Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2024 - 2025

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

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Unit 1.5a
Carbon Capture and Storage (CCS)
Docente: **Valentina Volpi**

Unit 1.5a – Carbon Capture and Storage (CCS)

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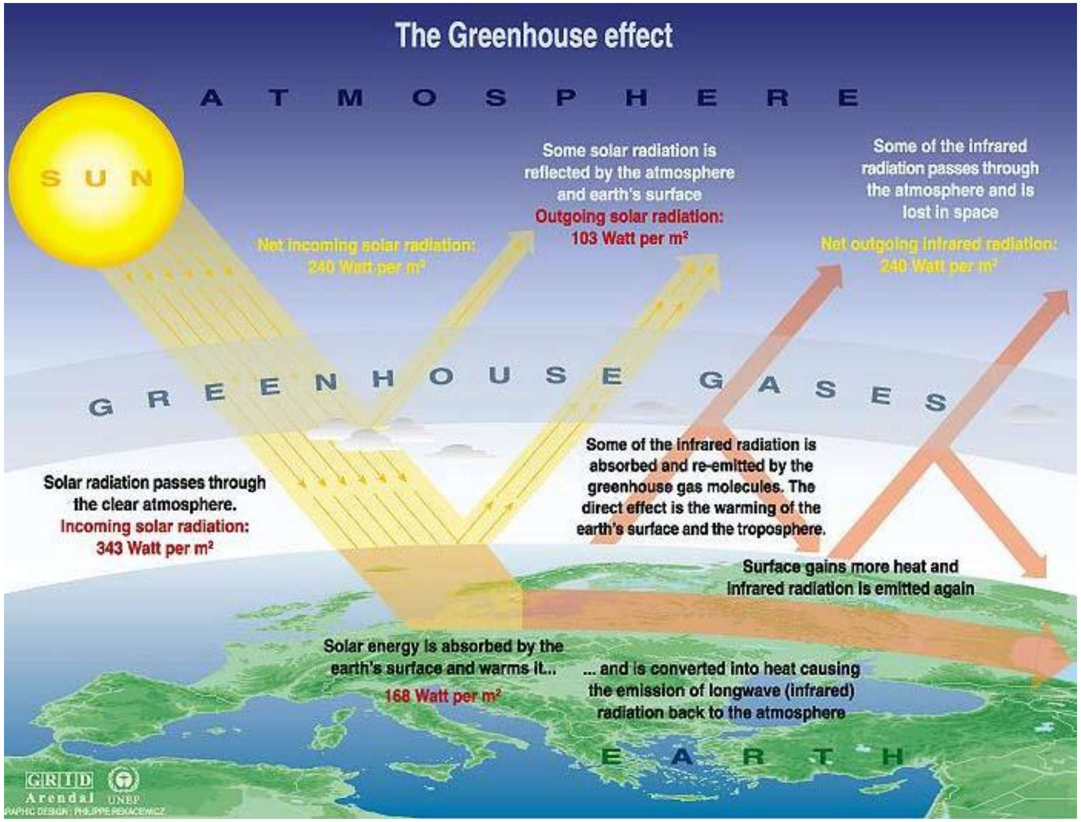
Outline:

- CCUS, technology to reduce CO_2 emissions
- CO_2 geological storage
- CO_2 storage potential in Italy

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

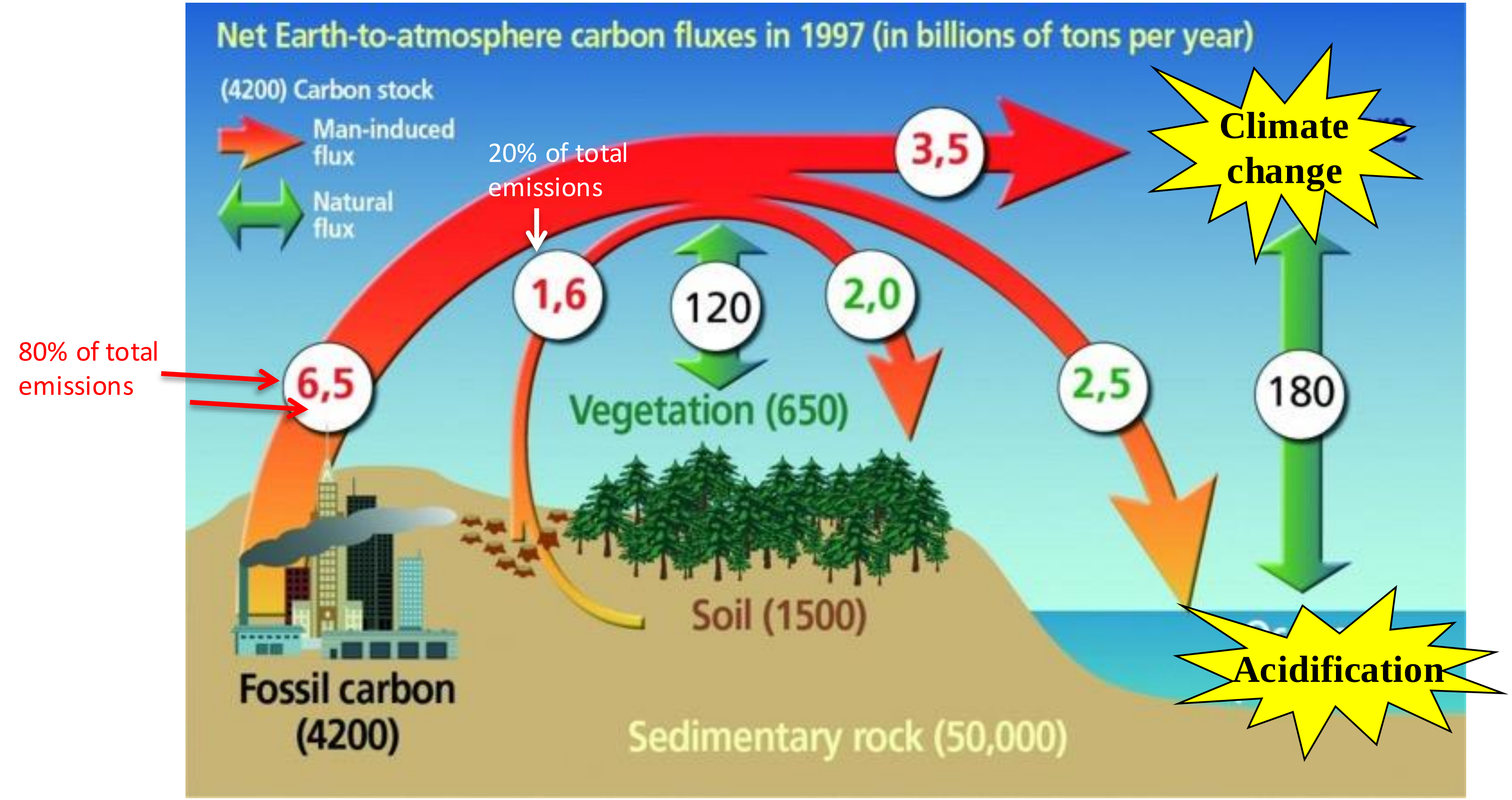
This process consists of the global warming due to the emission of gas (CO_2, water steam, methane...) in the atmosphere. Greenhouse gases allow sunlight to pass through the atmosphere while obstructing the passage to the space of the infrared radiation from the Earth's surface and lower atmosphere (the 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.

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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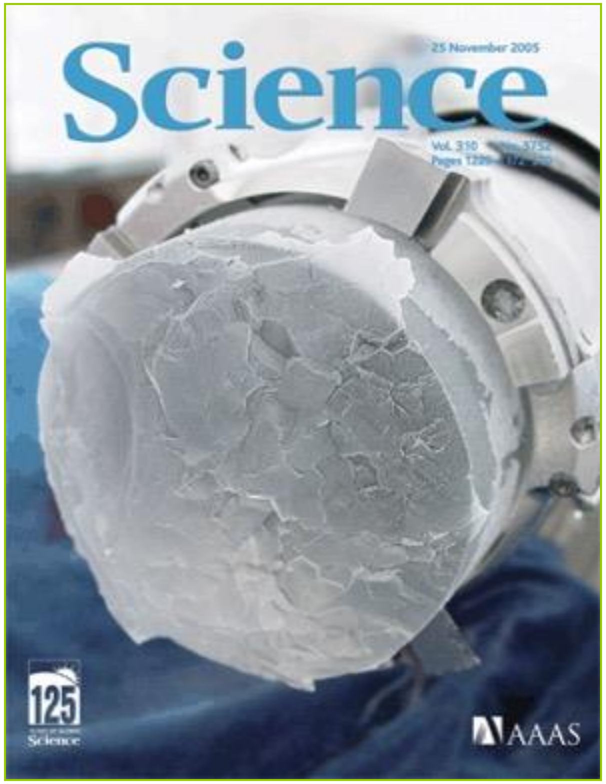
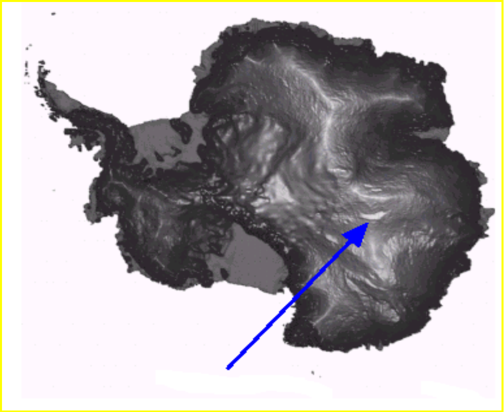
World emissions of CO_2 from the usage of fossil fuels:

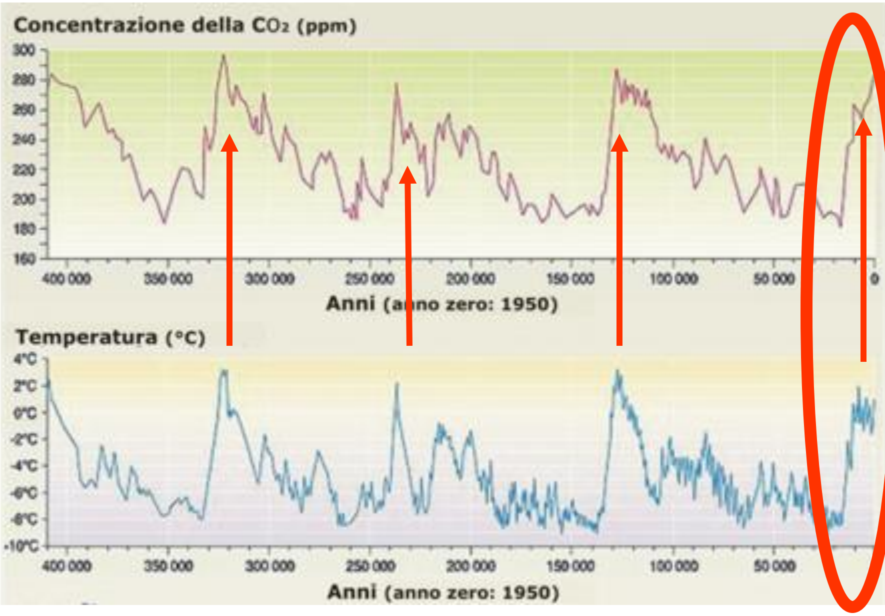
6.5 Gt C/y (o 24 Gt CO_2/a)





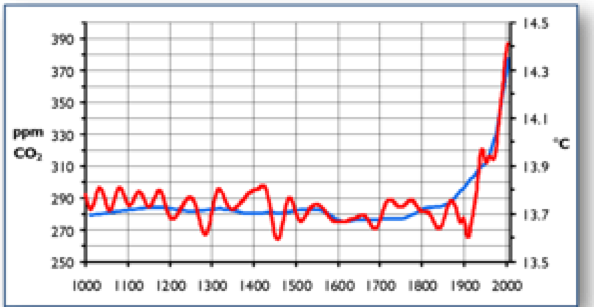
Ice cores from Antarctica have allowed to reconstruct the temperature trend and the CO_2 concentration in the atmosphere for the the last 400.000

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)



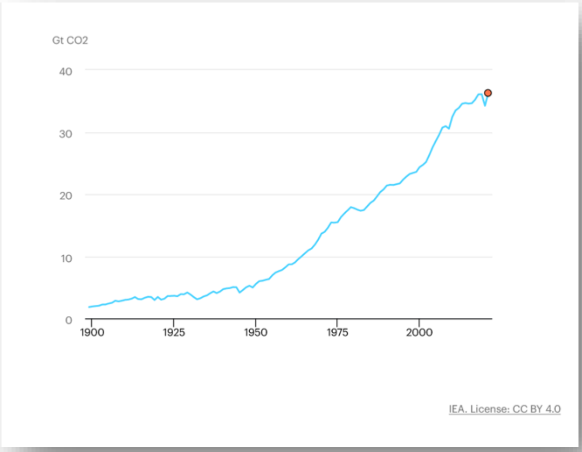
Global variation of the temperature (red) and the CO_2 present in the atmosphere (blu) in the last 1000 years.

