UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Earth and Environmental Sciences

ESCWA

GEOLOGICAL CO_2 STORAGE POTENTIAL IN THE ARAB REGION.

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University of Geneva

Expert Group Meeting on "Carbon Capture, Utilization and Storage in ESCWA Member States: Enhancing the Sustainability of the Energy System in a Carbon Constrained Development Context"
6-7 November 2013
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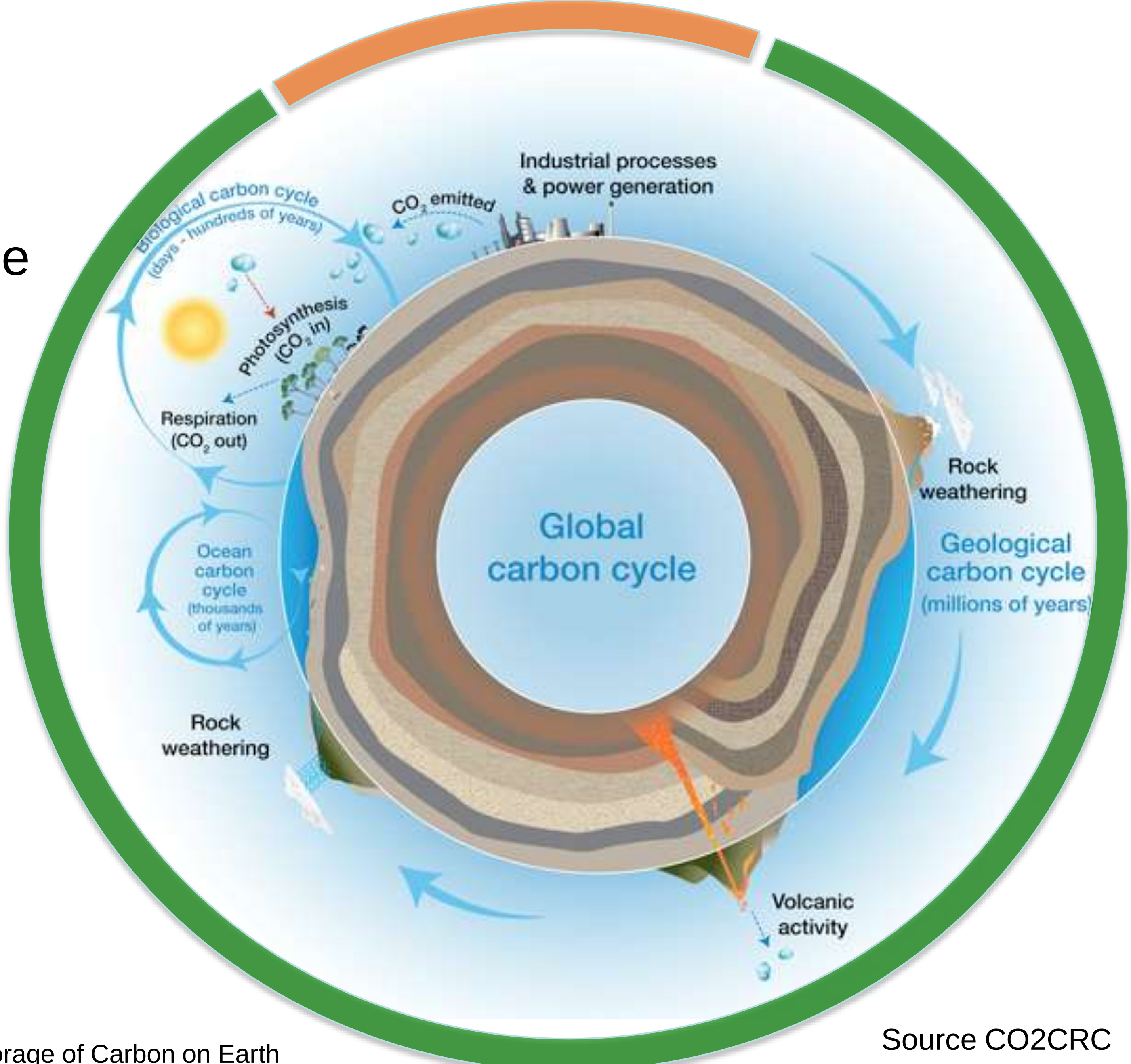
  - General Principles and review of CO_2 sources and distribution in the ESCWA region
- The geology of ESCWA region and implications for CCS - sinks
- CO_2 geological storage
  - Subsurface options
  - Challenges and Uncertainties
- Recommendations

Introduction

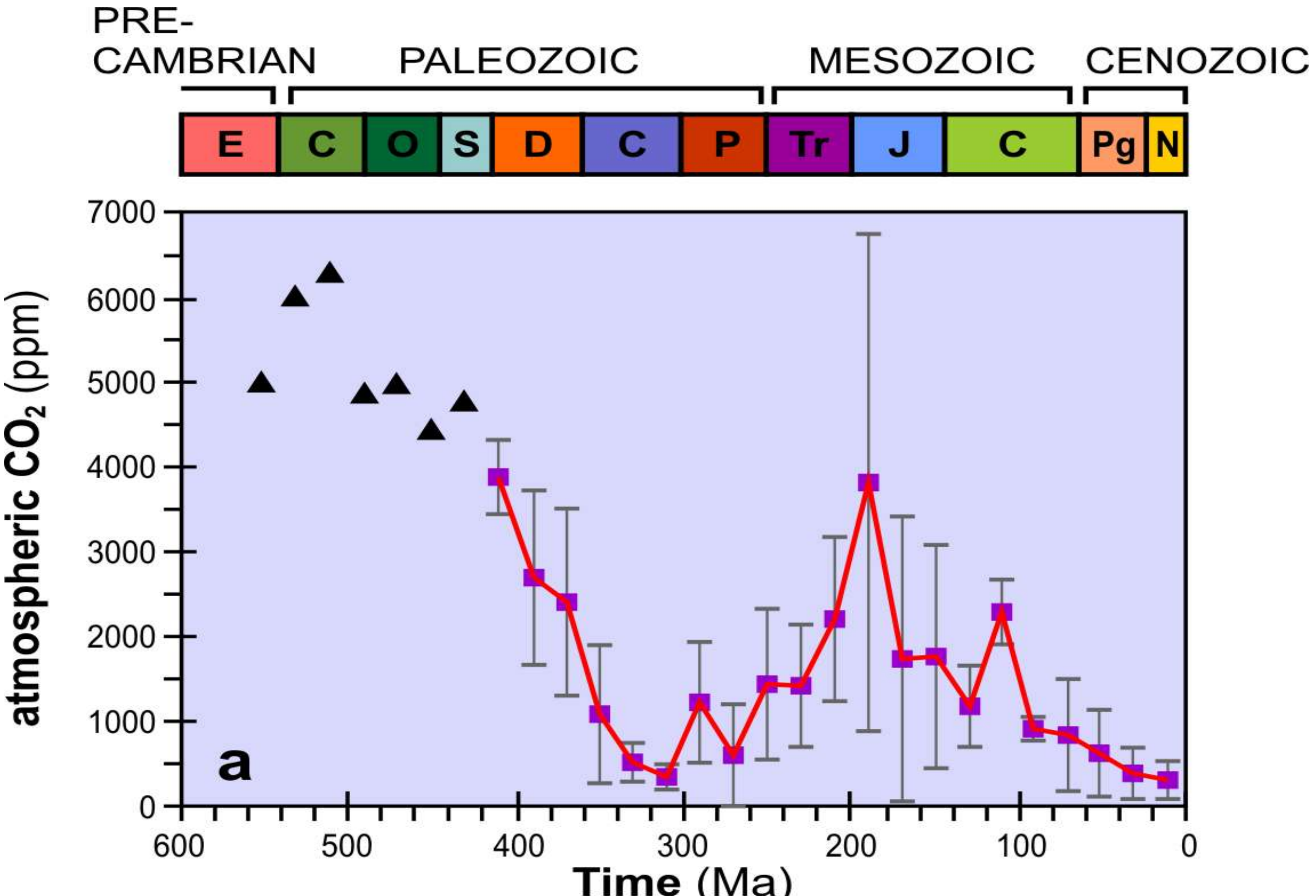
CCS GENERAL PRINCIPLES AND REVIEW OF CO_2 SOURCES AND DISTRIBUTION IN THE ESCWA REGION

The Global Carbon Cycle: a natural source of CO_2

Carbonate rocks: the largest storage of Carbon on Earth



Source CO2CRC

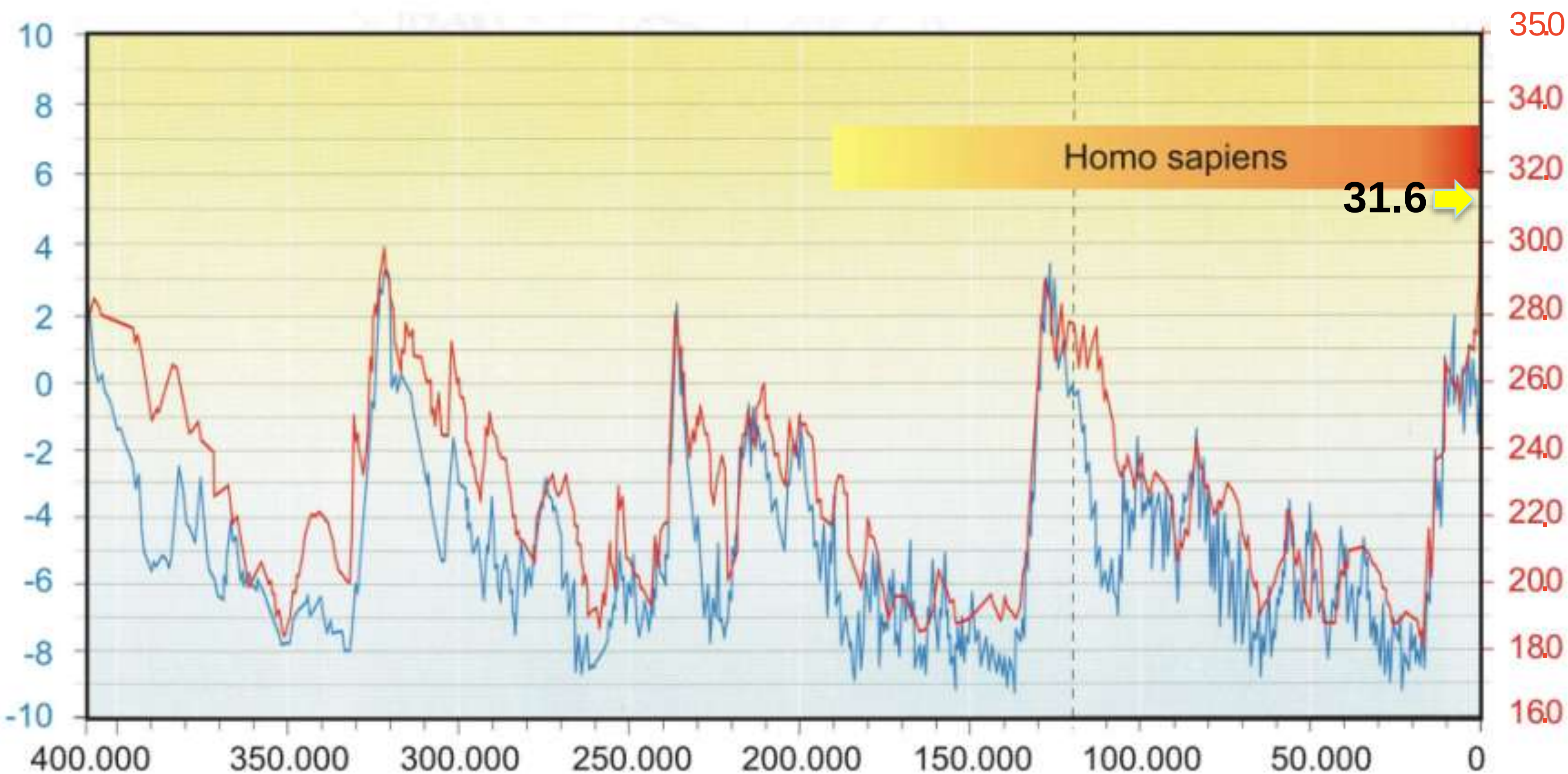


Royer et al (2004) CO_2 as a primary driver of Phanerozoic climate. GSA Today 14/3

