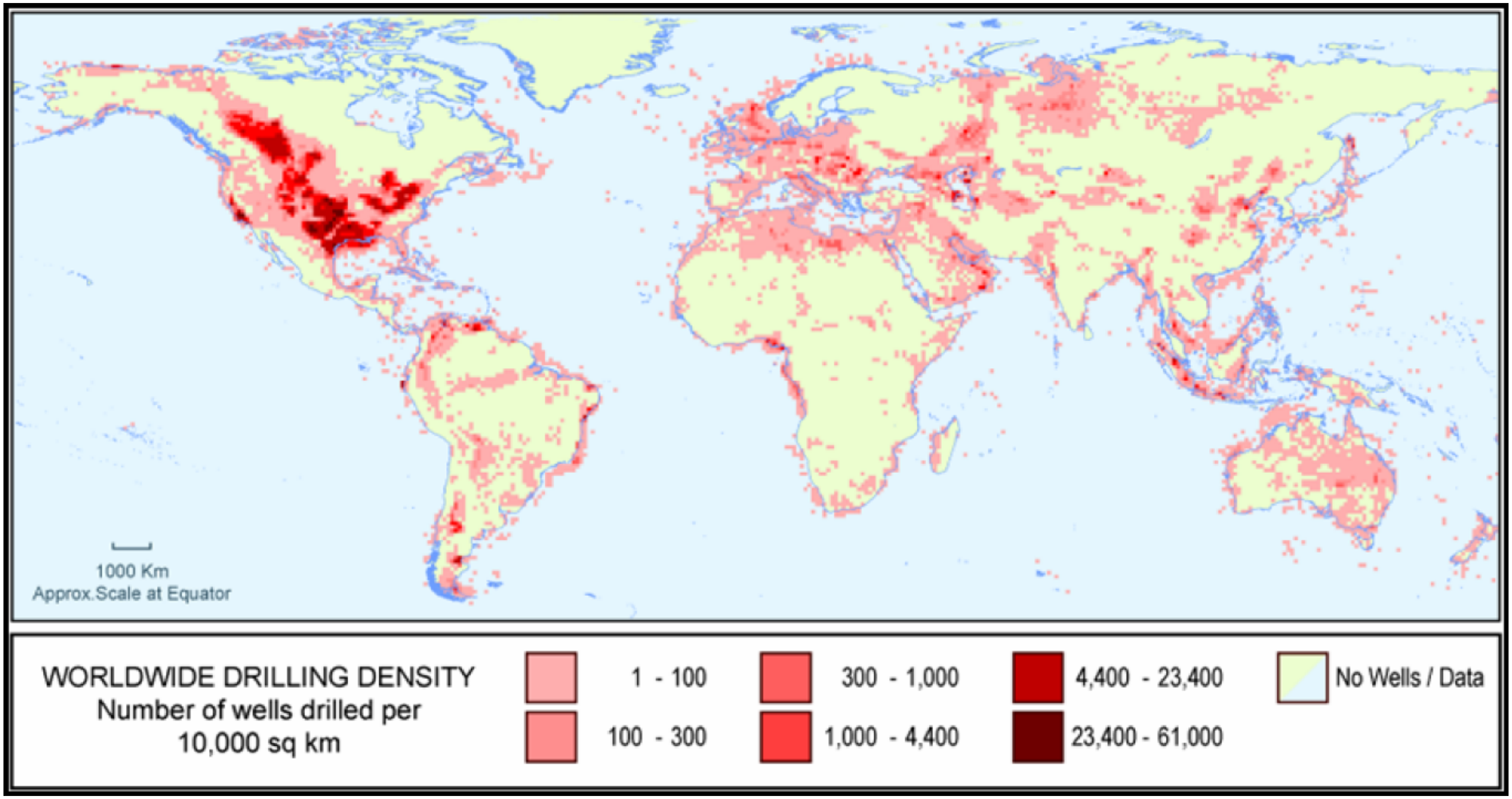


- Varies with location – different geologic and geochemical processes

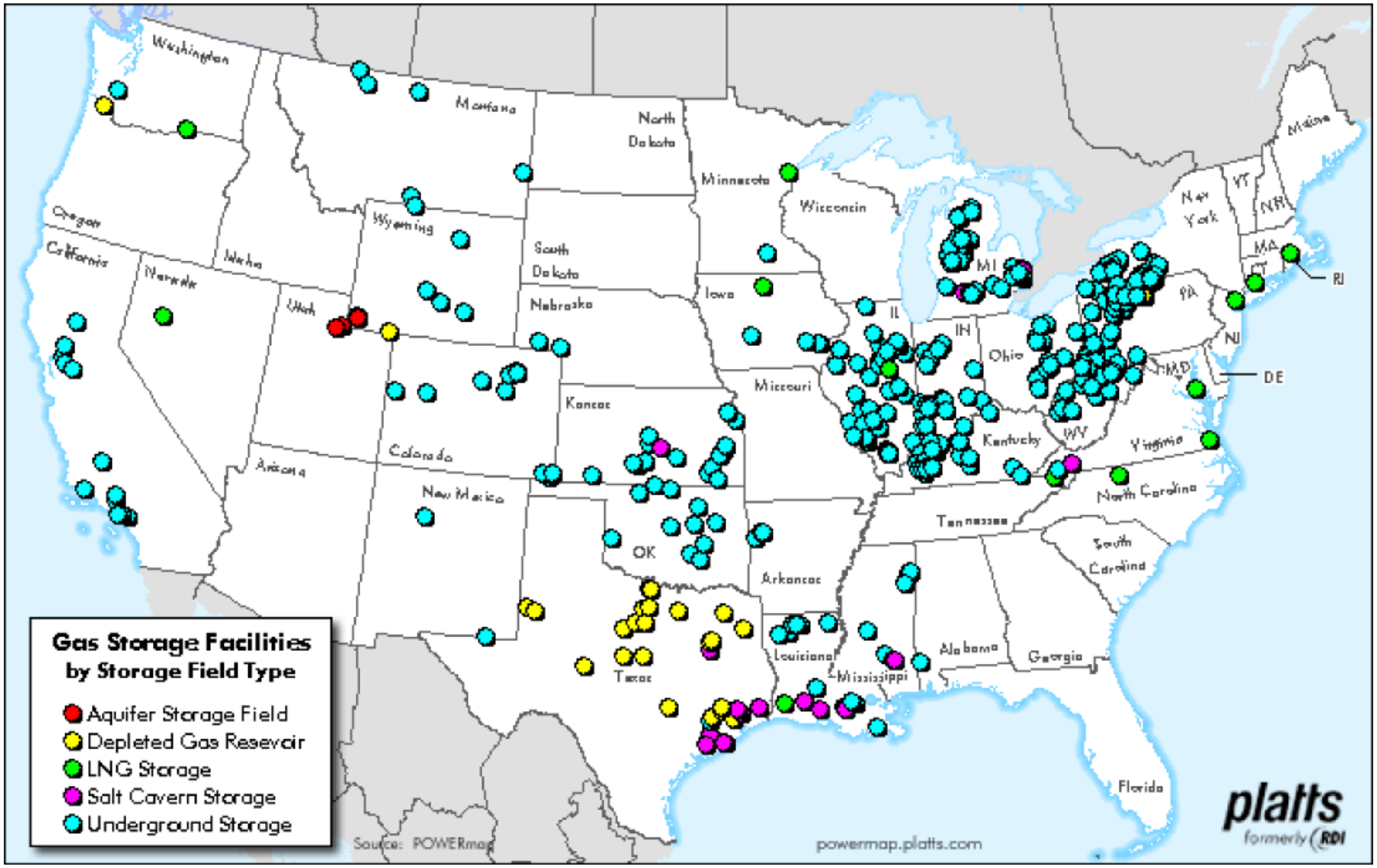
Evidence That Geologic Sequestration Could be Successful

- Natural analogues
  - Oil and gas reservoirs
  - CO_2 formations
- Industrial analogues
  - Natural gas storage
  - Liquid waste disposal
  - CO_2 injection for enhanced oil and gas recovery

