Principles of CO_2 geological storage

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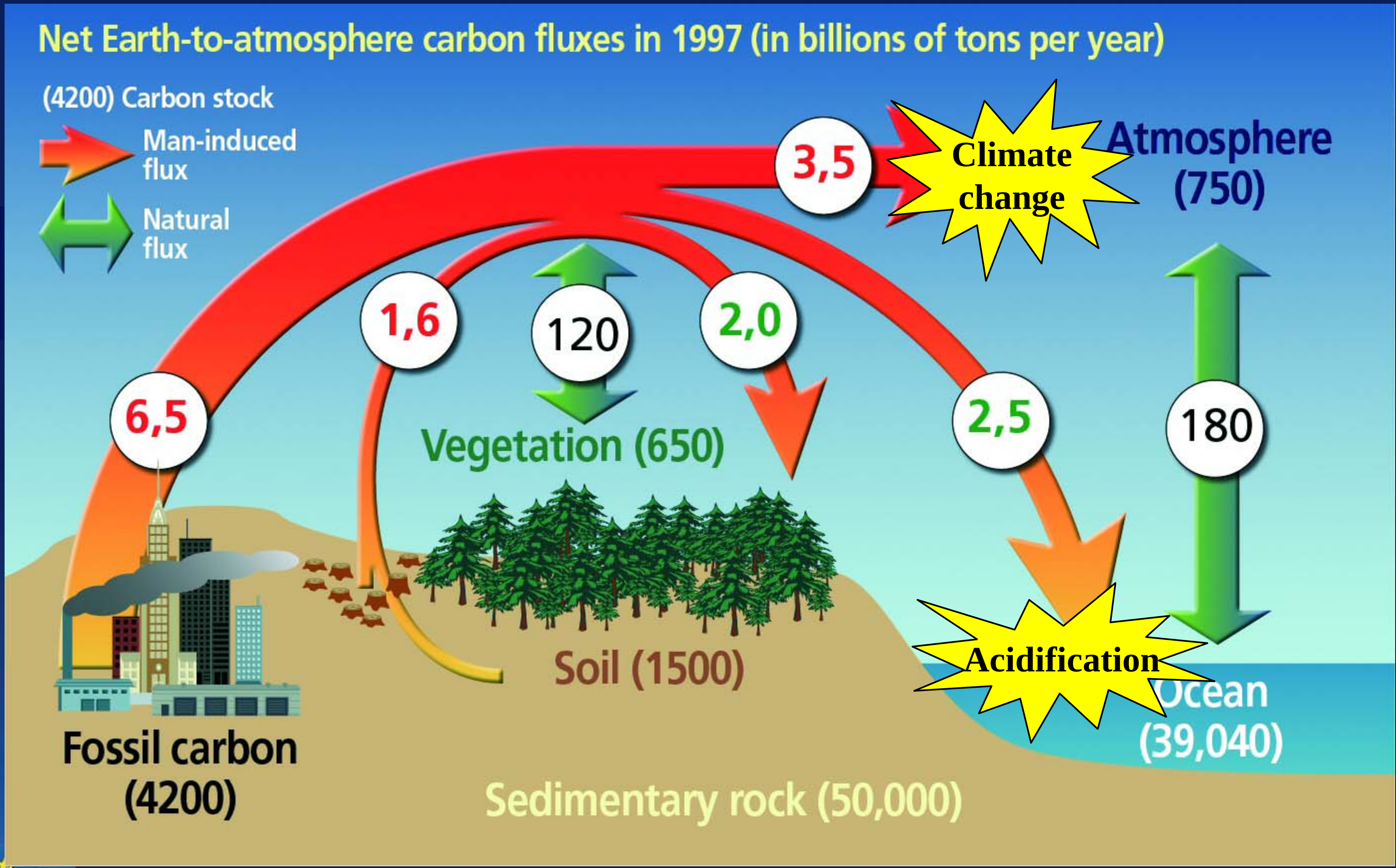
Outline

1. Putting carbon back into the ground!
2. Main options for CO_2 geological storage
3. Trapping processes in the reservoir
4. The pioneer storage projects
5. Key challenges for widespread deployment
6. The role of CO_2GeoNet Network of Excellence

- 1. Putting carbon back into the ground!

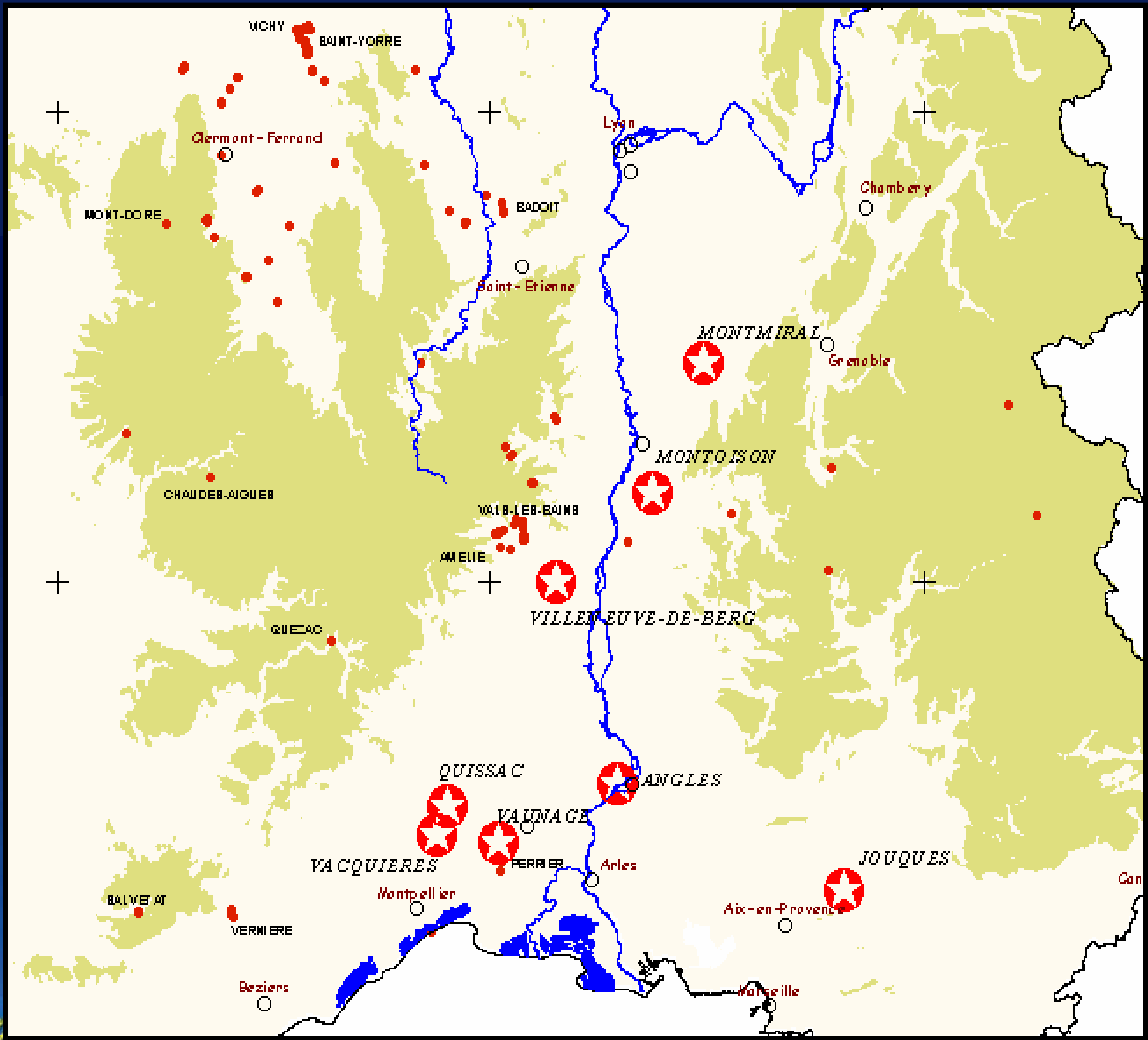
CO_2 fluxes between the Earth and the atmosphere (in billion tons of carbon per year)