Variations of temperature and CO_2 in the atmosphere

Variations of temperature compared to present day

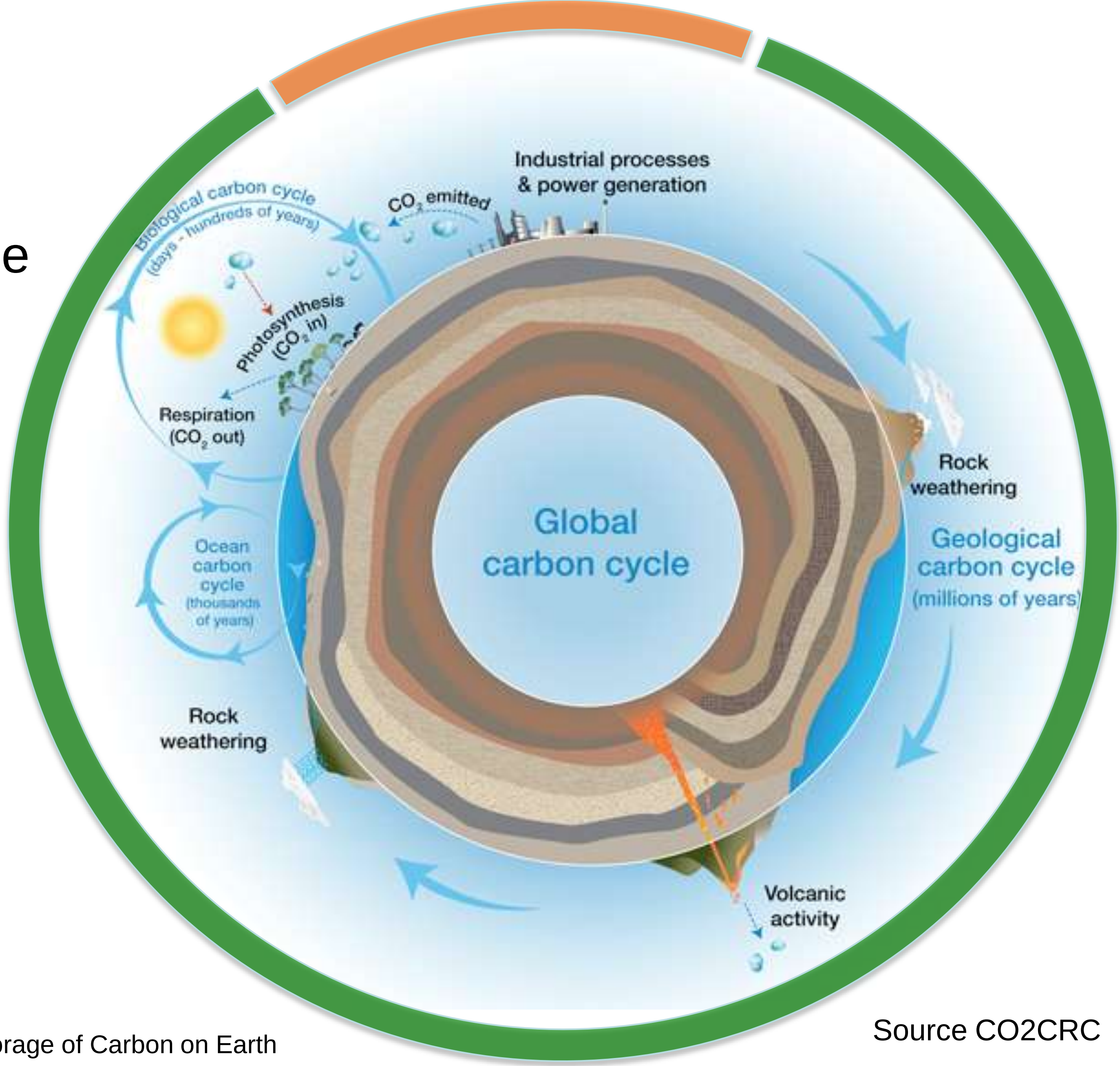
CO_2 concentration in the atmosphere (Gt)



Years Before Present

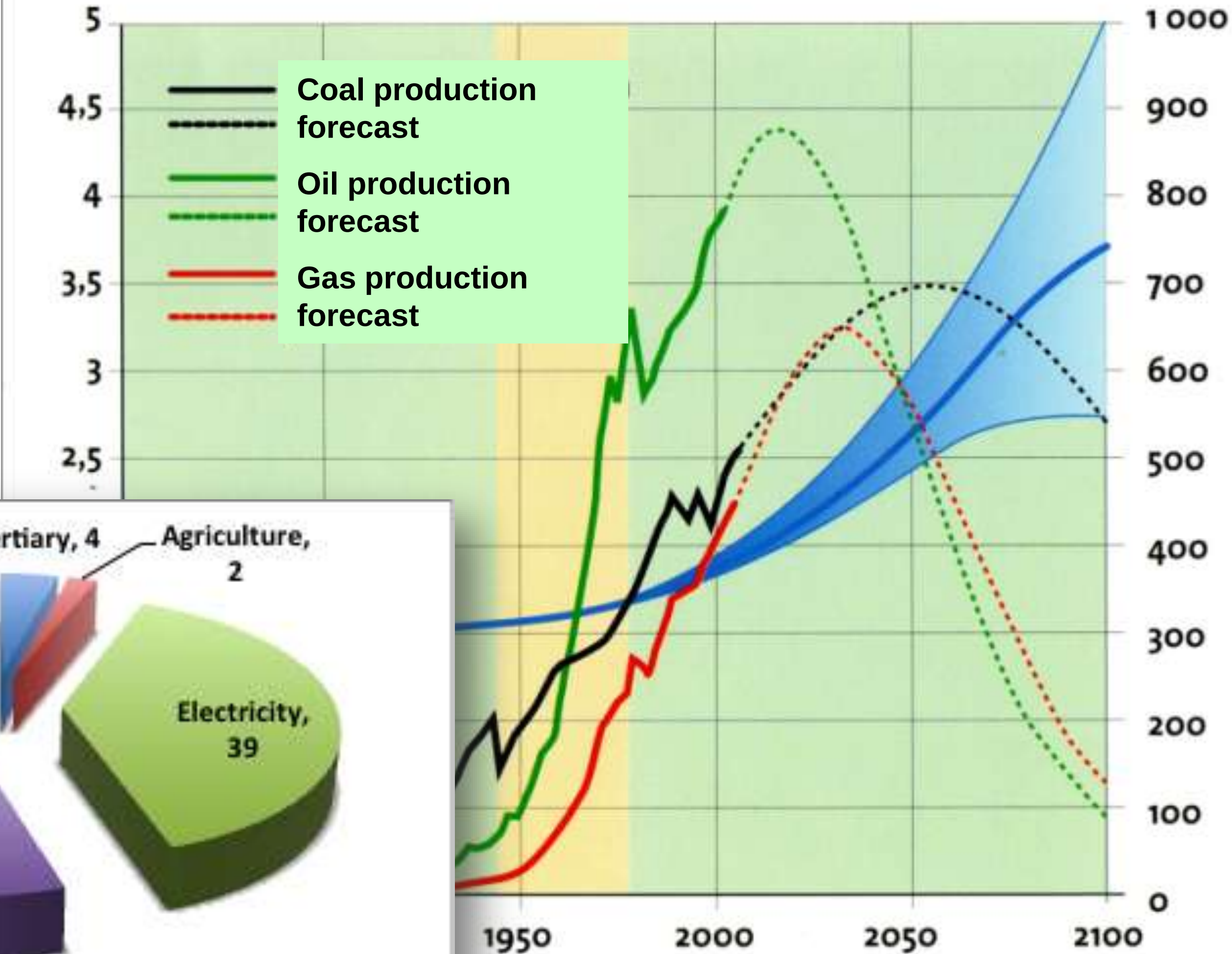
The Global Carbon Cycle: a natural source of CO_2

Carbonate rocks: the largest storage of Carbon on Earth



Source CO2CRC

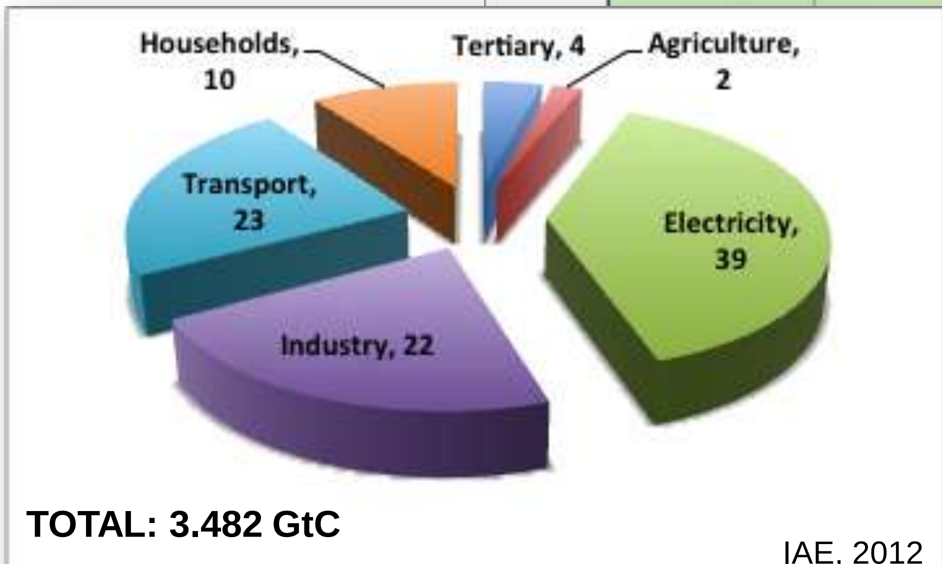
IPCC forecast of CO_2 emissions in the atmosphere



...ospheric concentration of CO_2, according to IPCC

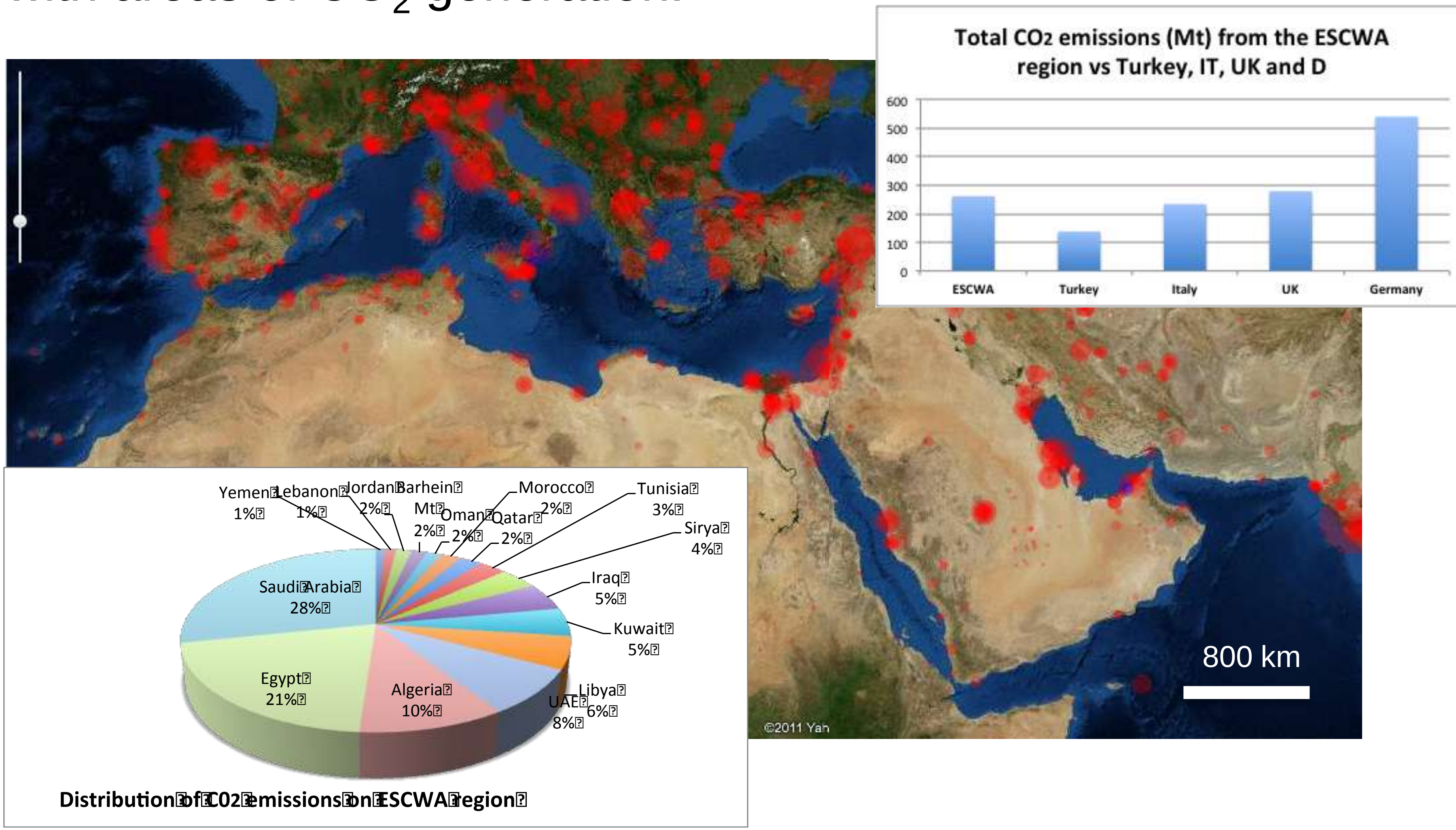
Average value of the above evolution

Distribution of anthropic sources of CO_2 worldwide

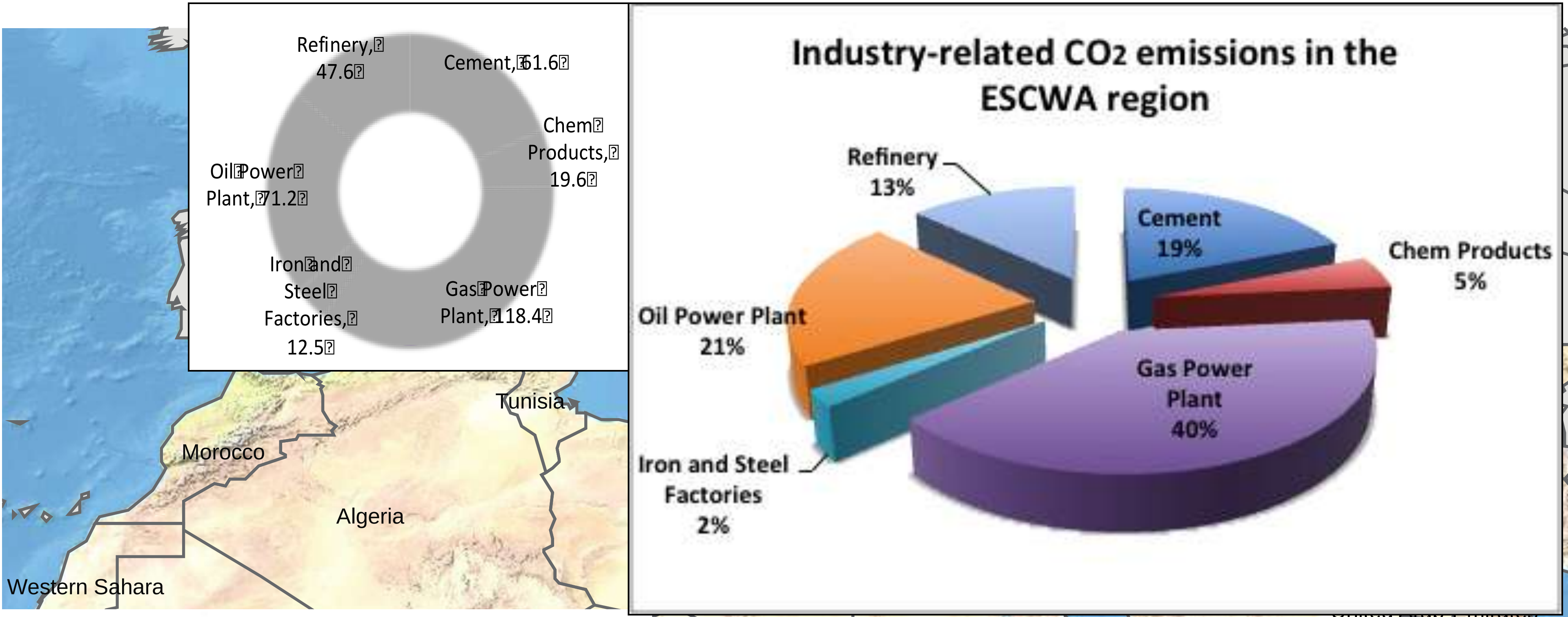


1 gigaton (Gt) = 1,000,000,000,000 or 10^{12} kg

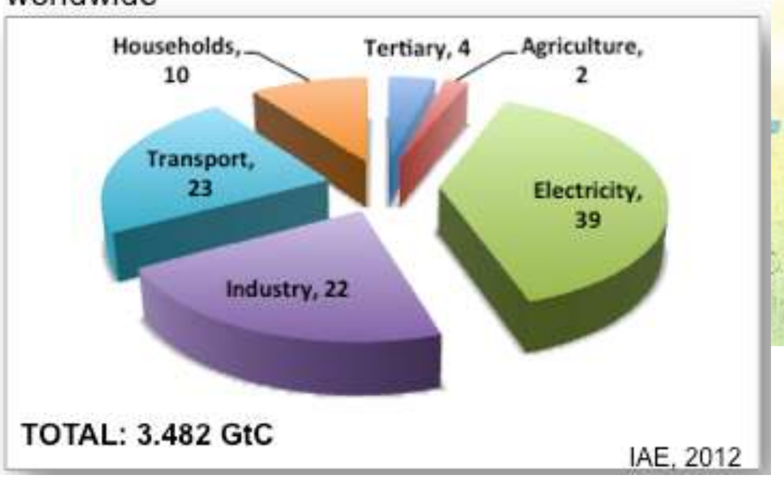
Geographical outline of the ESCWA and neighbor regions with areas of CO_2 generation.