World Oil and Gas Well Distribution



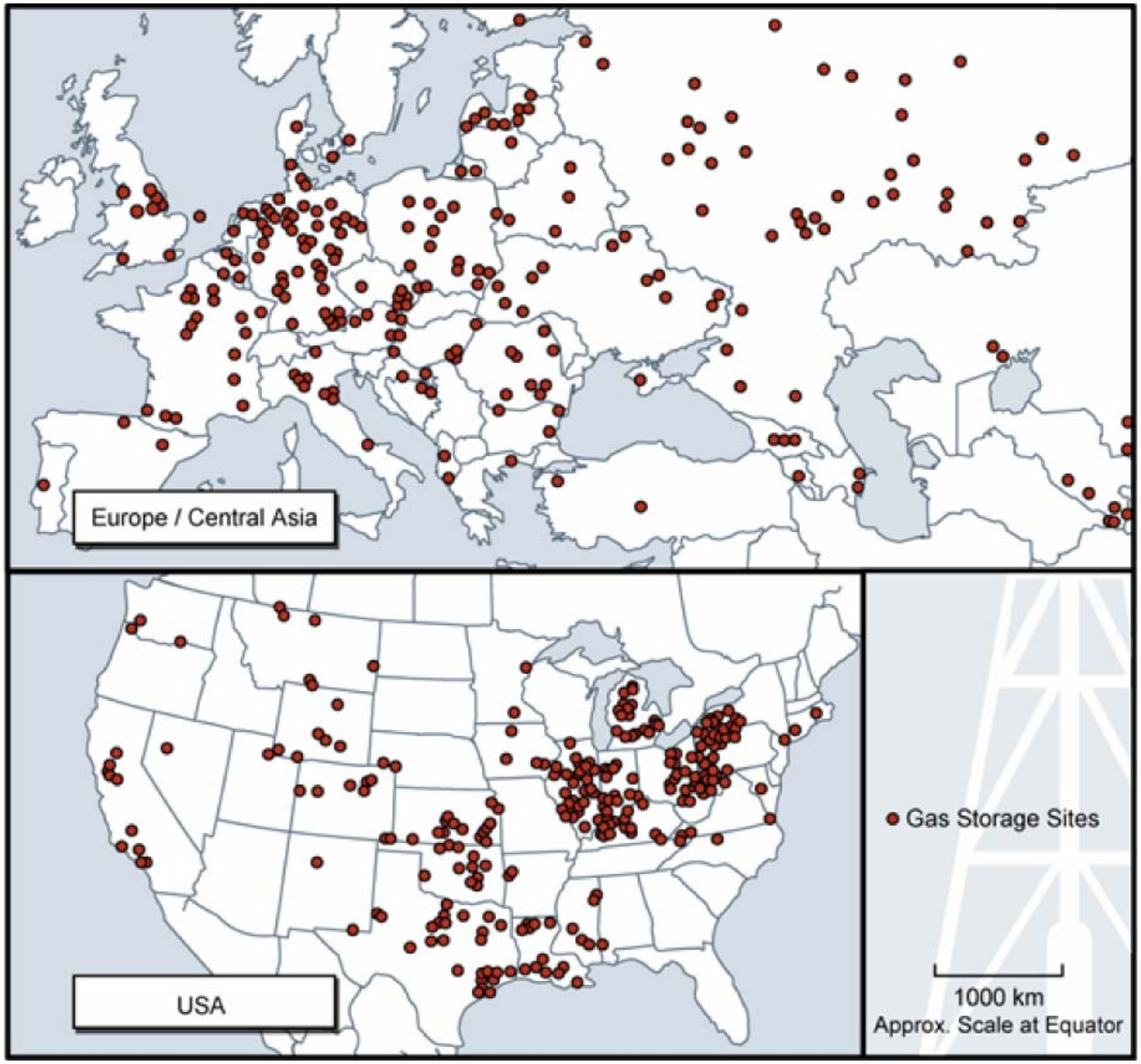
Industrial Analogues



Natural Accumulations of CO_2

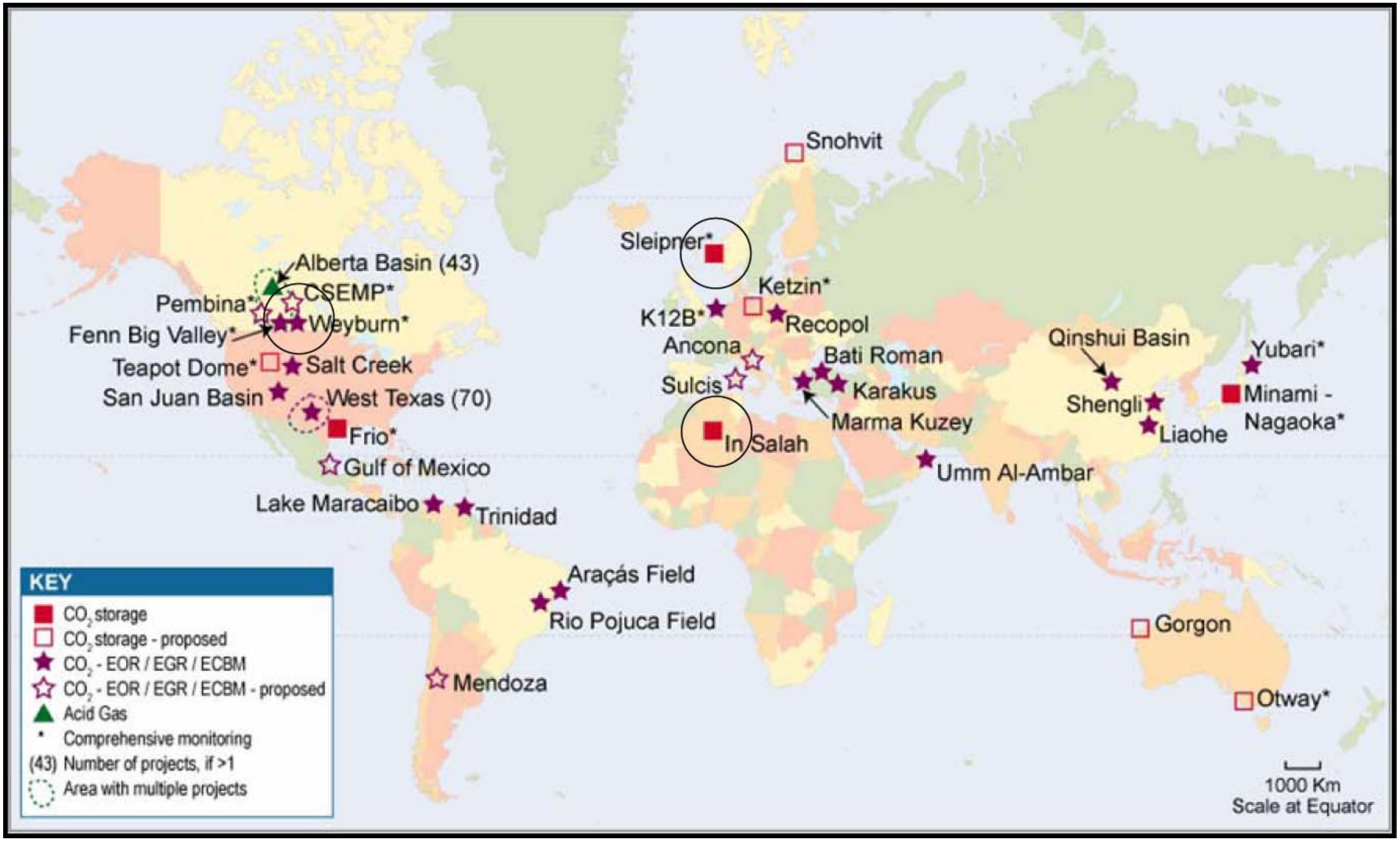
Release rates less than 10^{-7}/year