Concentration of CO_2 in 2020

31.5 Gt - 412.5 ppm (50% higher than when the industrial revolution began)

IN 2021 : 36 Gt

IEA (2021), Global Energy Review 2021, IEA, Paris https://www.iea.org/reports/global-energy-review-2021



CO_2 emissions from energy combustion and industrial processes, 1900-2021

CO_2 GEOLOGICAL STORAGE CARBON CAPTURE (USE) AND STORAGE

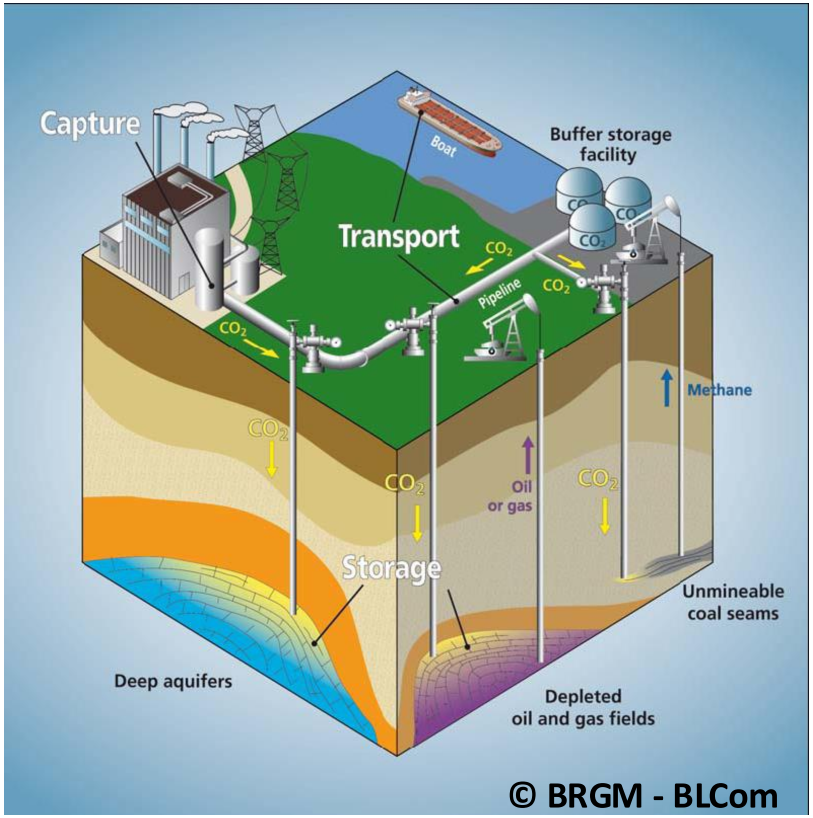
Three main phases:

Capture: the CO_2 produced by the combustion processes of large industrial plants is separated from the other gases

Transport: Once captured, the CO_2 is compressed and transported through pipelines or by ship to storage sites

Use: in the food industry, urea production, water treatment, fire retardant production, refrigerant

Storage: CO_2 is injected underground in suitable rock formations

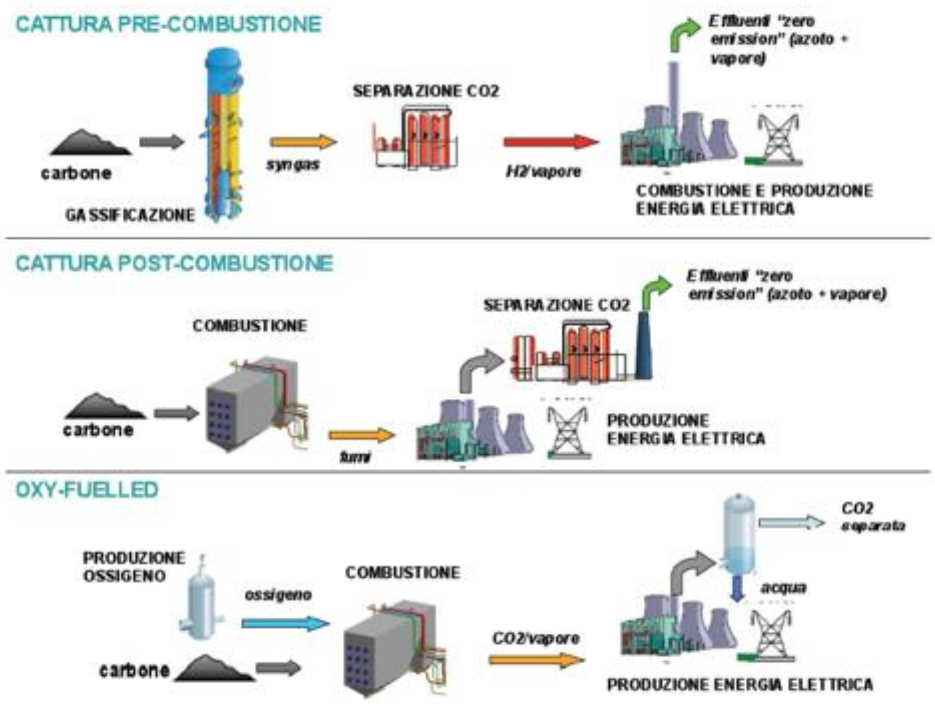


MAIN CO_2 EMITTORS

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
- CHEMICALS REFINERIES

CAPTURE PROCESSES



- **PRE- COMBUSTION:** the fuel (coal, gas) is first treated by transforming it into syngas (gas di sintesi) and subsequently separating it in two gas flows: one with a high concentration of hydrogen for the combustion (or other uses) and CO_2.
- **POST- COMBUSTION:** separation of CO_2 from flue gases at the end of the cycle; it does not need substantial modification to the power plant.
- **OXYGEN COMBUSTION:** The primary fuel is combusted in oxygen instead of air, which produces a flue gas containing mainly water vapor and a high concentration of CO_2 (80%). The flue gas is then cooled to condense the water vapor, which leaves an almost pure stream of CO_2.

TRANSPORT OF CO_2

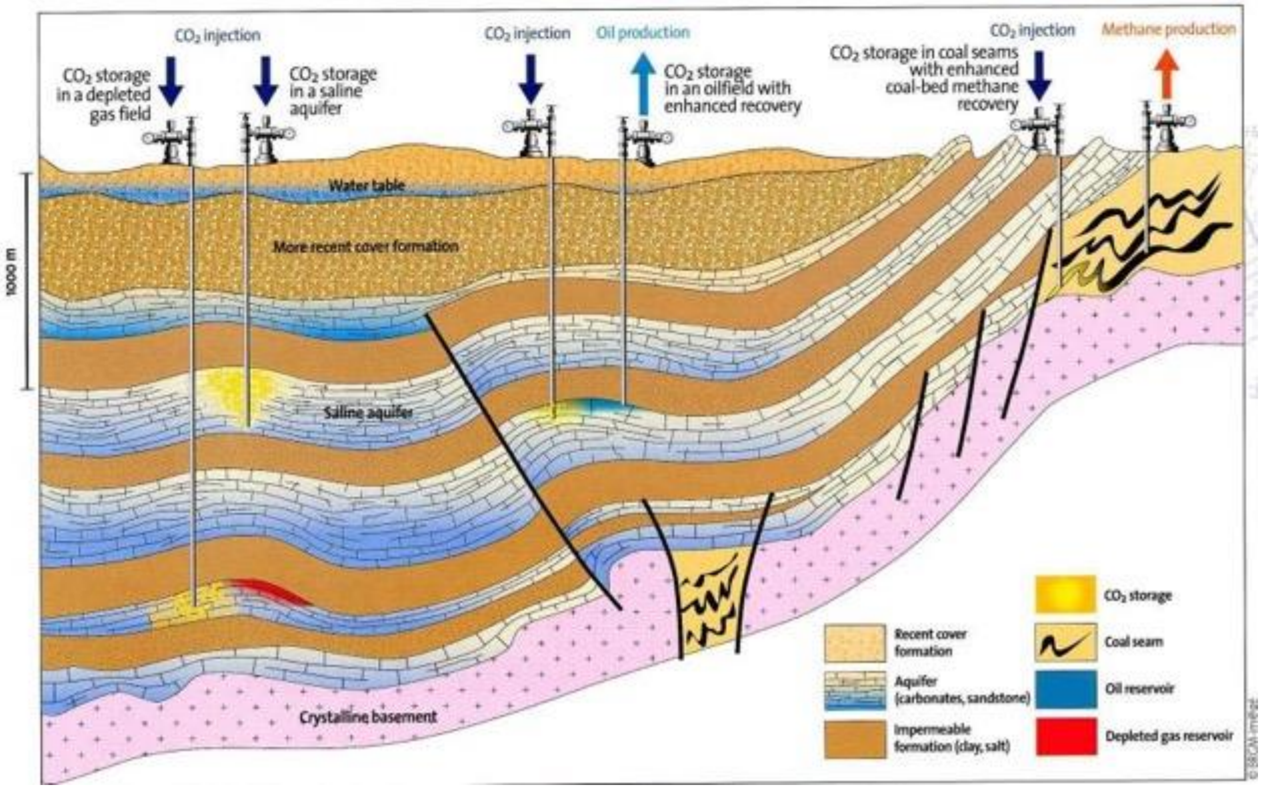
La CO_2 can be transported, both onland and offshore, in three phases:

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

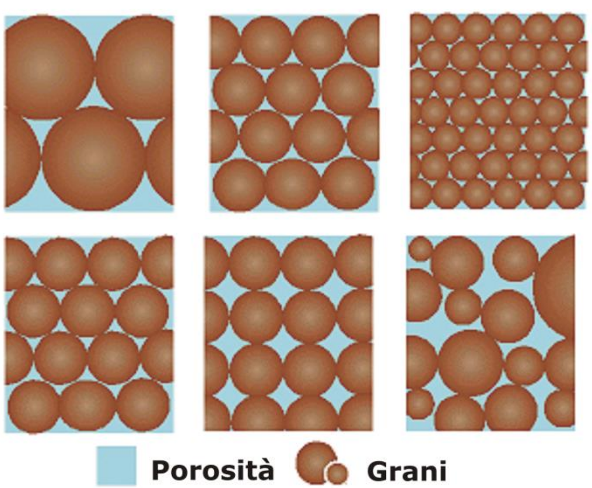
Tectonic setting/seismicity: the area must be stable to ensure the structural conditions for storage

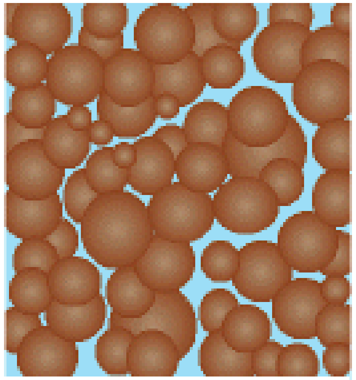
CO_2 STORAGE

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

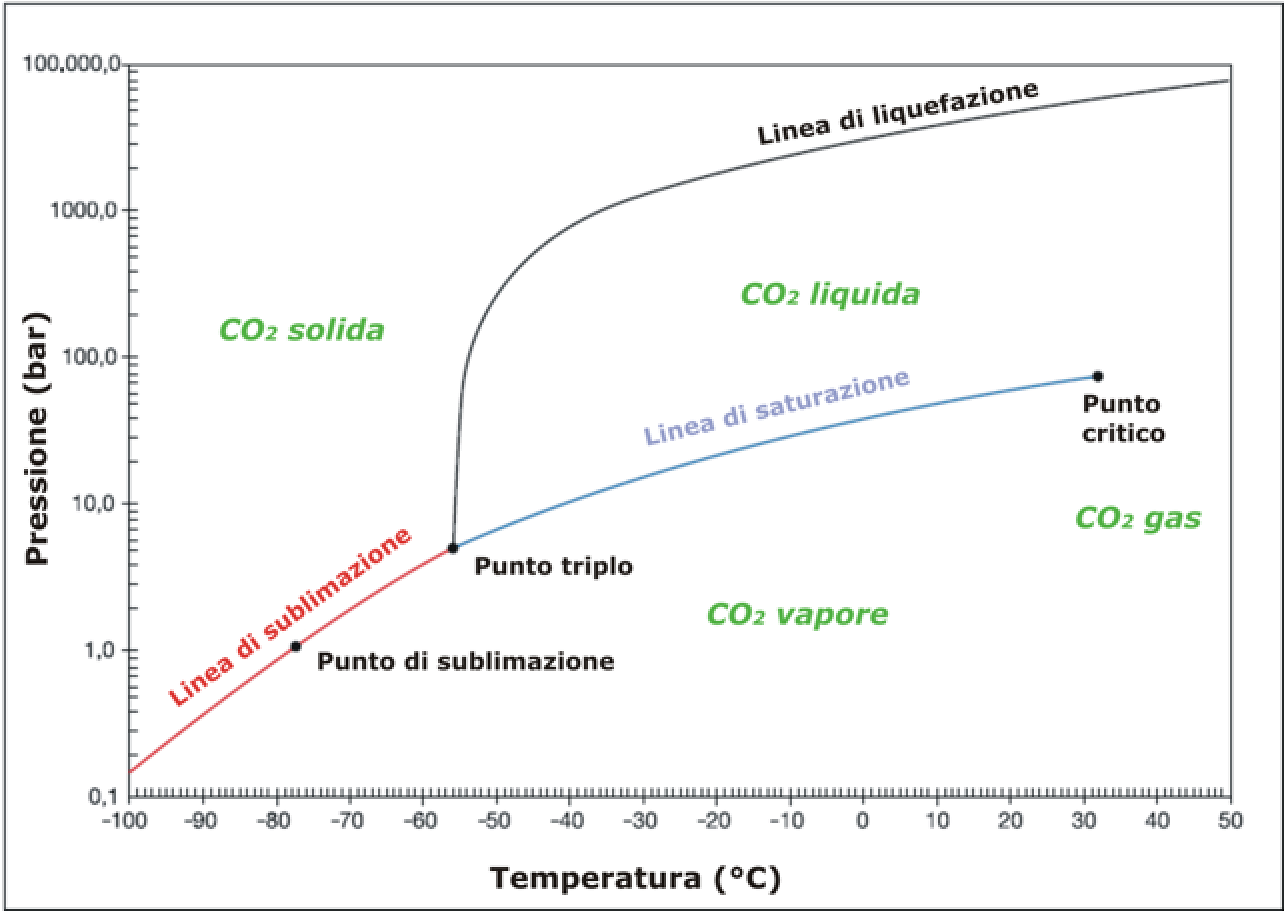
- **they must be at a DEPTH between 800 (so that the CO_2 remains in conditions of supercritical state) and 1500 m;**