Source from IAE's GHG program, modified from http://bellona.org/ccs/)



Distribution of anthropic sources of CO_2 worldwide

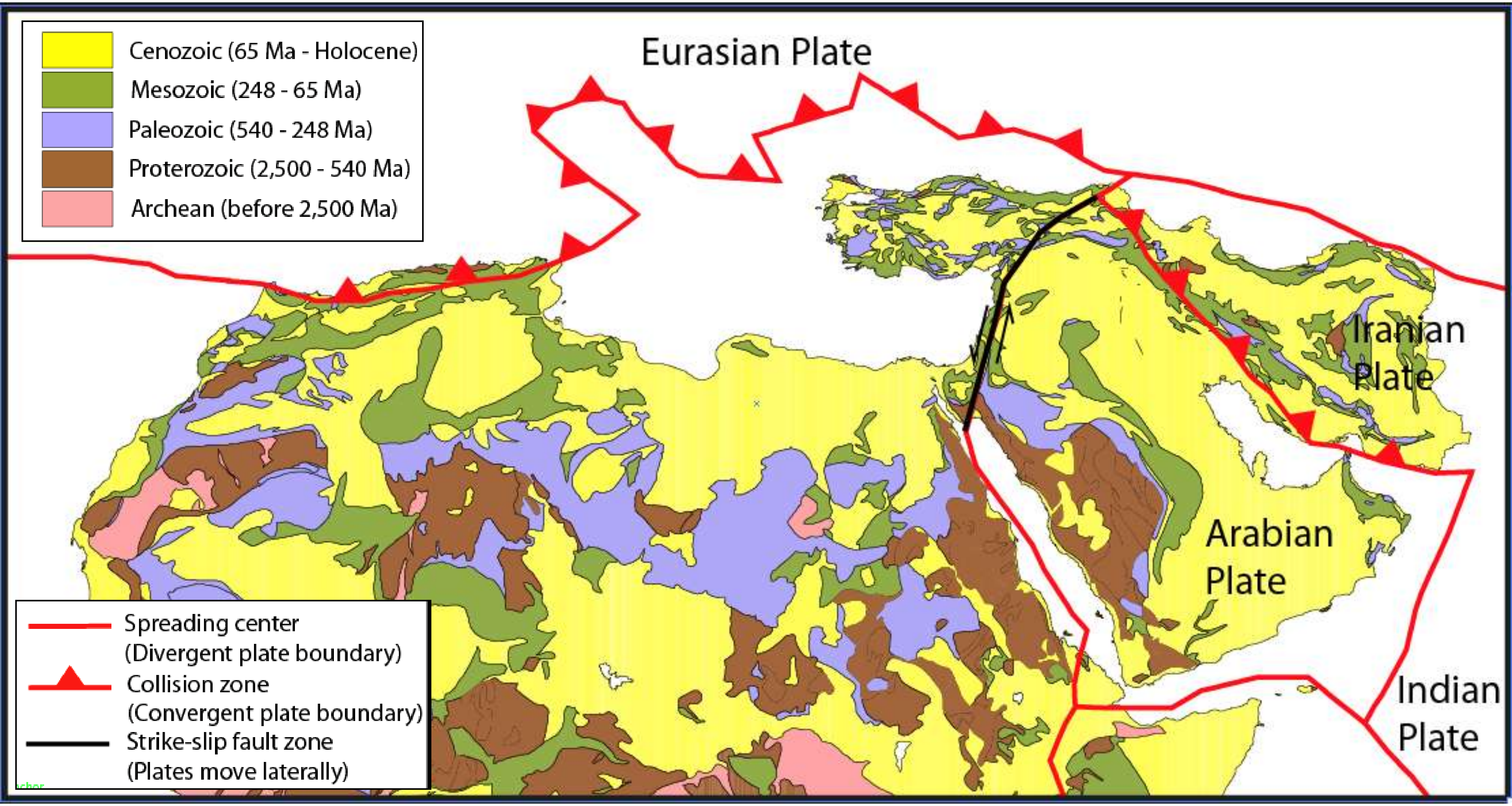


Source from IAE's GHG program

Subsurface Geology

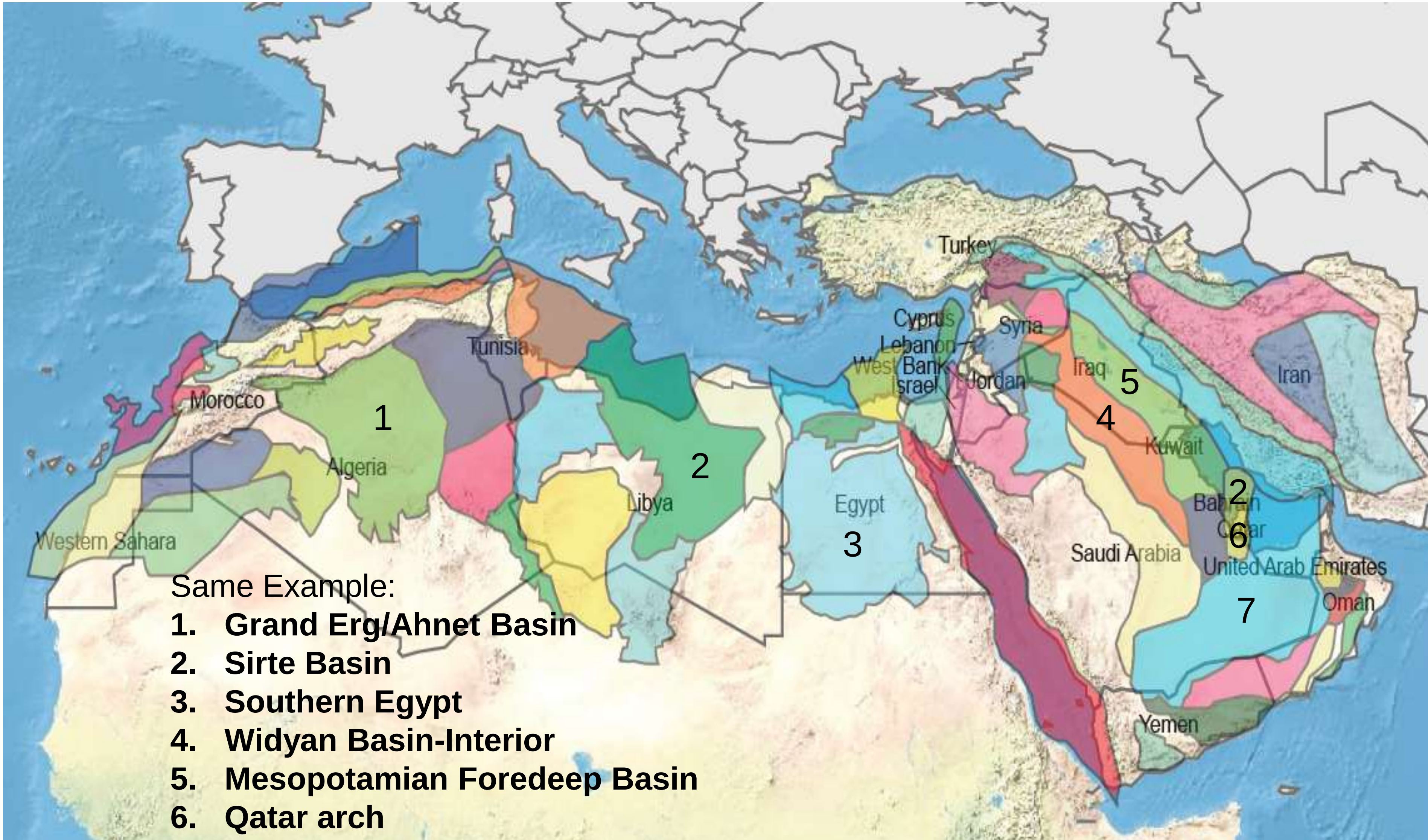
THE GEOLOGY OF ESCWA REGION AND IMPLICATIONS FOR CCS - SINKS

GEOLOGY OF NORTH AFRICA AND MIDDLE EAST



Source Taylor et al., 2005, USGS

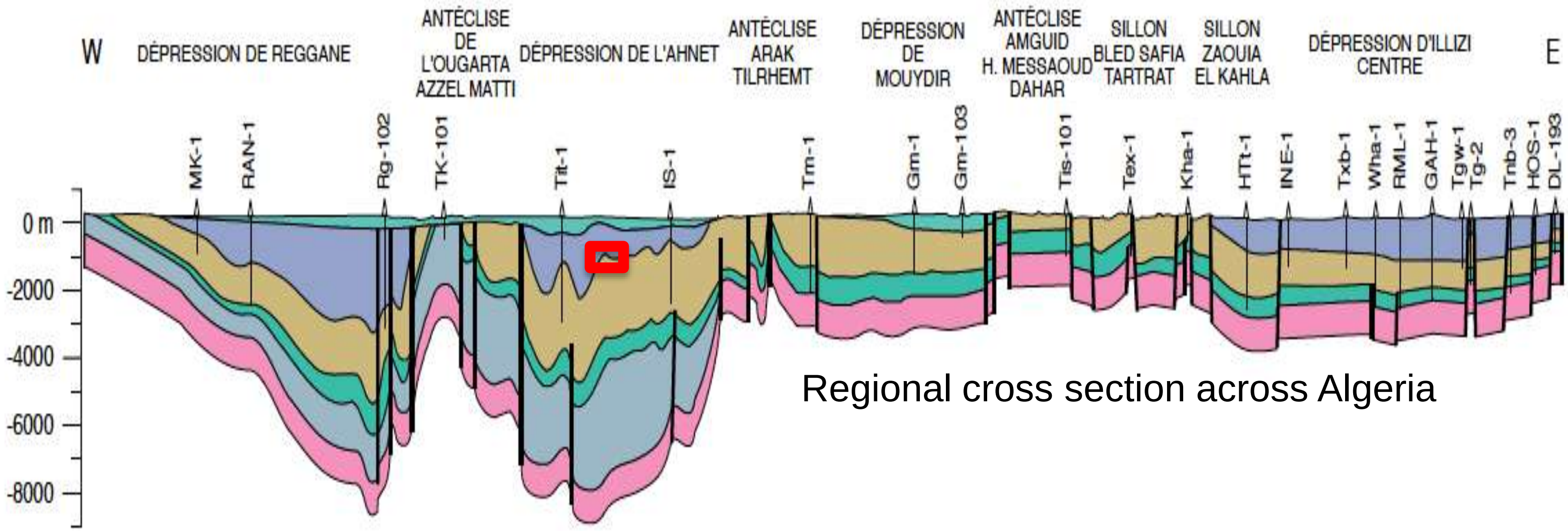
Sedimentary Basins in the MENA region



Same Example:

1. **Grand Erg/Ahnet Basin**
2. **Sirte Basin**
3. **Southern Egypt**
4. **Widyan Basin-Interior**
5. **Mesopotamian Foredeep Basin**
6. **Qatar arch**
7. **Rub Al Khali Basin**