Natural Gas Storage Projects

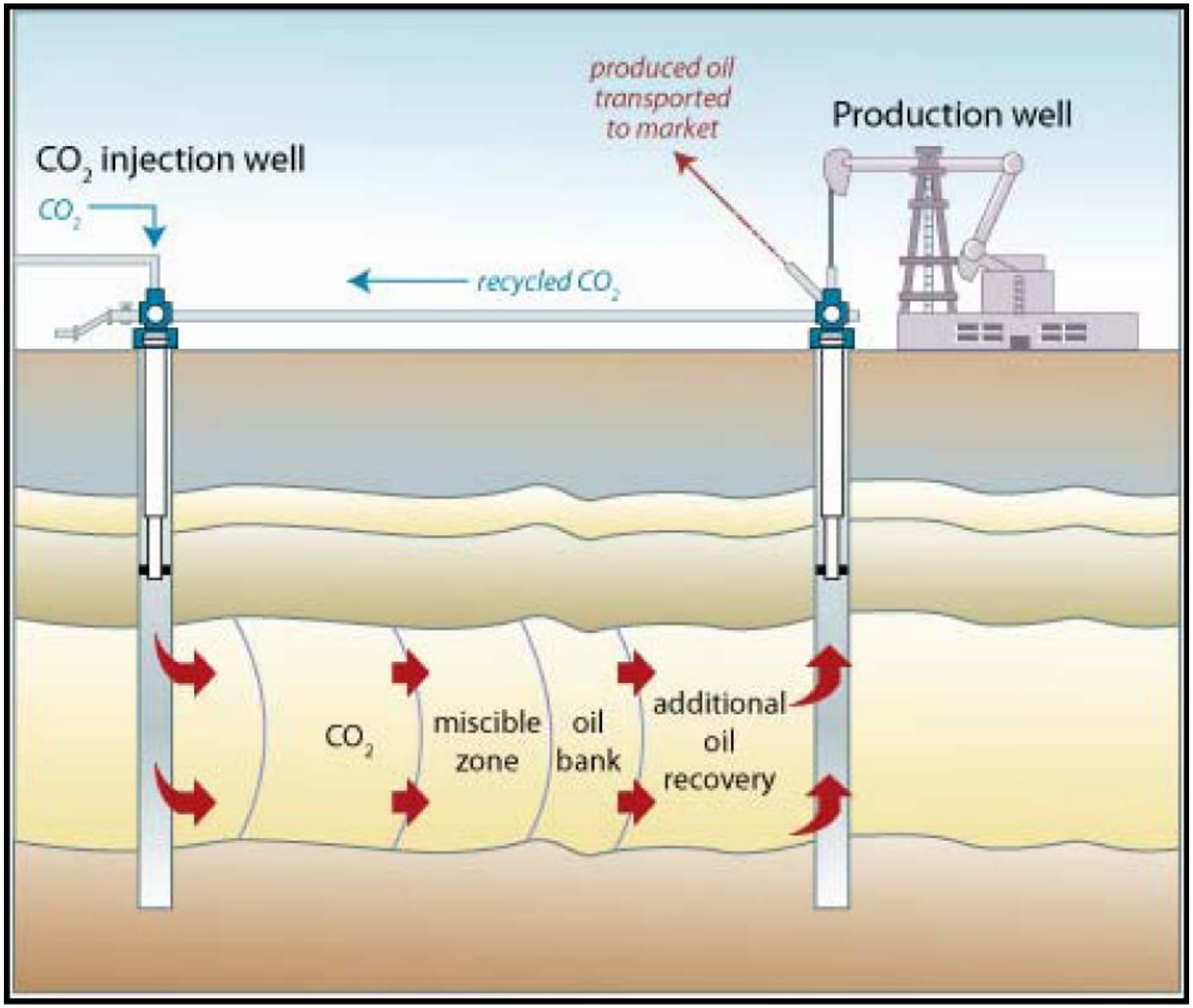


- Projects have more than 10,000 facility-years of operations
- Release rates $<10^{-4}$ to 10^{-6}/yr

