Università di Trieste
Corso di Laurea in Geologia

Anno accademico 2015 - 2016

Geologia Marina

Parte VI

Modulo 6.3 Confinamento geologico della CO_2

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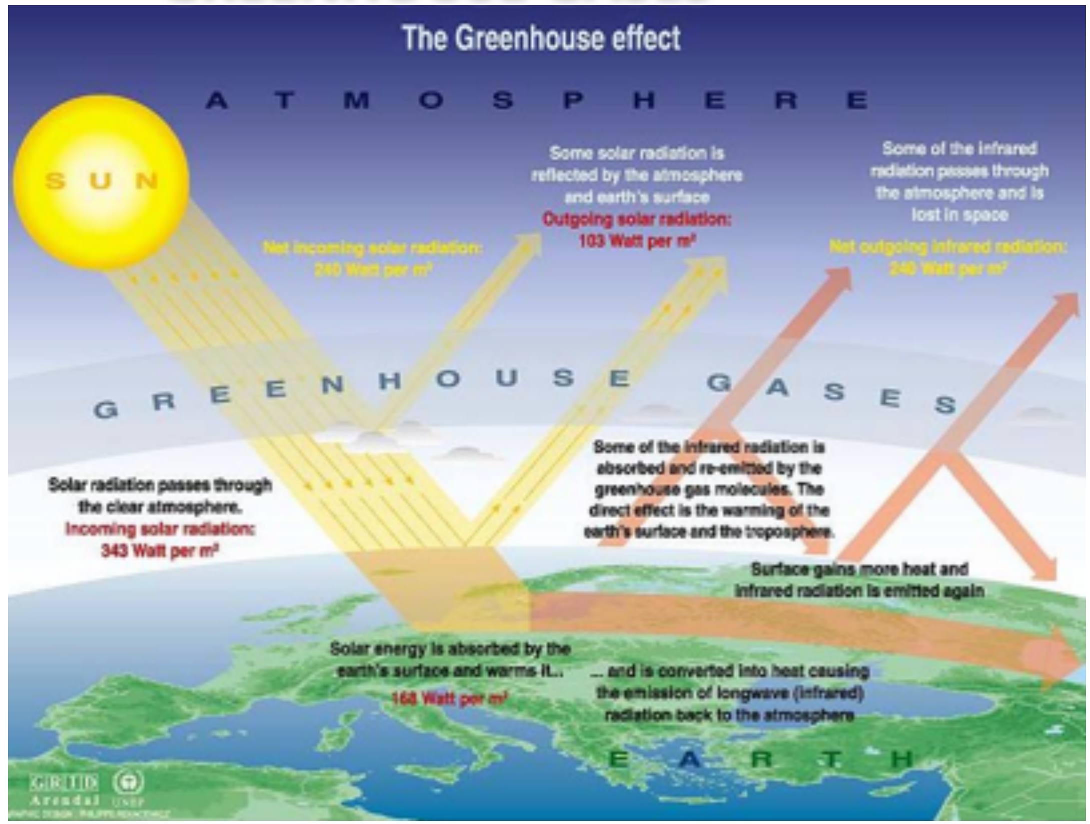
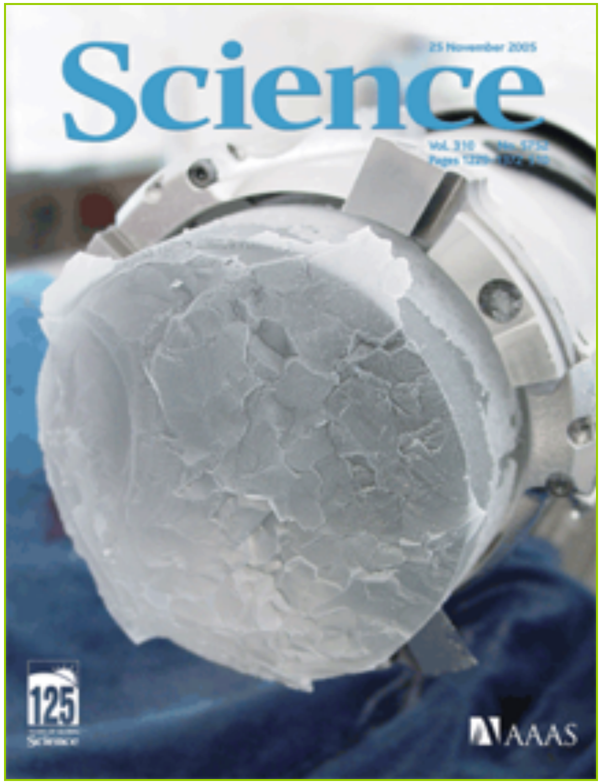
Global warming and **climate change** are terms for the observed century-scale rise in the average temperature of the Earth's climate system and its related effects.

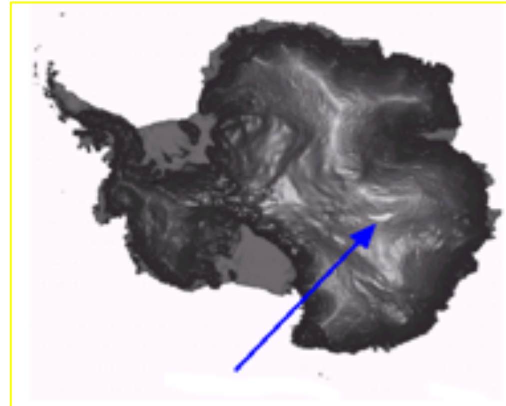
GREENHOUSE GASES

This process consists of the global warming due to the emission of gas (CO_2, water steam, methane…) in the atmosphere. Greenhouse gases allow sunlight to pass through the atmosphere while obstructing the passage to the space of the infrared radiation from the Earth's surface and lower atmosphere (the heat re-issued); in practice they behave like the glass of a greenhouse and help to regulate and maintain the temperature of the earth with today.



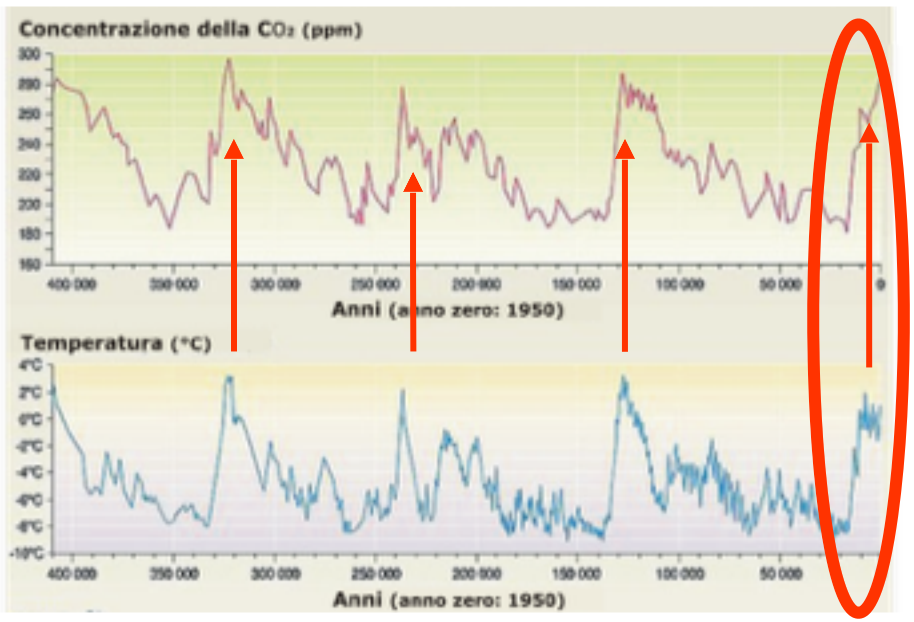
This is a natural process and allows that the temperature of the Earth be 33°C higher than what it would be without the presence of the gases.





Ice cores from Antarctica have allowed to reconstruct the temperature trend and the CO_2 concentration in the atmosphere for the the last 400.000

GLOBAL WARMING



Correlation between temperature increase and concentration of CO_2 in the atmosphere over the last 400,000 years (drilling of ice in Antarctica)

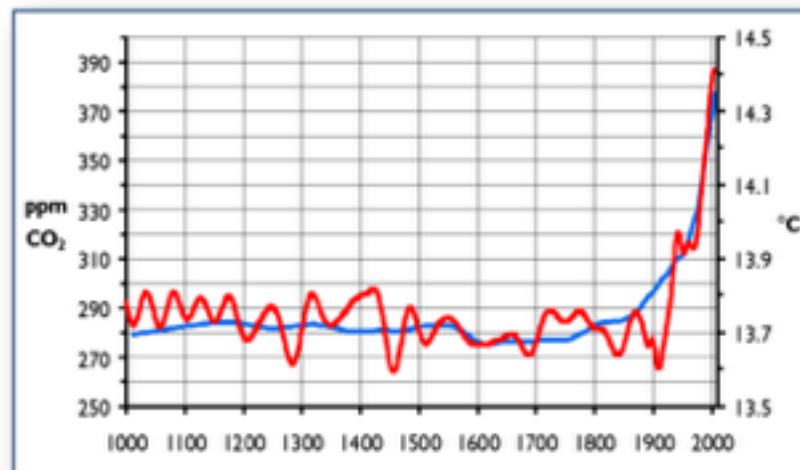
CO_2concentration in the atmosphere is increased by circa ~**40%** from 1750 (Rivoluzione Industriale; IPCC, 2014)

Maximun concentration of CO_2 (last 400.000 years)

300 ppm

IN 2005:

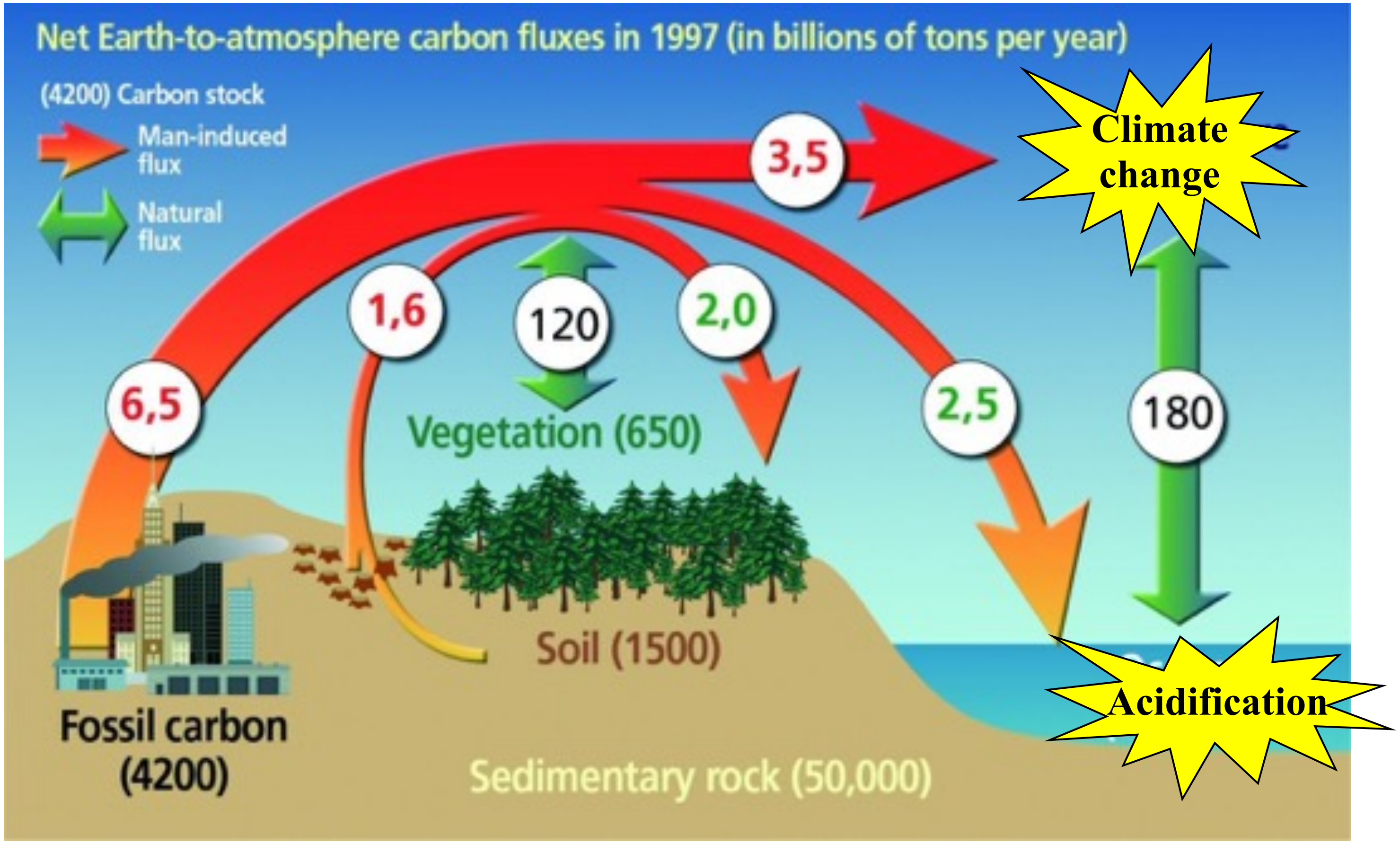
381 ppm



Global variation of the temperature (red) and the CO_2 present in the atmosphere (blu) in the last 1000 years.

CO_2 exchange between Earth and Atmosphere (Billiontons/years of Carbon)

Total amount of emitted CO_2 : 30 billion tons /year or 8.1 billiontons/years of carbon



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World emissions of CO_2 from the usage of fossil fuels:

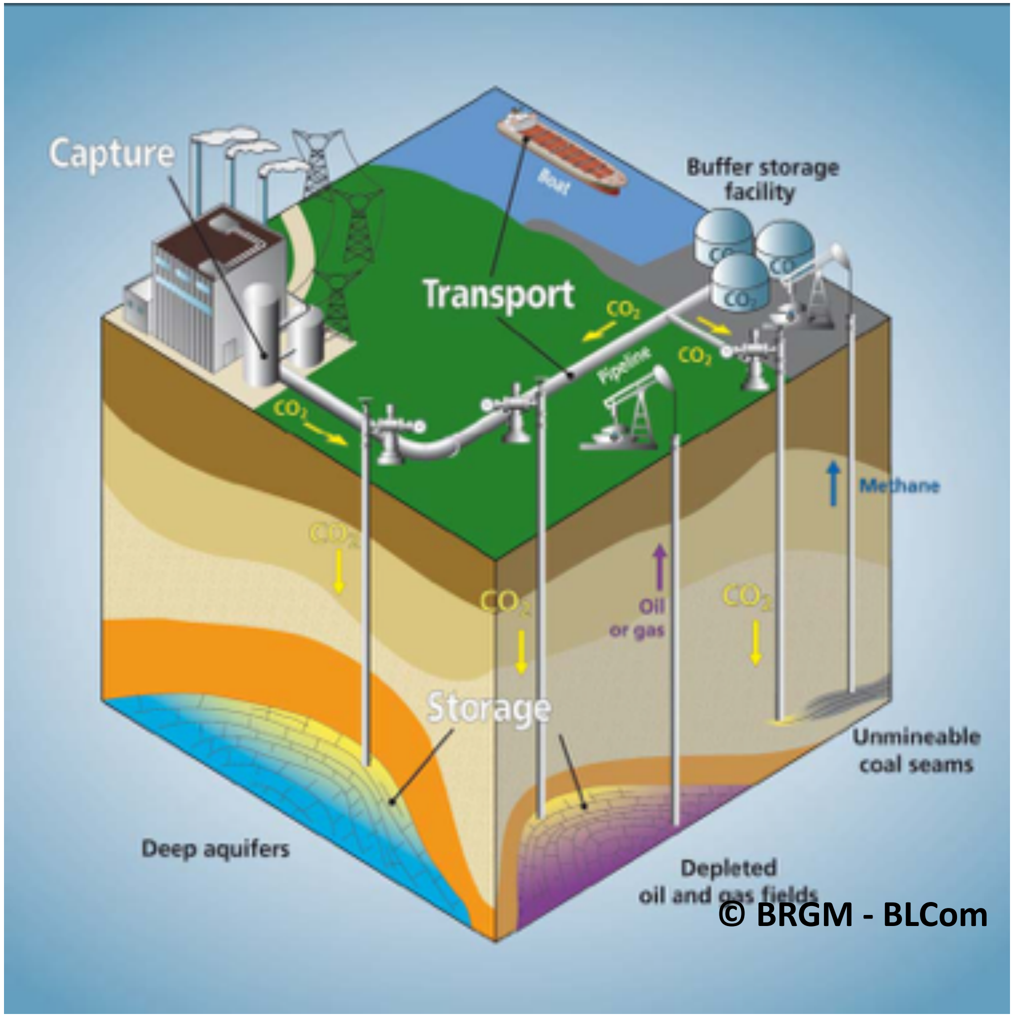
6.5 Gt C/y (o 24 Gt CO_2/a)

CO_2 GEOLOGICAL STORAGE
CARBON CAPTURE AND STORAGE

.. one of the options to reduce the global CO_2 emissions by 2050

Three main phases:

1. Capture
2. Transport
3. Storage



CO_2 CAPTURE: MAIN CO_2 EMISSIONS

The main sources of CO_2 emissions consist of the **BIG STATIONARY SOURCES**:

- fossil fuel power plants
- industrial installations for the production of iron, steel, cement and
- chemicals refineries

CAPTURE PROCESSES

➢**POST- COMBUSTION:** separation of CO_2 from other products (water vapor, N_2 ...) of combustion of primary resources and being absorbed by chemical solvents. The CO_2 is separated from the solvent and compressed to be transported and stored.