- **they must have a certain <u>porosity</u> and <u>permeability</u>;**





CO_2 PHASE: "supercritical state"



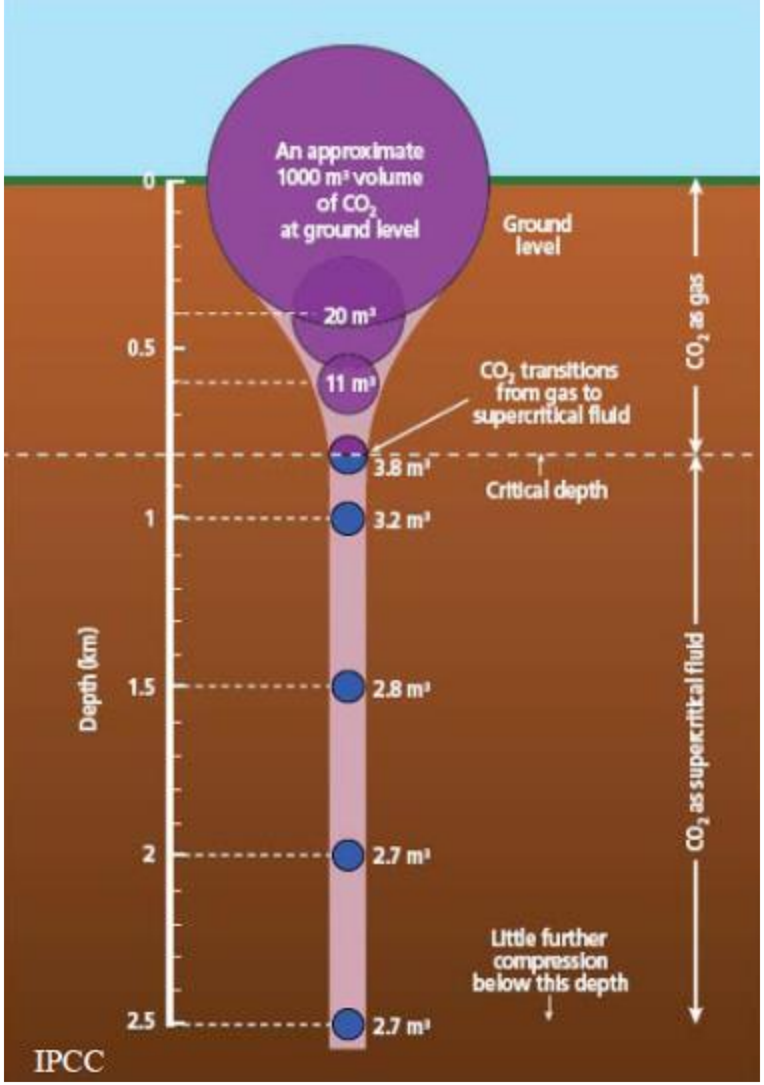
- T>31.1° C
- P>73.9 bar

...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



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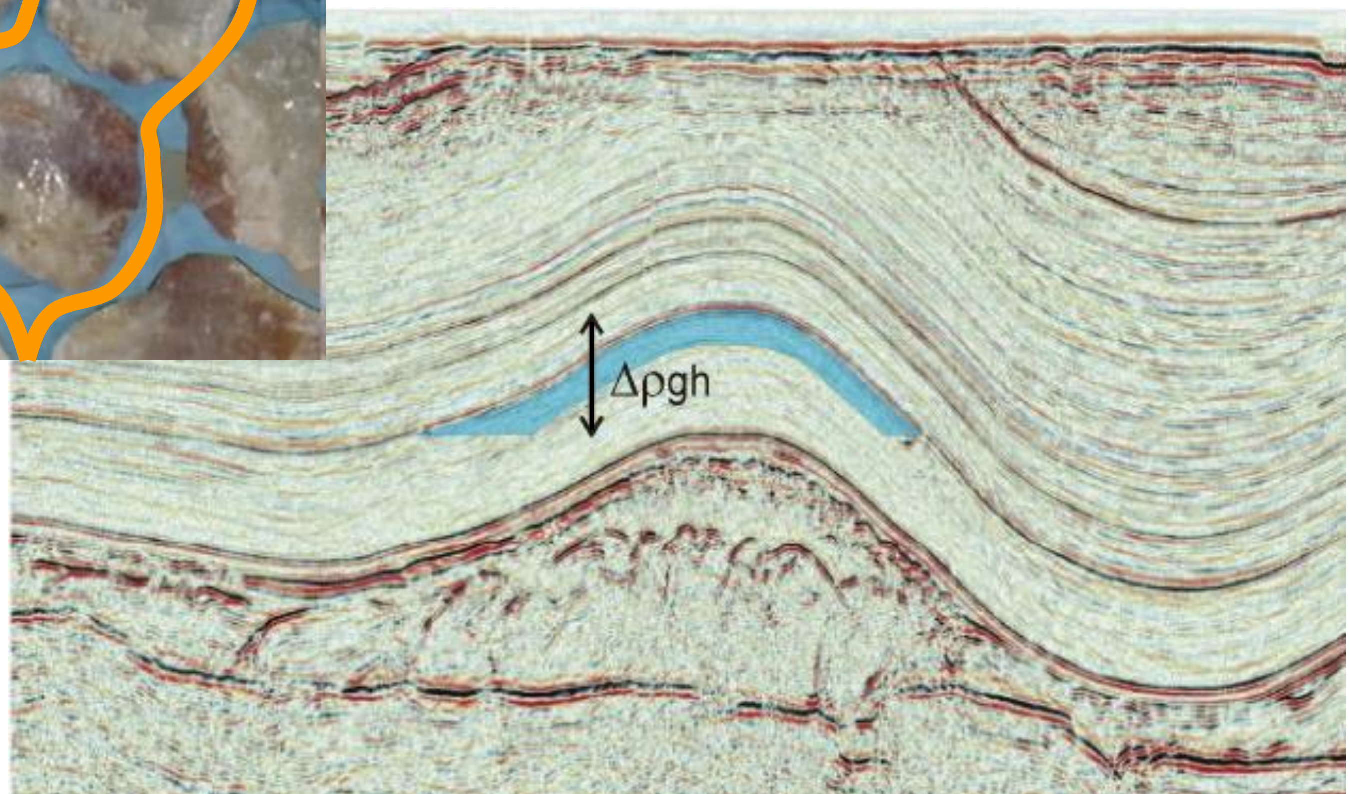
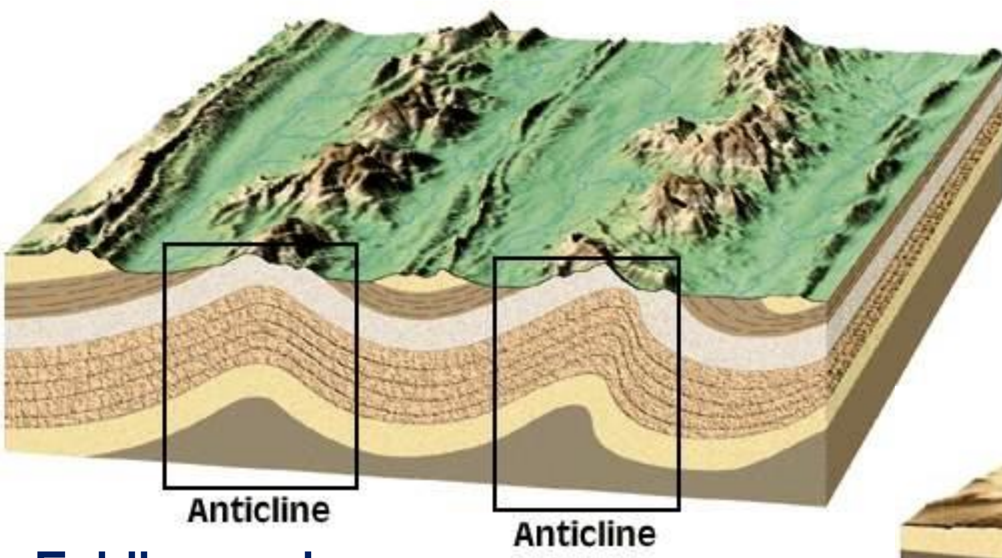
The CO_2 at supercritical conditions tends to rise ...

ESSENTIAL PRESENCE OF SEALING ROCK FORMATIONS (CAPROCK)

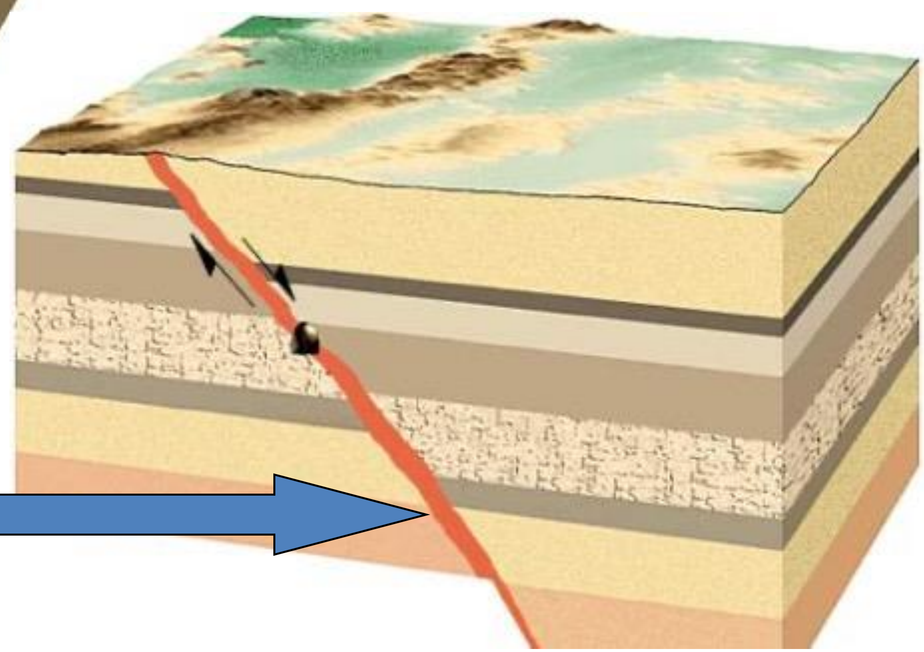


STRUCTURAL TRAPS



Folding and anticlines

Faults and unconformities



Fault consists of different material

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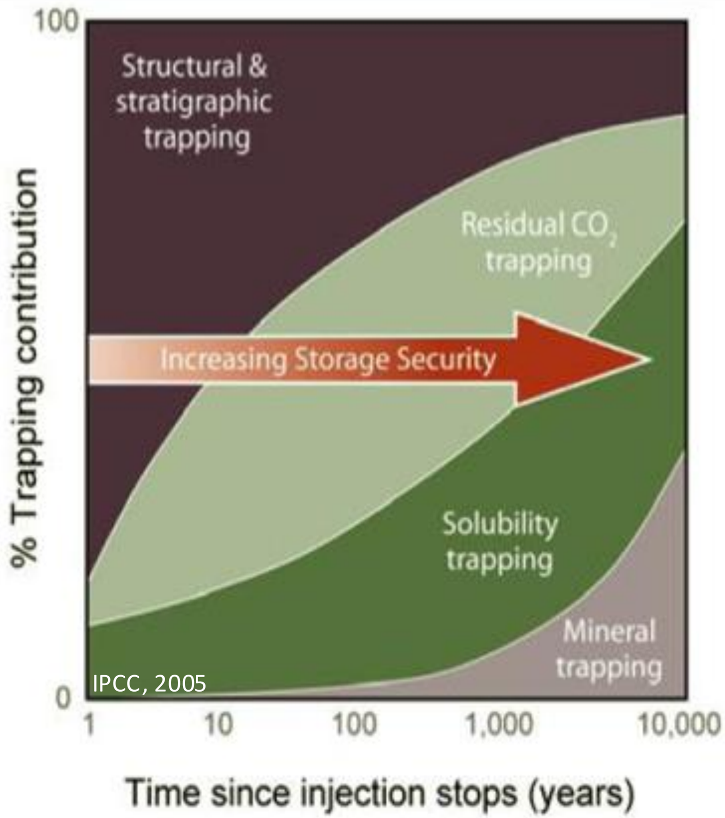
Trapping mechanisms



- **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 CO_2 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