Existing Gas Storage Sites

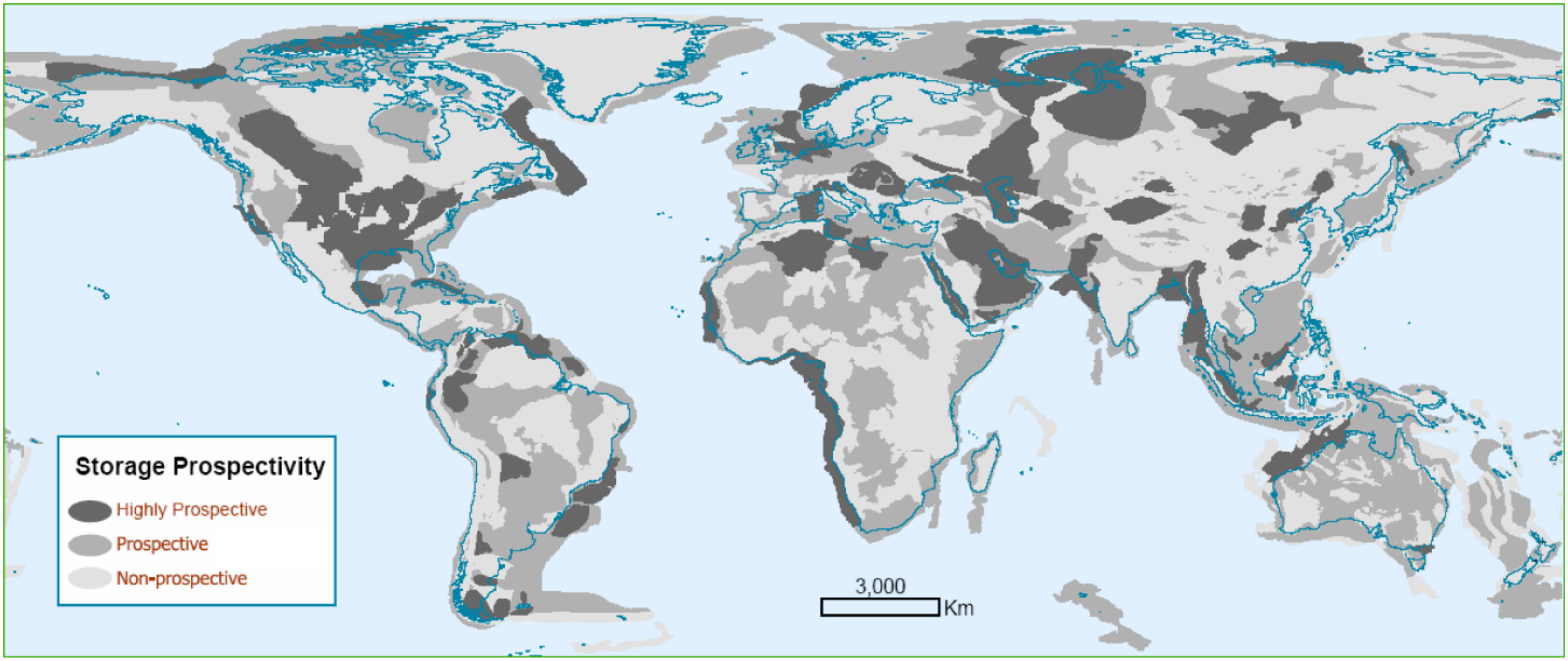


Injection of CO2 for Enhanced Recovery of Hydrocarbons



- >100 Mt injected
- Limited data show flux near zero

World-Wide Geologic Storage Potential



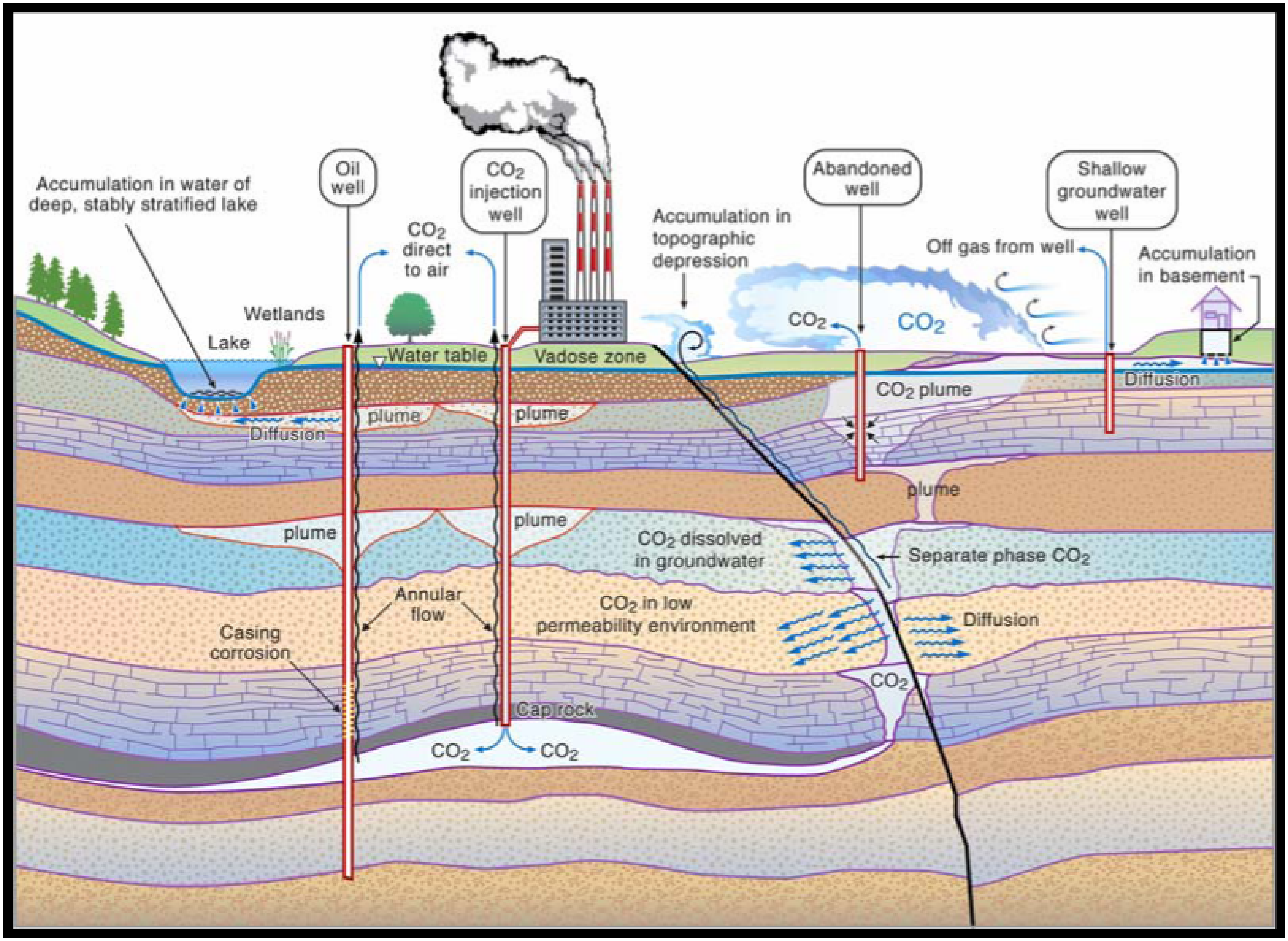
Capacity for Geologic Sequestration

Reservoir Type	Lower Estimate of Storage Capacity ($GtCO_2$)	Upper Estimate of Storage Capacity ($GtCO_2$)
Oil and gas fields	675[a]	900[a]
Unminable coal seams (ECBM)	3–15	200
Deep saline formations	1000	Uncertain, but possibly 10^4

a. Estimates would be 25% larger if undiscovered reserves were included.

"Available evidence suggests that worldwide, it is likely that there is a technical potential of at least about 2,000 GtCO-2 (545 GtC) of storage capacity in geological formations."