➢**PRE- COMBUSTION:** treatment of the fuel with oxygen or air and / or steam before combustion to produce a gas mixture consisting of carbon dioxide and hydrogen, separated before emission

➢ **OXYGEN COMBUSTION:** oxygen is separated from the air before combustion and mixed with fuel at high pressure. This combustion process produces only vapor and concentrated CO_2 that can be treated easily and sent to be stored.

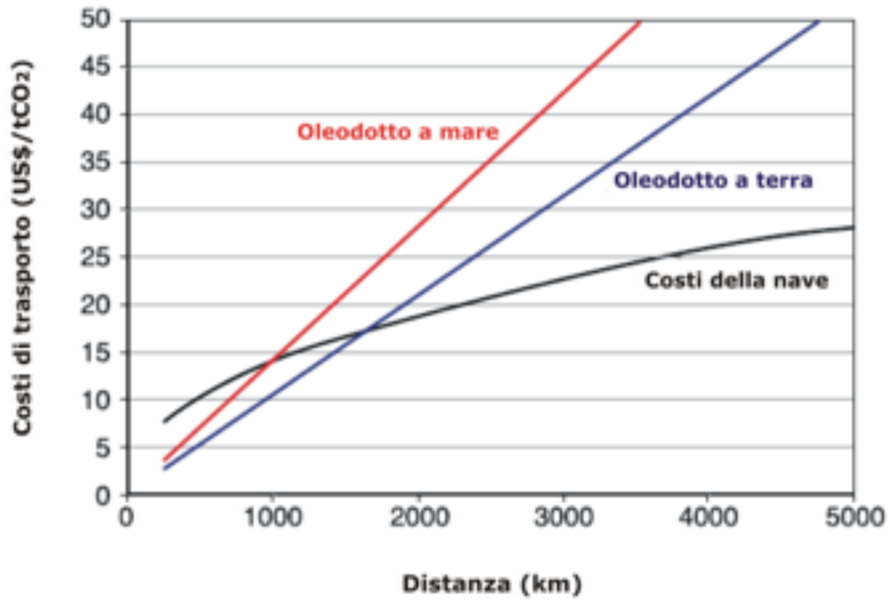
TRANSPORT OF CO_2

La CO_2 can be transported, both onland and offshore, in three phases:

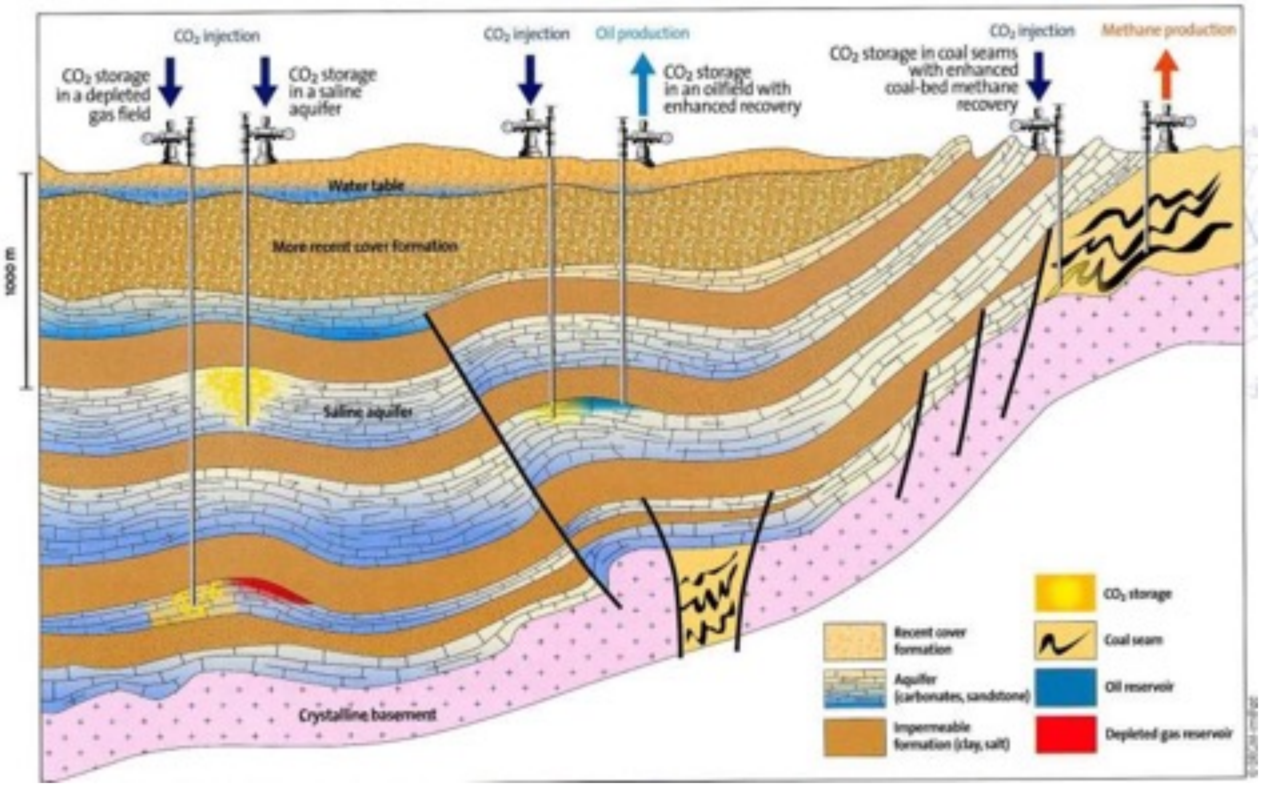
GAS LIQUID SOLID

Tanks, pipelines and ships

Not economically convenient



STORAGE OPTIONS



Existing Reservoir

- **Saline aquifers**
- **Oil and gas filed depleted**
- **Coal seams**

CRITERIA FOR IDENTIFICATION OF SUITABLE SITES FOR CO_2 STORAGE

Depth : between 800 (to allow the CO_2 supercritical stage) and 2000-3000 m

Characteristics of the reservoir: good porosity e permeability

Caprock: presence of a sealing geological formation

Distance: within a radius of 200 km from the source of emission of CO_2

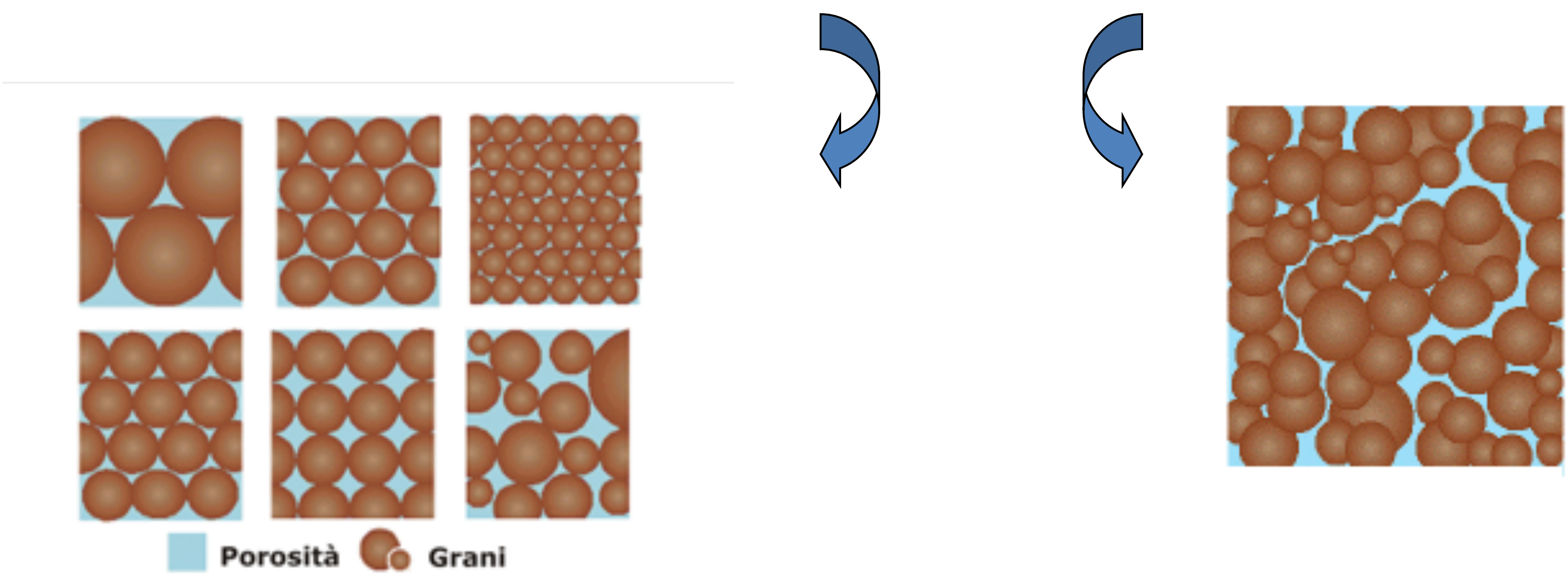
Heat flow: the heat flow does not have to be high, in order not to alter the conditions of stability of CO_2

Tectonic setting/seismicity: the area must be stable to ensure the structural conditions for storage

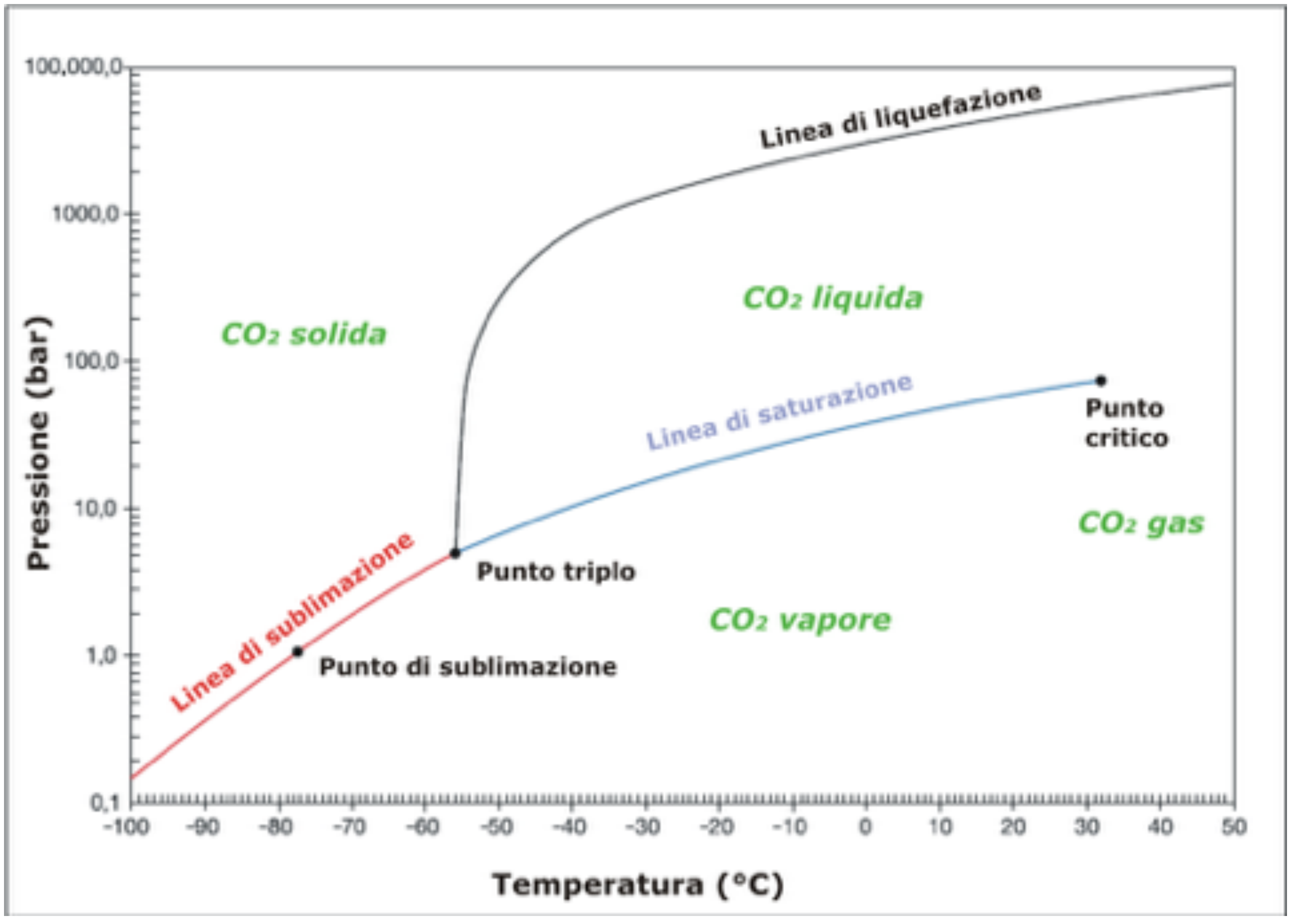
CO_2 STORAGE

For the purposes of CO_2 storage, the rock that serves as a reservoir must meet the following requirements *:*

- **they must be at a DEPTH between 800 (so that the CO_2 remains in conditions of supercritical state) and 1500 m;**
- **they must have a certain porosity and permeability;**



CO_2 PHASE: “supercritical state”



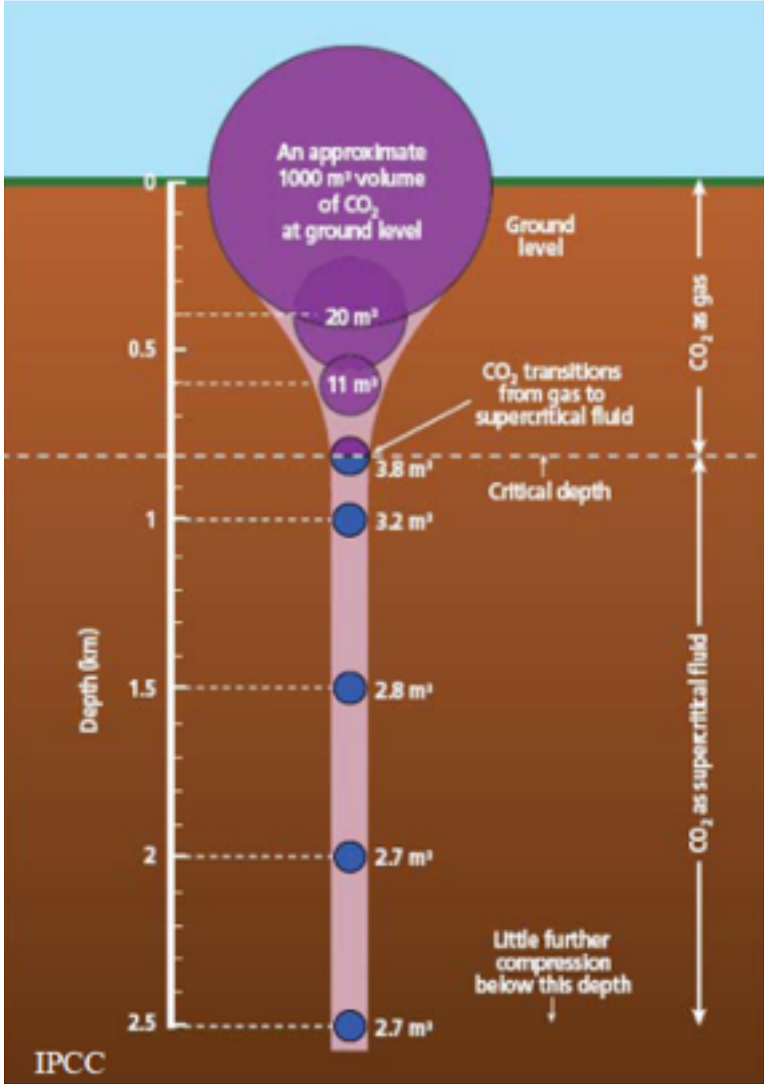
- T>31.1° C
- P>73.9 bar

...CO_2 in supercritical state is liquid or gas?