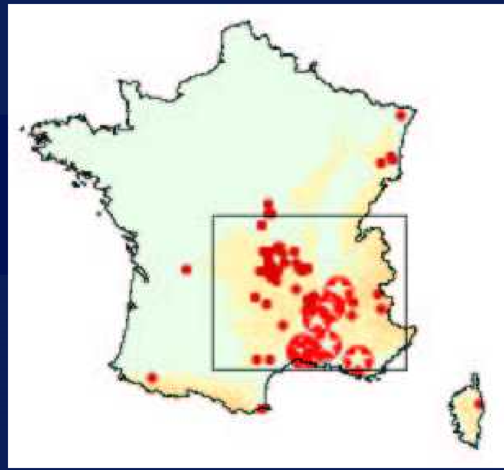
Worldwide CO_2 emissions from fossil fuel use: 6.5 Gt C/y (or 24 Gt CO_2/y)

Putting carbon back into the ground!

Nature's geological CO_2 storage projects



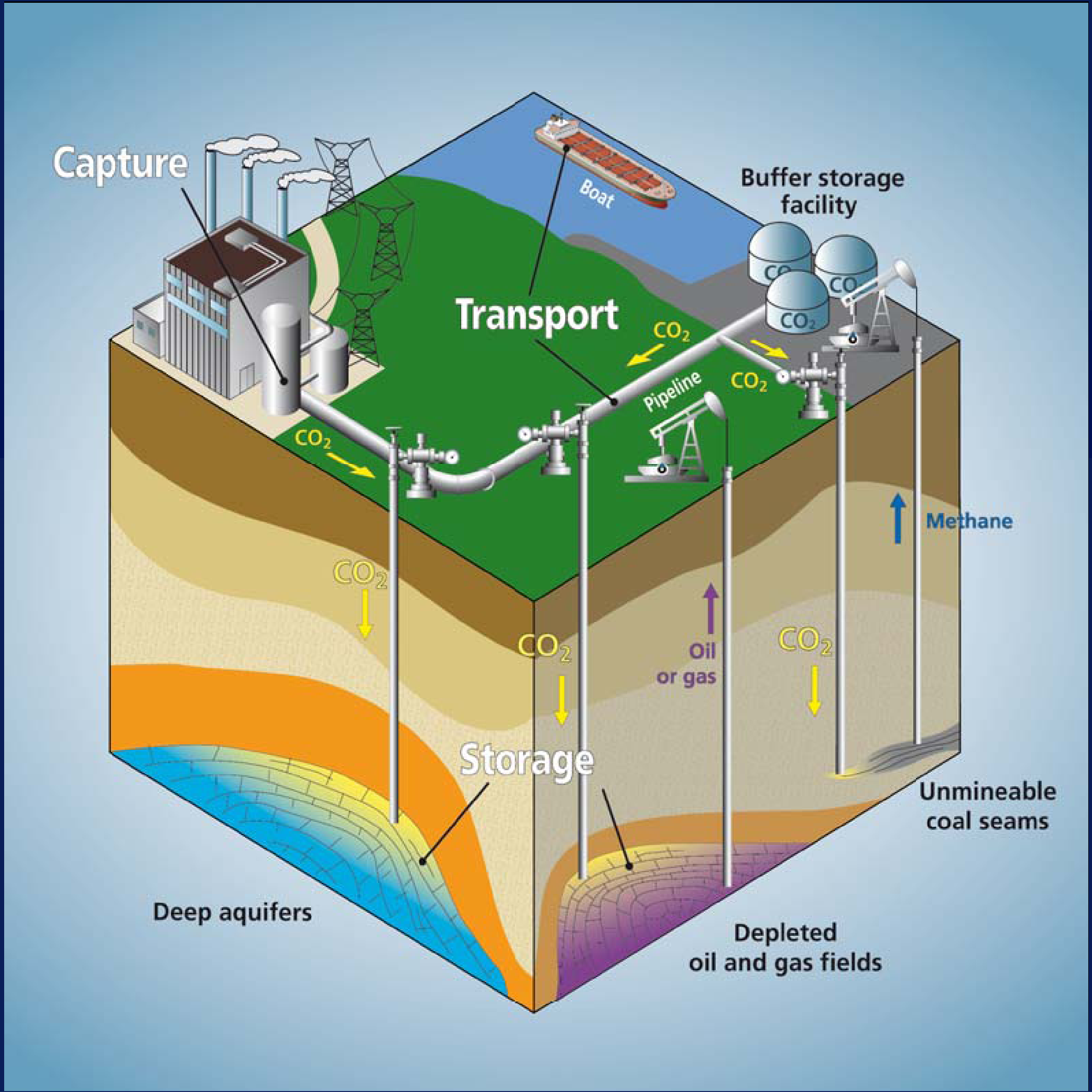
France's carbogaseous province



- Natural CO_2 fields
- Exploited carbogaseous waters (drinking water, spa)