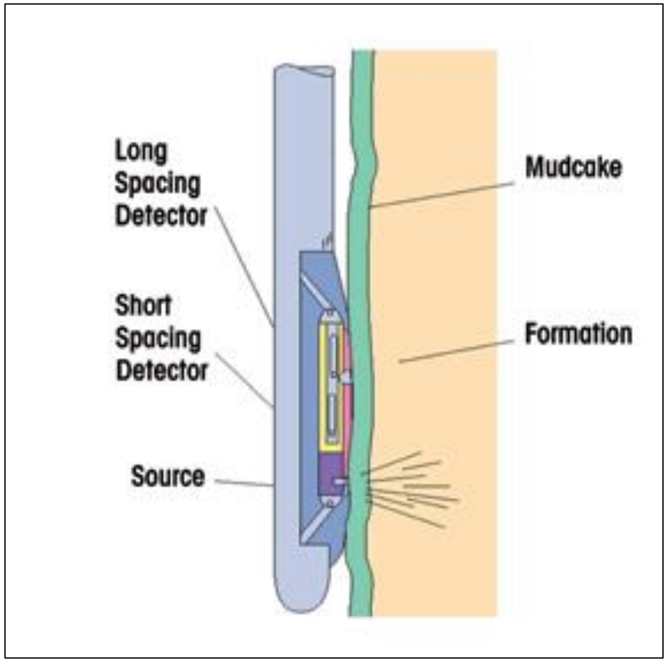
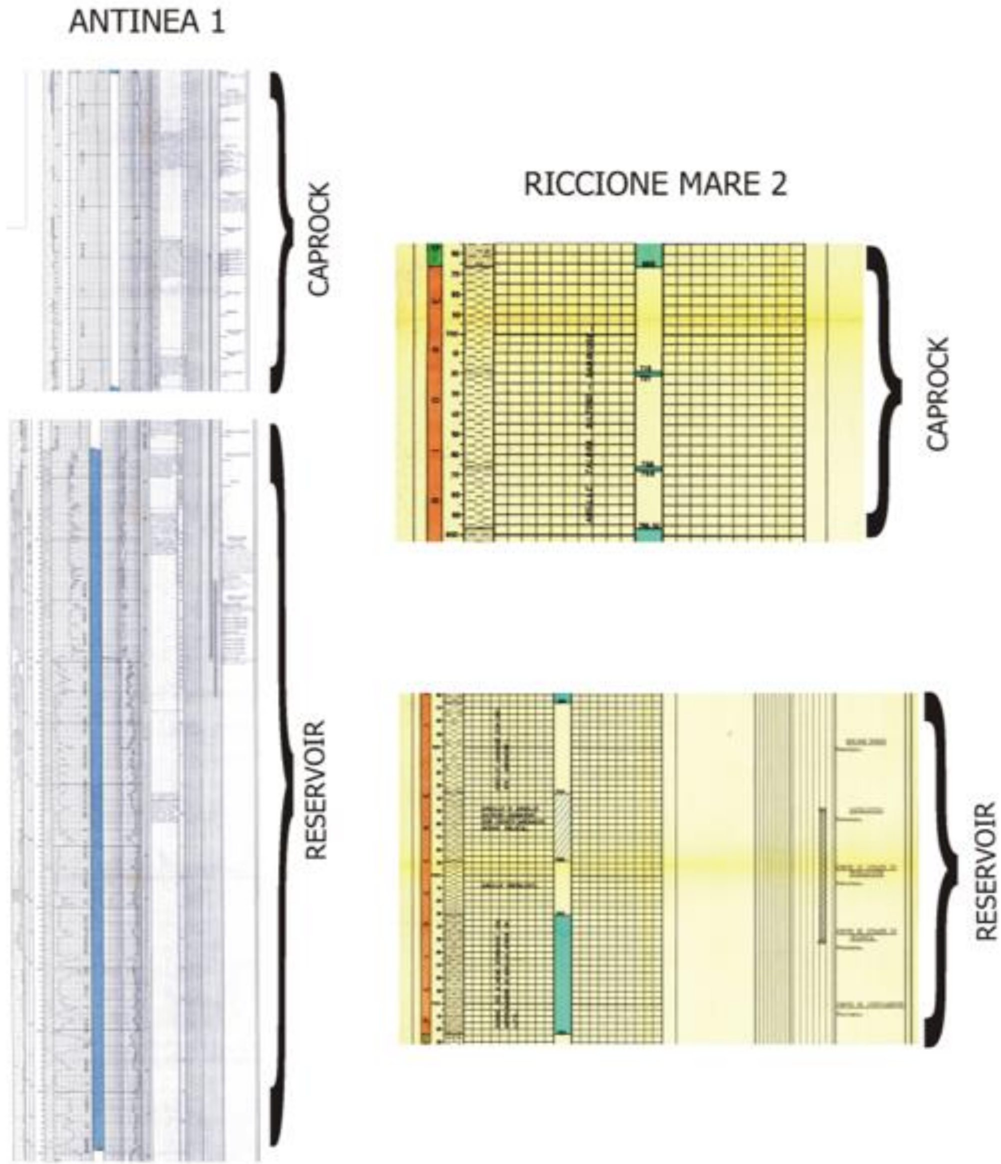
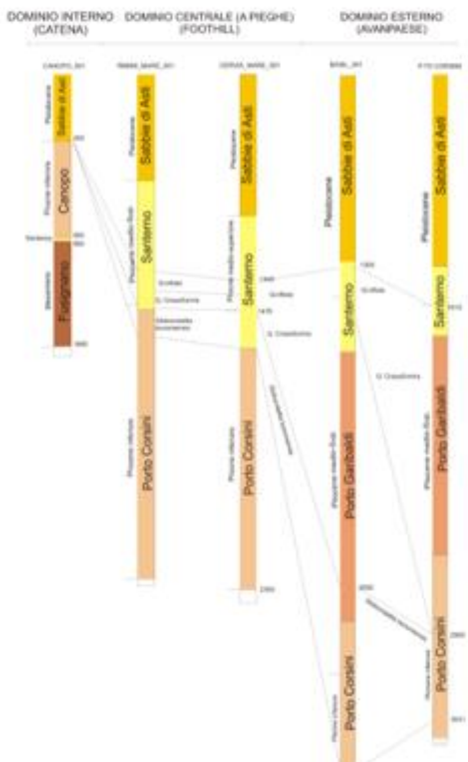


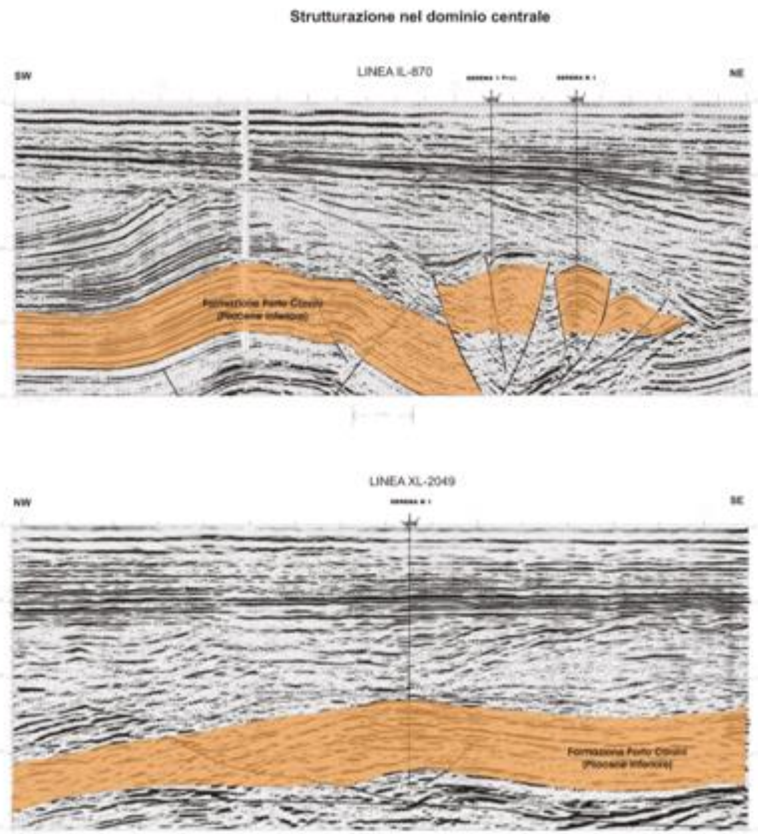
Image of a logging tool in a hole

CHARACTERIZATION RESERVOIR-CAPROCK: WELL DATA analysis



CHARACTERIZATION RESERVOIR-CAPROCK: SEISMIC DATA ANALYSIS





Main characteristics of a potential site for CO_2 storage

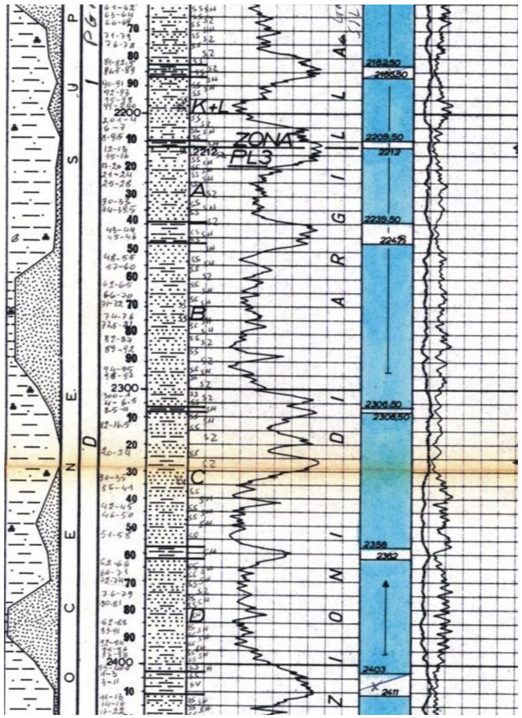
- *Capacity*, to contain the amount of CO_2 to be stored; key parameter: **porosity**
- *Injectivity*, to inject the CO_2 a certain rate of injection; key parameter: **permeability of reservoir**
- *Containment*, to avoid CO_2 leakage; key parameter: **permeability of caprock**

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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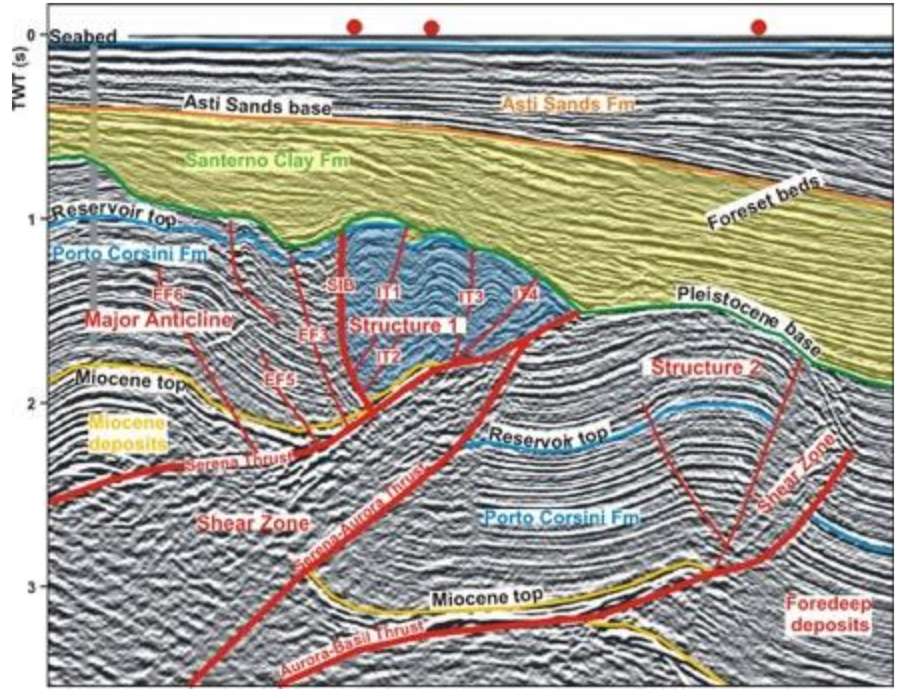
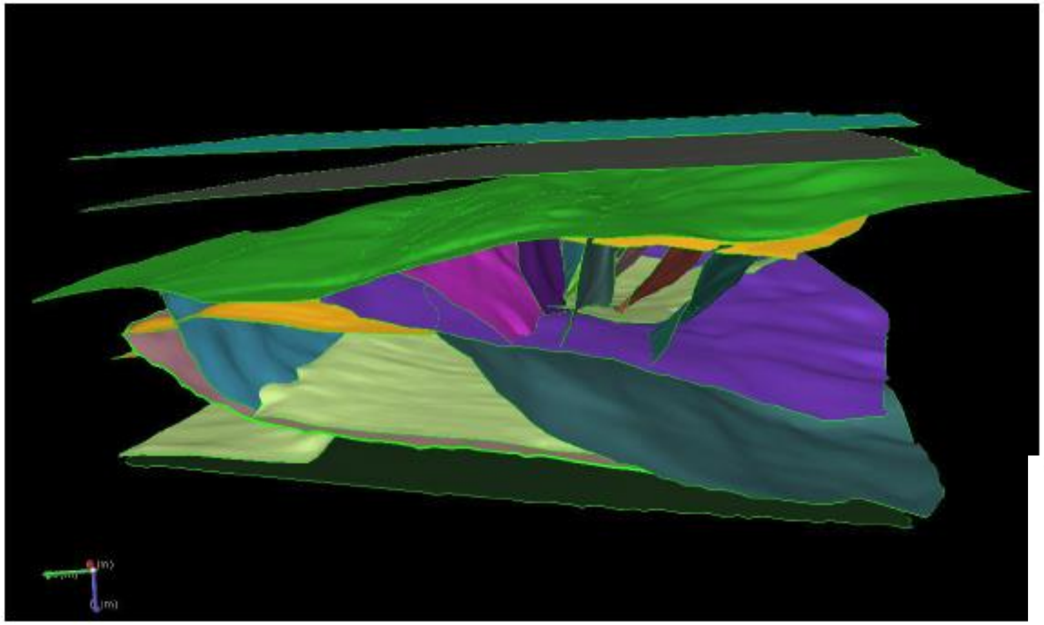
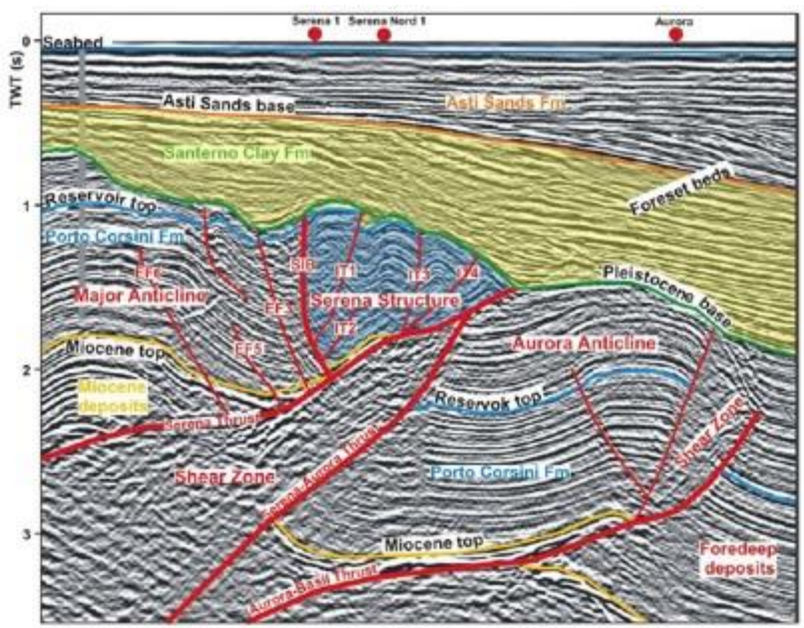
Seismostratigraphic and structural interpretation of multichannel seismic profiles