ANSWER:

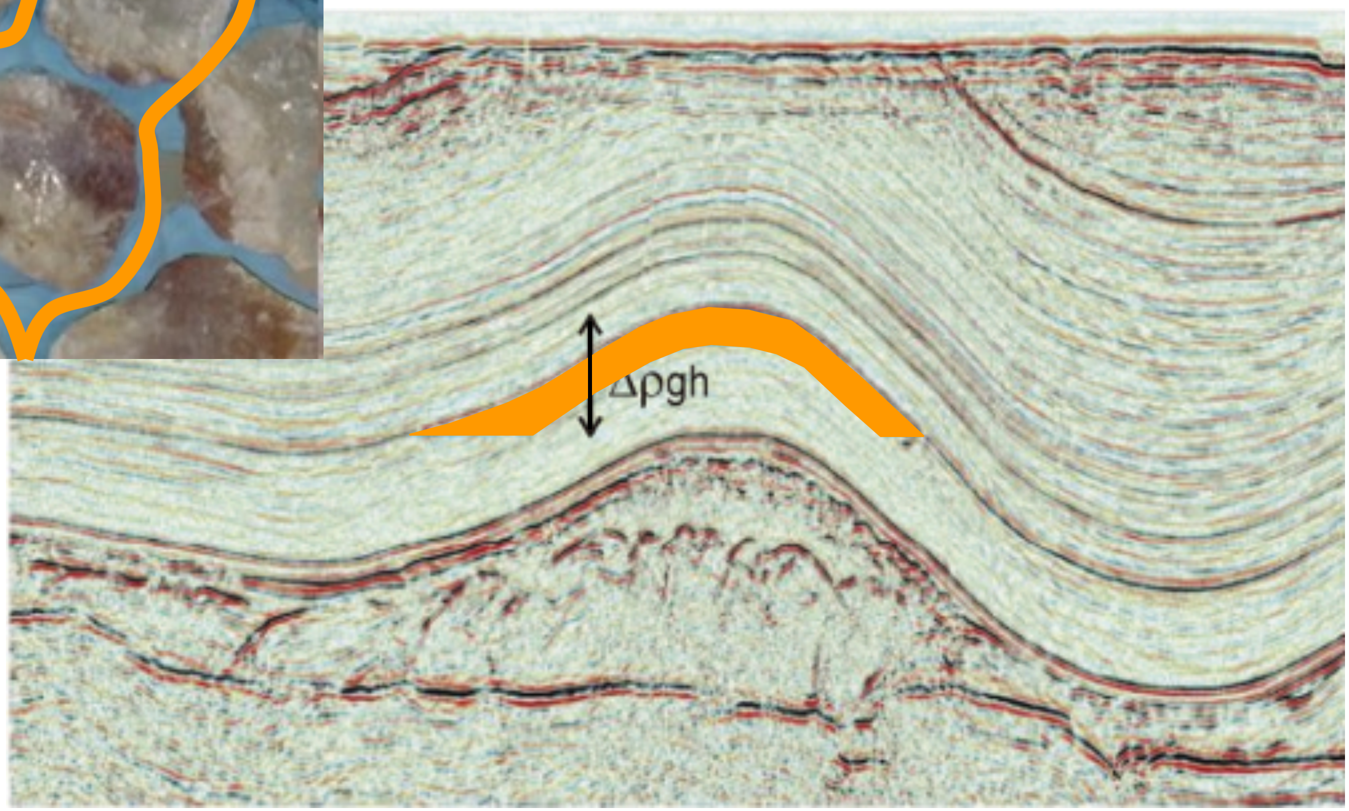
- density similar to liquid
- viscosity similar to gas

T=100°C, P=280bar (2800m)	density (kg/m3)	Viscosity (cP)
CO_2 supercritic	615	0.05
water	804	0.16
gas (methan)	150	0.02

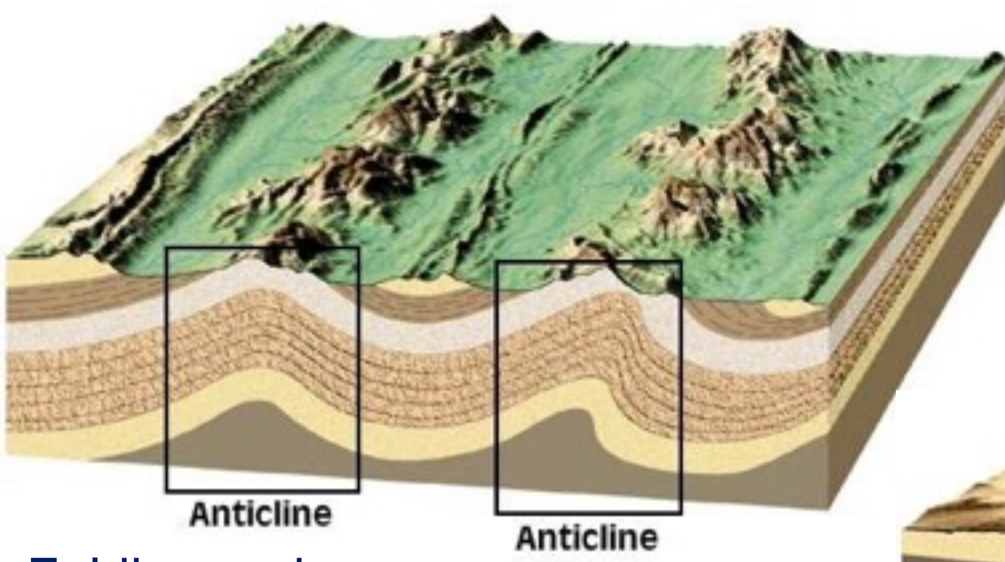


The CO_2 at supercritical conditions tends to rise ...

ESSENTIAL PRESENCE OF SEALING ROCK FORMATIONS (CAPROCK)

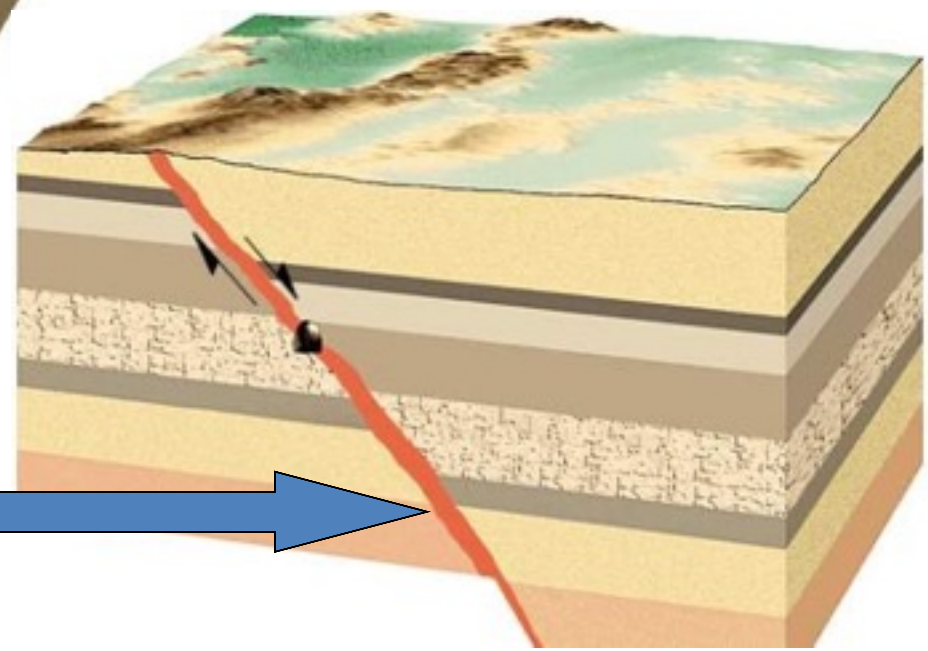


STRUCTURAL TRAPS



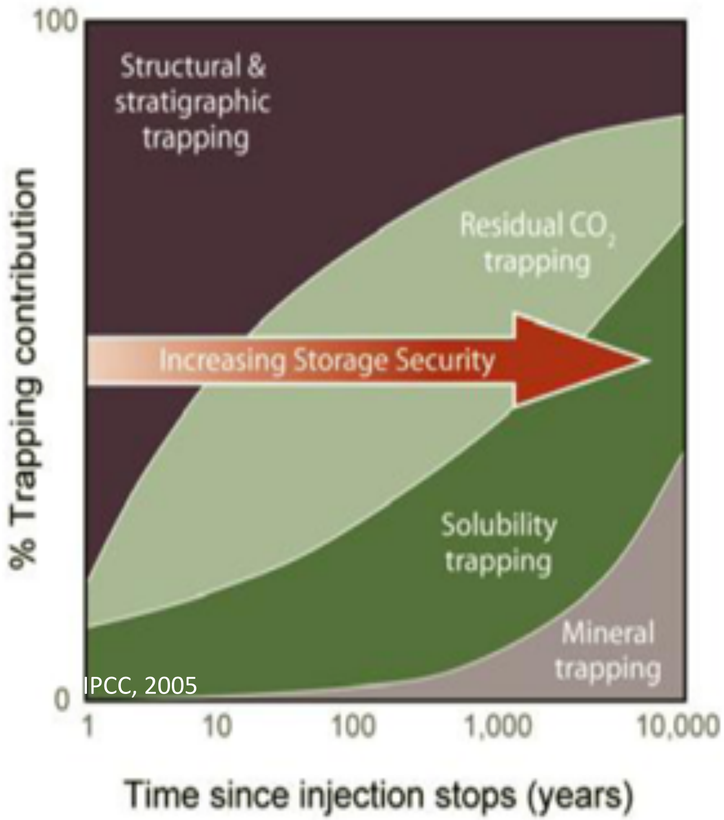
Folding and anticlines

Faults and unconformities



Fault consists of different material

Trapping mechanisms



- **Structural trapping:** the CO_2 is lighter than the salt water present in the interstices of the rock and it tends to rise upward and trapped by the impermeable rocks (caprock)

- **Hydrodynamic trapping**, where CO_2 is injected into supercritical conditions at depths> 800 m and it moves the present salt water

- **Dissolution trapping:** once injected CO_2 starts to dissolve in salt water. The water now becomes heavier and tends to drop. This mechanisms put in contact water with dissolved CO2 with fresh water, promoting additional dissolution. After 10 years: 15% of injected CO_2 is dissolved; after 10.000 years 95% of CO_2 is dissolved.

- **Mineral trapping** where CO_2 reacts with some minerals in the aquifer to form crystalline carbonates

KEY DATA FOR THE CHARACTERIZATION OF A RESERVOIR-CAPROCK SYSTEM

Wellbore data

- Logs (Sonic, Gamma Ray)
- Porosity e permeability of reservoir e caprock rock formations
- Temperature and pressure at reservoir depth

Multichannel seismic data

2D - regional scale

3D - site scale

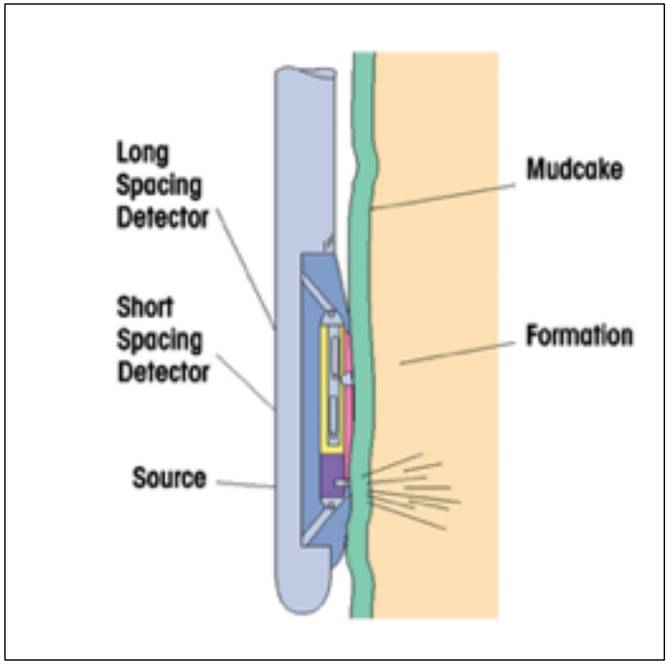
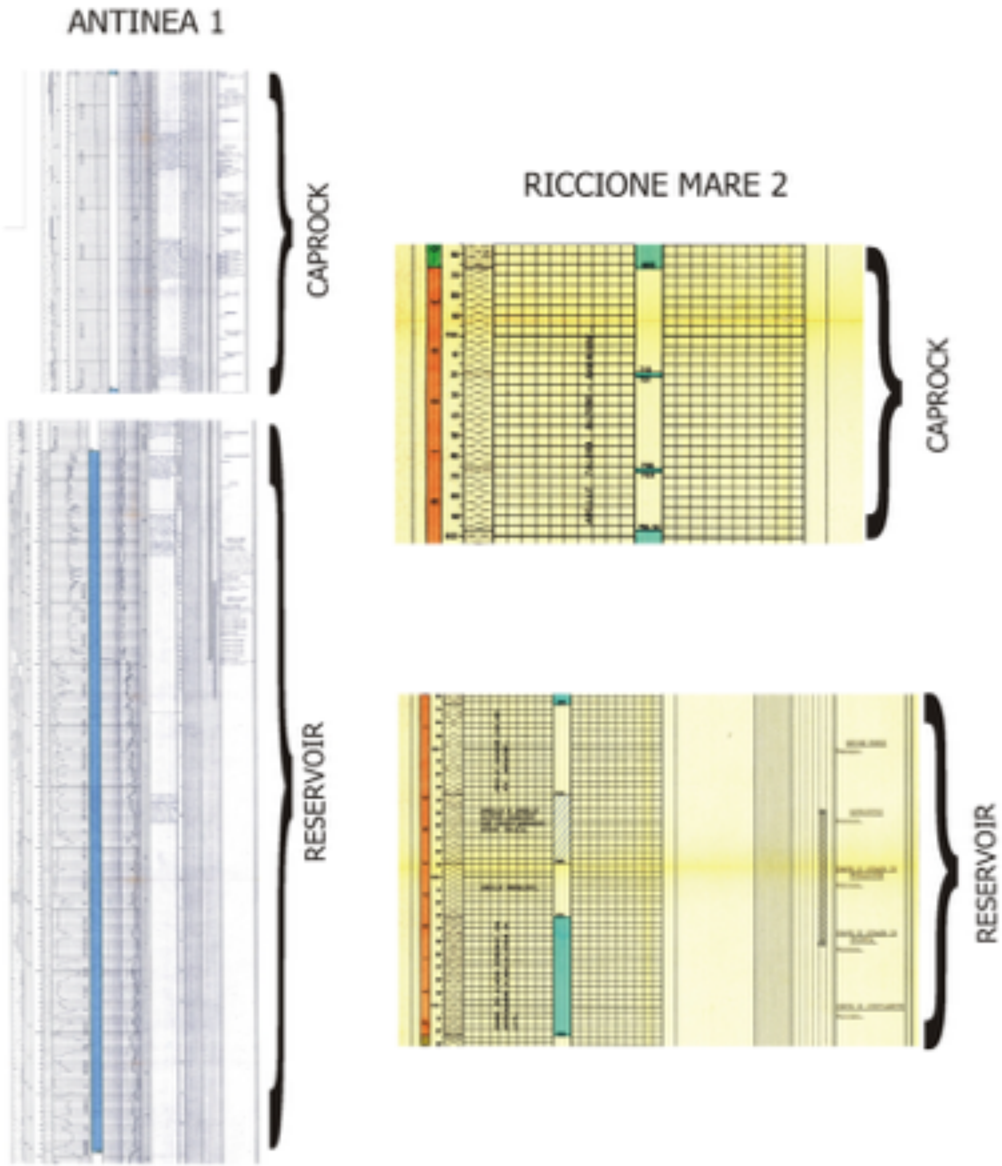
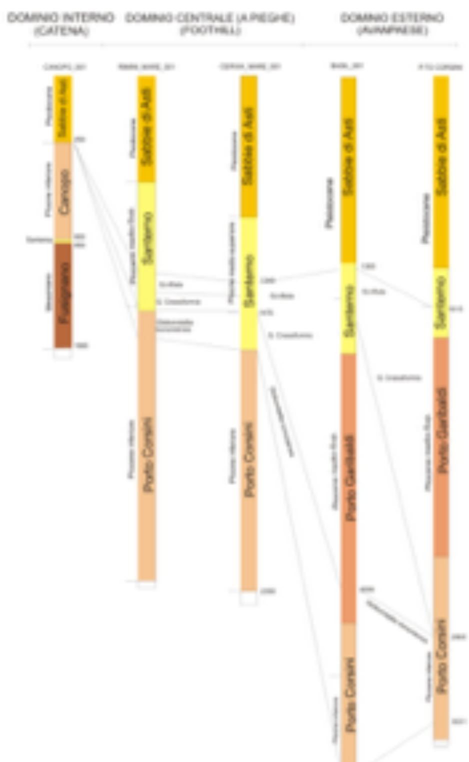