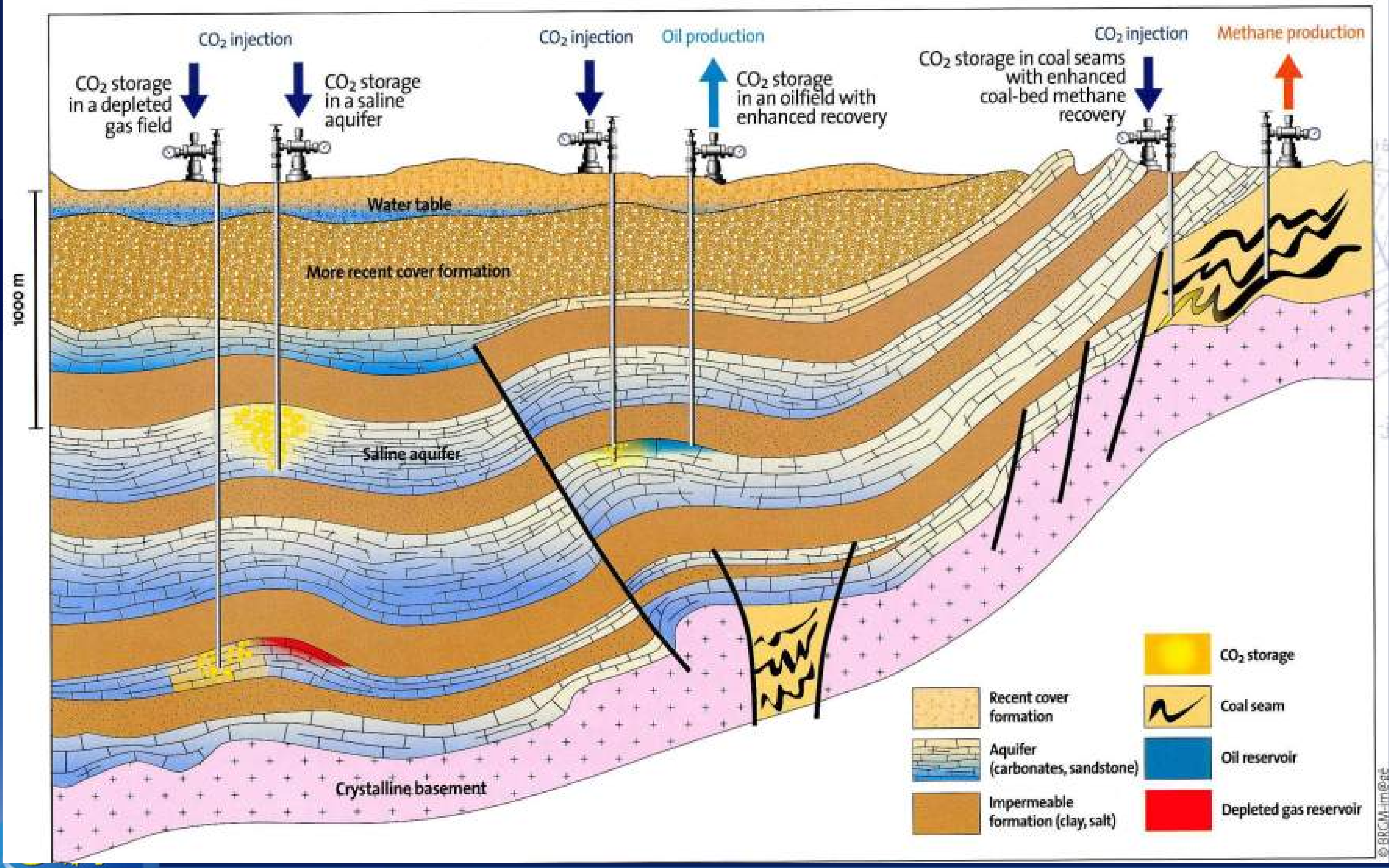
CO_2 Capture and Storage (CCS)