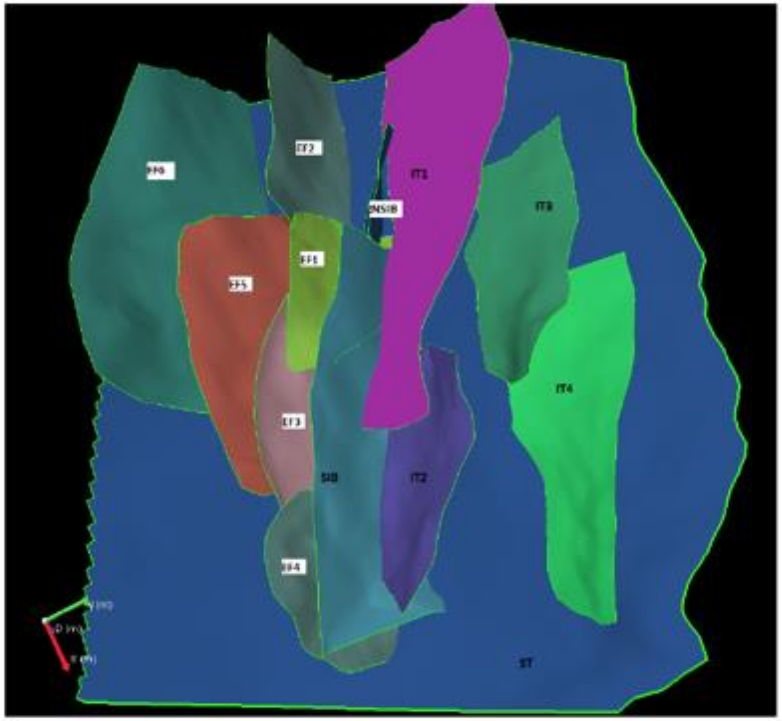


Geological modeling

Example of 3D geological model

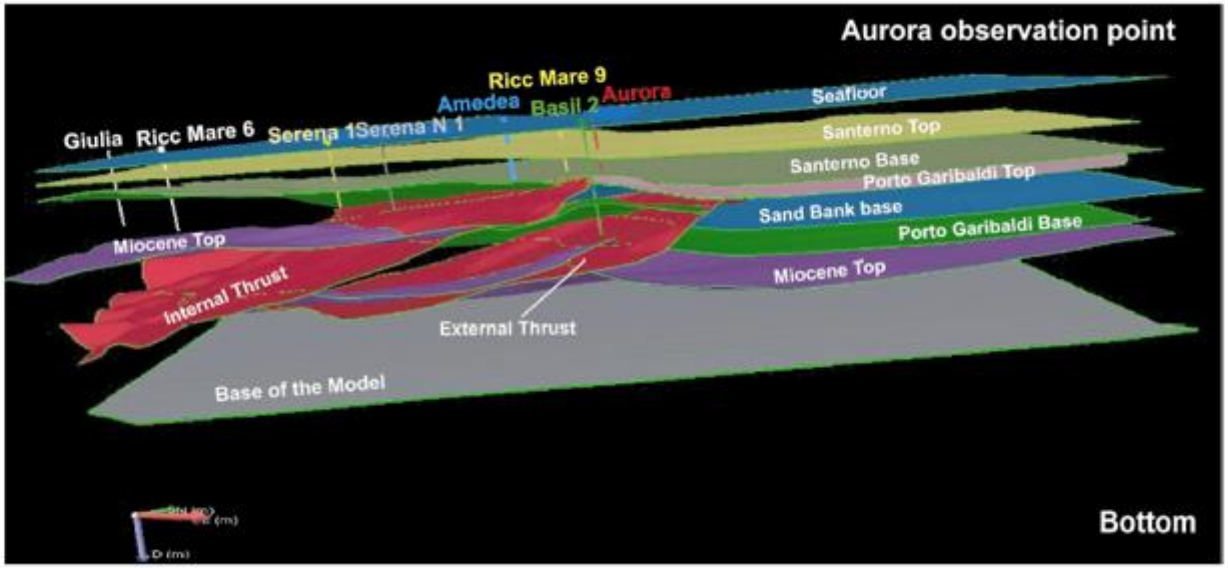


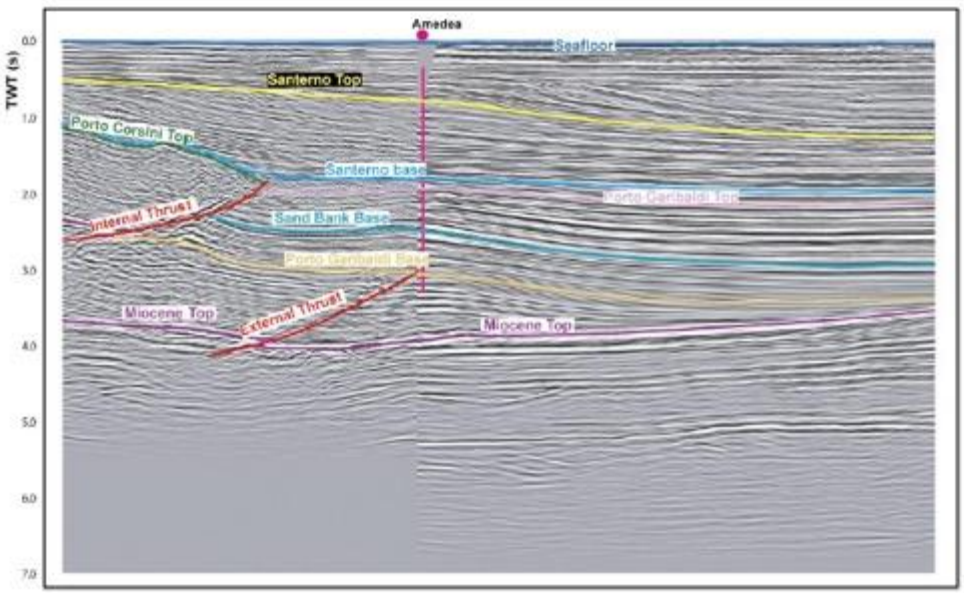


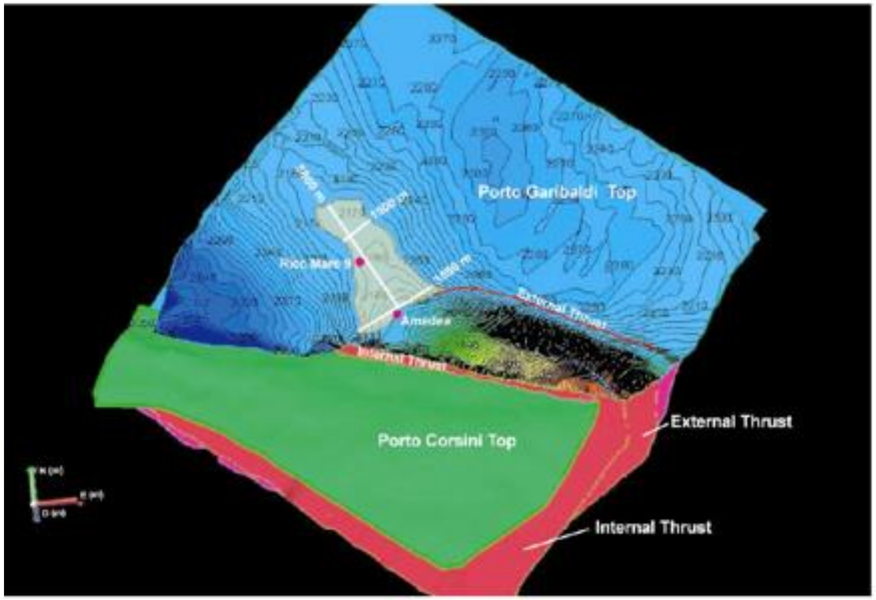


Geological modeling

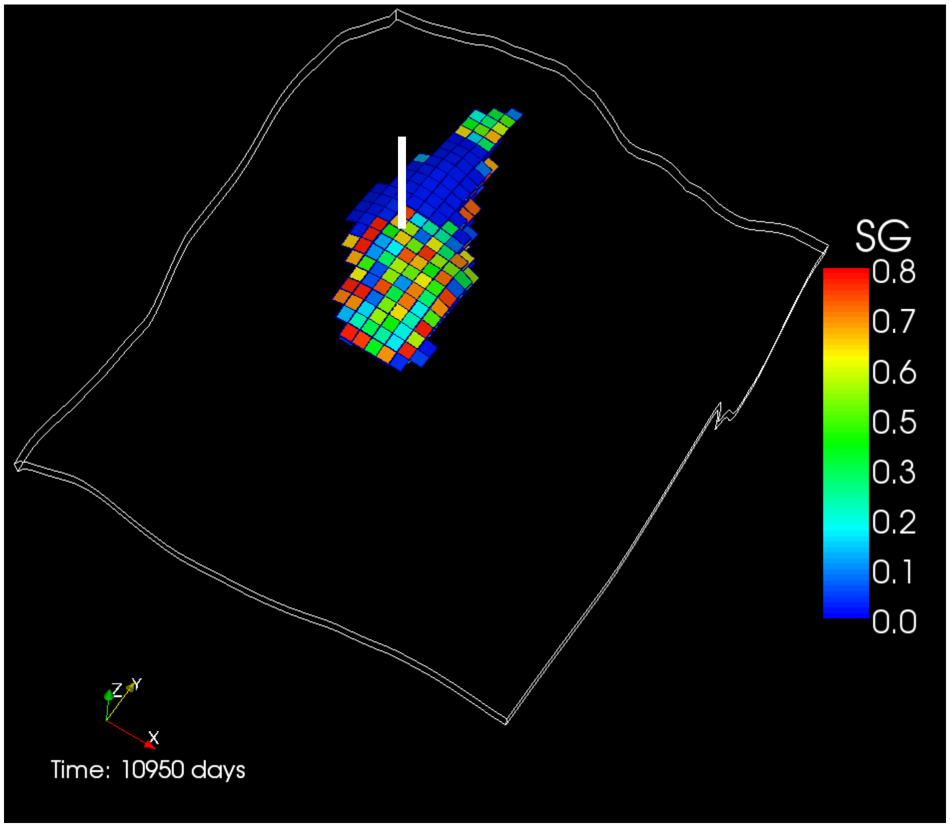
Example of
3D geological model



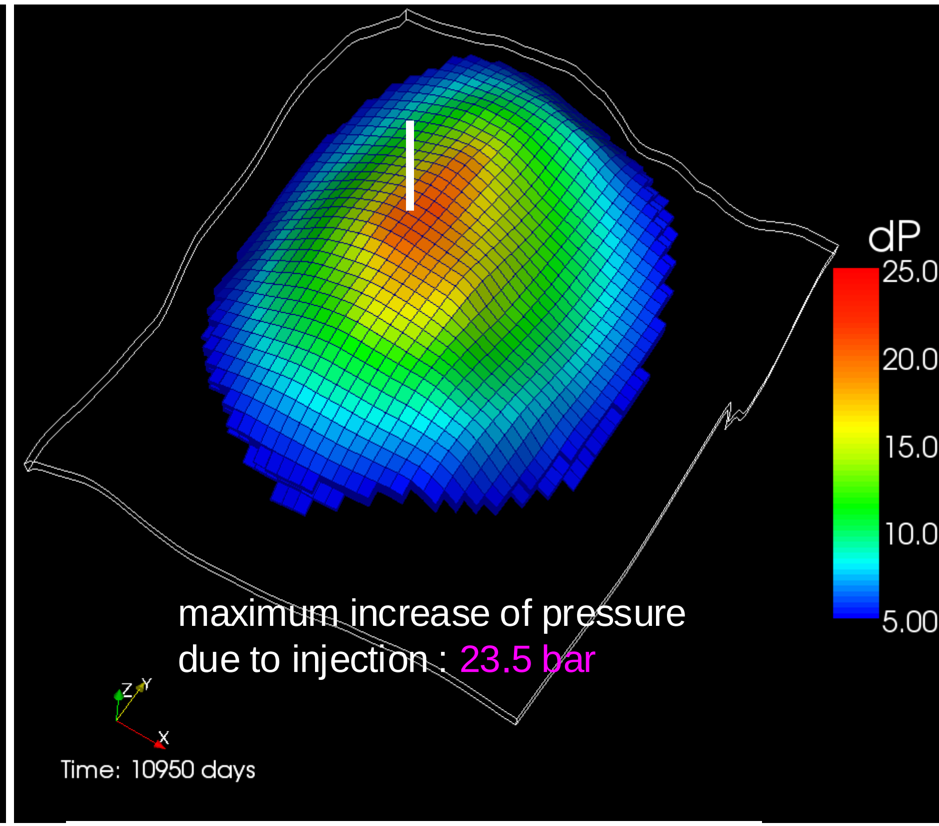




Modeling of CO_2 Injection
ONE WELL located on top of the anticline



Free CO_2 saturation