Source: Ahlbrandt et al., 2000, USGS + compilation from literature

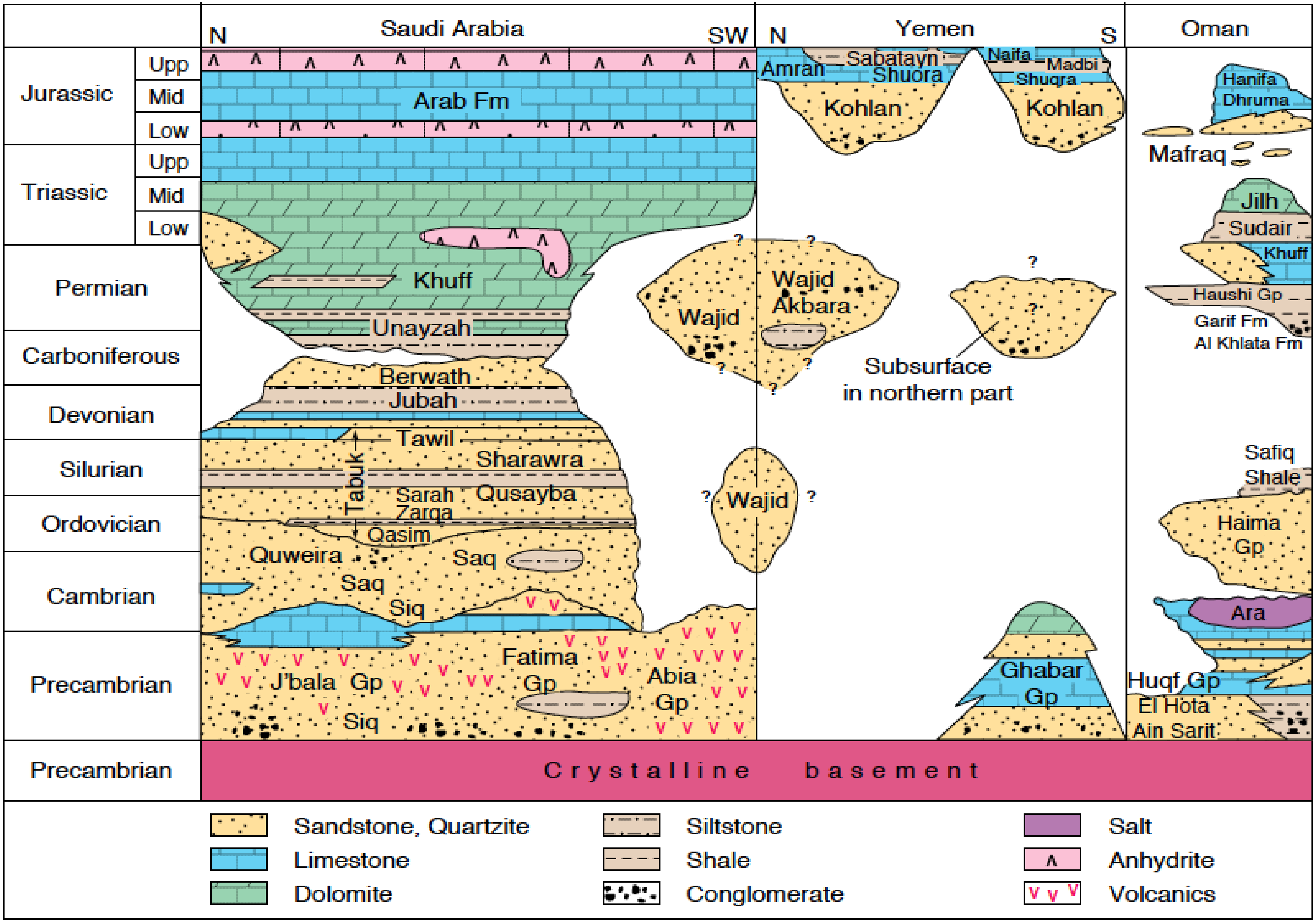


Regional cross section across Algeria

Jebel Akhmar, Oman:
an exhumed large scale structure. An excellent reservoir analogue

Foto courtesy F. Mondino

Example of lateral variability of sedimentary successions across neighboring basins

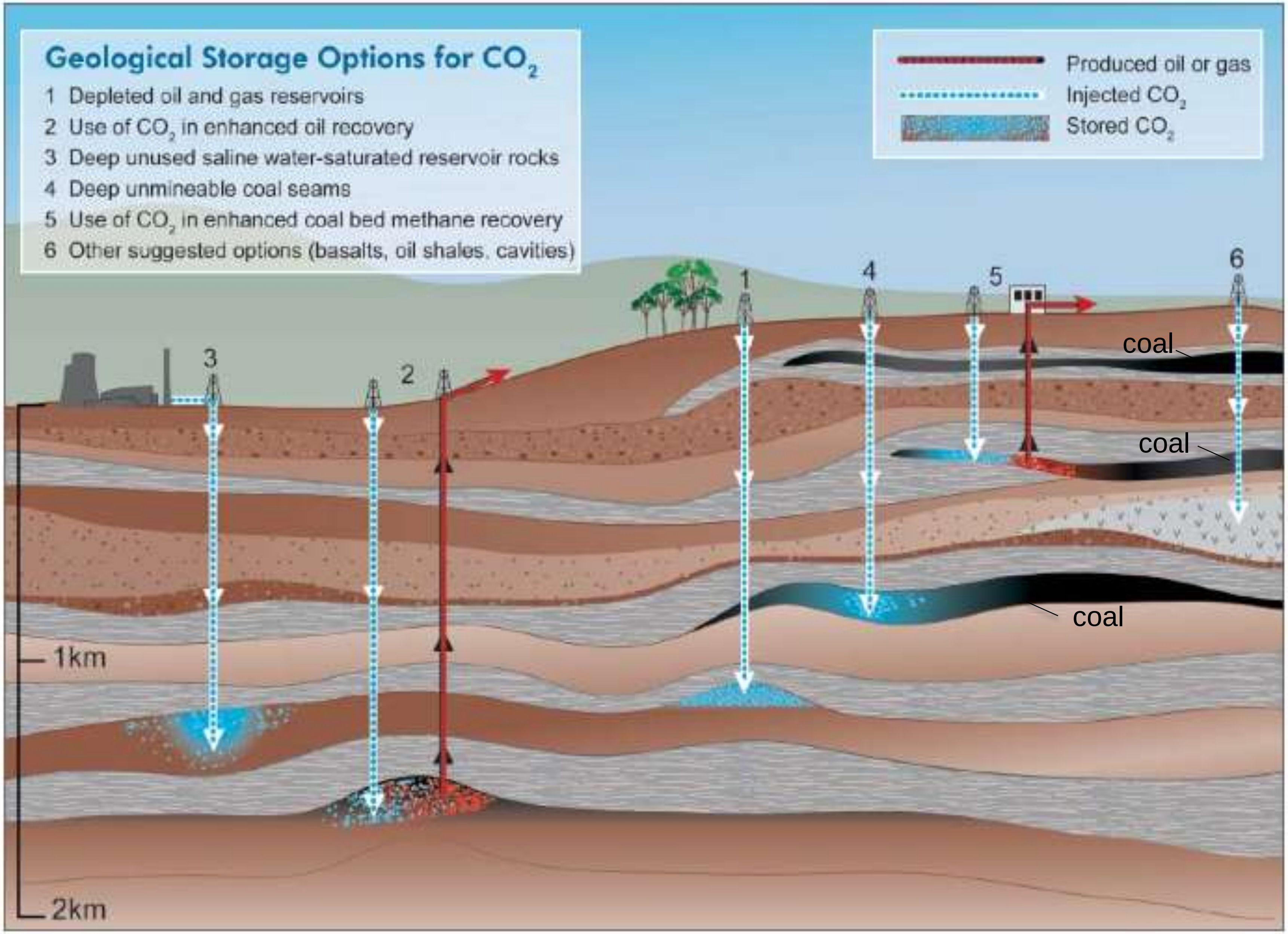


CO_2 geological storage

OPTIONS

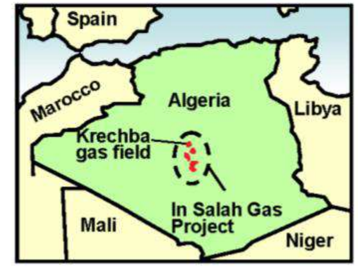
Options

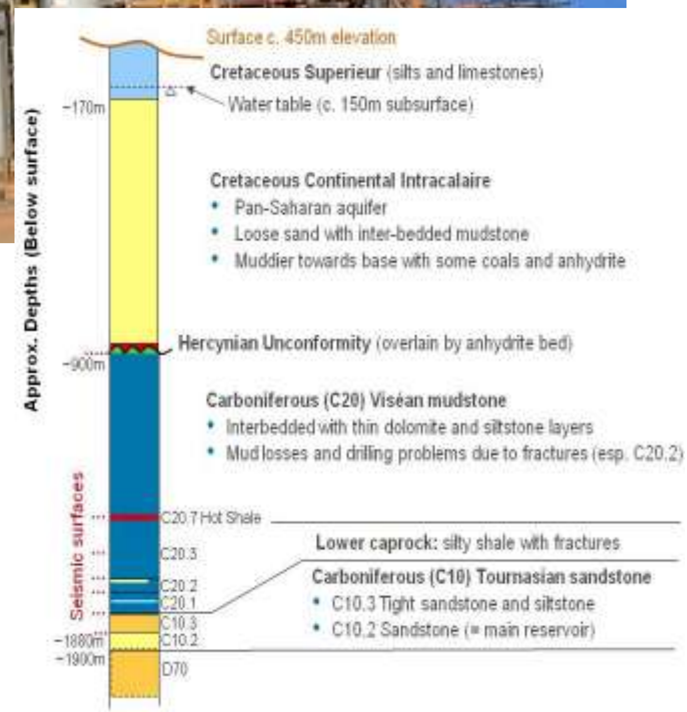
1. CO_2 Injection in to saline aquifers
2. CO_2 Injection into depleted gas reservoirs
3. CO_2- Enhanced Oil Recovery (EOR) practices
4. CO_2- Enhanced Gas Recovery (EGR) potential
5. Storing CO_2 in coal bed seams.



Variety of options for the long-term subsurface storage of CO_2 (from www.co2crc.com.au)

In Salah Industrial-scale CCS in action

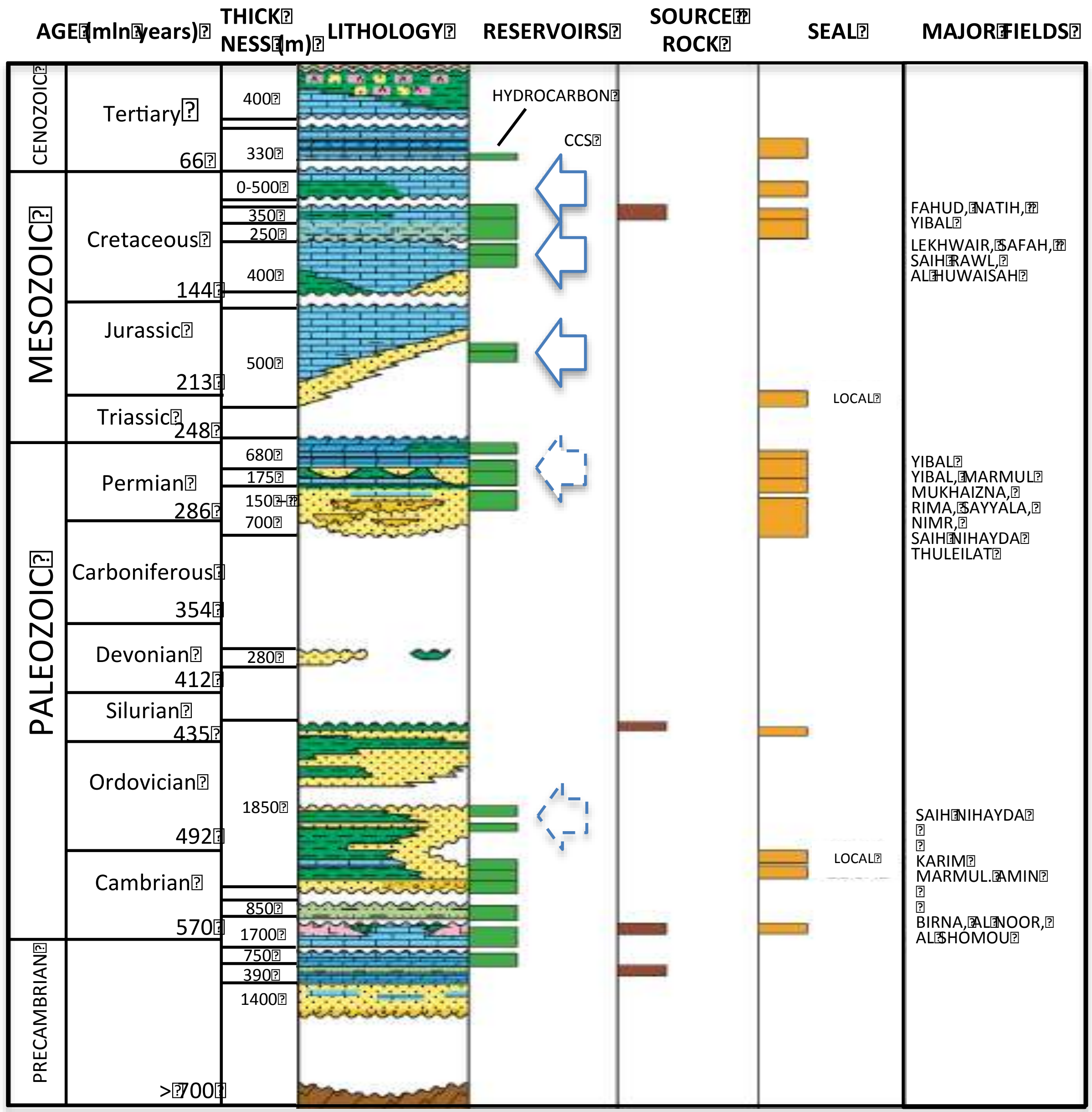




- In Salah project in operation since 2004.
- More than 3 Mt of CO_2, separated during gas production stored in a deep saline formation.
- Operated by BP, Sonatrach and Statoil.
- Objective: total 17 Mt over the next 20 years.