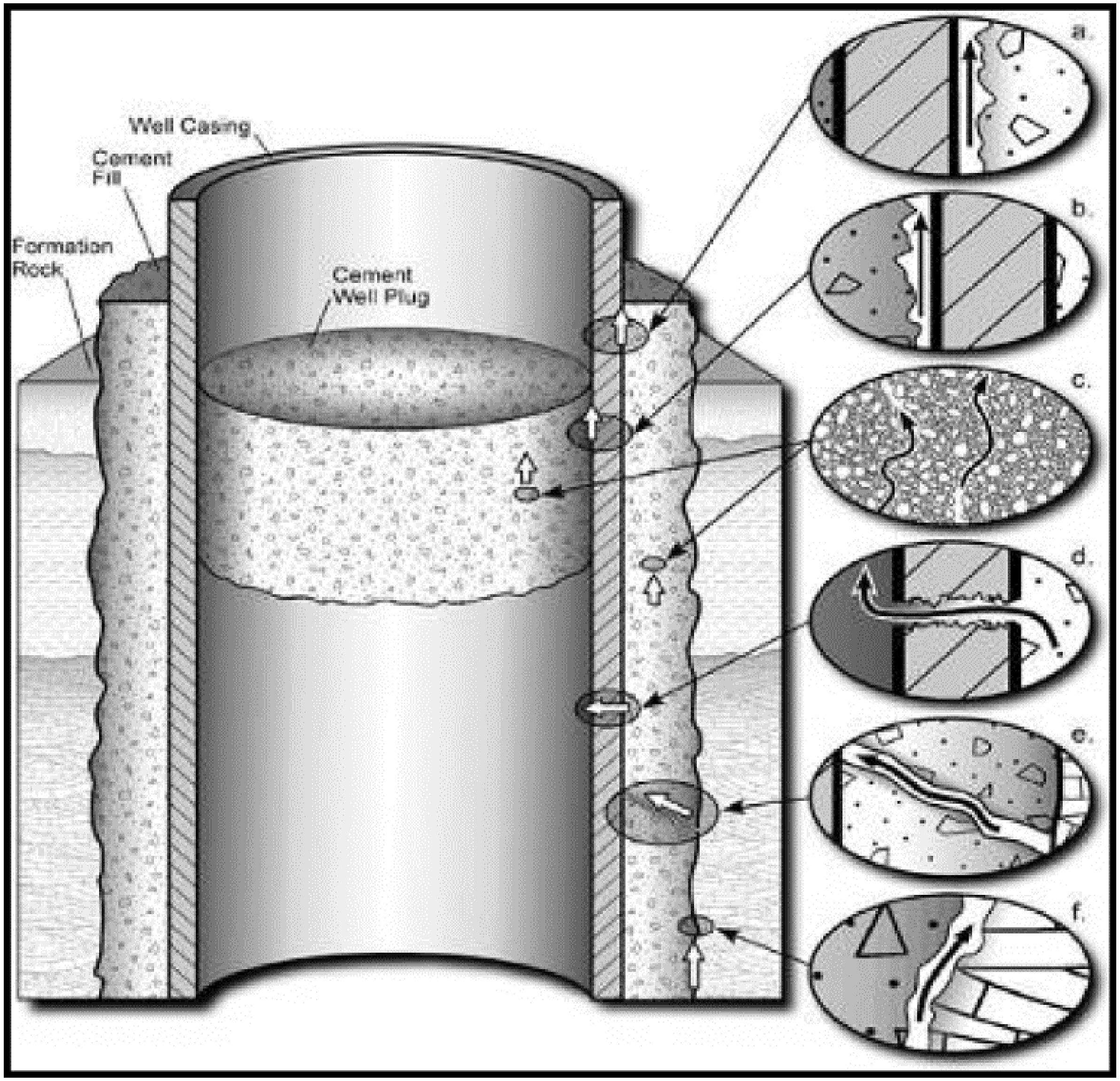
Potential Release Pathways



Many Oil and Gas Fields Have Numerous Abandoned Wells

Near Andrews, Texas

Leakage Pathways in Abandoned Wells



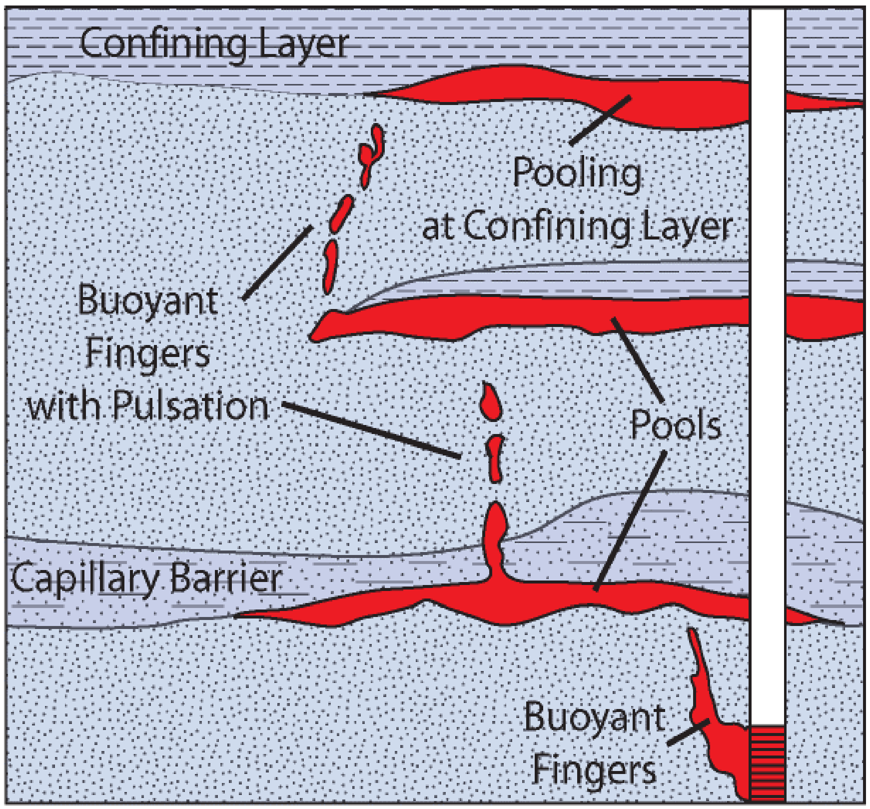
Storage Cost Estimates

			US$/t$CO_2$ stored		
Option type	**On or offshore**	**Location**	**Low**	**Mid**	**High**
Saline formation	Onshore	Australia	0.2	**0.5**	5.1
Saline formation	Onshore	Europe	1.9	**2.8**	6.2
Saline formation	Onshore	USA	0.4	**0.5**	4.5