A promising option to help cut worldwide CO_2 emissions in half by 2050

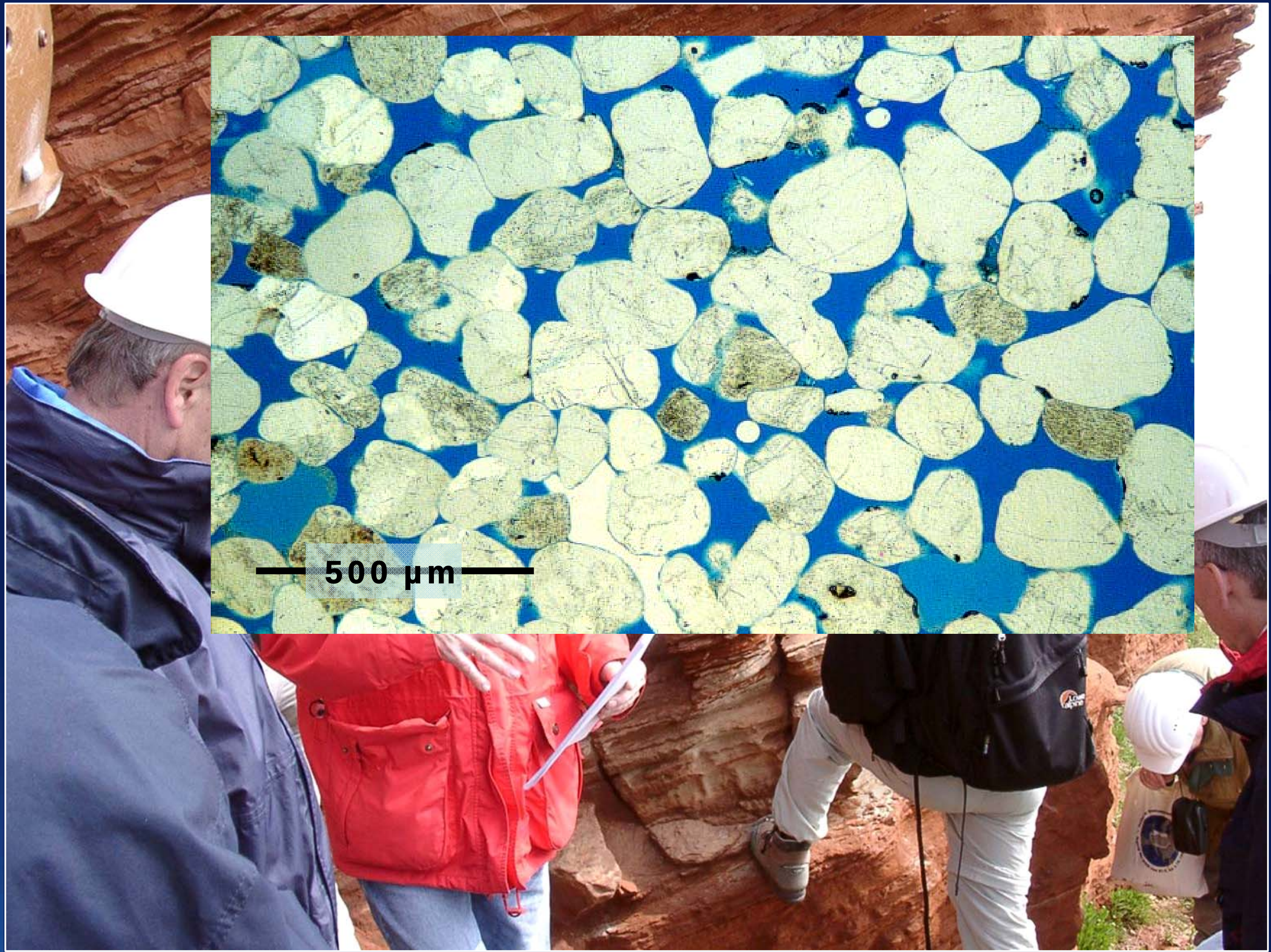


- 2. Main options for CO_2 geological storage

CO_2 Geological storage options



Porous Reservoir Rocks



Tight Cap Rocks

Unconsolidated Clay

Clay Stone

Marl

Salt Rock

Comparison of storage options

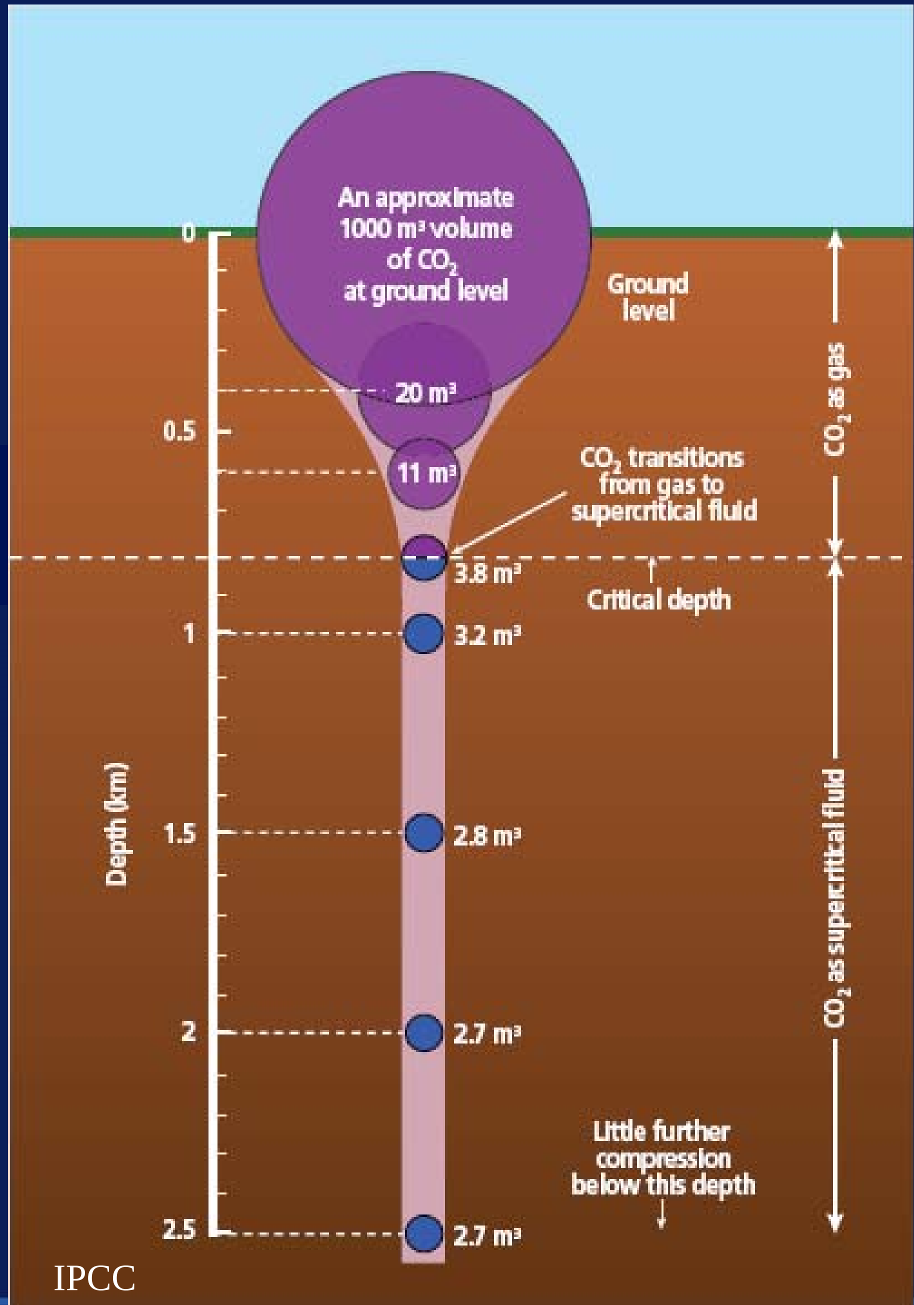
The different types of storage			IEA, GHG, 2004
	CO_2 Capacity (in Gt)	Advantages	Disadvantages
Hydrocarbon reservoirs	930 Gt	Trapping structures impermeable to non-reactive gases. Well-known structures. Economic potential through EOR.	Generally far from CO_2 emission sites. Storage capacities often limited.
Deep saline aquifers	400 to 10,000 Gt	Widespread geographic distribution and vast storage potential. Facilitates the search for storage sites close to the sources of CO_2 emissions. Water unfit for drinking.	Poorly characterized to date.
Unmineable coal seams	40 Gt	Near CO_2 emission sites. Economic potential through methane recovery.	Injection problems due to the poor permeability of coal. Limited storage capacities.

Geological storage capacity is at least 2000 Gt CO_2 (IPCC SRCCS 2005), i.e. enough to store several centuries of CO_2 industrial emissions

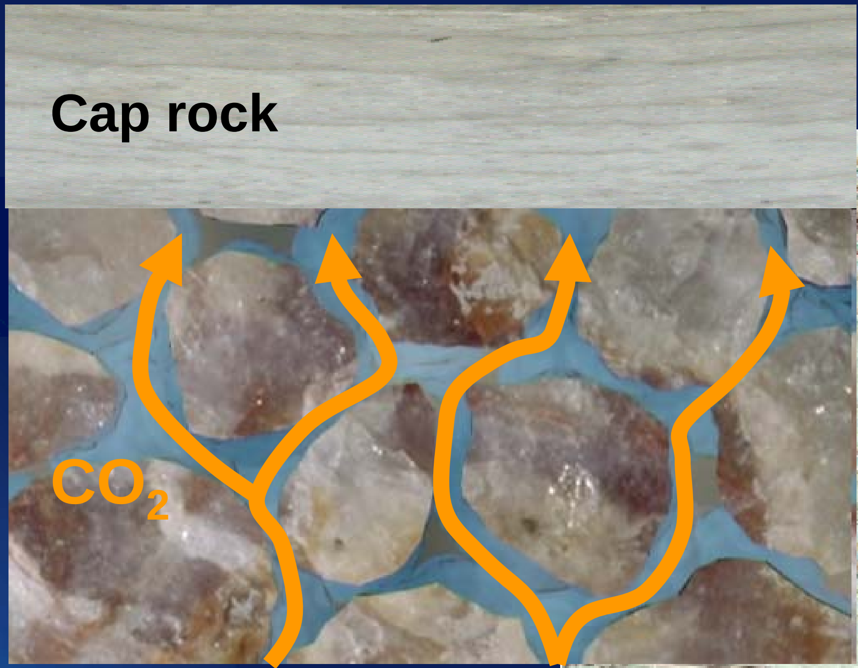
- 3. Trapping processes in the reservoir