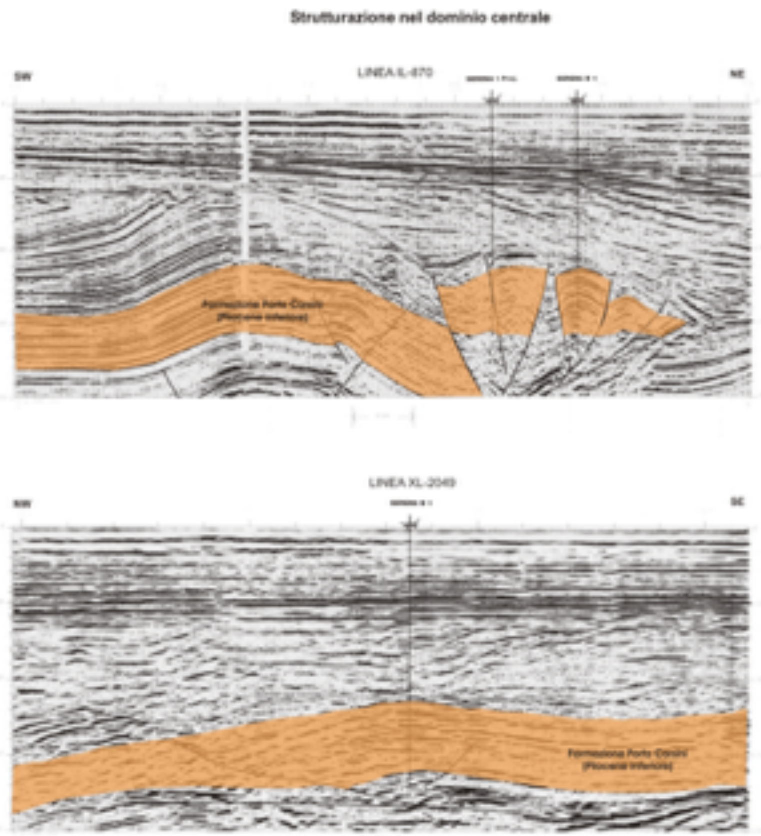
Image of a logging tool in a hole

CHARACTERIZATION RESERVOIR-CAPROCK: WELL DATA analysis



CHARACTERIZATION RESERVOIR-CAPROCK: SEISMIC DATA ANALYSIS





Main characteristics of a potential site for CO_2 storage

- *Capacity*, to contain the amount of CO_2 to be stored; key parameter: **porosity**
- *Injectivity*, to inject the CO_2 a certain rate of injection; key parameter: **permeability of reservoir**
- *Containment*, to avoid CO_2 leakage; key parameter: **permeability of caprock**

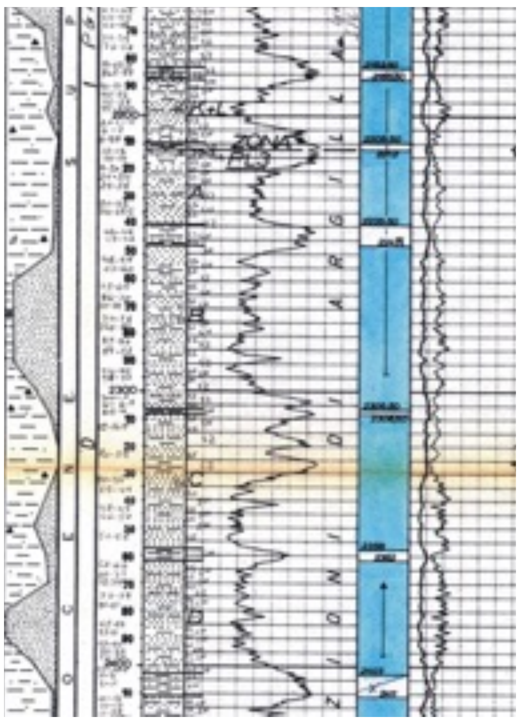
CCS Project

Main steps

1. Identification of the potential storage site
2. Modelling of CO_2 injection
3. Monitoring (pre-, during and post-injection)
4. Risk evaluation and remediation plan

Data analysis

Geophysical log analysis



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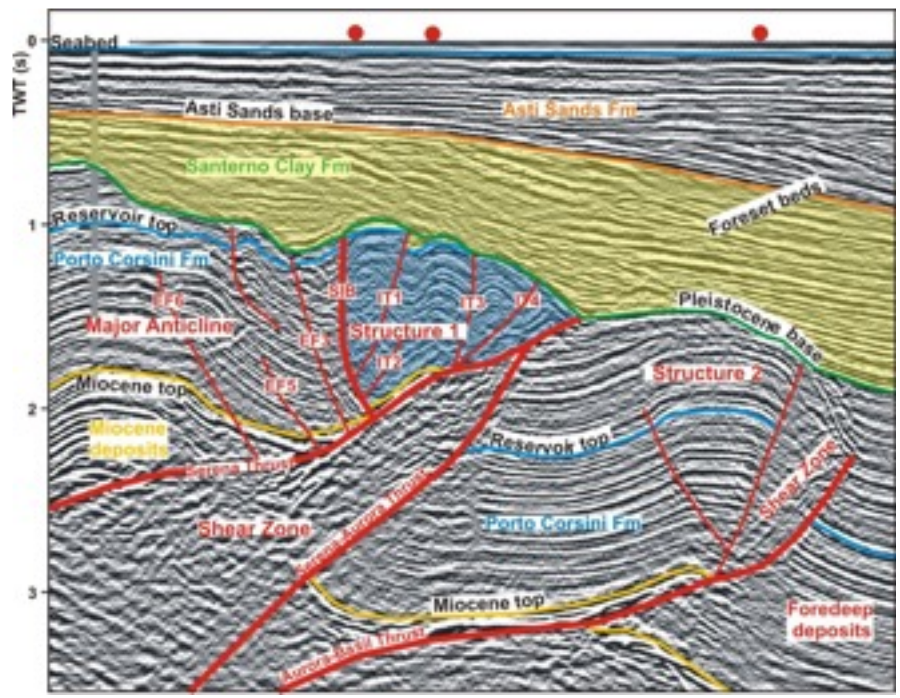
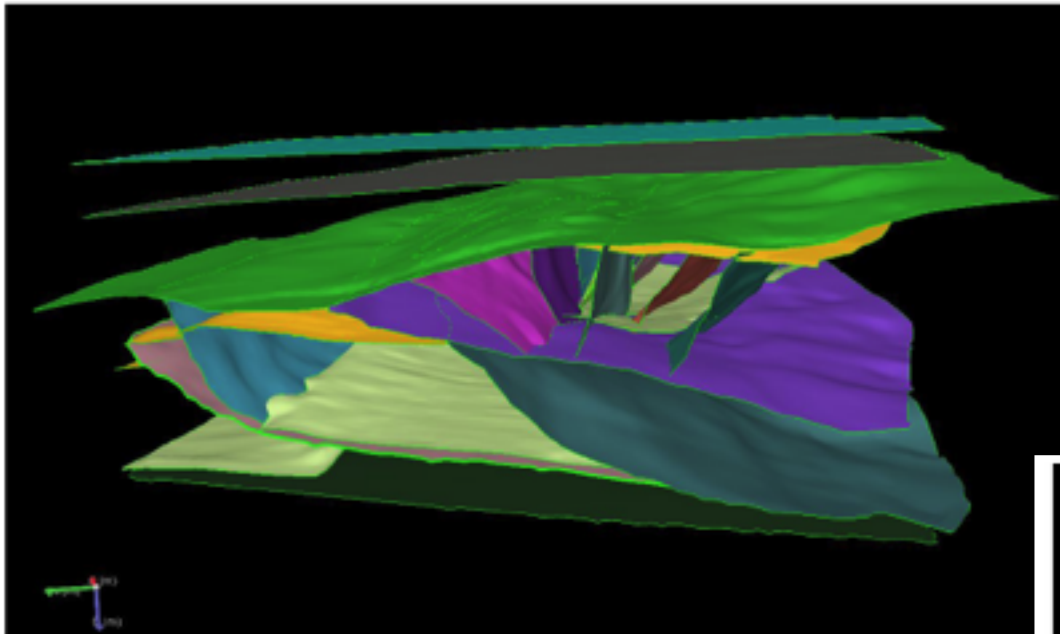
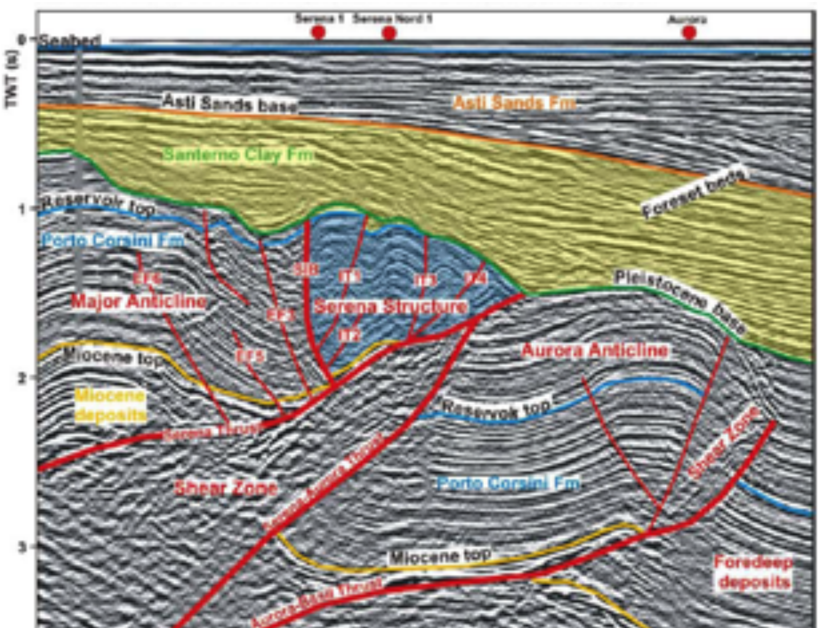
Seismostratigraphic and structural interpretation of multichannel seismic profiles