Saline formation	Offshore	Australia	0.5	**3.4**	30.2
Saline formation	Offshore	N. Sea	4.7	**7.7**	12.0
Depleted oil field	Onshore	USA	0.5	**1.3**	4.0
Depleted gas field	Onshore	USA	0.5	**2.4**	12.2
Disused oil/gas field	Onshore	Europe	1.2	**1.7**	3.8
Disused oil/gas field	Offshore	N. Sea	3.8	**6.0**	8.1

Monitoring costs - $0.16 to $0.30/ton

Development of Monitoring Technologies at the University of Mississippi

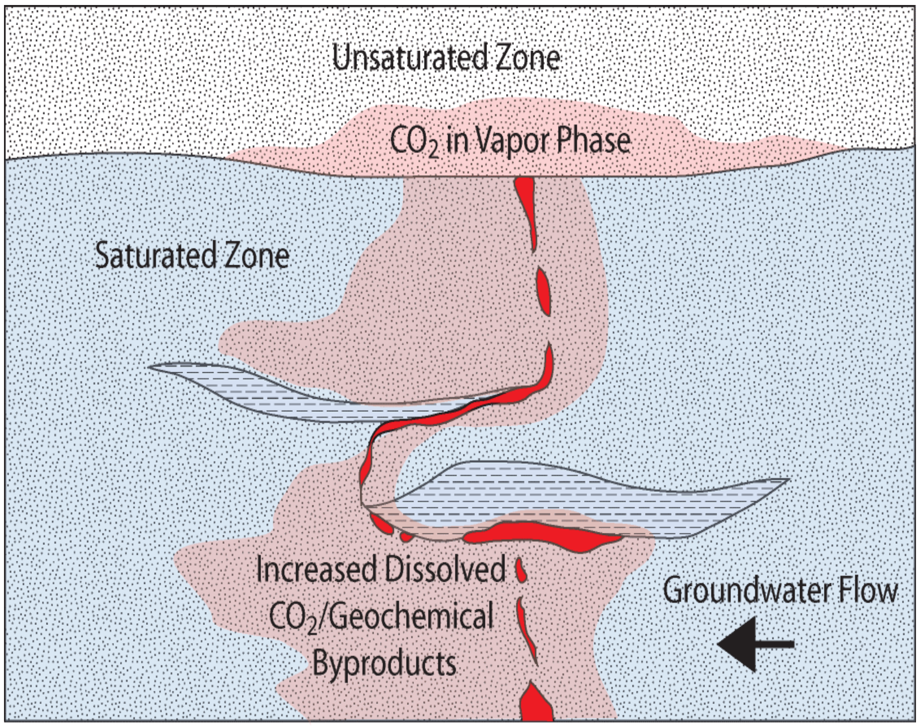
Conceptual model for CO2 transport in the saturated zone