Pressure increase (>5bar) from static conditions

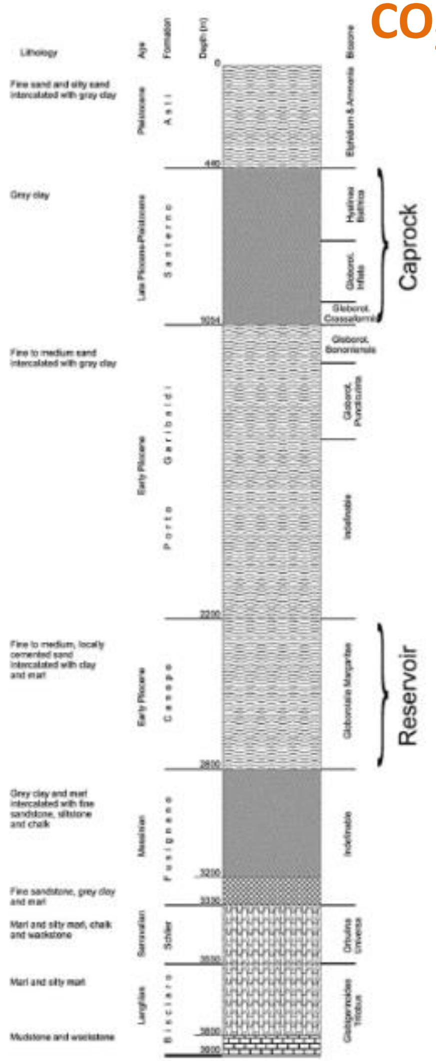
Potential areas suitable for CO_2 geological storage in siliciclastic formations

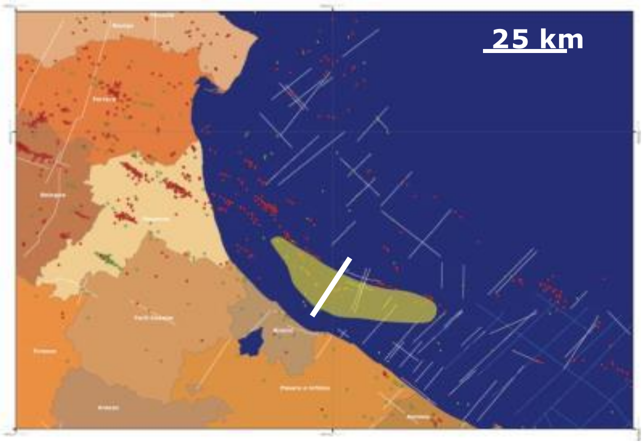
PRELIMINARY ESTIMATES OF THE STORAGE CAPACITY: ~ 12 Gt

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

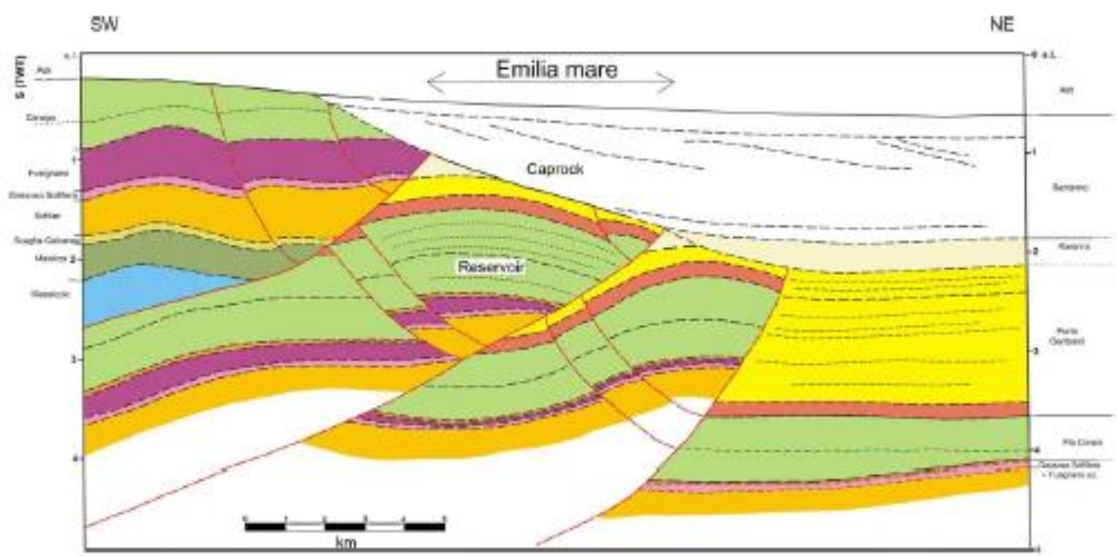
Donda et al., 2011

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

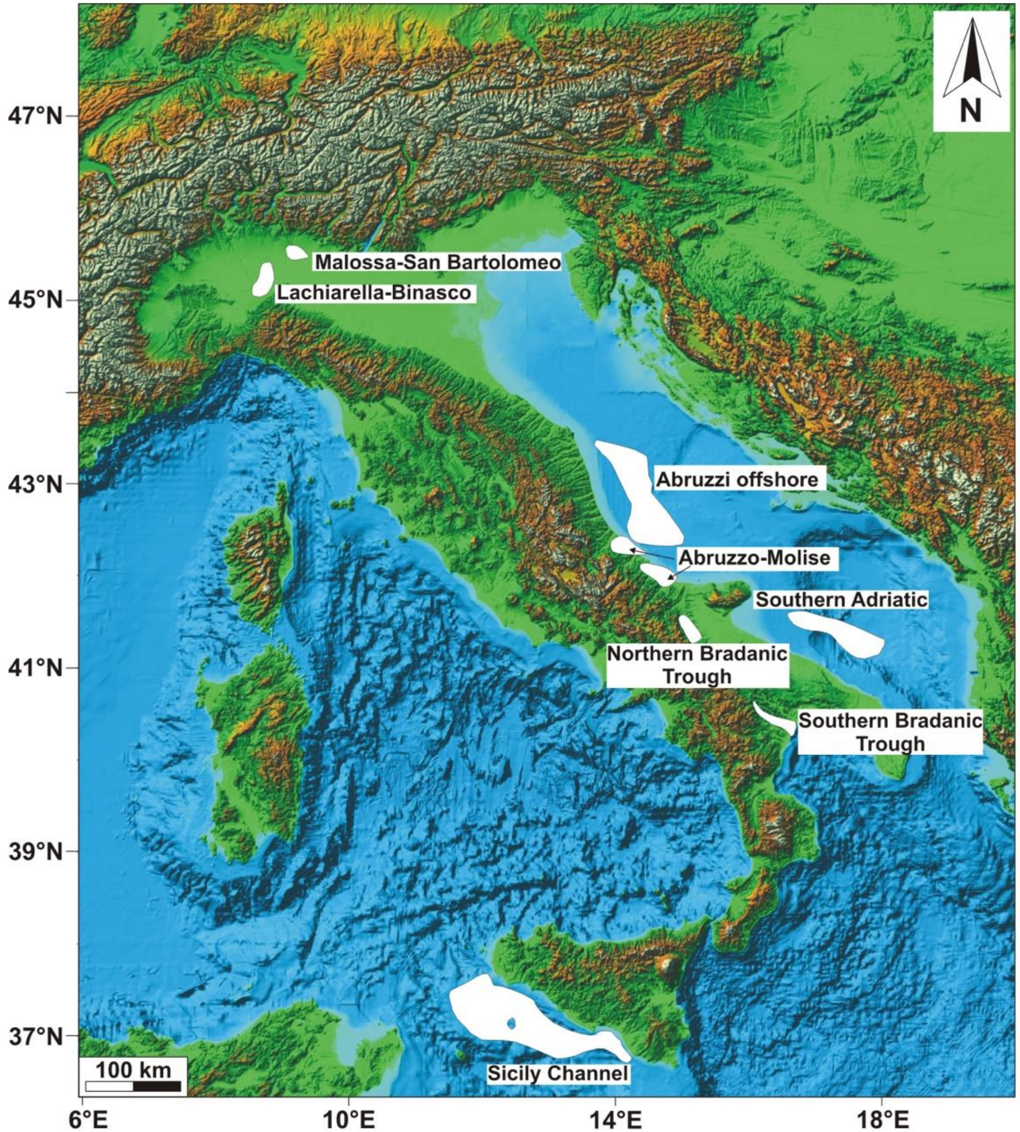




"EMILIA MARE"