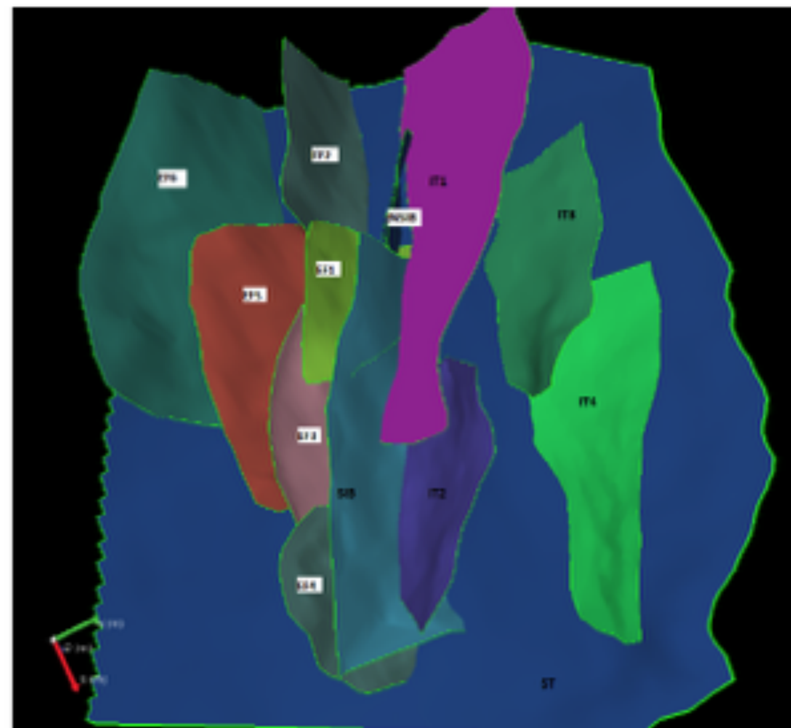


Geological modeling

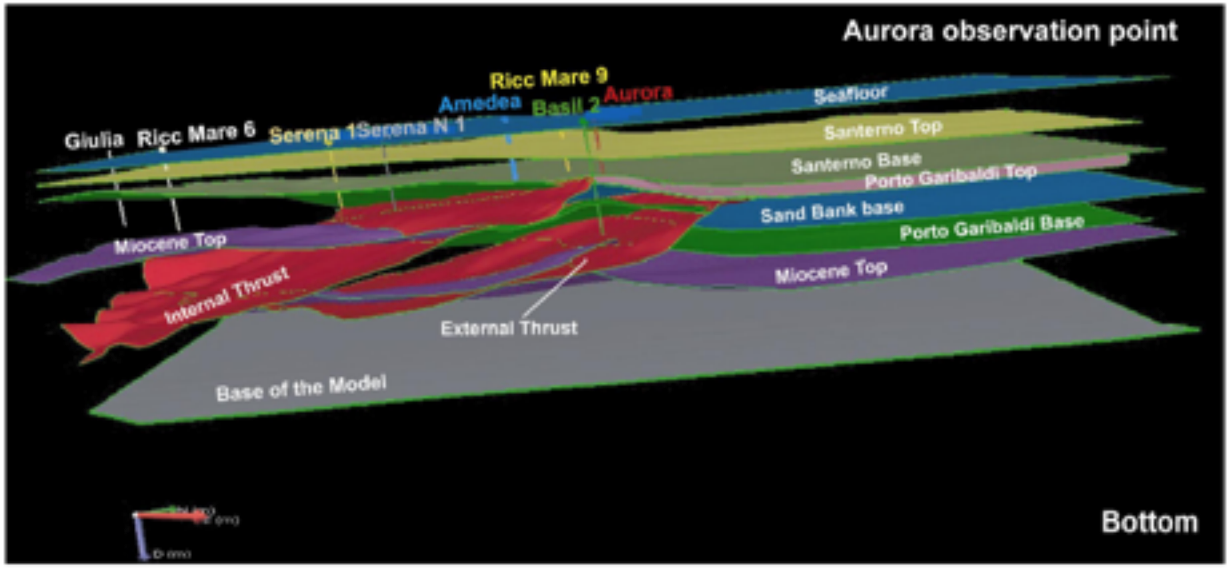
Example of 3D geological model



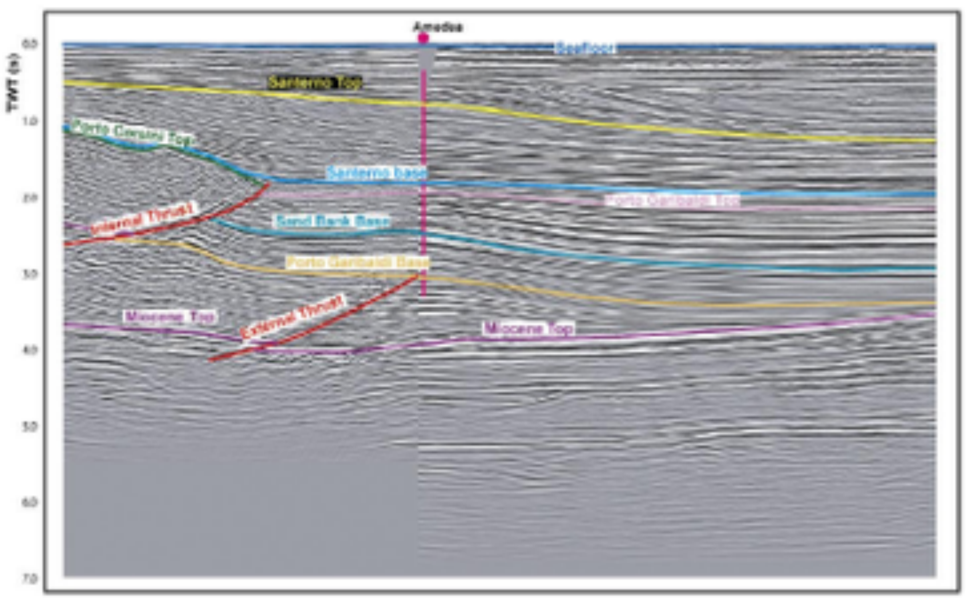


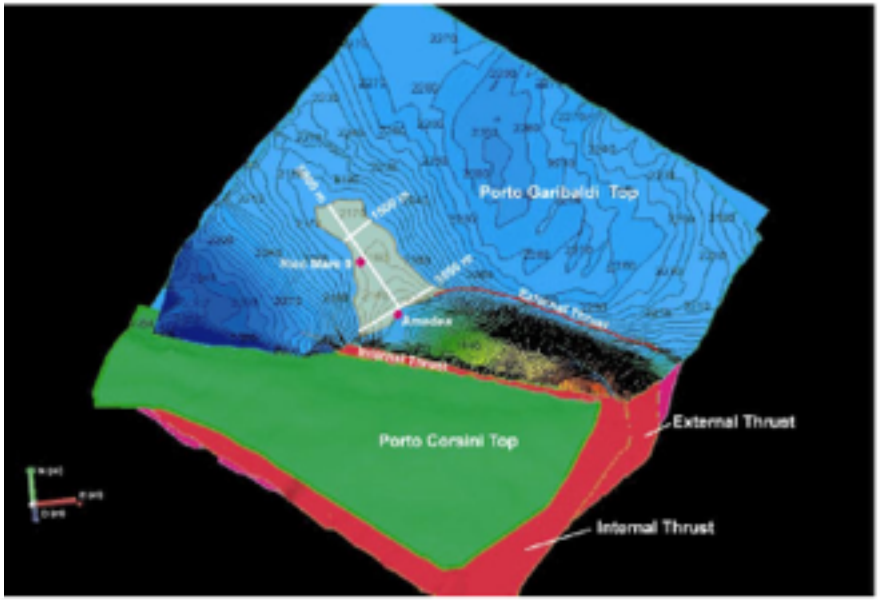


Geological modeling

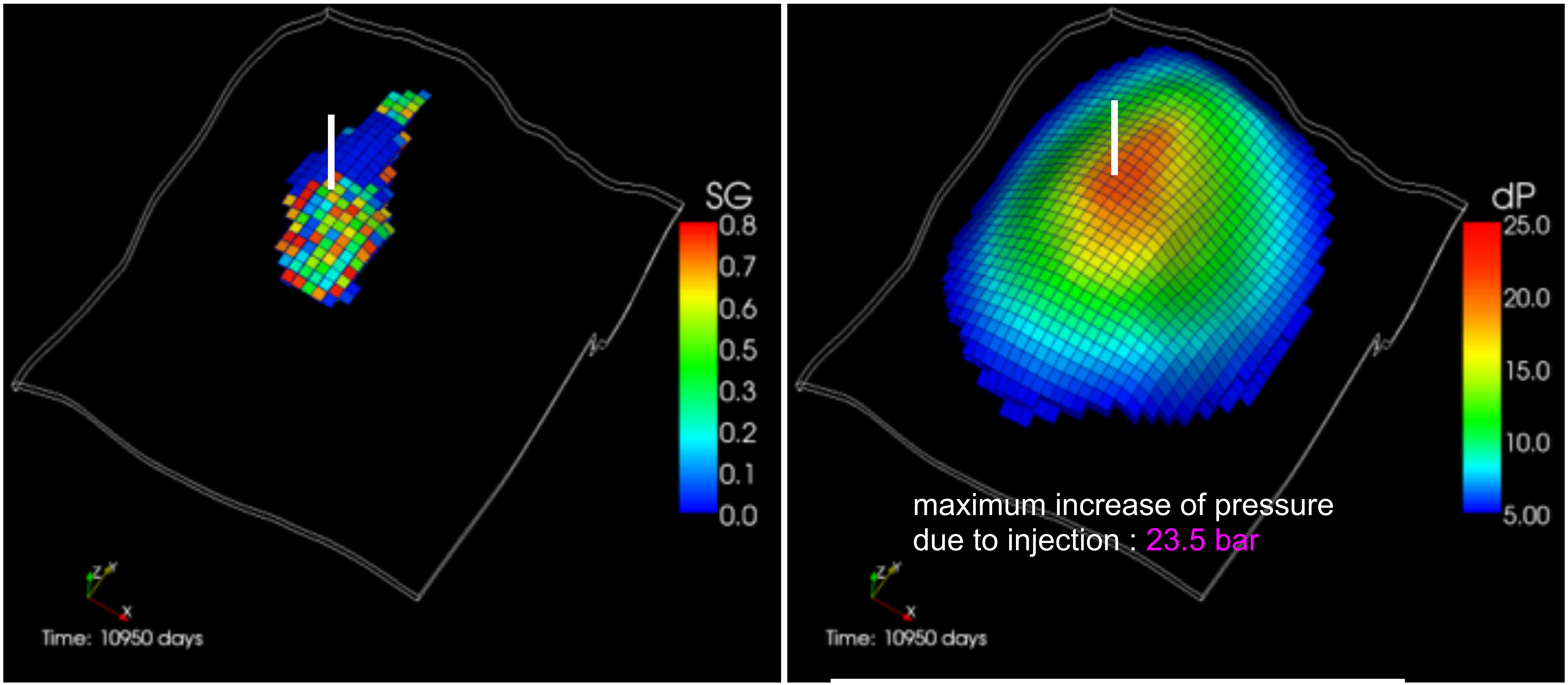


Example of 3D geological model



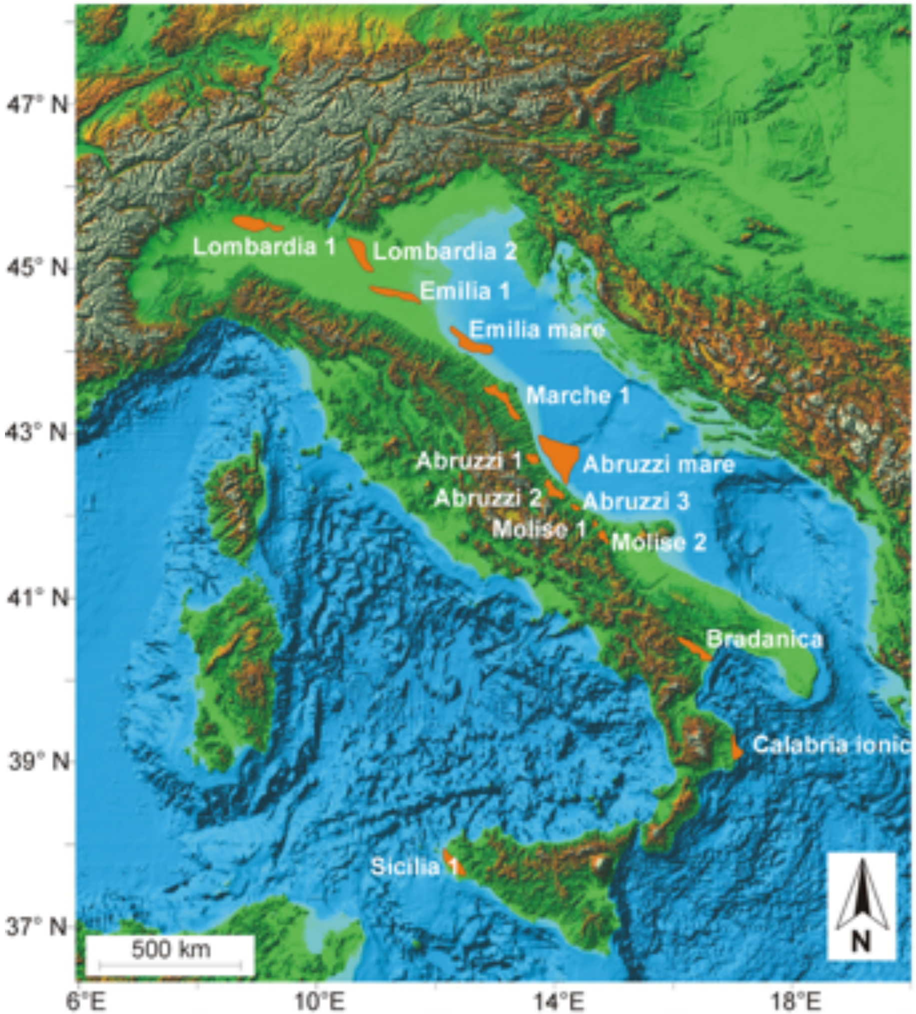


Modeling of CO_2 Injection
ONE WELL located on top of the anticline



Free CO_2 saturation

Pressure increase (>5bar) from static conditions



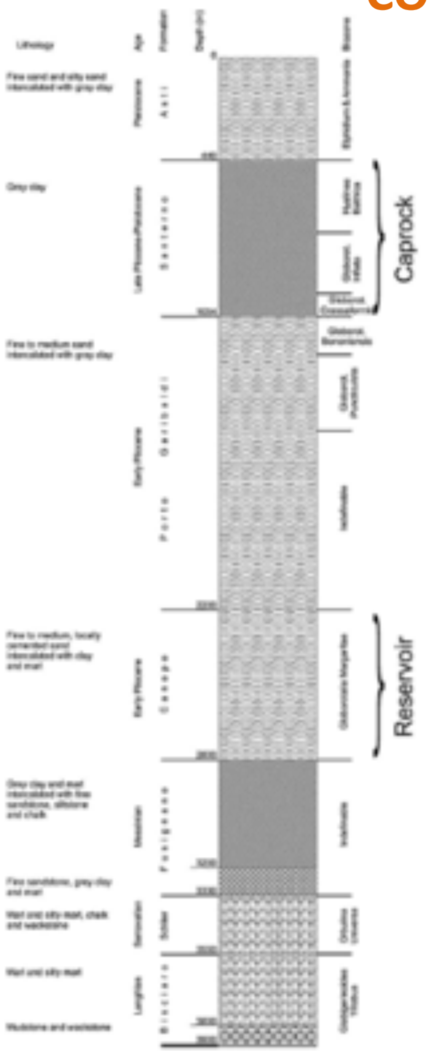
Potential areas suitable for CO_2 geological storage in siliciclastic formations

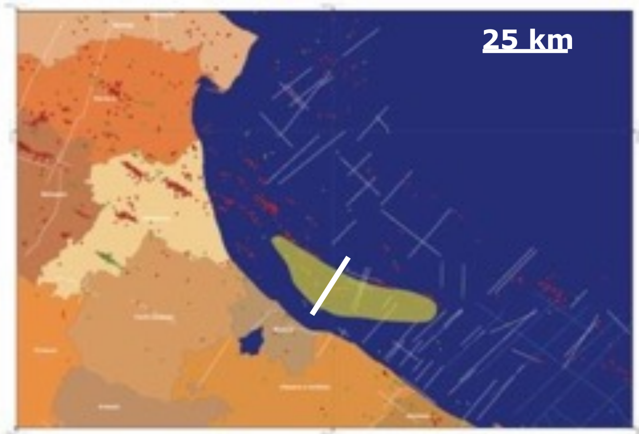
PRELIMINARY ESTIMATES OF THE STORAGE CAPACITY: ~ 12 Gt

Storage of Italy's annual CO_2 emissions for the next 50 years

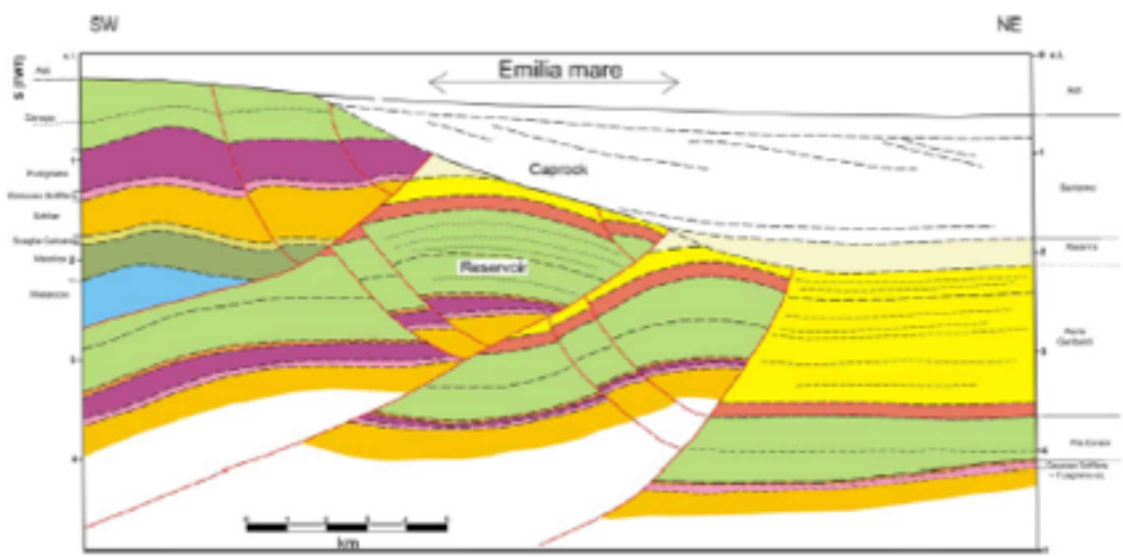
Donda et al., 2011

Example of a potential area suitable for CO_2 geological storage in a terrigenous formation

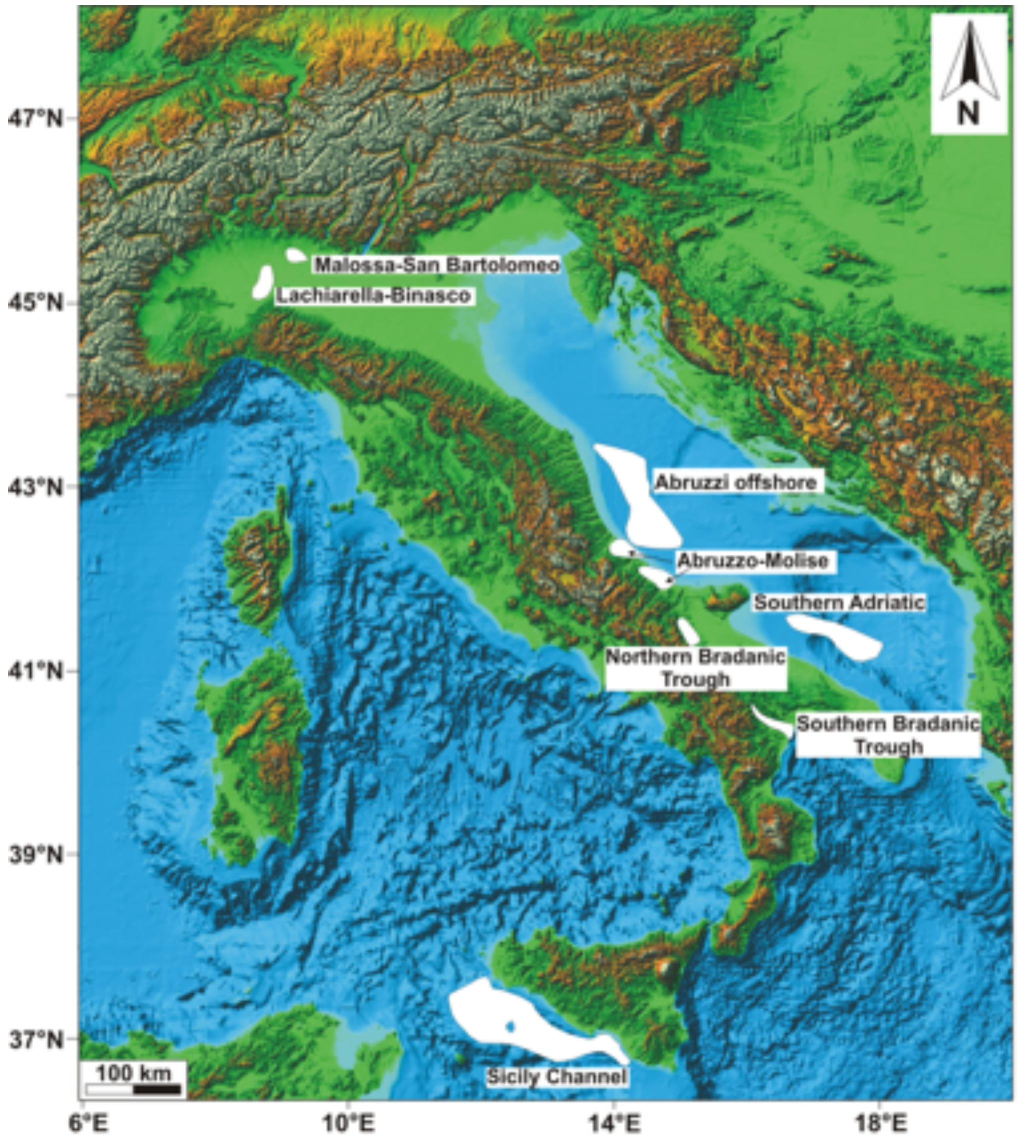




"EMILIA MARE"