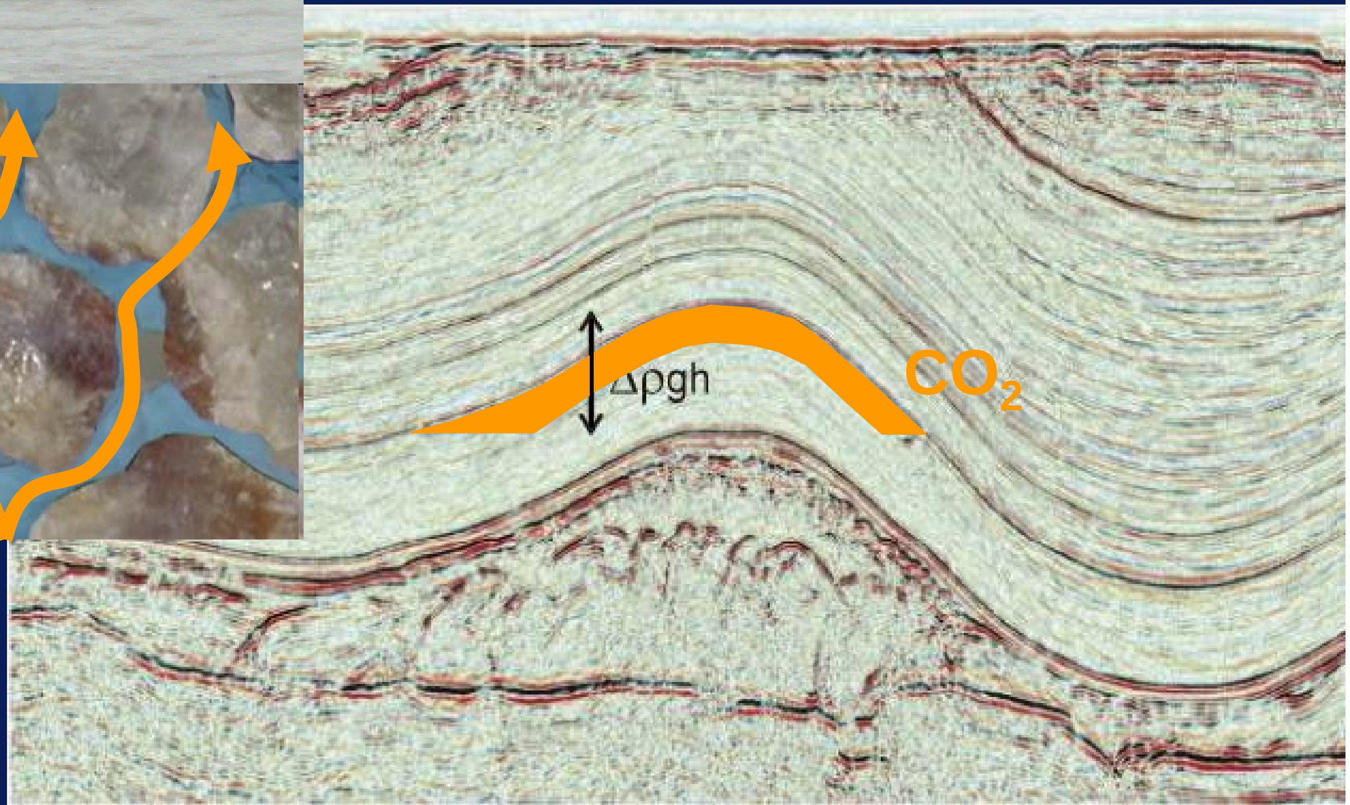
CO_2 stored at depths greater than 800m in a dense ("supercritical") state

Critical point: 31°C, 73 bars



Rapid rise of CO_2 upwards in the reservoir–accumulation beneath the caprock





Partial and slow dissolution of CO_2 in the salty reservoir fluid

Dense CO_2

Partial and slow dissolution of CO_2 in the salty reservoir fluid

Partial and slow dissolution of CO_2 in the salty reservoir fluid

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Partial and slow dissolution of CO2 in the salty reservoir fluid

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Partial and slow dissolution of CO_2 in the salty reservoir fluid

Partial mineralization on the very long term

Precipitation of carbonate minerals (calcite $CaCO_3$, etc.)

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CO_2 trapping forms in aquifers

- Physical trapping
  - Dense supercritical CO_2 phase (> 31°C at 73 bars)
- Chemical trapping
  - Solubility trapping: CO_2(aq), HCO_3^-, $CaHCO_3^+$, $MgHCO_3^+$, $NaHCO_3^0$, …
  - Mineral trapping: $CaCO_3$ (calcite), $FeCO_3$ (siderite), $NaAlCO_3(OH)_2$ (dawsonite), ...

Increasing importance with time

Geological criteria for a good storage site

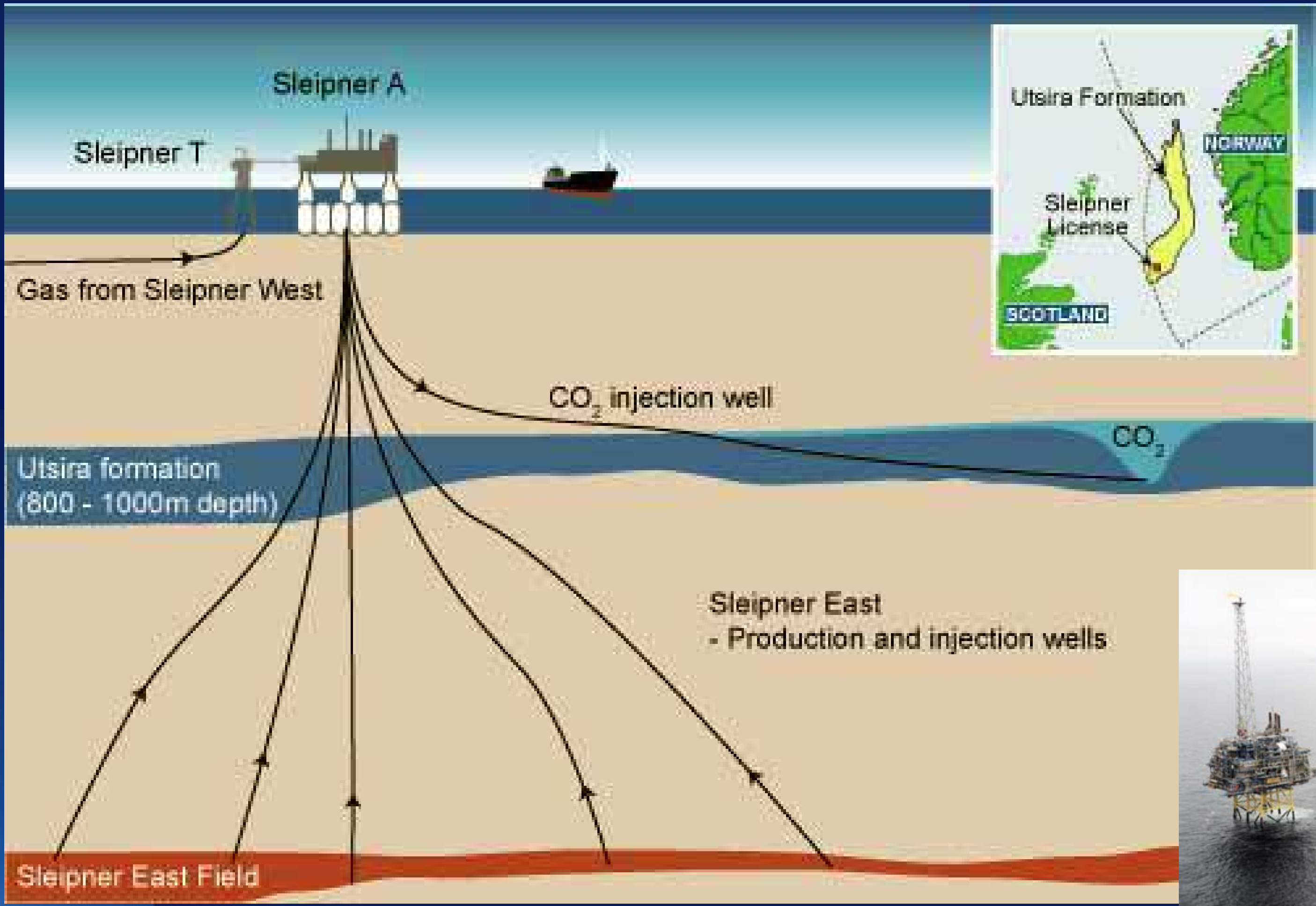
- Depth greater than 800 m
- Sufficient porosity, permeability and geographic extension to enable good injectivity and large storage capacity
- Impermeable caprock on top of the reservoir, without defaults, faults and fractures, to ensure long term containment
- Structural trap (dome shape) helps to better control the lateral extension of the CO_2 plume