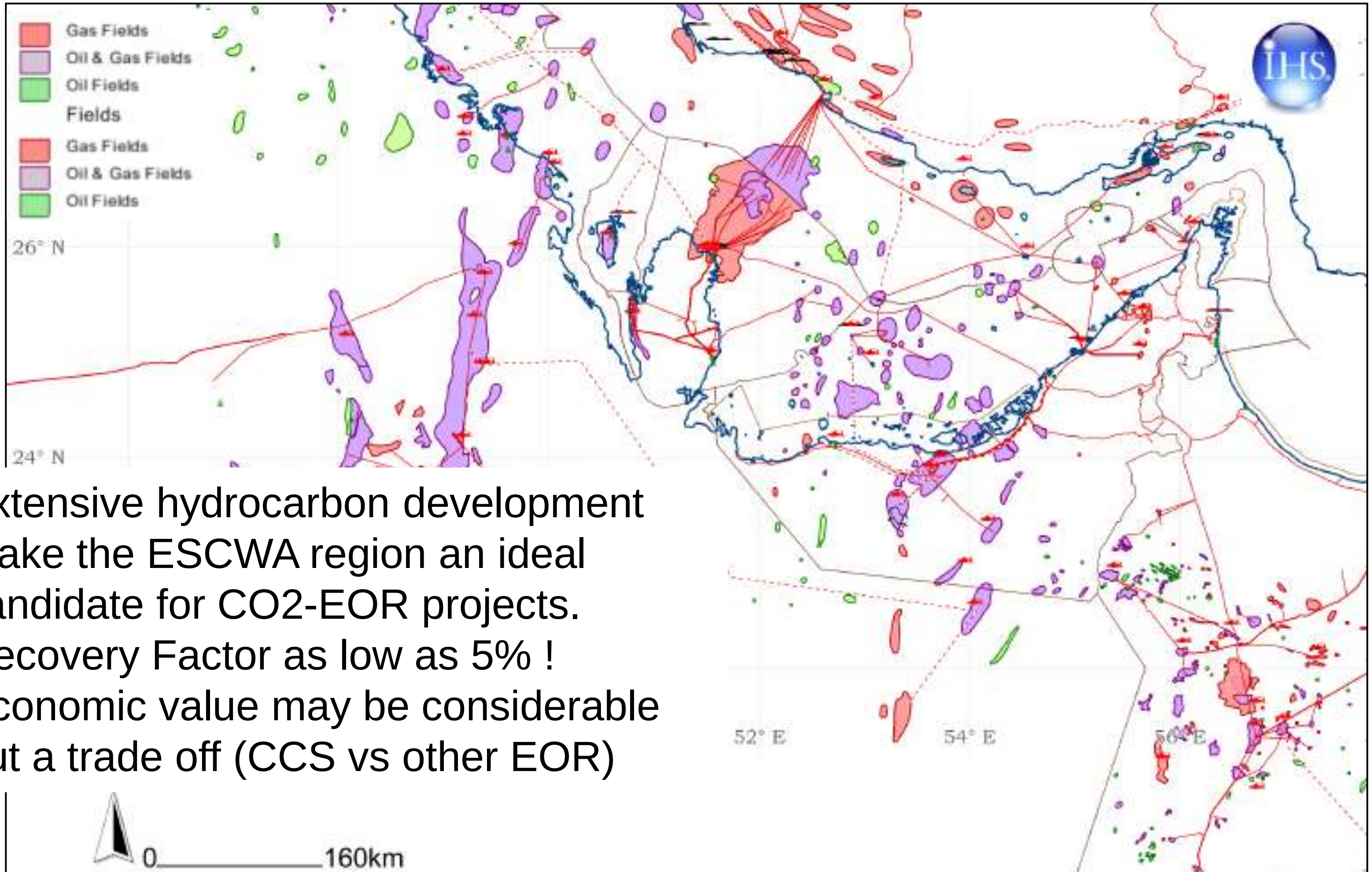
Source: http://www.insalahco2.com/

Deep saline reservoir options in the Oman Basin



Moscariello, 2013

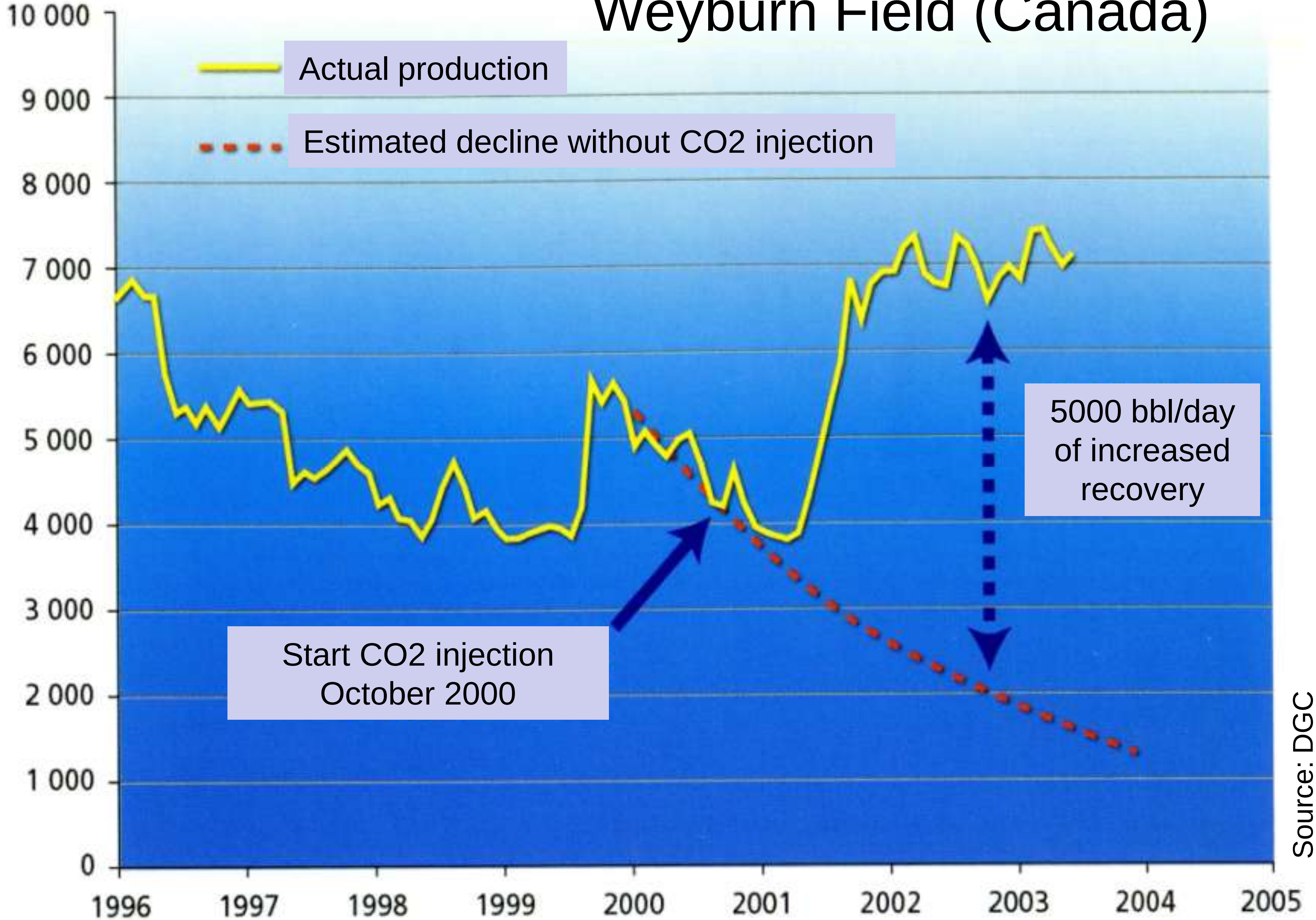
CO_2-EOR: what is possible ?



- Extensive hydrocarbon development make the ESCWA region an ideal candidate for CO2-EOR projects.
- Recovery Factor as low as 5% !
- Economic value may be considerable but a trade off (CCS vs other EOR)

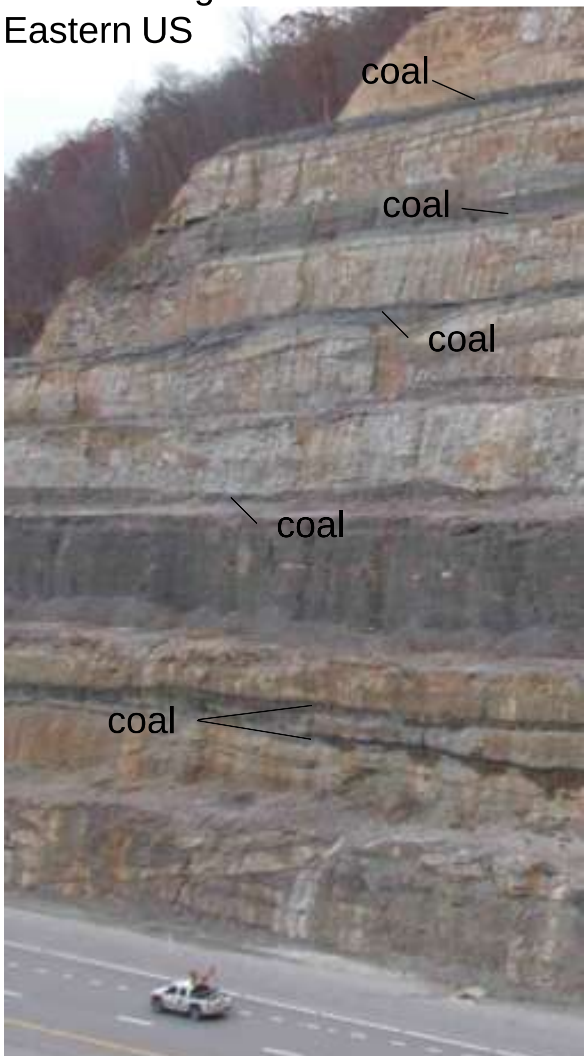
Source courtesy of IHS Global

Results of CO2-EOR in the Weyburn Field (Canada)

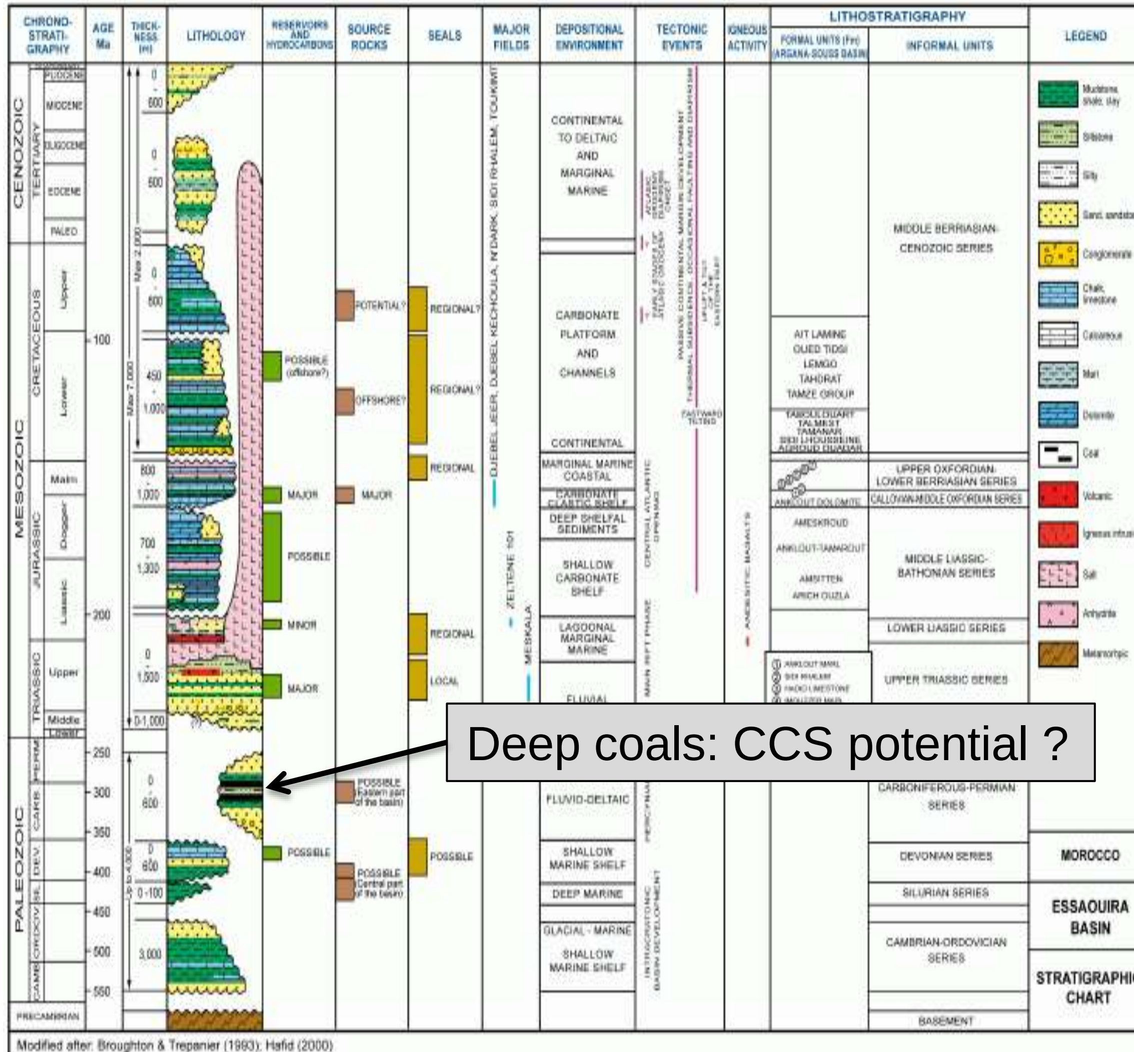


Storing CO_2 in coal-bed seams.