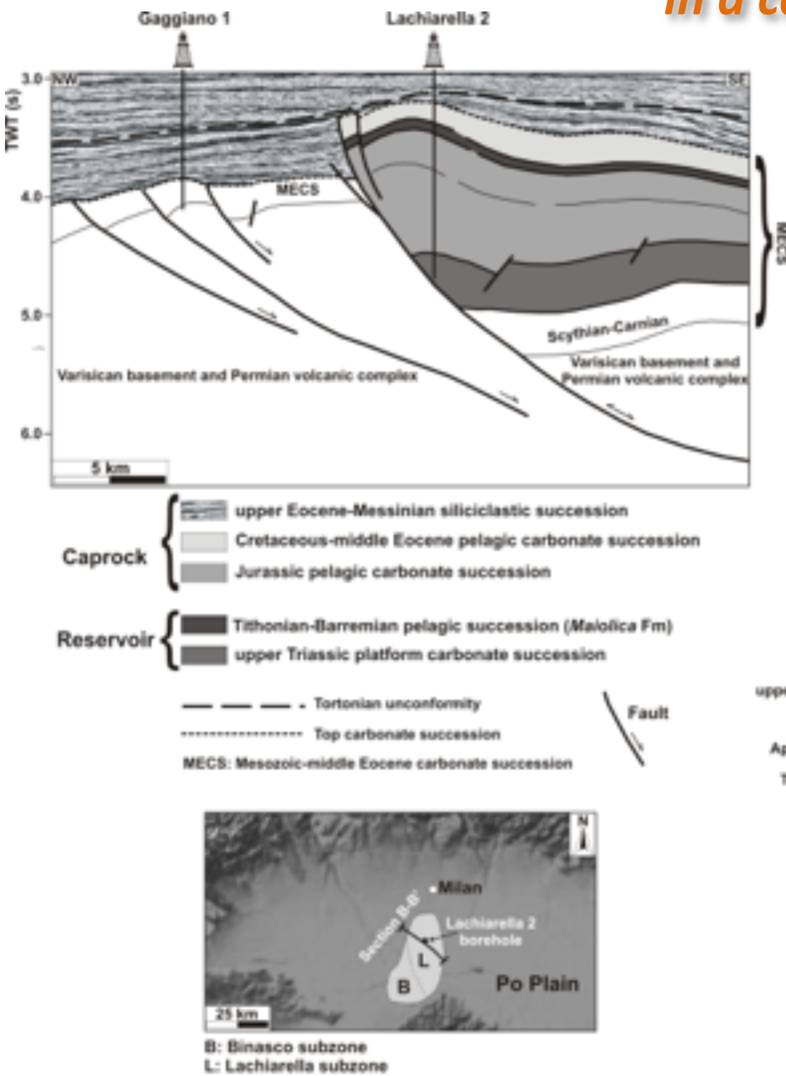
Donda et al., 2011

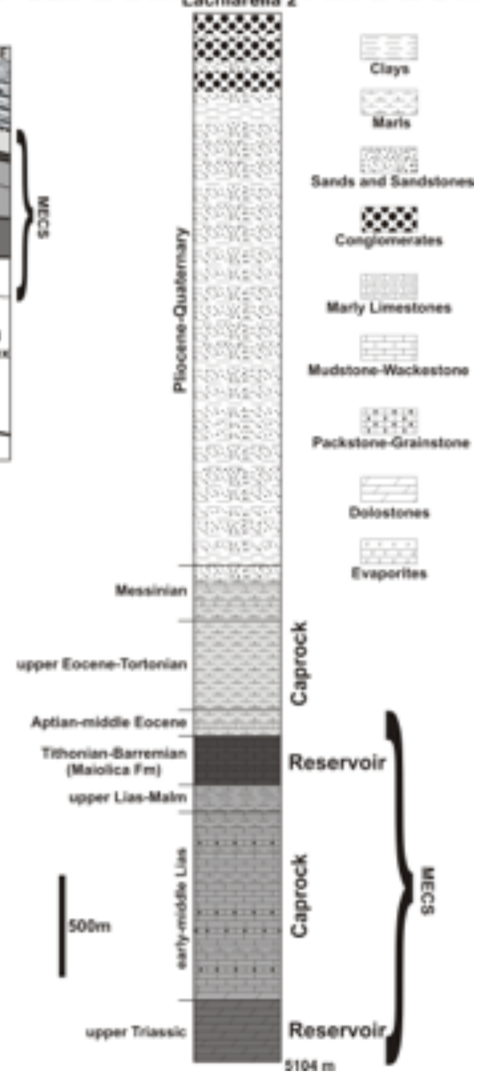


Potential areas suitable for CO_2 geological storage in carbonate formations

Civile et al., 2013

Example of a potential area suitable for CO_2 geological storage in a carbonate formation

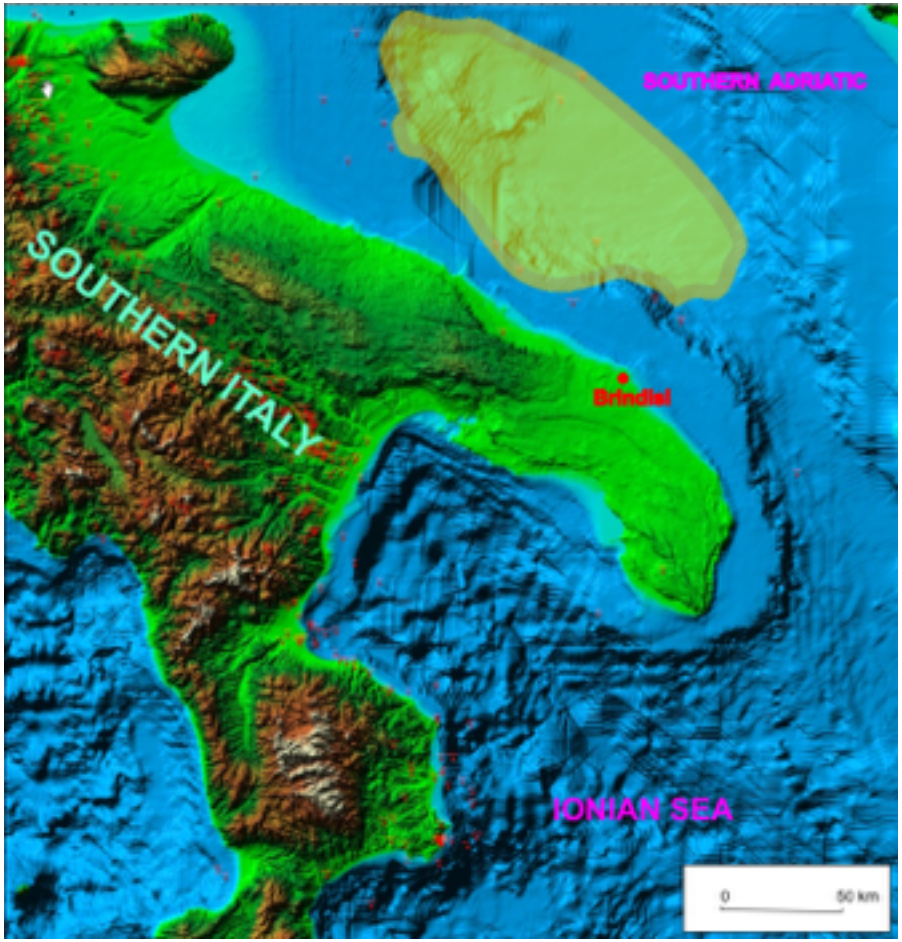




"Lachiarella–Binasco"

Civile et al., 2013

CHARACTERISTICS OF THE SOUTHERN ADRIATIC SITE OPTIONS



Storage options

- ➢ Saline aquifer/structural trap

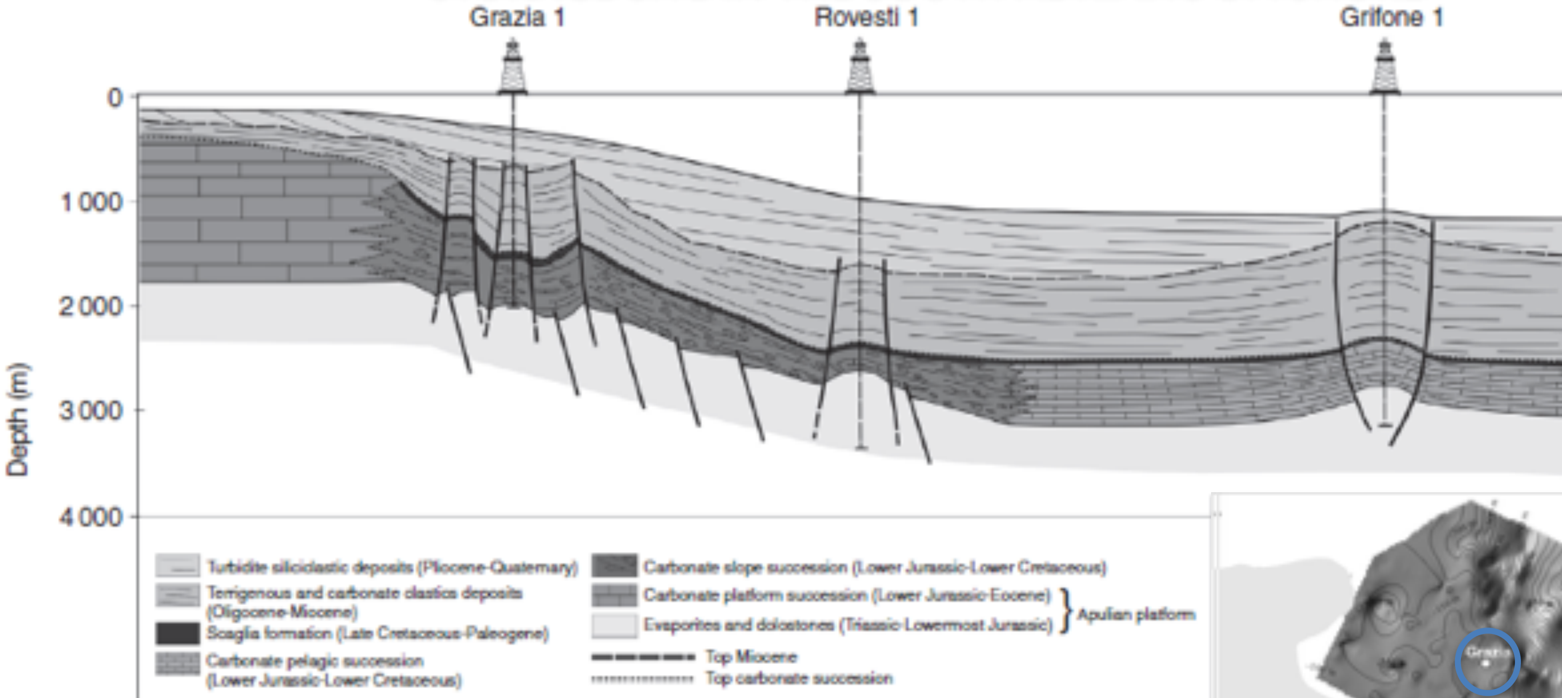
Location

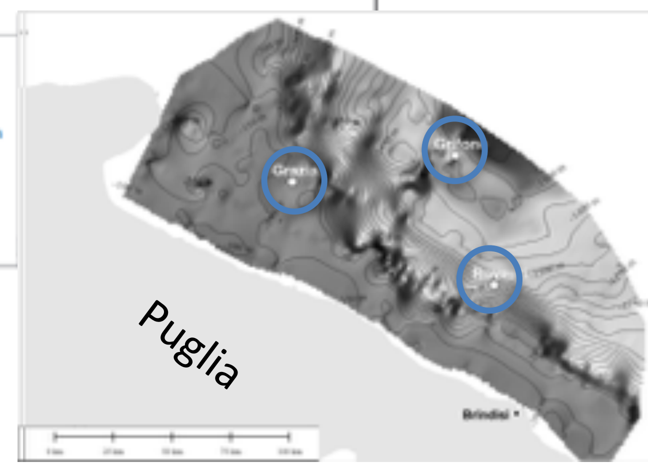
- ➢Off shore

Lithology

- ➢Carbonate reservoir

STORAGE SITE IN THE SOUTH ADRIATIC OFFSHORE

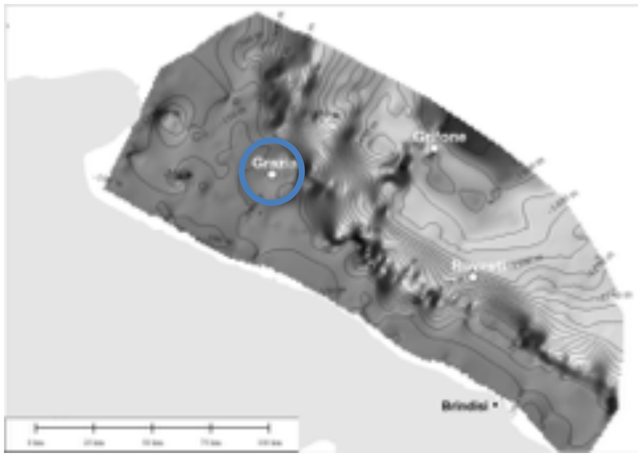


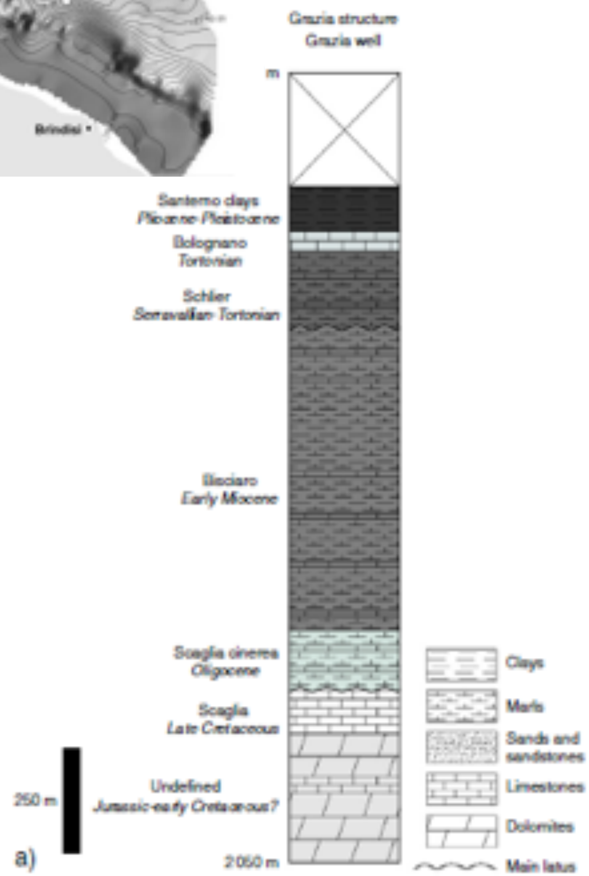


Name	Storage type	Area E+6 (M⁶)	Bulk Volume E +6 (M⁶)	Porosity (Scaglia)
Rovesti	Oil and Gas reservoir	1.7	195	13 -15 %
Grifone	Saline aquifer	1.0	191	10 – 20%
Grazia	Saline aquifer	1.3	241	2 - 13 %