- 4. The pioneer storage projects

Pioneer commercial CCS projects

- Sleipner, **deep saline aquifer, Norway, 1 Mt CO_2/y since 1996 (Statoil)**
- Weyburn, **oil reservoir, Canada, 1,8 Mt CO_2/y since 2000 (EnCana)**
- In-Salah, **gas reservoir, Algeria, 1 Mt CO_2/y since 2004 (BP)**

The Sleipner CO_2 storage project

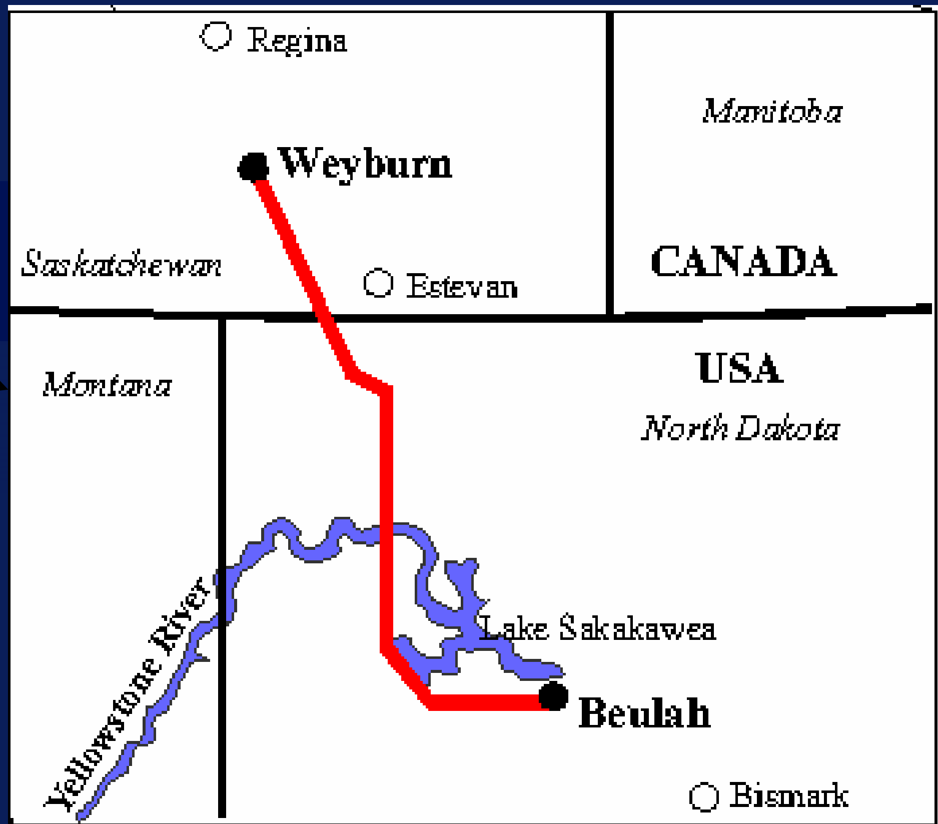