Coal bearing successions in Eastern US



Essaouira Basin, Morocco



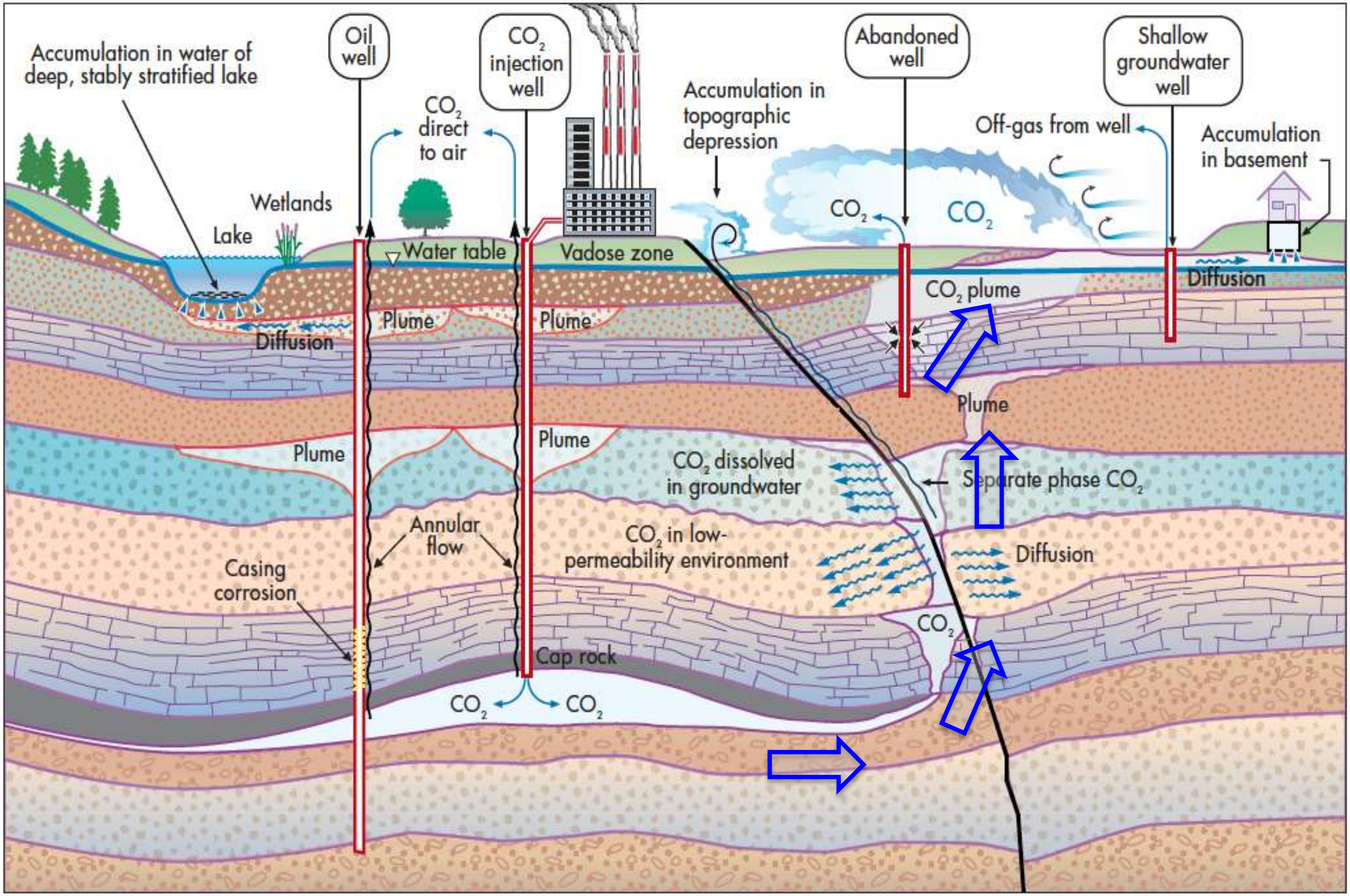
Source courtesy of IHS Global

CO_2 geological storage

UNCERTAINTIES AND CHALLENGES

Some considerations:

- Properly located, engineered, and managed geological CCS reservoirs are expected to retain stored CO_2 for hundreds to thousands of years.
- Understanding physical and chemical behavior of CO_2 underground (interaction with hosting rocks) is key of any CCS project's success
- Effective monitoring systems will have to consider possible underground CO_2 migration paths through soils and groundwater and likely escape routes, including seismic fissures, abandoned water wells, and the injection wells themselves.

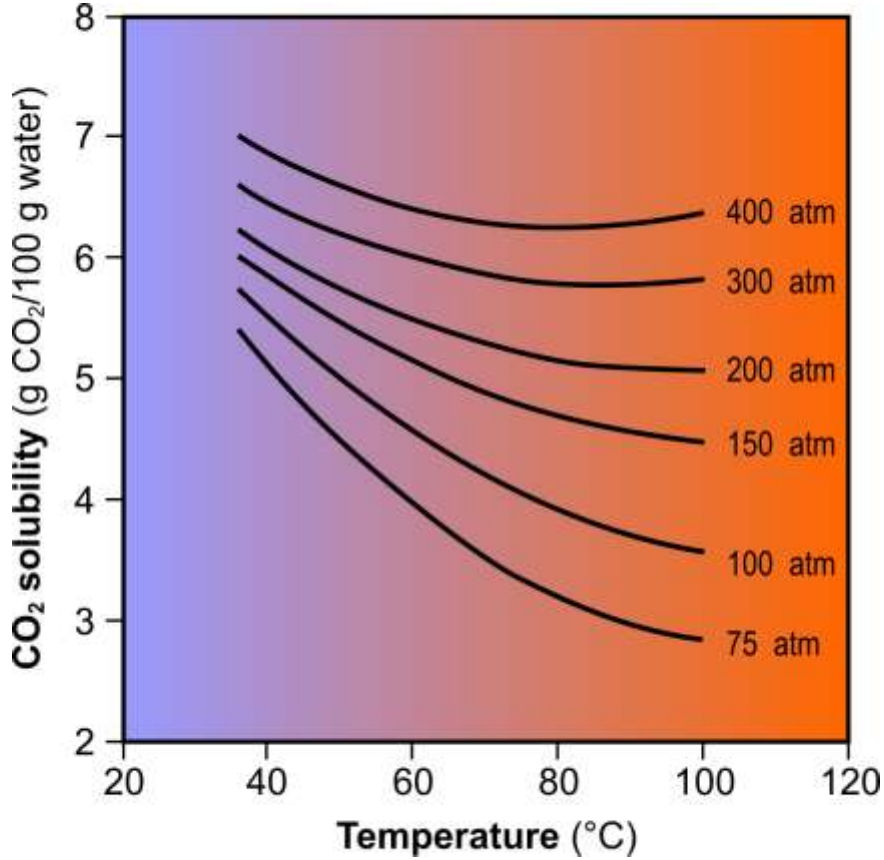


Source: Douglas, 2003

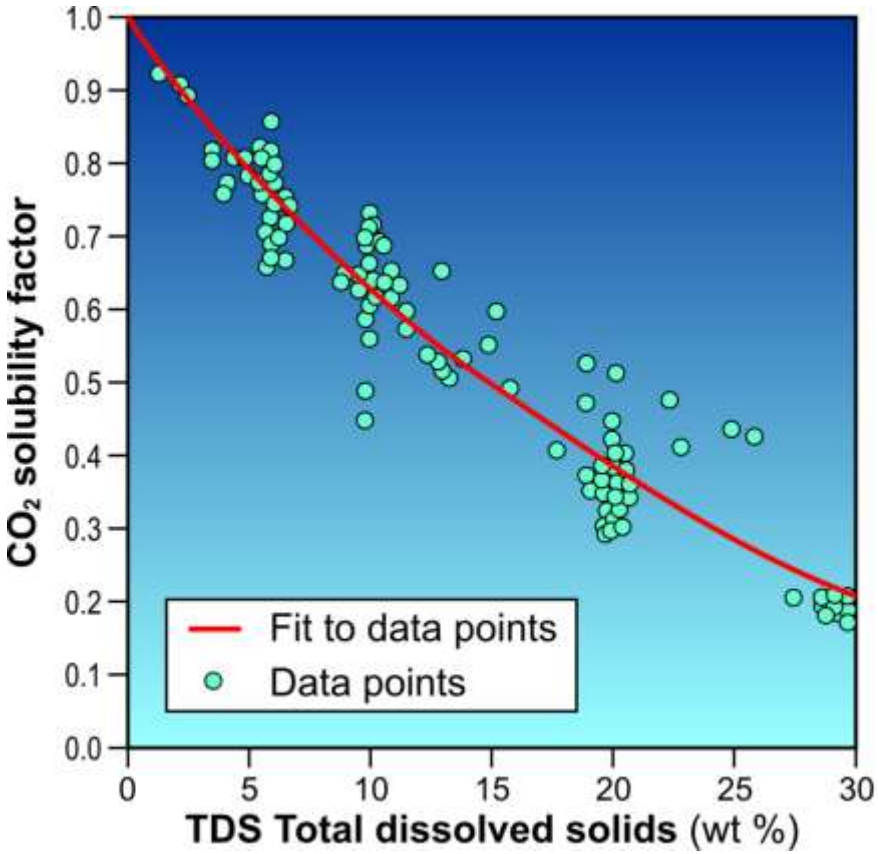
A variety of issues

- Subsurface mineralization
  - Subsurface physical and chemical reaction
- Cap-rock and fault integrity
  - CO_2 retention and fault (re)activation by increase buoyancy pressure
- Well integrity
  - e.g.: pipe corrosion
- Field monitoring
  - e.g. plume behaviour, geophysical well logging', 'down-hole fluid chemistry', 'pressure-temperature monitoring', etc.
- Safety
  - Permanent CO_2 retention ➔ overall public perception
- CO_2 supply – possible cross-border agreements

Solubility of CO_2 depending on Reservoir P &T

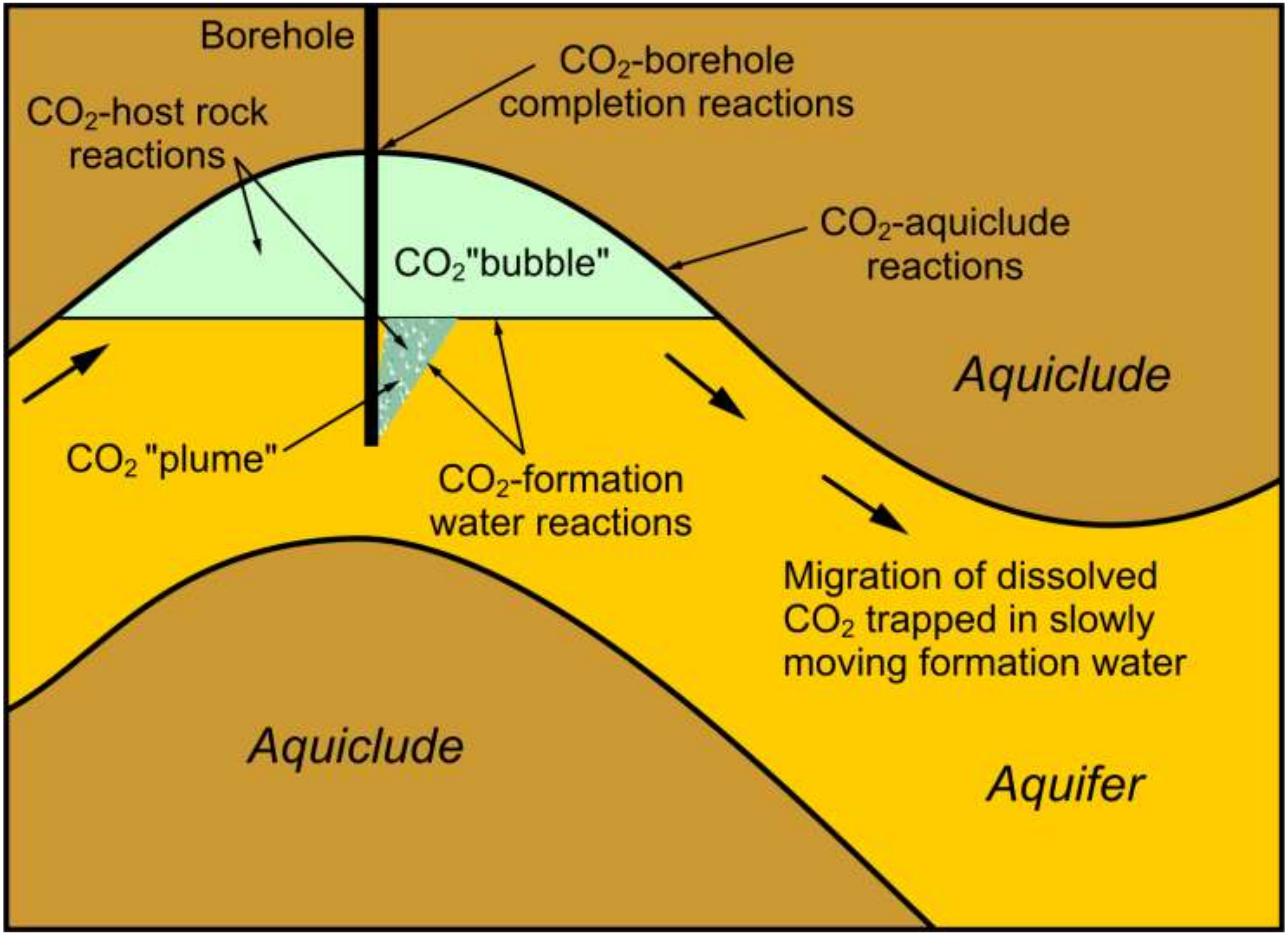


Solubility of CO_2 depending on water salinity



Source: Rochelle et al., 2004

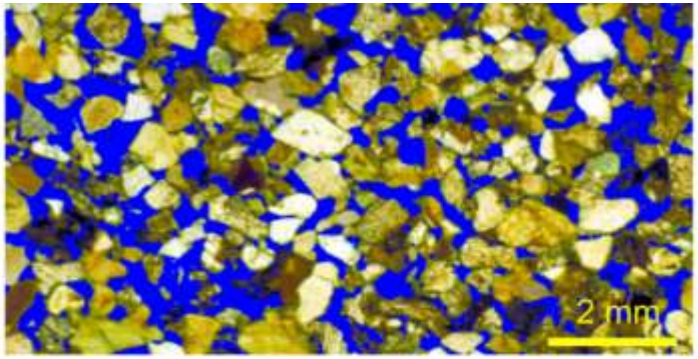
CCS in saline or HC depleted reservoirs: impact of chemical reactions on CO2 storage



Source: Rochelle CA et al., 2004

Effects of CO_2 interaction with hosting reservoir rock

sandstone

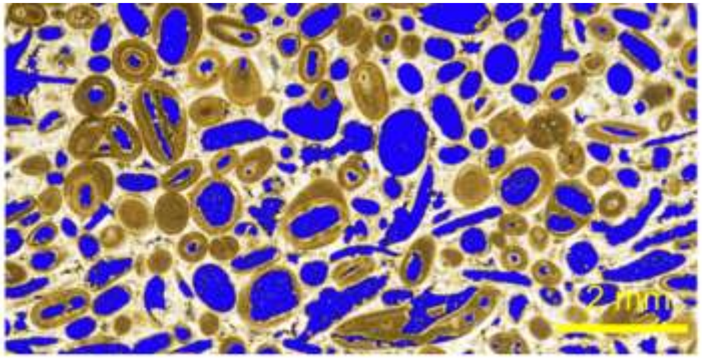


Buffer effect (maintenance of relatively constant pH)