Volpi et al., 2014. Southern Adriatic Sea as a potential area for CO2 geological storage. Oil and Gas Science and Technology, IFP Energies nouvelles; DOI: 10.2516/ogst/2014039

GRAZIA STRUCTURE





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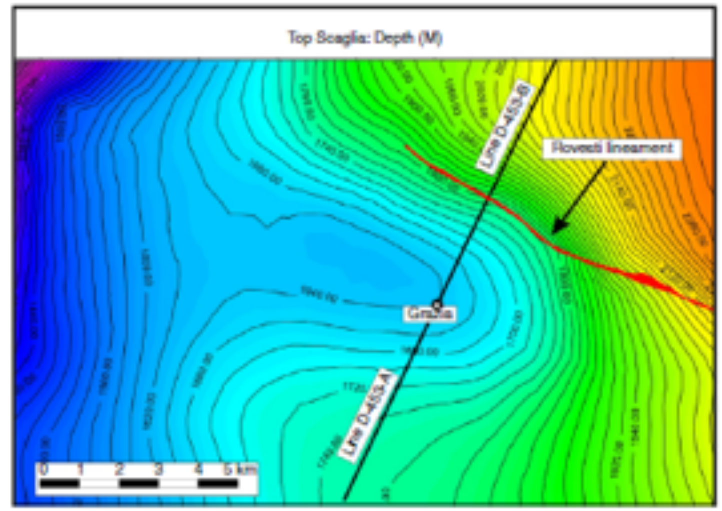
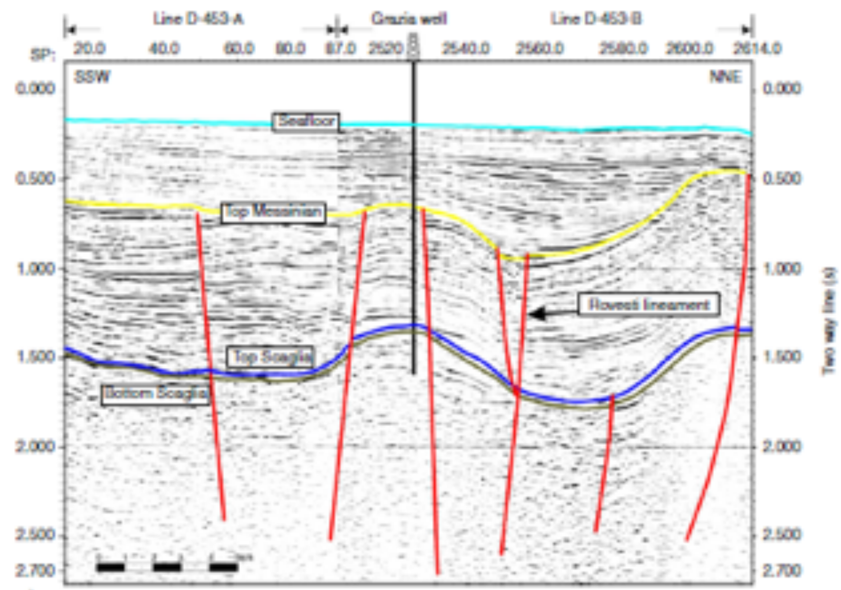
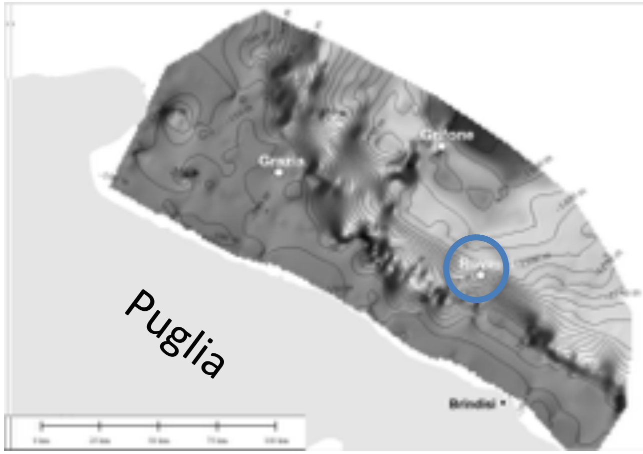


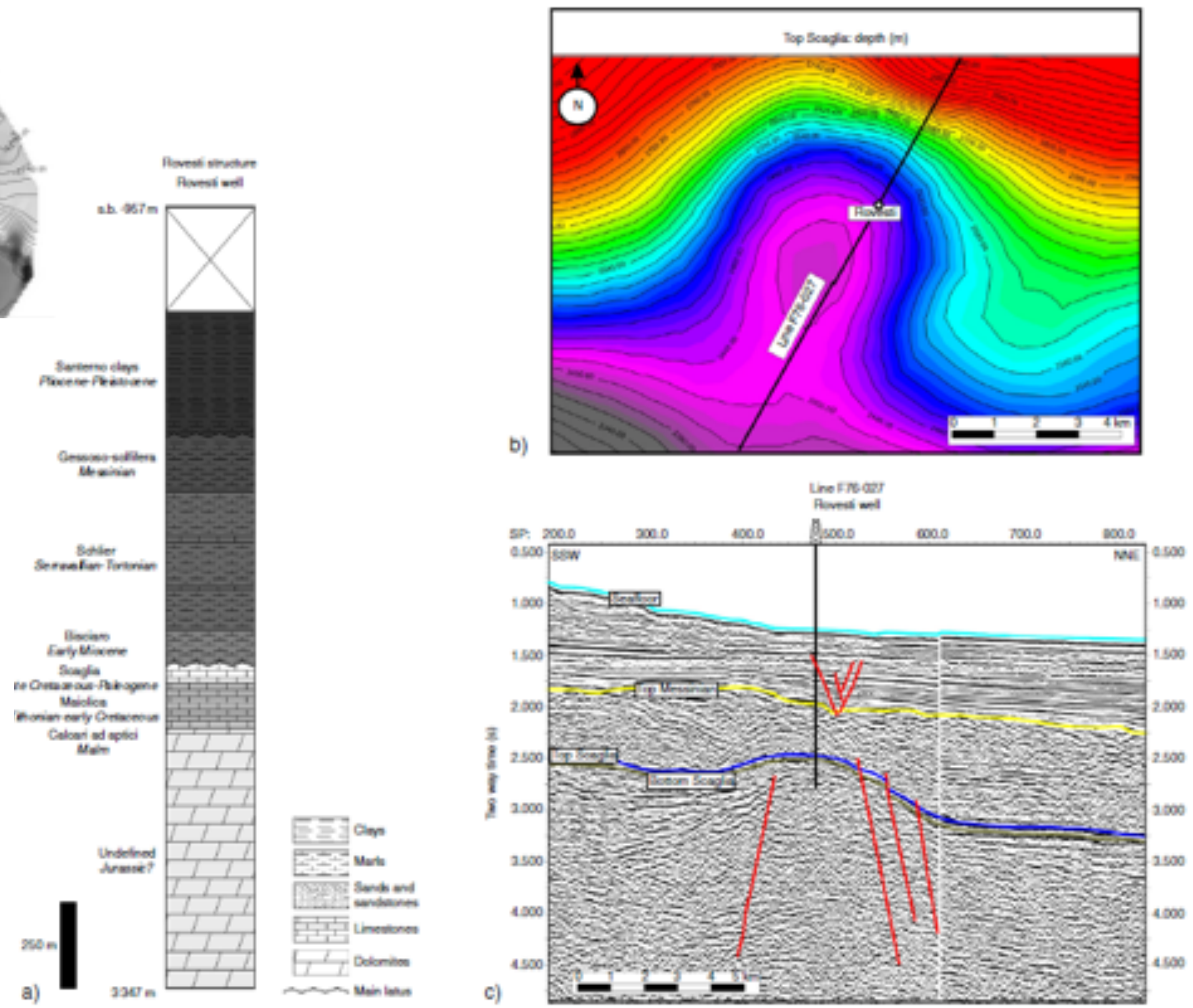
b)



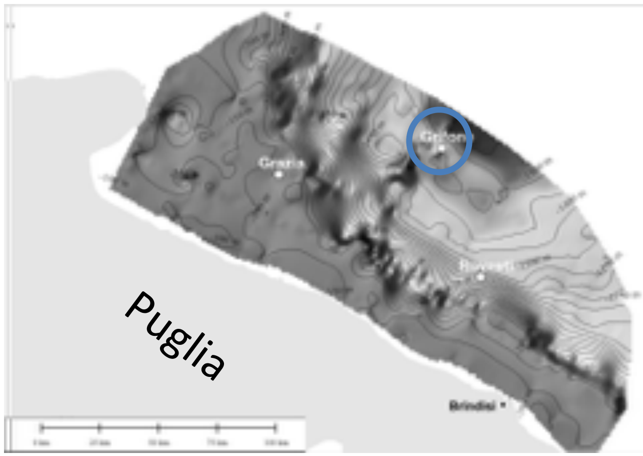
c)

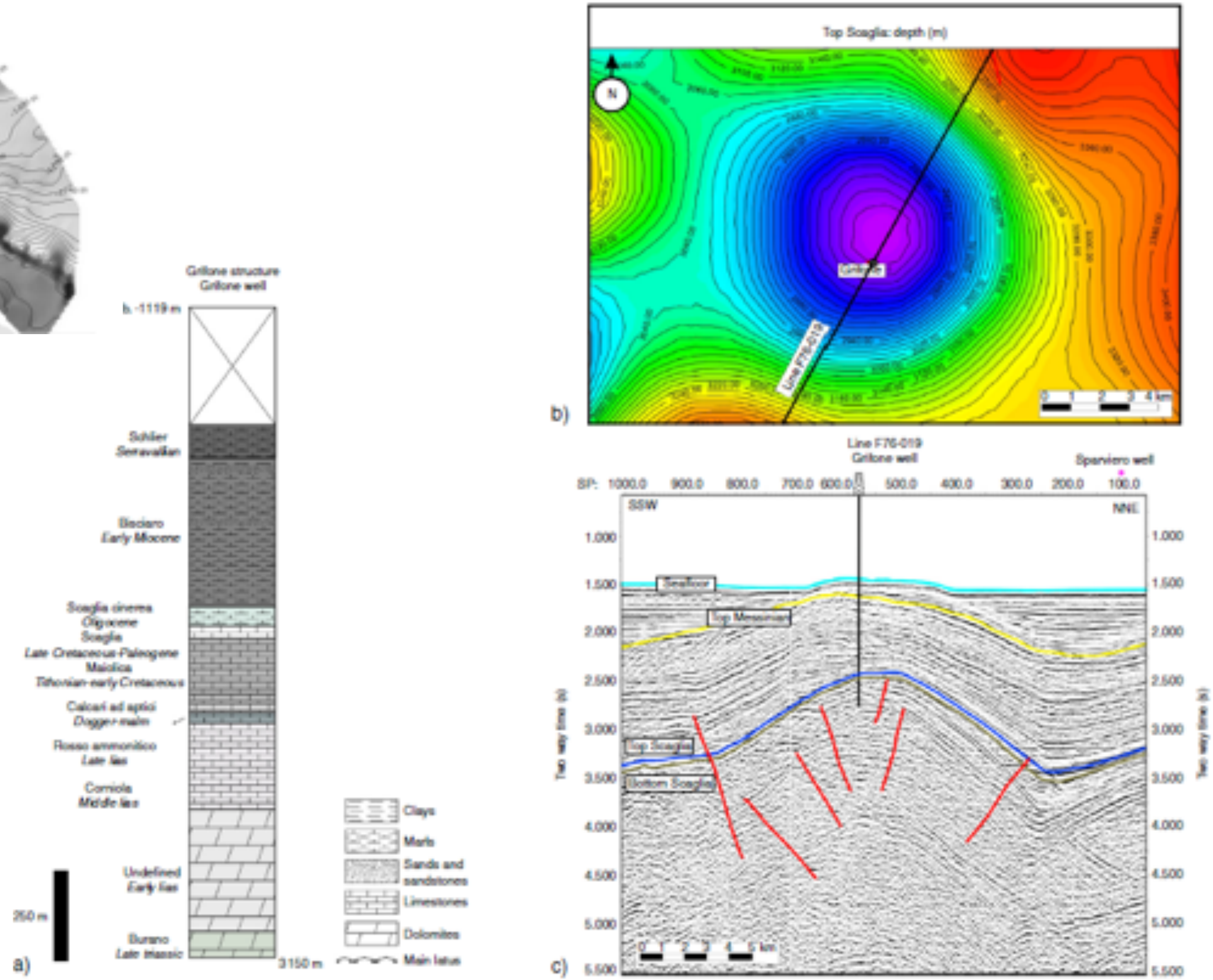
ROVESTI STRUCTURE





GRIFONE STRUCTURE



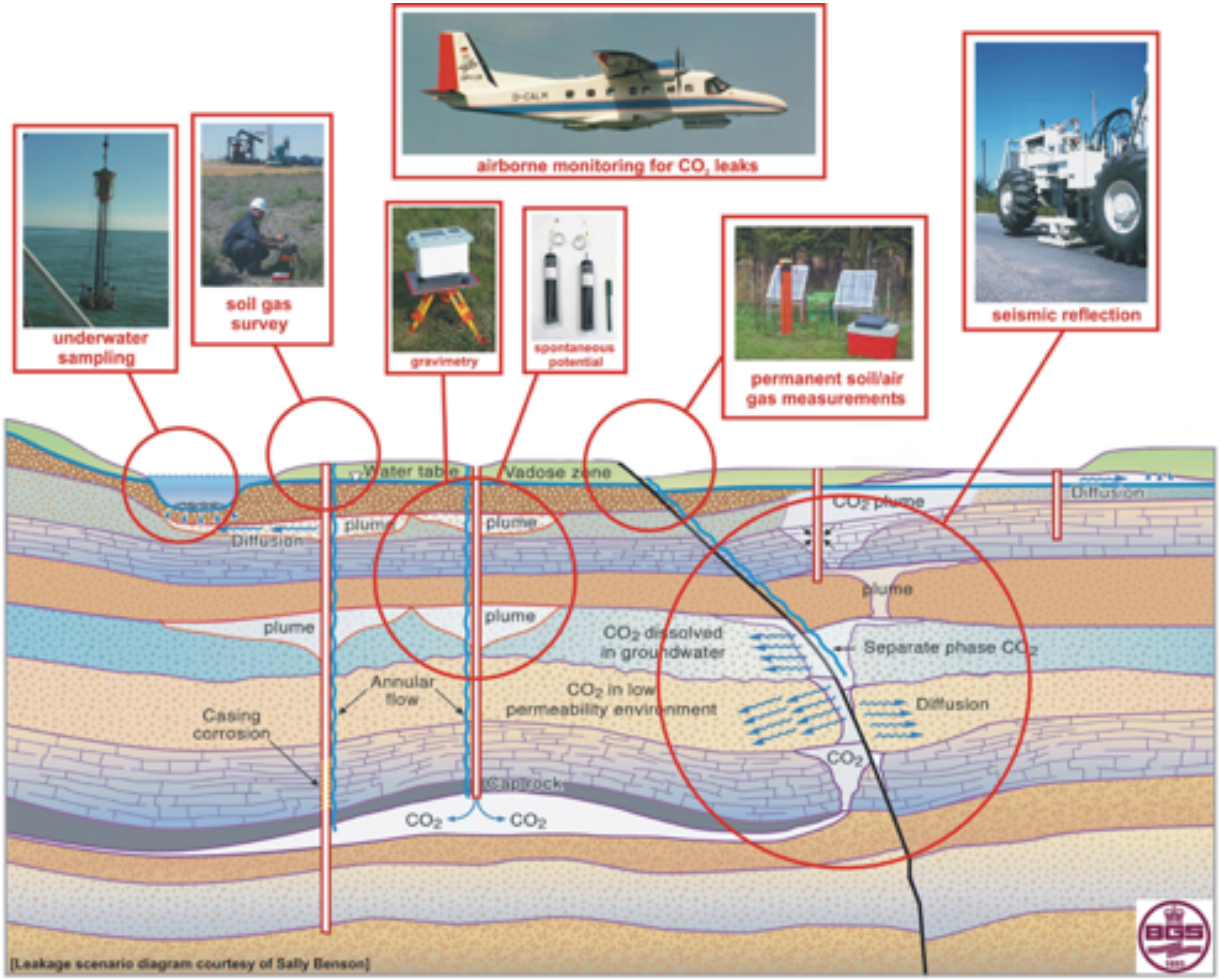


Monitoring of the selected sites

Monitoring is required in order to see whether:

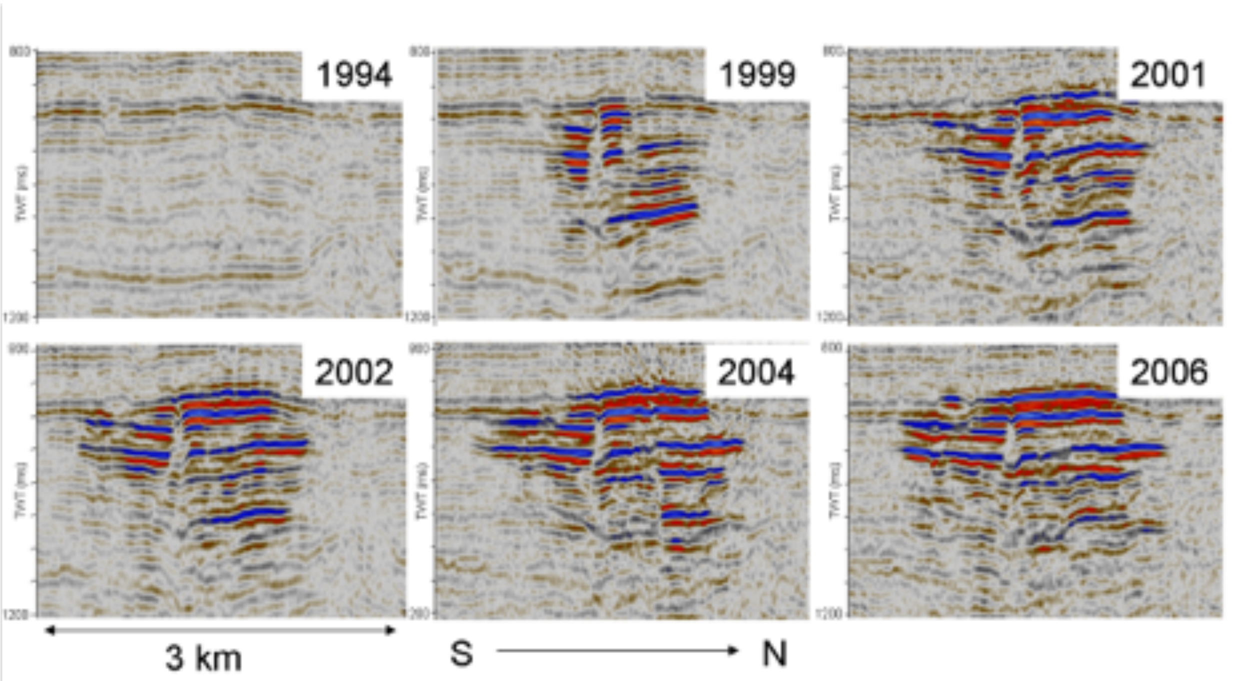
- stored CO_2 behaves as expected
- migration or leakage occurs
- identified leakage damages environment or human health

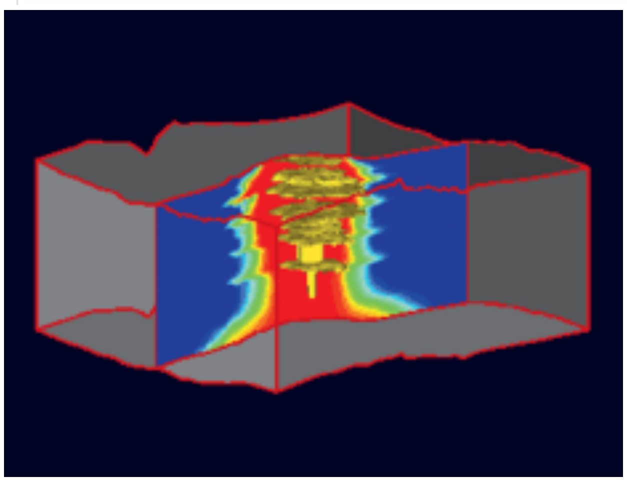
Monitoring of storage site



Benson, S.M., Gasperikova, E. and Hoversten, :, 2004. Overview of monitoring techniques and protocols for geologic storage projects. IEAGHG Report. NO. PH4/29.

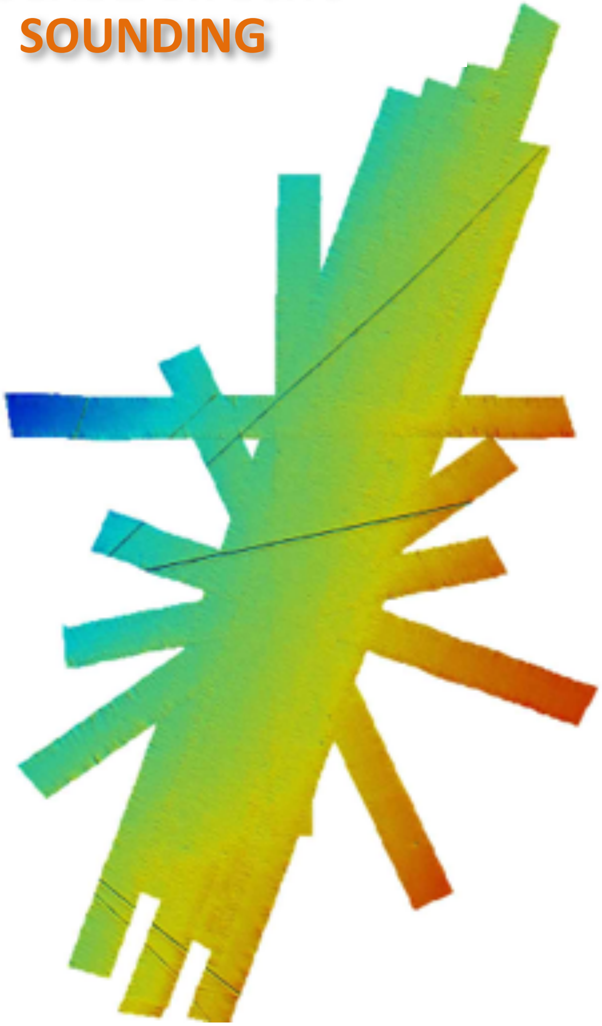
IDENTIFICATION AND MONITORING OF CO_2 BEHAVIOUR AFTER INJECTION



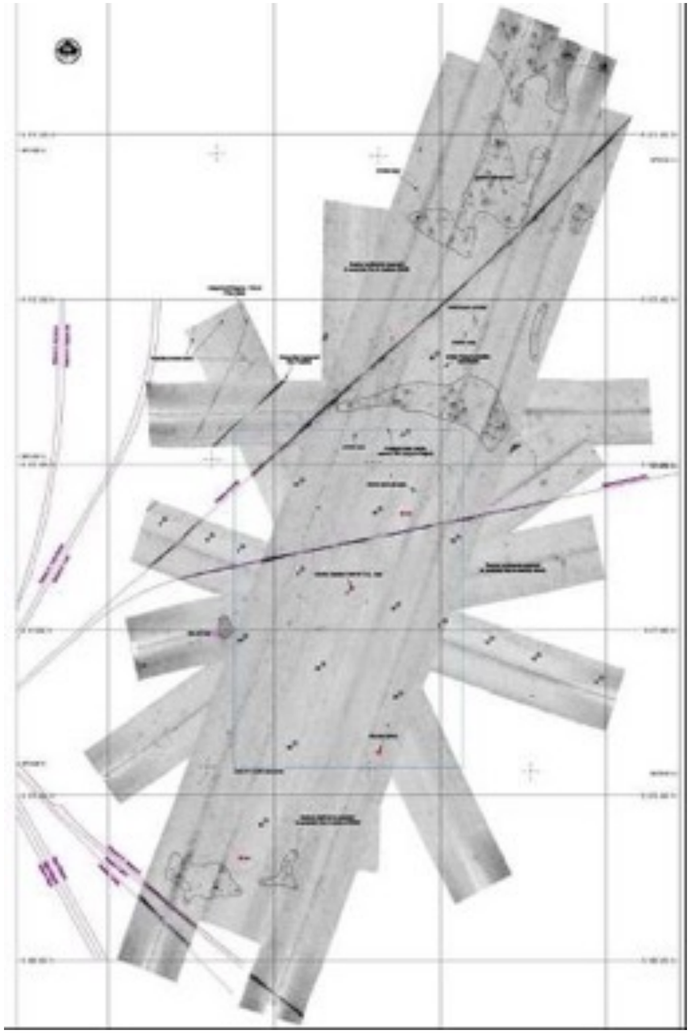


Courtesy Statoil/CO2STORE project

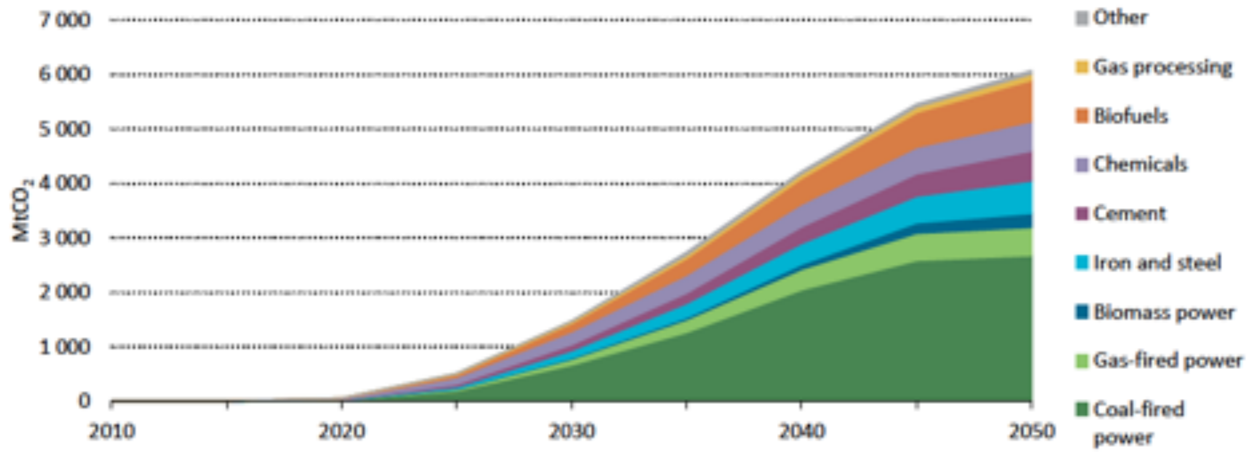
SEAFLOOR DEPTH, FROM MULTIBEAM ECHO SOUNDING



MOSAIC OF SIDE SCAN SONAR DATA

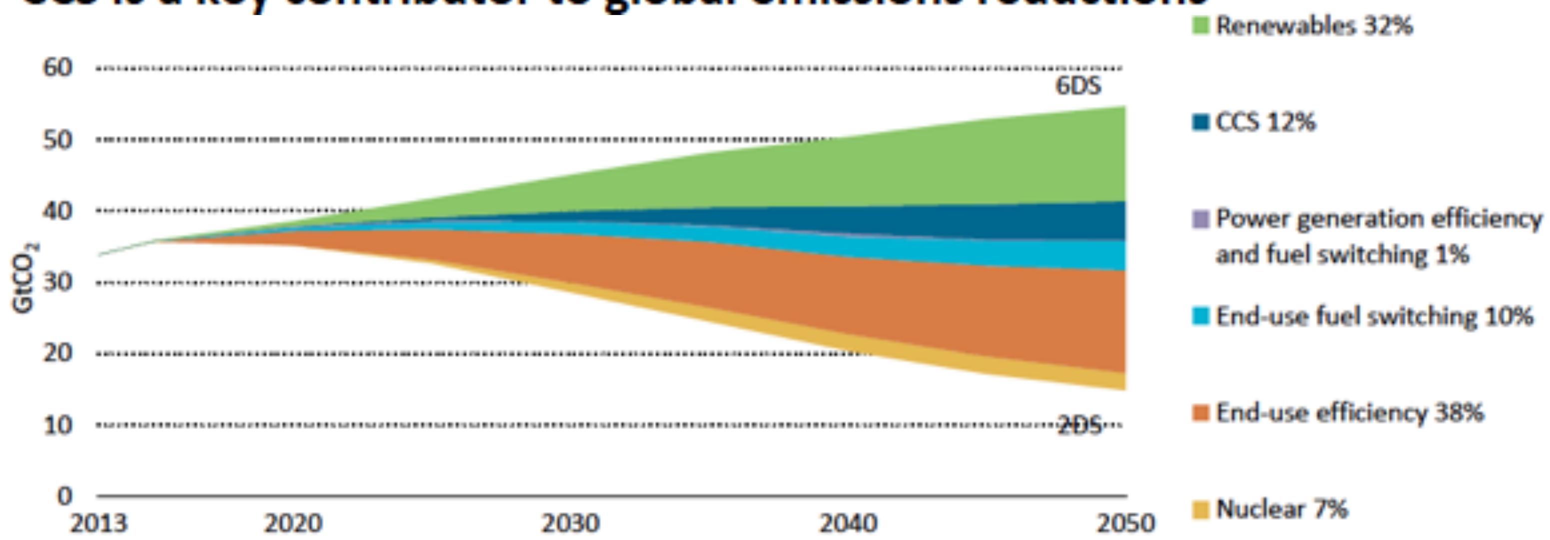


Power and industry are the predominant sources of CO_2 captured in the 2DS



Source: Derived from IEA (2016b), *Energy Technology Perspectives 2016.*

CCS is a key contributor to global emissions reductions



Source: IEA (2016b), *Energy Technology Perspectives 2016.*

Large-scale CCS projects in operation

Project name	Location	Operation date	Industry	Capture type	Capture capacity (Mtpa)	Transport type	Primary storage type
Val Verde Natural Gas Plants	United States	1972	Natural Gas Processing	Pre-combustion capture (natural gas processing)	1.3	Pipeline	Enhanced oil recovery
Enid Fertilizer CO2-EOR Project	United States	1982	Fertiliser Production	Industrial Separation	0.7	Pipeline	Enhanced oil recovery
Shute Creek Gas Processing Facility	United States	1986	Natural Gas Processing	Pre-combustion capture (natural gas processing)	7.0	Pipeline	Enhanced oil recovery
Sleipner CO2 Storage Project	Norway	1996	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.9	No transport required (direct injection)	Dedicated Geological Storage
Great Plains Synfuel Plant and Weyburn-Midale Project	Canada	2000	Synthetic Natural Gas	Pre-combustion capture (gasification)	3.0	Pipeline	Enhanced oil recovery
Snøhvit CO2 Storage Project	Norway	2008	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.7	Pipeline	Dedicated Geological Storage
Century Plant	United States	2010	Natural Gas Processing	Pre-combustion capture (natural gas processing)	8.4	Pipeline	Enhanced oil recovery
Air Products Steam Methane Reformer EOR Project	United States	2013	Hydrogen Production	Industrial Separation	1.0	Pipeline	Enhanced oil recovery
Coffeyville Gasification Plant	United States	2013	Fertiliser Production	Industrial Separation	1.0	Pipeline	Enhanced oil recovery
Lost Cabin Gas Plant	United States	2013	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.9	Pipeline	Enhanced oil recovery
Petrobras Santos Basin Pre-Salt Oil Field CCS Project	Brazil	2013	Natural Gas Processing	Pre-combustion capture (natural gas processing)	1.0	No transport required (direct injection)	Enhanced oil recovery
Boundary Dam Carbon Capture and Storage Project	Canada	2014	Power Generation	Post-combustion capture	1.0	Pipeline	Enhanced oil recovery
Quest	Canada	2015	Hydrogen Production	Industrial Separation	1.0	Pipeline	Dedicated Geological Storage
Uthmaniyah CO2-EOR Demonstration Project	Saudi Arabia	2015	Natural Gas Processing	Pre-combustion capture (natural gas processing)	0.8	Pipeline	Enhanced oil recovery
Abu Dhabi CCS Project (Phase 1 being Emirates Steel Industries (ESI) CCS Project)	United Arab Emirates	2016	Iron and Steel Production	Industrial Separation	0.8	Pipeline	Enhanced oil recovery