1 Mt/y since 1996

IEA Weyburn CO_2 Monitoring and Storage Project

CO_2 EOR and storage

Operator : EnCana

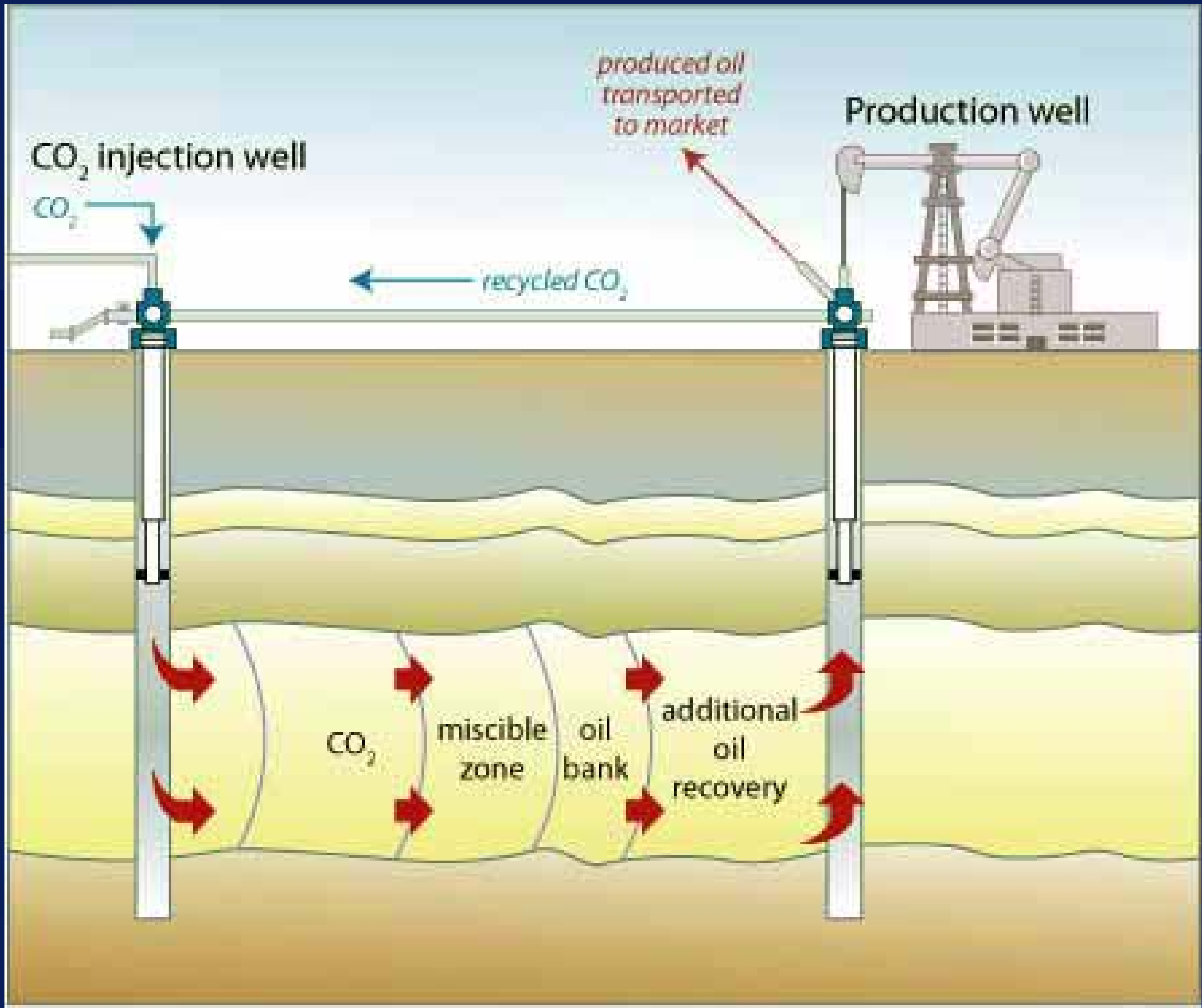


Pipeline 330 km

5000 t CO_2 / day

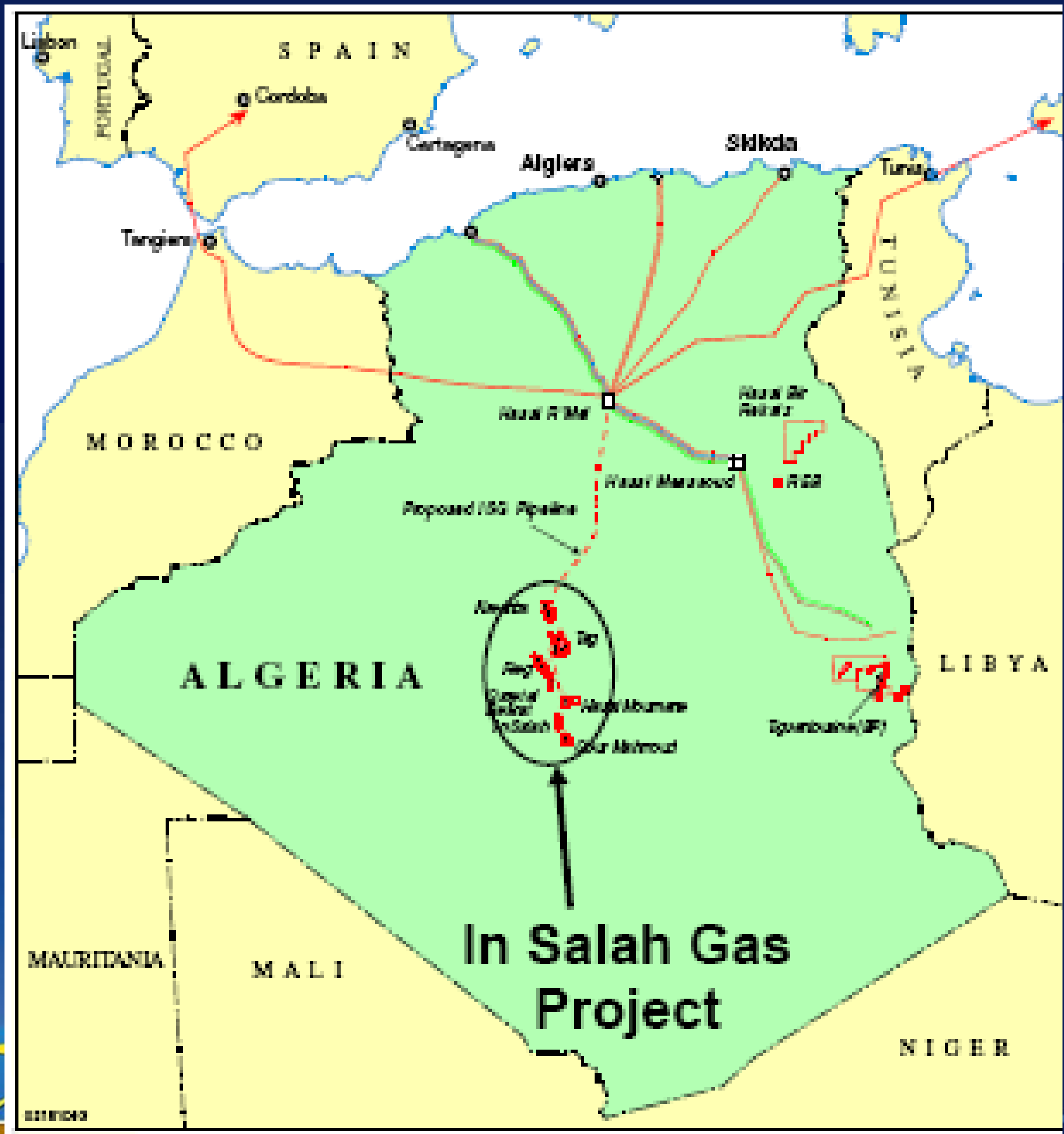
1,8 Mt/y since Sept. 2000

Scheme for EOR through CO_2 storage



Source: IPCC

In-Salah (Algeria)