- Buoyancy-driven fingering (with pulsation) through coarse layers
- Trapping behind fine-grained layers
- Fingering and breakthrough when CO_2 pressure exceeds the non-wetting phase entry pressure
- Trapping beneath aquifer confining layers with the development of large pools, or
- For phreatic aquifers, movement into the unsaturated zone and pooling above the capillary fringe

Monitoring Requires Observations of CO_2 and its Geochemical Byproducts

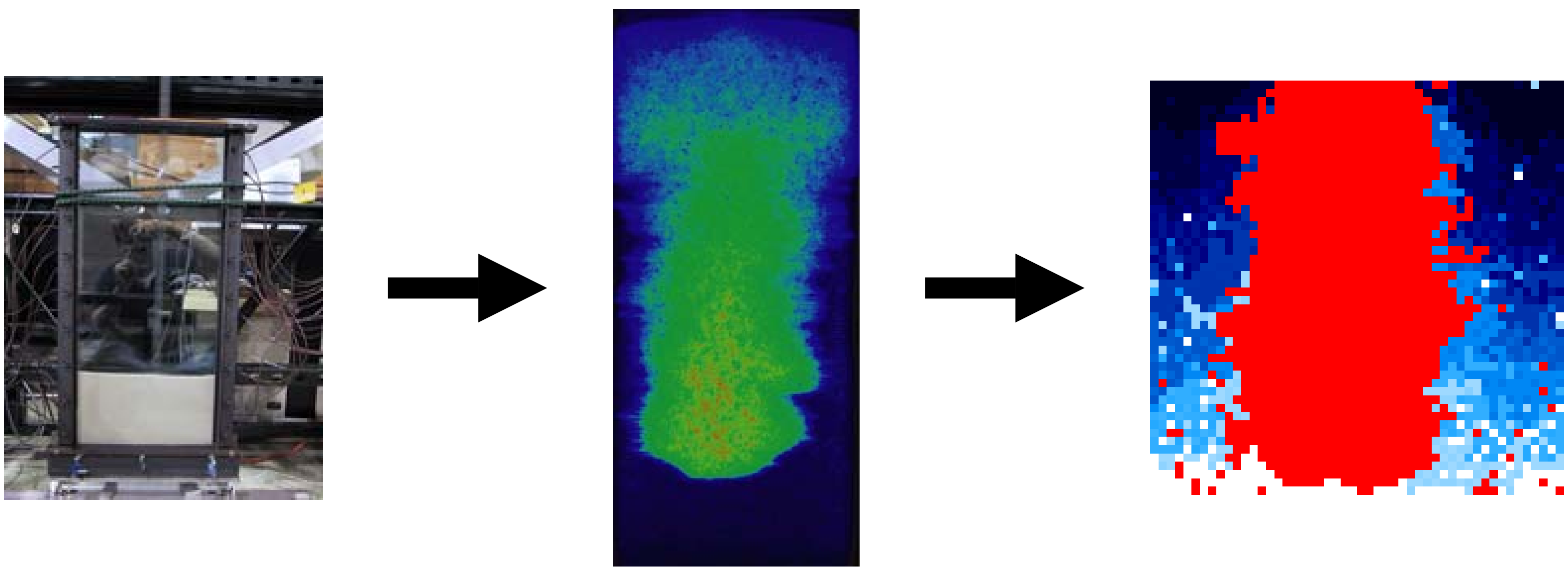
Basic science questions:



1) What controls CO_2 partitioning and dissolution into the aqueous phase? *(surface area of CO_2 blobs)*
2) What chemical reactions will occur and what are their rates? *(grain surface chemistry, reaction rates)*
3) What is the size of zones of detectable CO_2 and byproducts? *(capillary heterogeneity, dissolution rates, reaction rates, ambient flow, source term)*
4) What type of monitoring design will be required to insure detection? *(source term size, heterogeneity, reaction/dissolution rates, action level)*

Bench-Scale Experiments to Answer Basic Science Questions 1-3 and Improve Field-Scale Tracer Test Design

- Use transmitted light techniques to visualize CO_2 phase structure evolution in heterogeneous sand chambers
- Quantify CO_2 dissolution into the aqueous phase and monitor geochemical evolution of by products in aqueous phase
- Simulate experimental results using continuum and Macroscopic Invasion Percolation modeling approaches
- Select modeling approach for field-scale tracer test design



Field-Scale Tracer Tests to Answer Basic Science Questions 3-4

- Define background chemistry of groundwaters and CO_2 content in the unsaturated zone vapor phase
- Characterize site-specific heterogeneity in the saturated and unsaturated zones
- Use simulations to design tracer tests and determine saturated and unsaturated zone monitoring locations
- Develop sampling procedures and protocols
- Conduct tracer tests