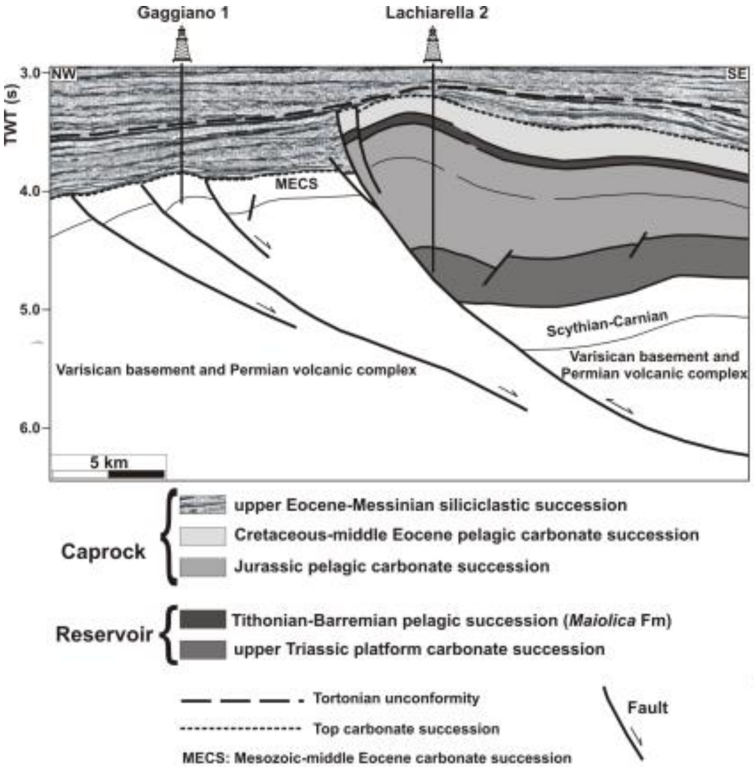
Donda et al., 2011

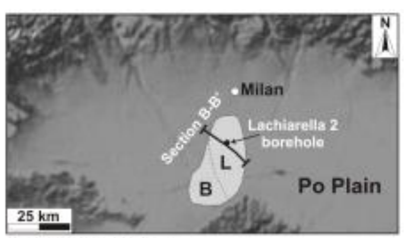


Potential areas suitable for CO_2 geological storage in carbonate formations

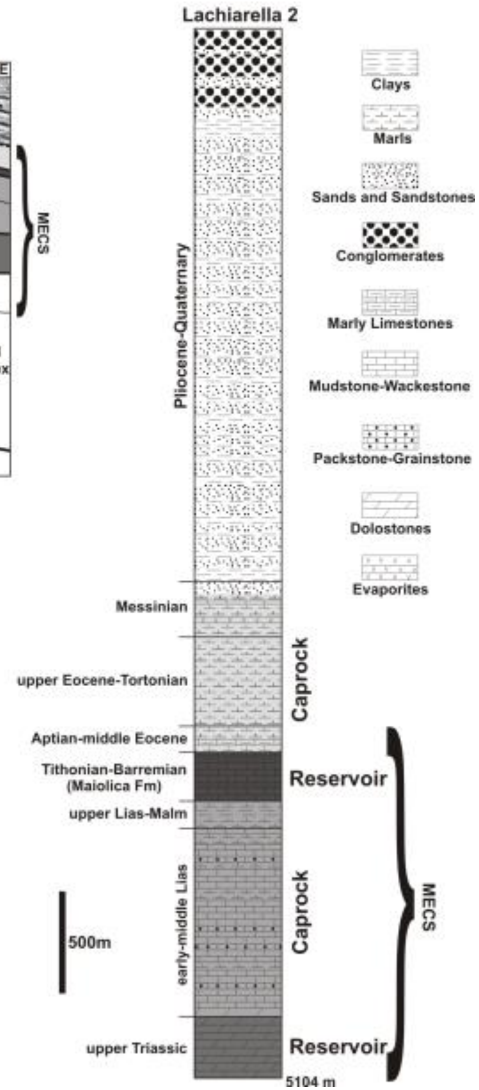
Civile et al., 2013

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





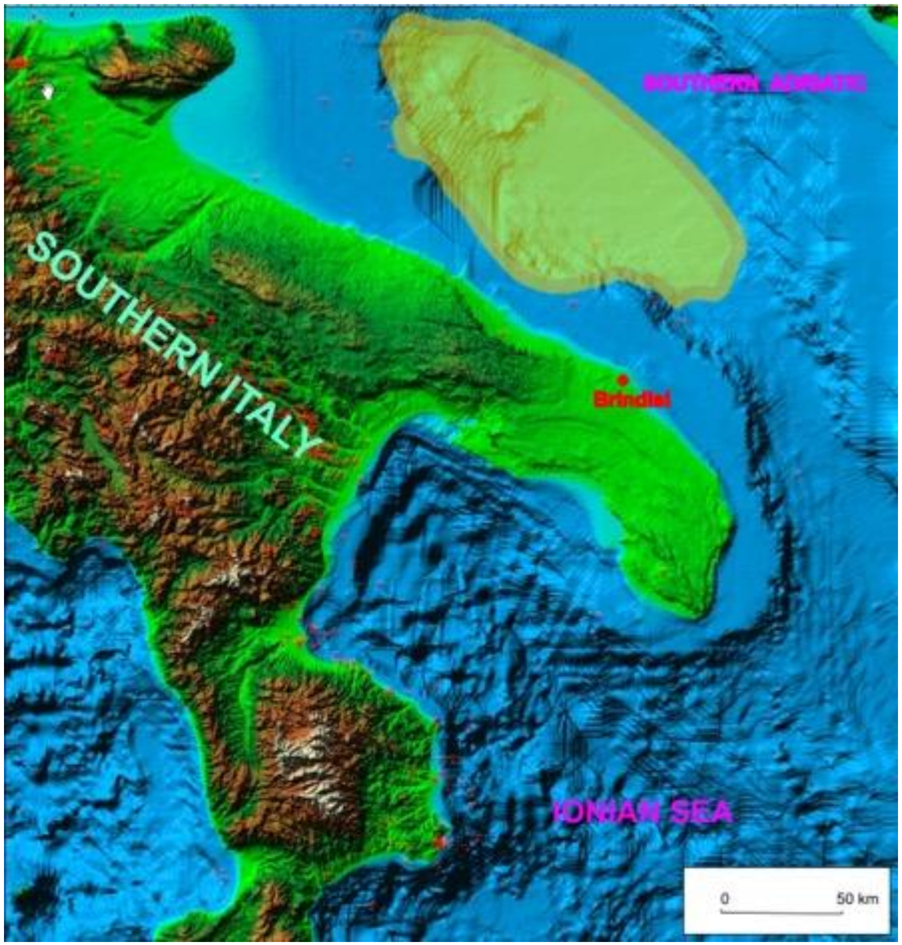
B: Binasco subzone
L: Lachiarella subzone



“Lachiarella–Binasco”

Civile et al., 2013

CHARACTERISTICS OF THE SOUTHERN ADRIATIC SITE OPTIONS



Storage options

- Saline aquifer/structural trap

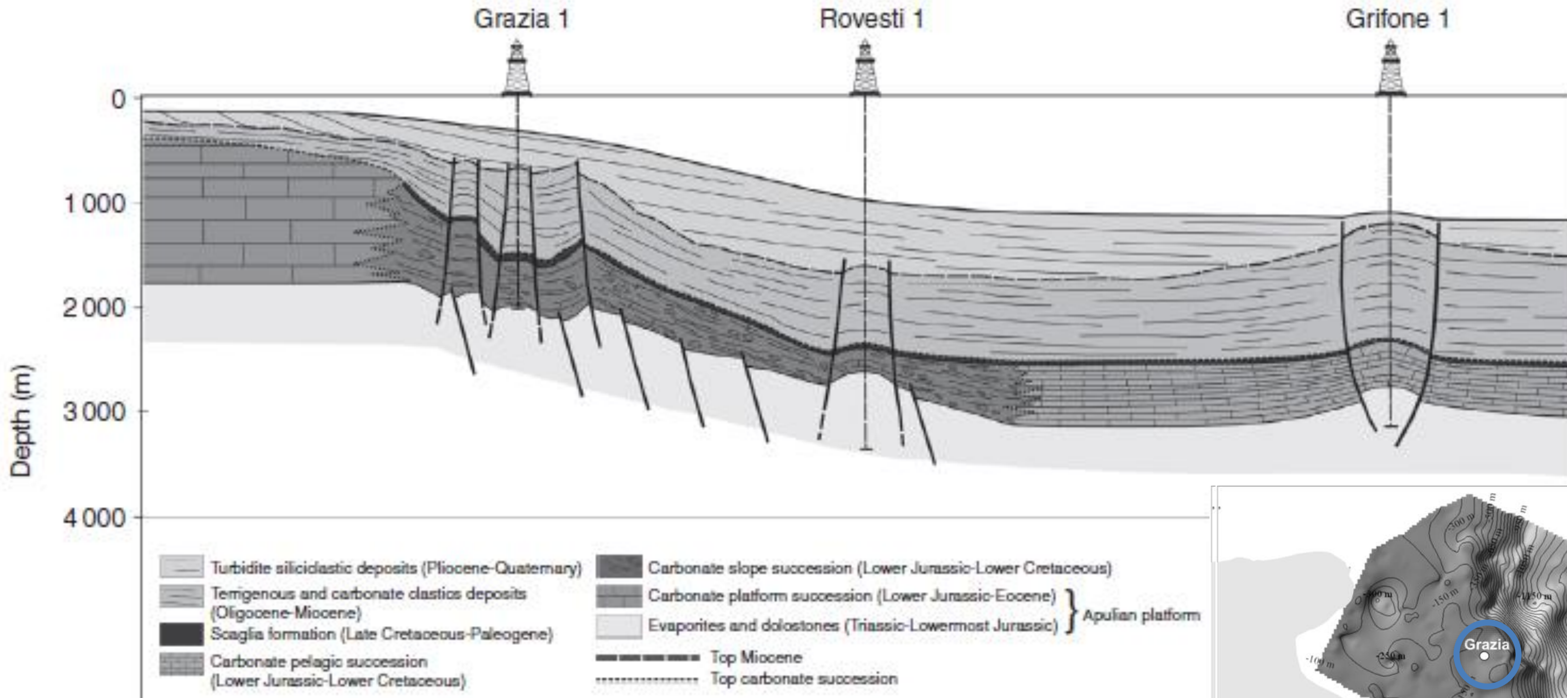
Location

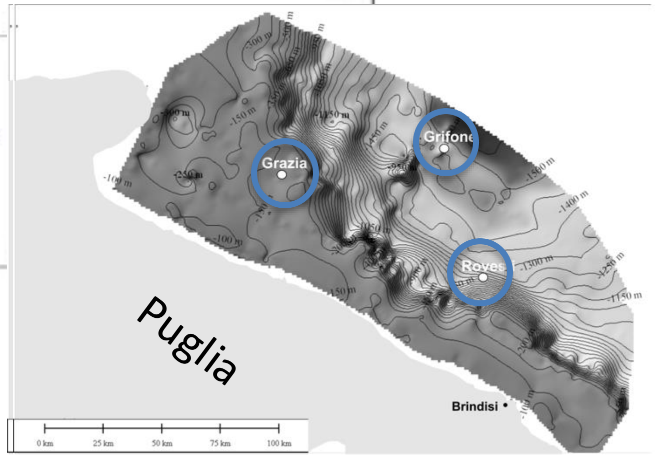
- Off shore

Lithology

- Carbonate reservoir

STORAGE SITE IN THE SOUTH ADRIATIC OFFSHORE

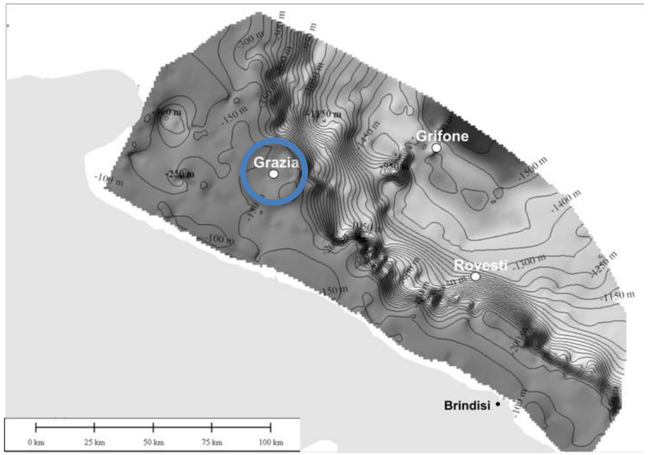


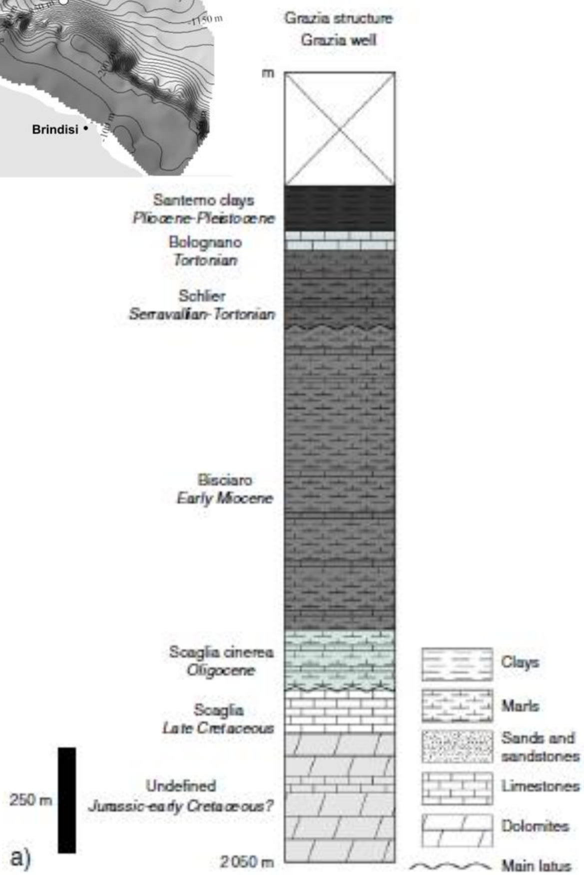


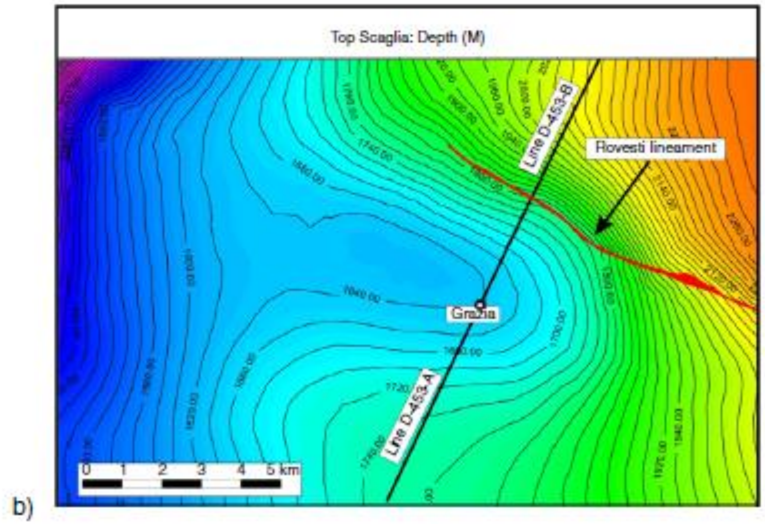
Name	Storage type	Area E+6 (M⁶)	Bulk Volume E+6 (M⁶)	Porosity (Scaglia)
Rovesti	Oil and Gas reservoir	1.7	195	13 -15 %
Grifone	Saline aquifer	1.0	191	10 – 20%
Grazia	Saline aquifer	1.3	241	2 - 13 %

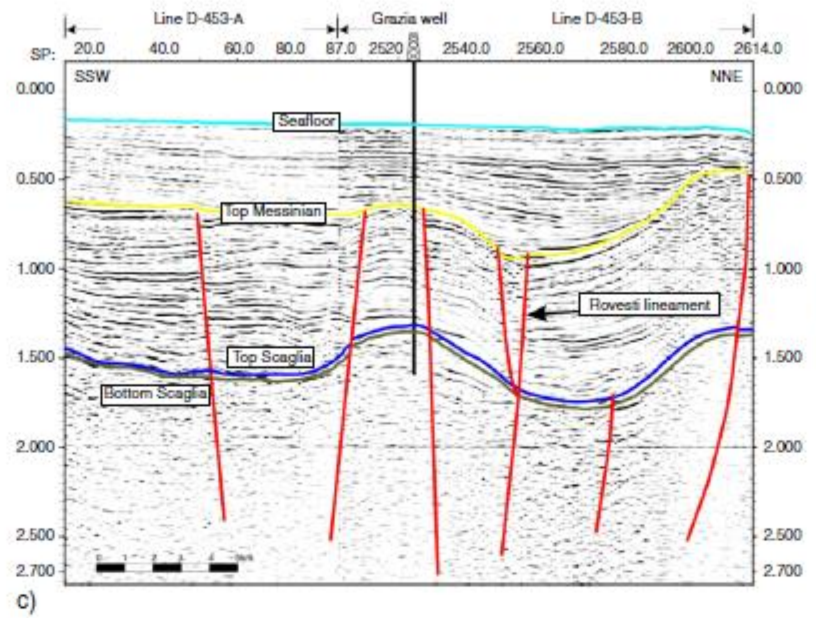
Volpi et al., 2014.