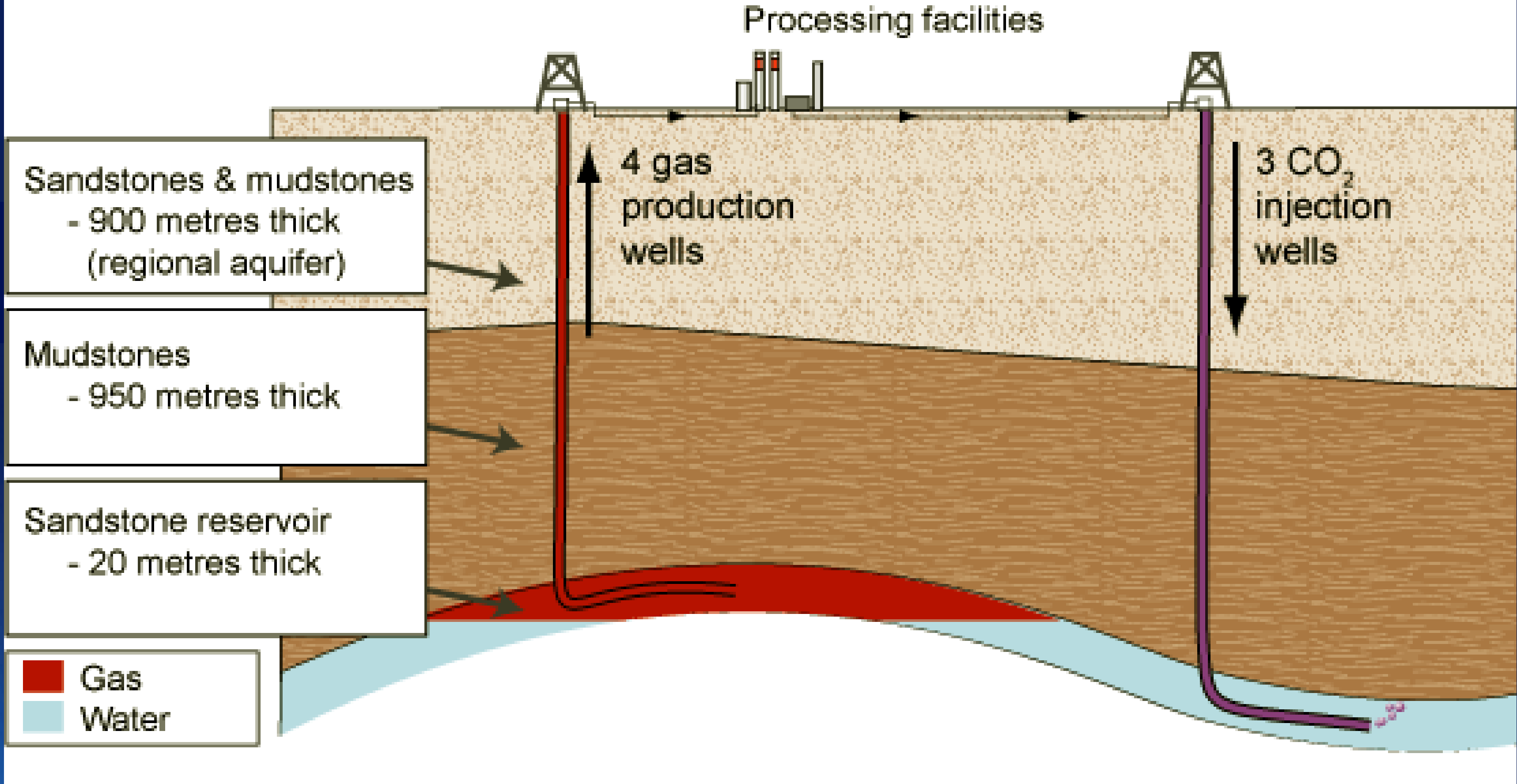


Storage in the aquifer adjacent to the gas reservoir

1 Mt CO_2/an since april 2004

Operator : BP

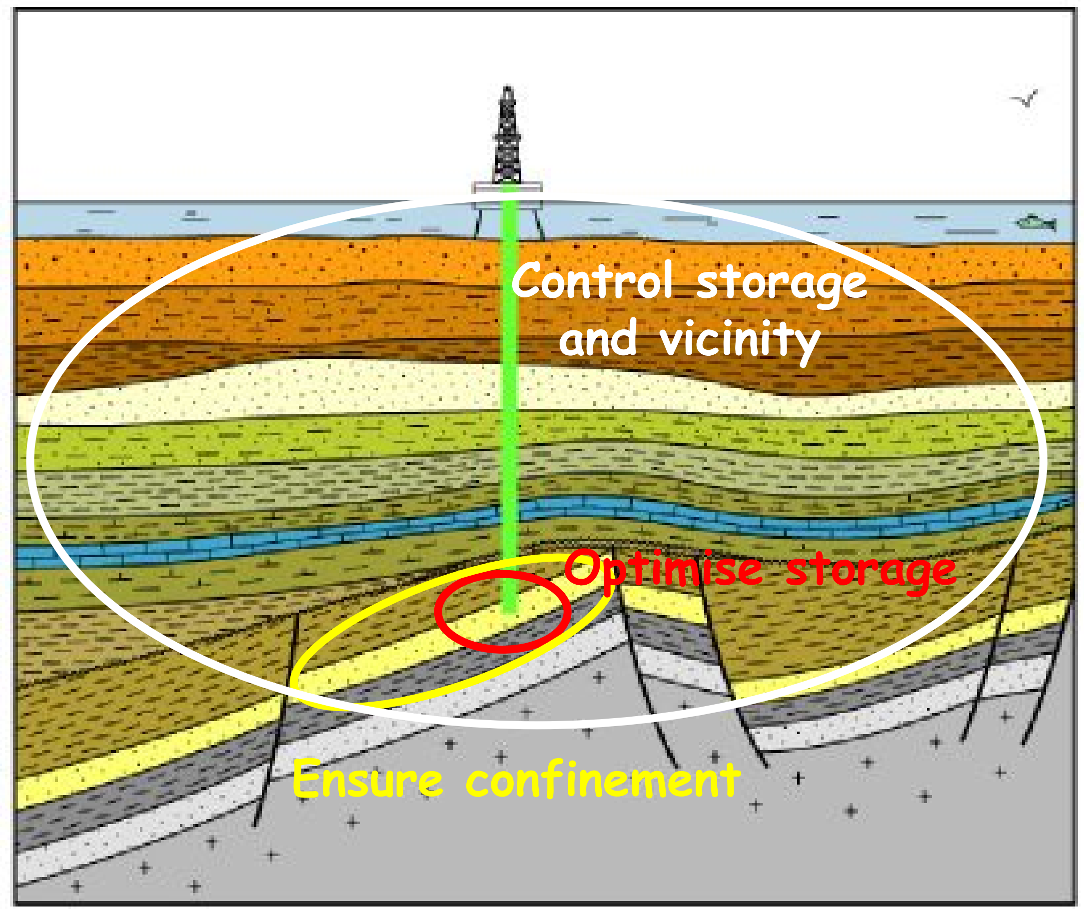
In-Salah (Algeria)



Source: CO2NET lectures

- 5. Key challenges for widespread deployment

Technical challenges for storage: efficiency and security up to several centuries



- Site selection, characterization and capacity assessment
- Injectivity in the reservoir
- Integrity of cap rocks and wells
- Predictive modelling of CO2 fate and reservoir behaviour,
- Monitoring methods (geophysical, geochemical, biogeochemical, remote sensing)
- Safety analysis of the sites
- Remediation methods
- Impact of impurities co-injected with the CO2

A step change is now vital

- Large portfolio of EC research projects since 1993
- Need now to learn by doing!
- EU Flagship Programme: 10-12 integrated, large-scale CCS demonstration projects Europe-wide by 2015 **- to demonstrate a diverse range of infrastructure, technologies, fuels and storage locations (**announcement in 2007)
- EU « Climate action and renewable energy package », approved in Dec. 2008
  - **Directive on the geological storage of CO2**
  - **Other measures to stimulate the demonstration of CCS in power plants, to catalyze the finance for CCS, and to prepare early for wide-scale deployment**
  - **Etc.**
- Public support will be essential

Main steps of a storage project

Site selection	~ t_0 + 1 yr
Site characterisation	~ t_0 + 3 yrs
Storage design & construction	~ t_0 + 5 yrs
Injection operations	~ t_0 + 40 yrs
Site closure	~ t_0 + 45 yrs
Post-closure	…

t_0 → Time

Knowledge of the site -
Confidence in the long-term evolution

- 6. The role of CO_2GeoNet Network of Excellence

CO_2GeoNet Network of Excellence

CO_2GeoNet is <u>the</u> EU scientific body on CO_2 geological storage:

integrated community of researchers with multidisciplinary expertise, <u>durably</u> engaged in enabling the efficient and safe geological storage of CO_2

- **13 partners over 7 countries, more than 150 researchers**
- **Activities:**
  - Joint research on all storage aspects
  - Training
  - Information / communication
  - Scientific advice
- **Created as a FP6 Network of Excellence with EC initial support for 5 years (6 million €, April 2004 – March 2009).**
- **An Association, legally registered under the French law, has been launched in 2008.**

Denmark: **GEUS**
France: **BRGM, IFP**
Germany: **BGR**
Italy: **OGS, URS**
The Netherlands: **TNO**
Norway: **NIVA, IRIS, SPR**
UK: **<u>BGS</u>, HWU, IMPERIAL**

An independent scientific body for Europe is essential to build trust on storage and to support wide scale implementation

Key events in 2009

- **March 18-20, Venice:** 4th CO_2GeoNet Open Forum
  a major international event open to a wide audience (policymakers, public authorities, industrial stakeholders, regulatory bodies, NGOs, engineers and scientists, etc.)

- **November 5-6, Paris:** 3rd International Symposium on CO_2 capture and storage organised by IFP, BRGM, ADEME

- **November 22-27, Austria:** ESF Research Conference on CO_2 storage organised by CO_2GeoNet

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