Dissolution of alumino-silicates

Precipitation *in situ* of Quartz, Kaolinite, Fe, Mg and Ca-carbonates

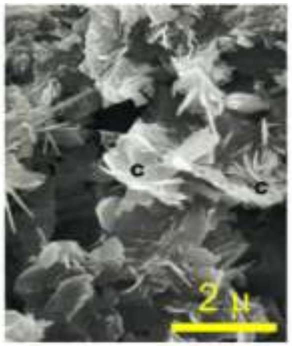
carbonates

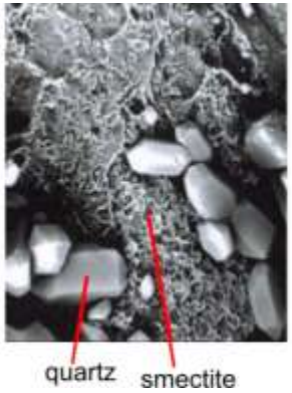


Carbonates dissolution

Delocalized re-precipitation of carbonates if CO_2 pressure decreases

shales



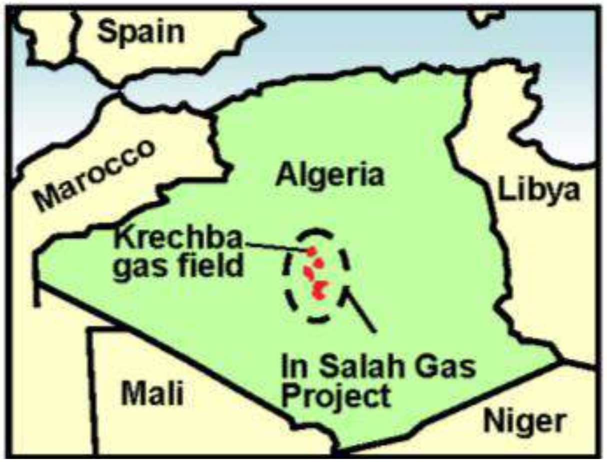


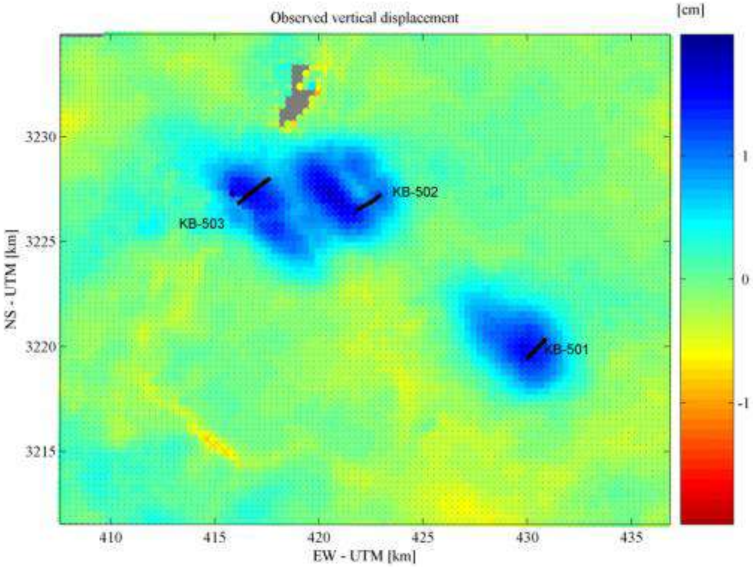
Dissolution of some phyllo-silicates

Precipitation *in situ* of Quartz and Fe, Mg and Ca-carbonates causing reduction of Porosity -> increased sealing capacity of the reservoir

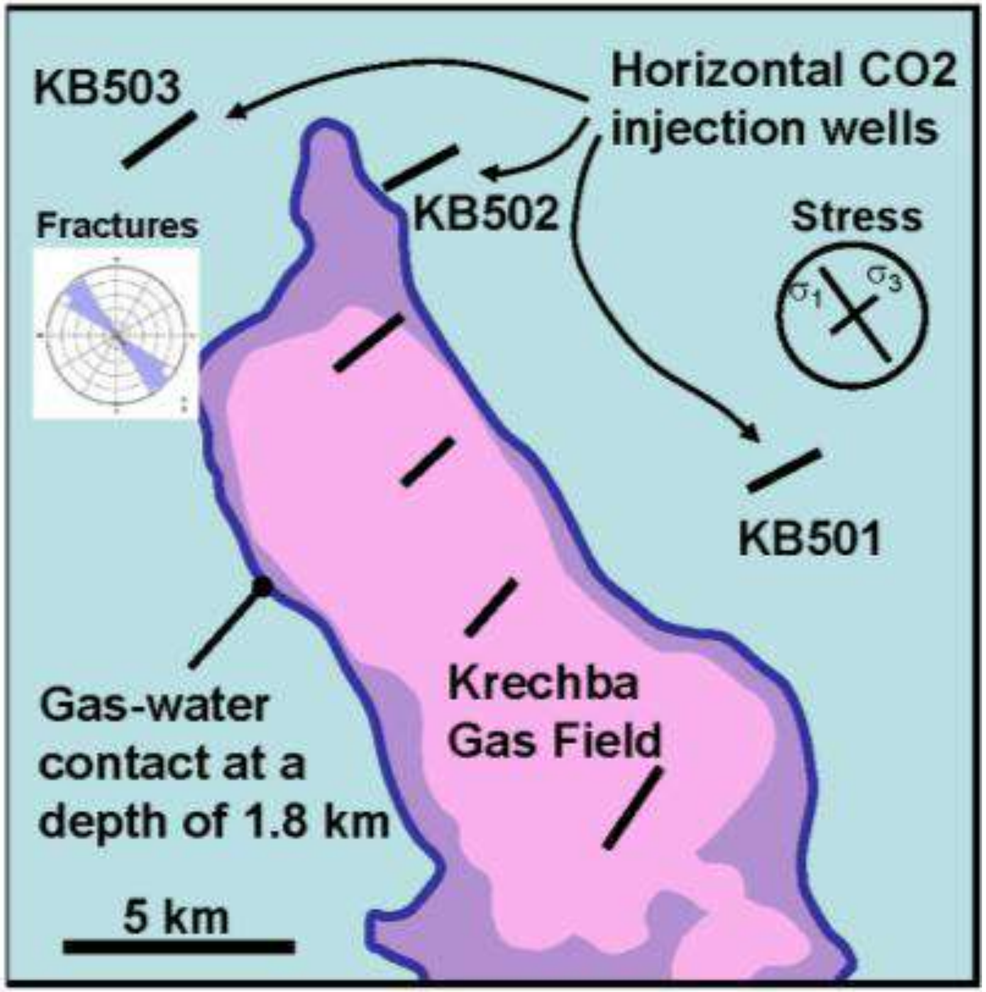
Source: Davaud, 2010

Plume monitoring on the Krechba gas field (In Salah Gas Project, Algeria)



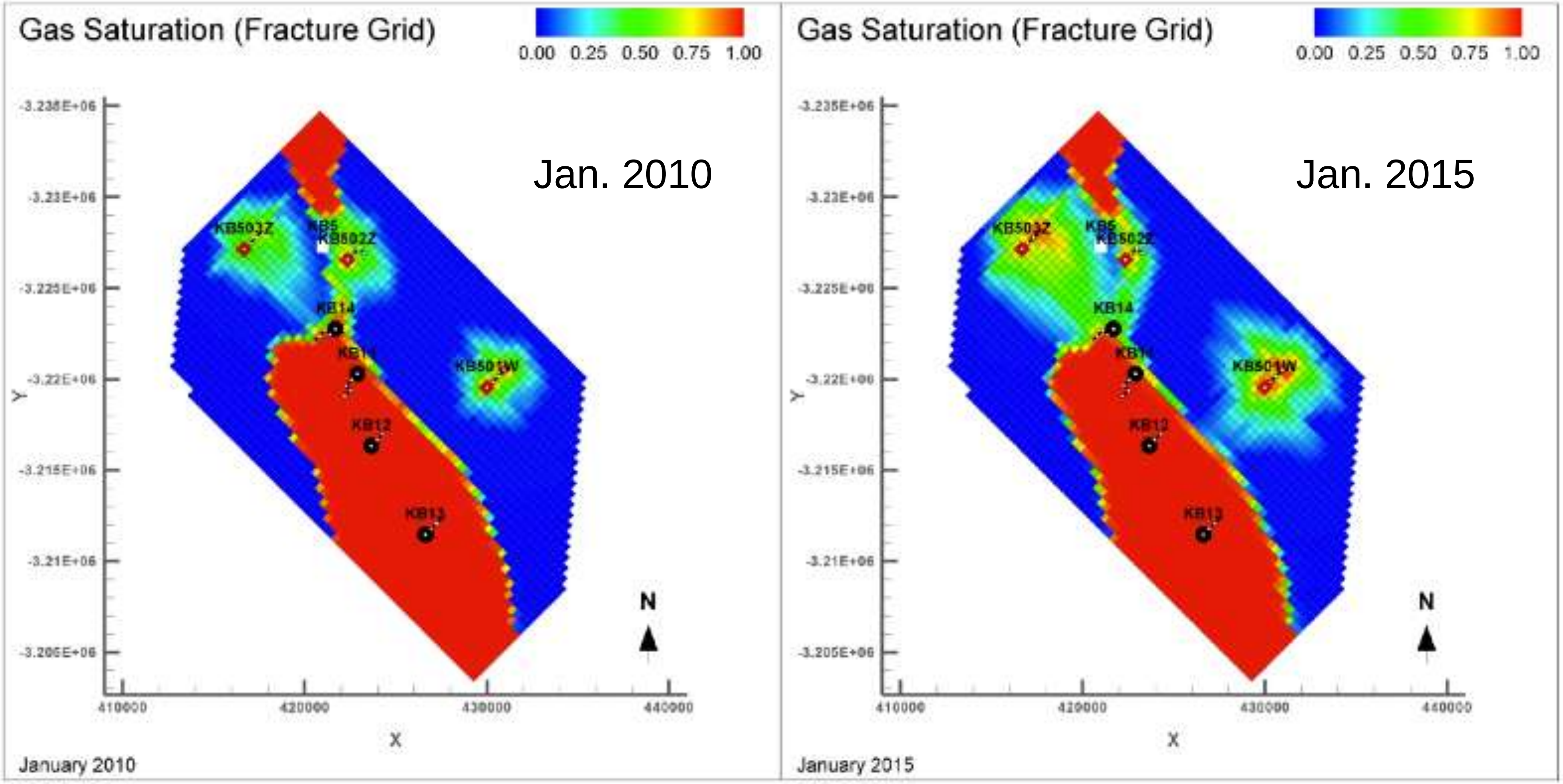


InSAR satellite image: convexity



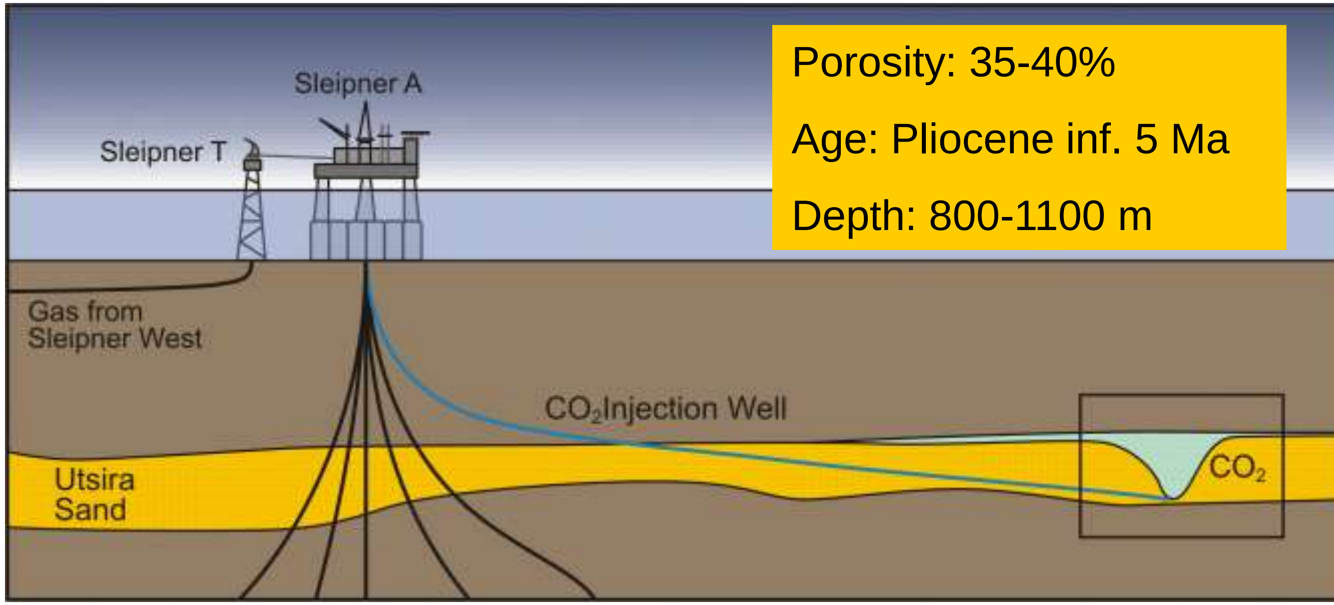
Source: Bissel et al., 2010; Vasco et al., 2010

CO_2 Plume monitoring

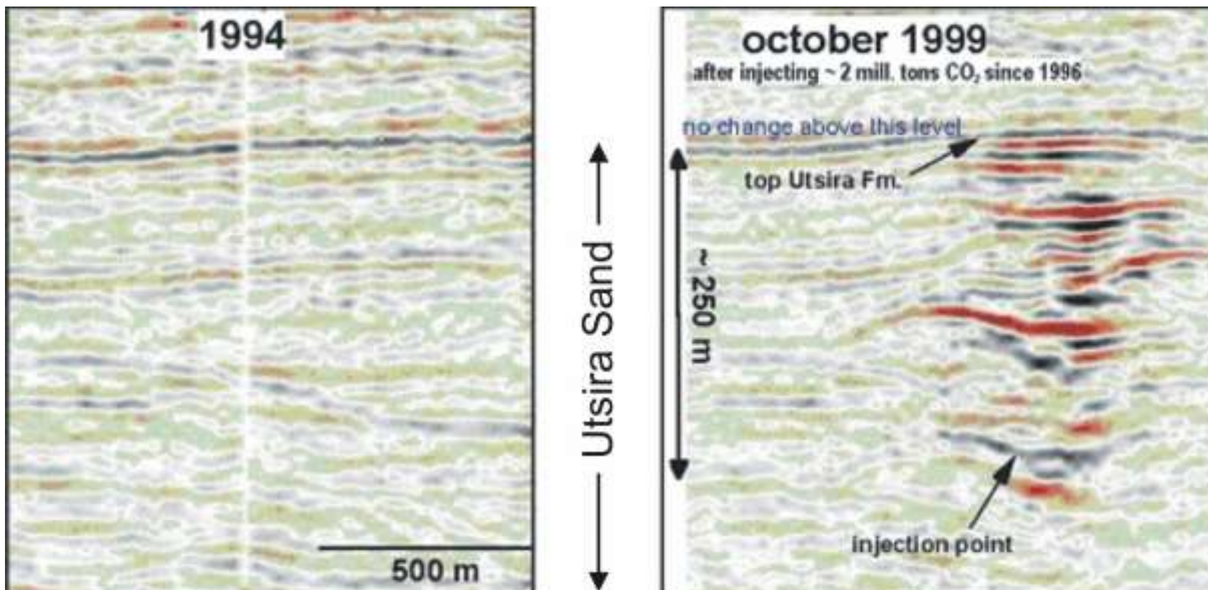


Geological sound models of the subsurface can help to predict CO_2 plume expansion through time and are key tools for CCS management projects.

Source: Vasco et al., 2010



Plume monitoring using Time-lapsed seismic offshore Norway, Sleipner field. (4D seismic)

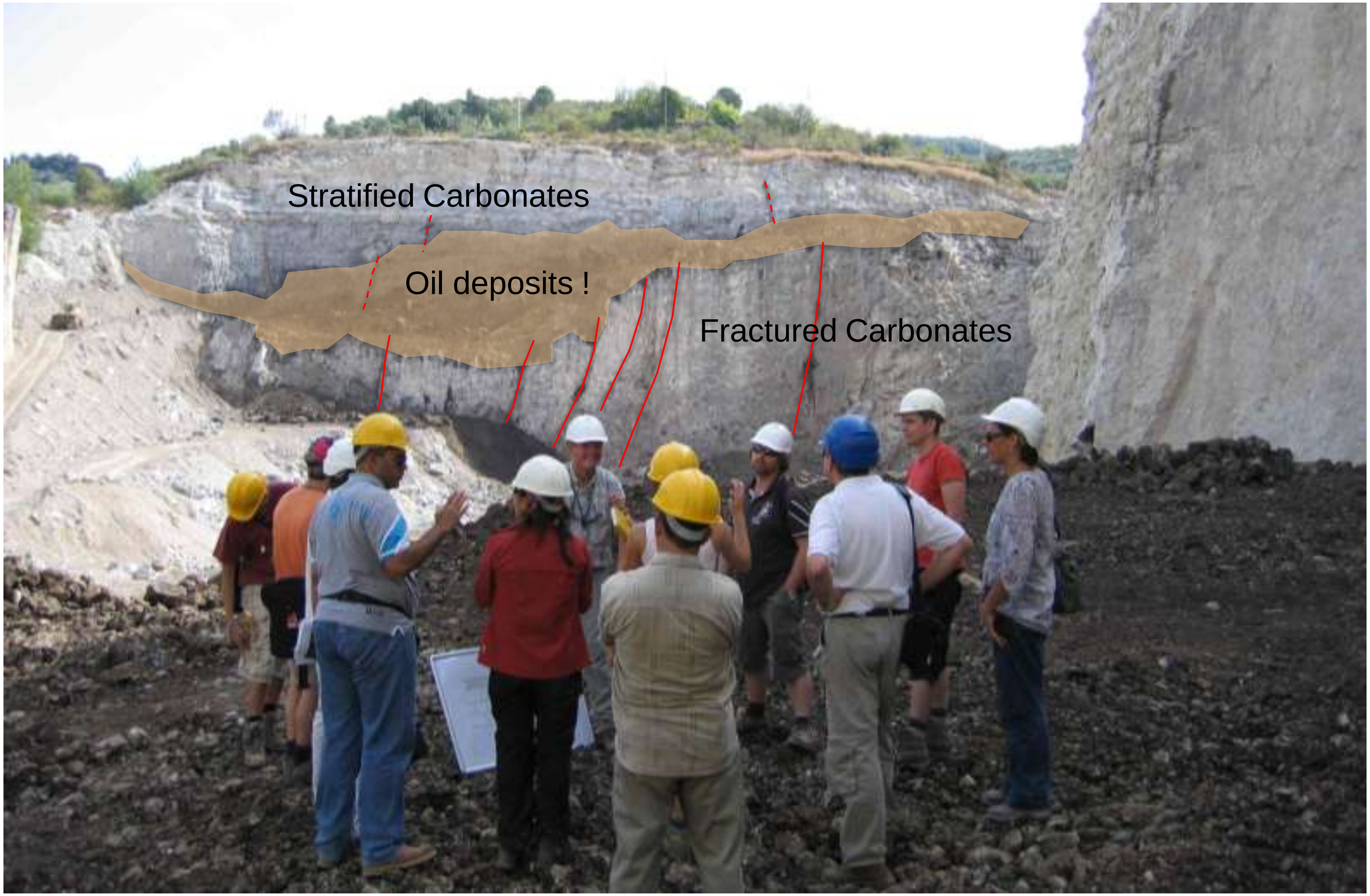


seismic image acquired before CO_2 injection

seismic image acquired after CO_2 injection

Source: Art, 2006

Reservoir integrity



Northern Syria - Foto courtesy of F. Mondino

Caprock integrity

Faults/fractures are preferential residence/reaction areas with CO_2. The impact of this on sealing capacity is not yet clear.

Carboniferous sandstone, Algeria / Sonatrach

- Geochemical reactions of CO_2 with the minerals present in the caprock could also improve the sealing properties in time.
- The occurrence of fractures needs to be assessed (open vs closed network)
- Fractures may be initiated and their propagation will depend on the rock property of the caprock.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- The overall geological characteristics of the ESCWA region support an extended CCS program throughout all countries examined.

- The complexity and heterogeneity of situations (e.g. geology, location of source compared to injection location), however, make the CCS development complex and country specific.

- Typically CCS projects require more time than conventional hydrocarbon projects as feasibility study followed by pilot and demonstration will still be required.

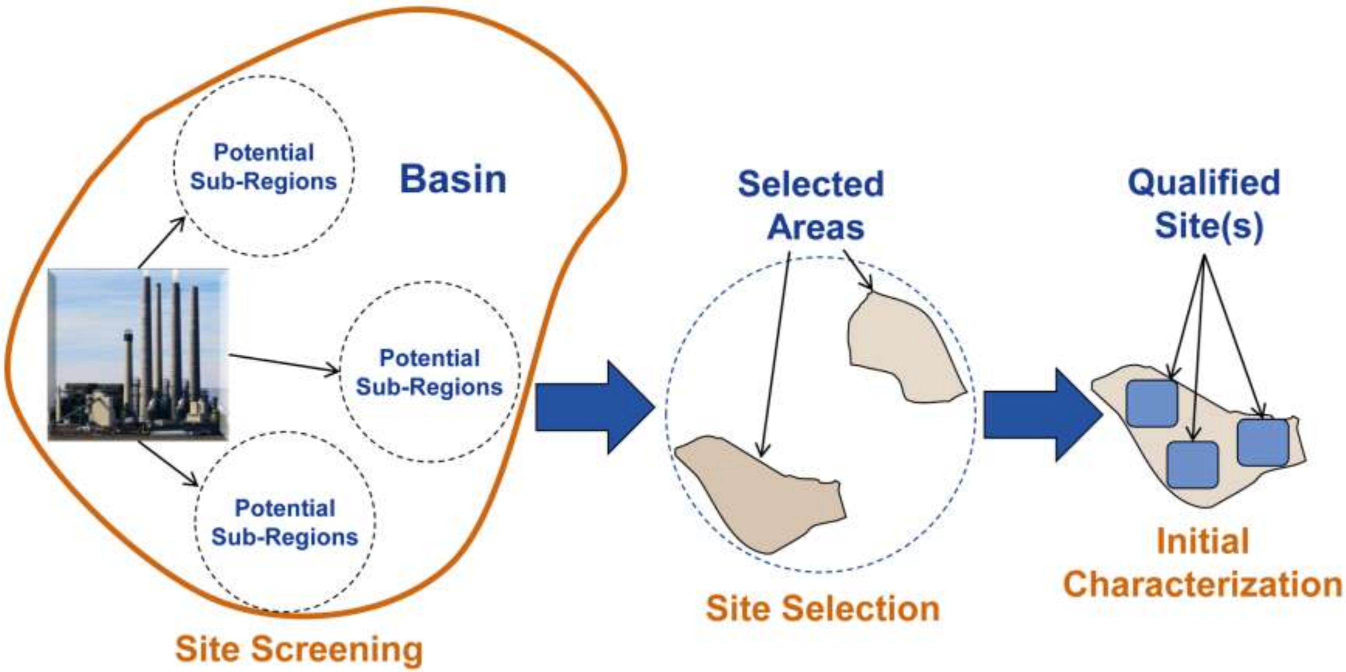
Conclusions

- The practice of geological trapping of CO_2 can still be considered in fact at the juvenile stage and several technical aspects still require investigation and testing (e.g. rock-fluid interaction, caprock and fault integrity, prosecution technology, field monitoring).

- Both generic and site-specific studies will still be needed in future to assess any risk of leaking posed by the combined effects of mechanical stresses and chemical reactions resulting from CO_2 injection.

Good planning and understanding of all risks and opportunities of individual projects is deemed necessary.

Identify – Assess – Define – Select – Operate



Conceptual representation of processes to identify qualified geologic storage sites through the Exploration Phase

Source: Rodosta et al., 2010

Application to the ESCWA region

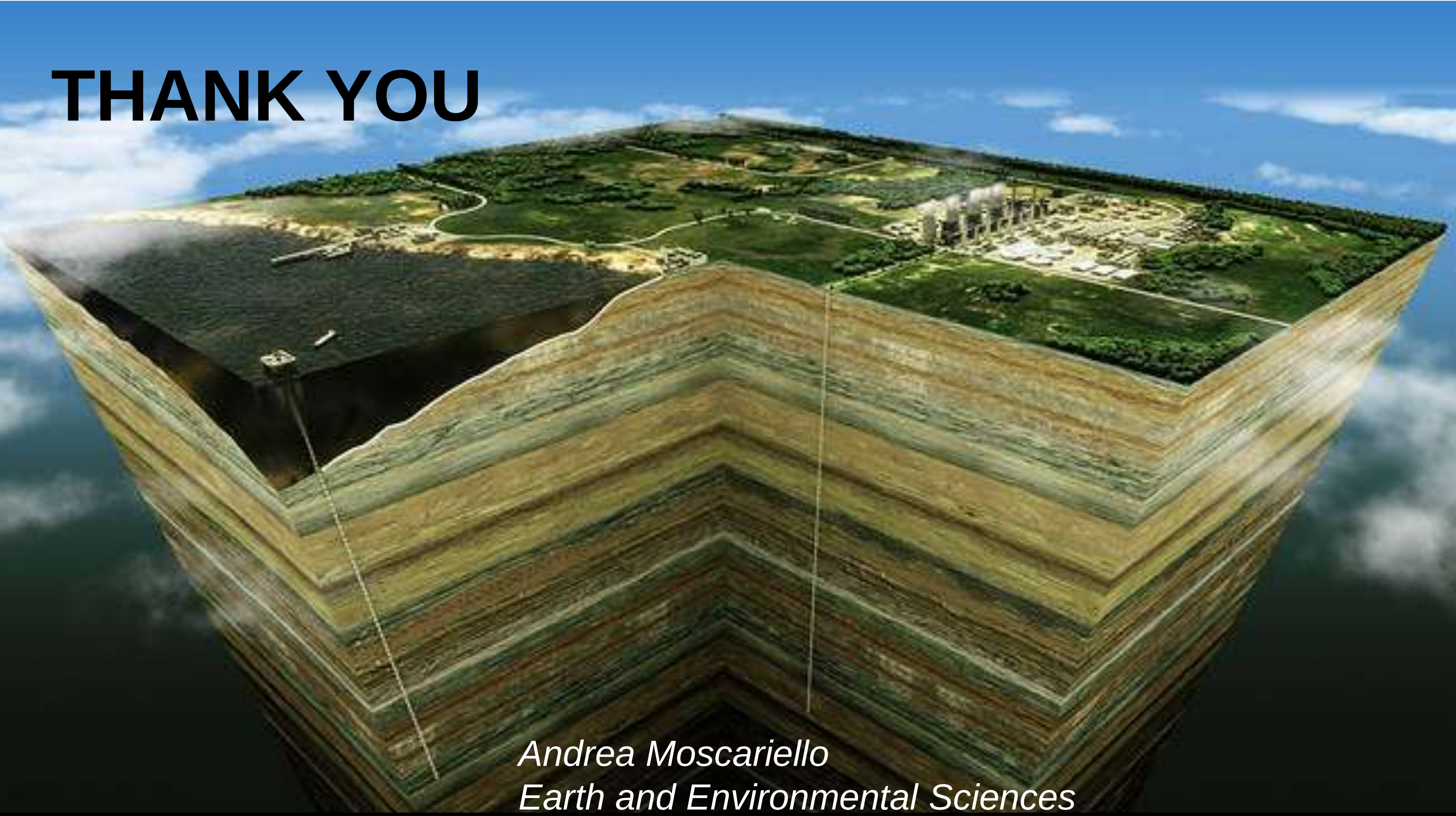
– CO_2 injection in saline aquifers can be considered the most likely to be implemented and possibly the option which may offer most cost effective conditions.

– CO_2-EOR projects, early implementation of the actual EOR phase can bring a larger amount of incremental oil production and be therefore beneficial.

– CO_2 injection in to GAS depleted reservoirs may be possible but as a long term plan due to the present relatively early stage of gas reservoirs production.

– Given the relative rare occurrence of coal-bearing formations, ECBM in the ESCWA region may not see large scale development in near future except on those countries where coal is available (Morocco, Algeria).

THANK YOU



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