GRAZIA STRUCTURE

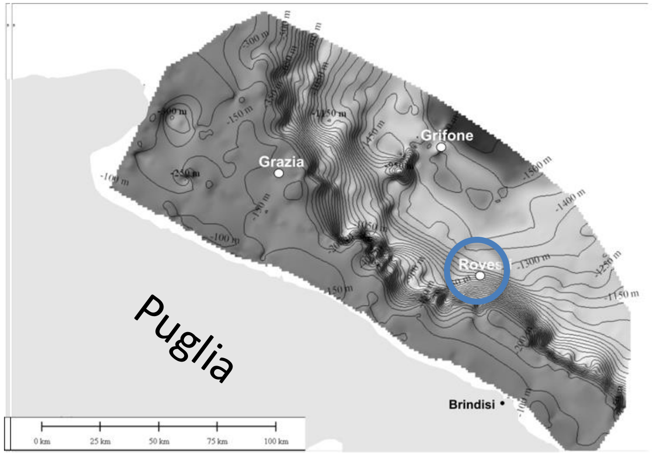


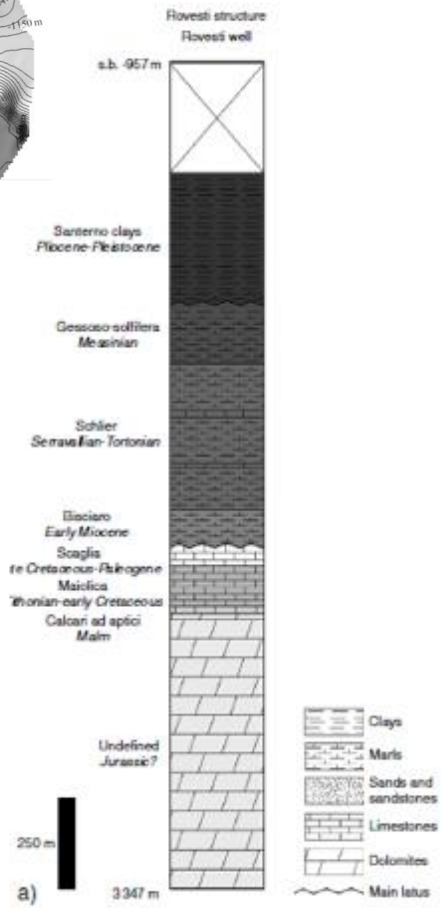


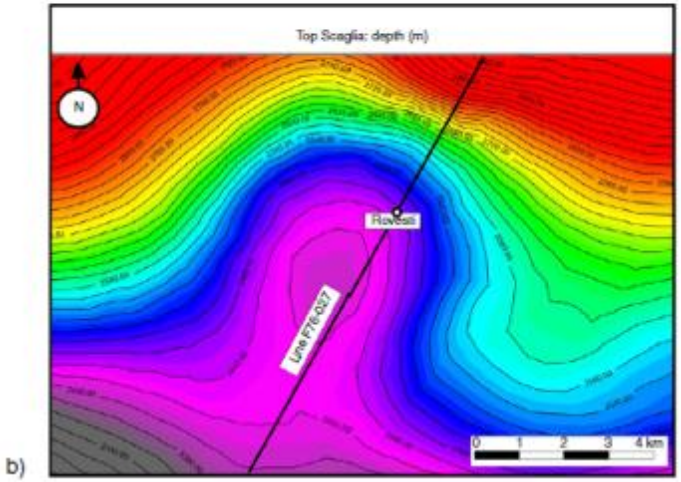


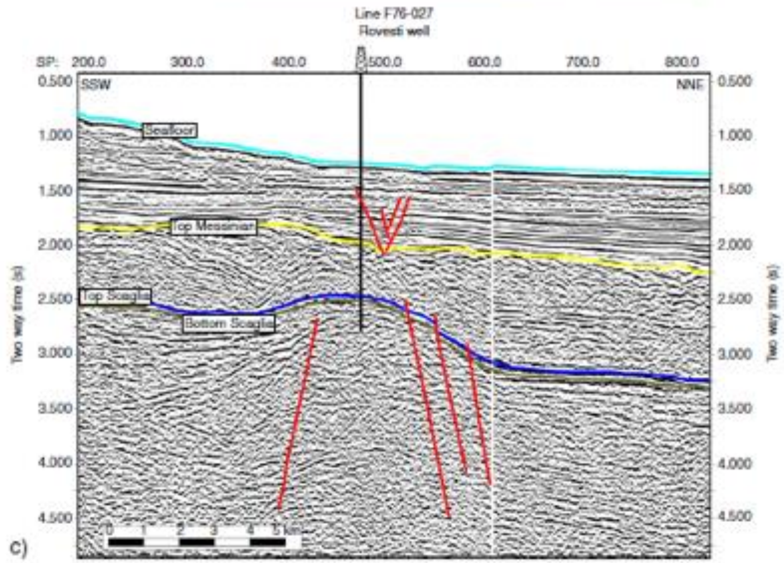


ROVESTI STRUCTURE

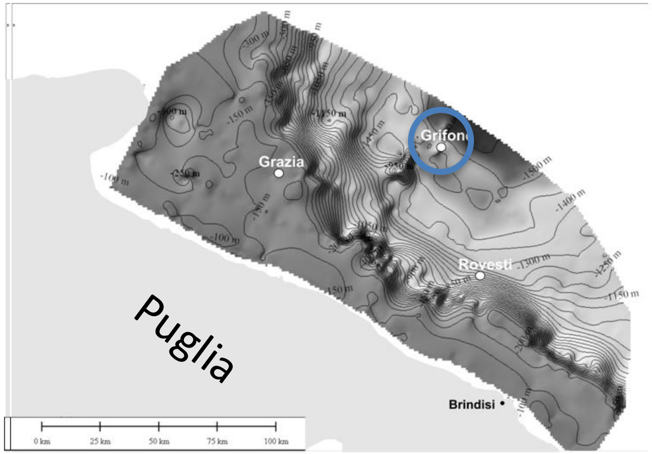


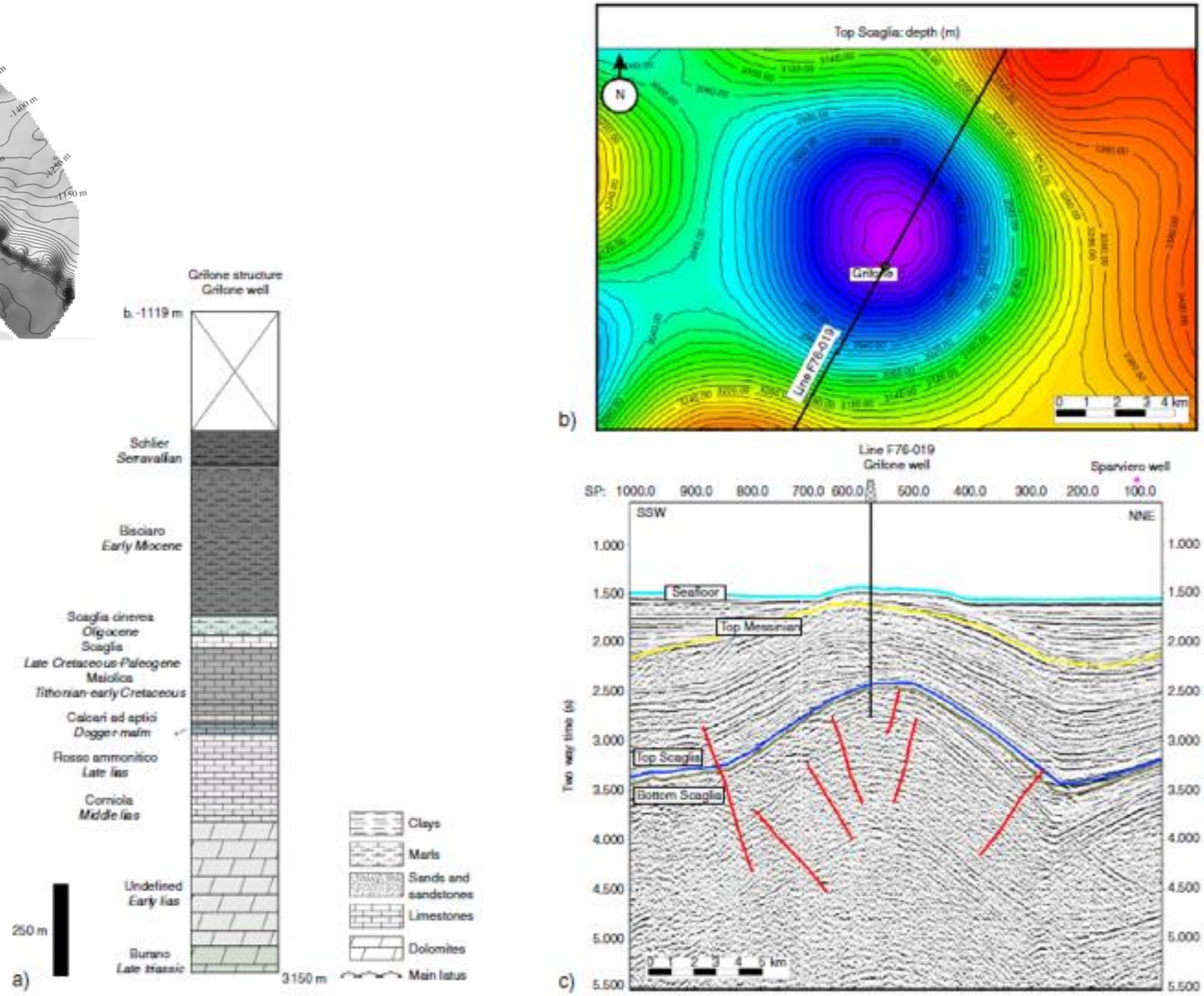






GRIFONE STRUCTURE



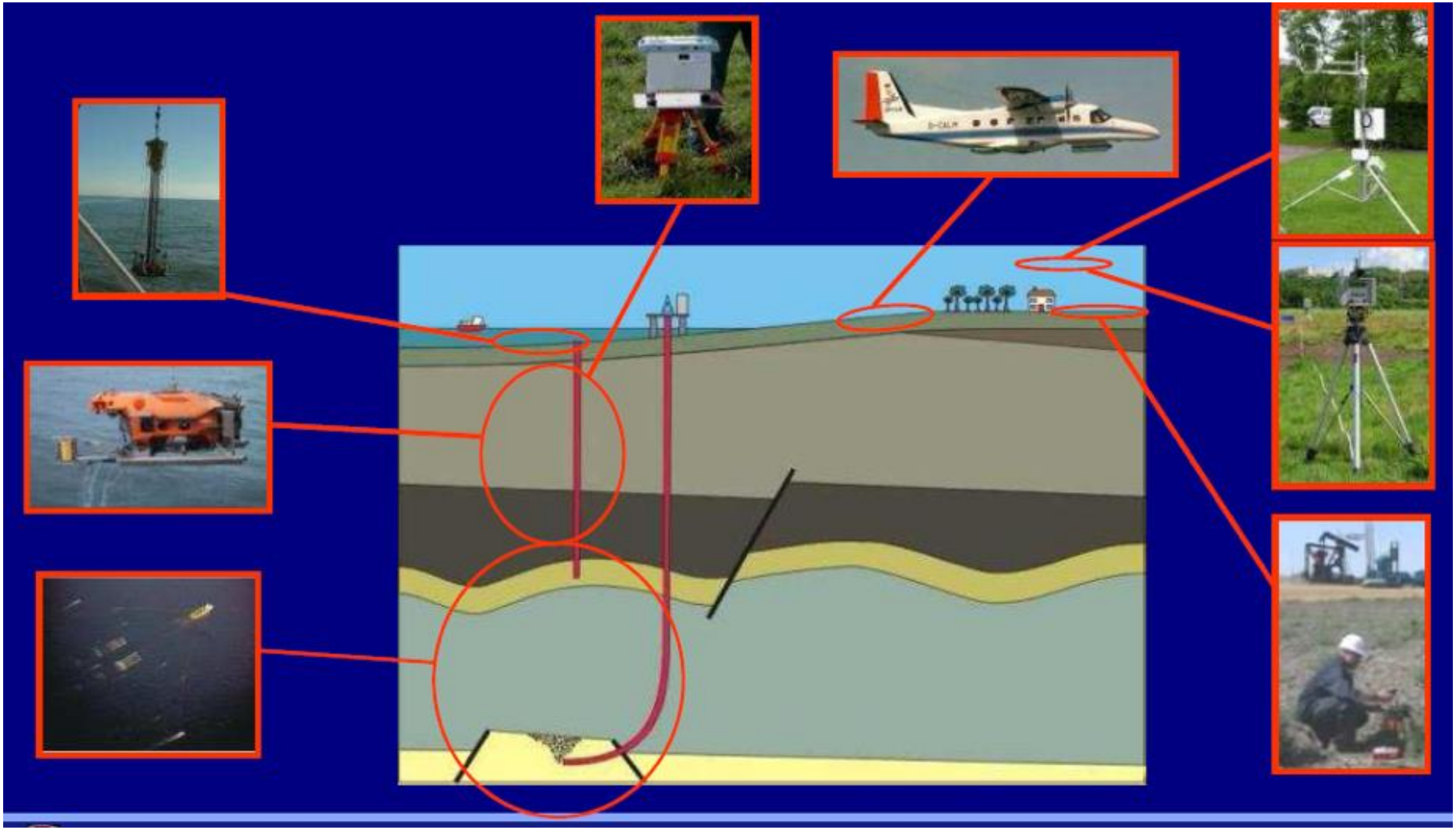


Monitoring of the selected sites

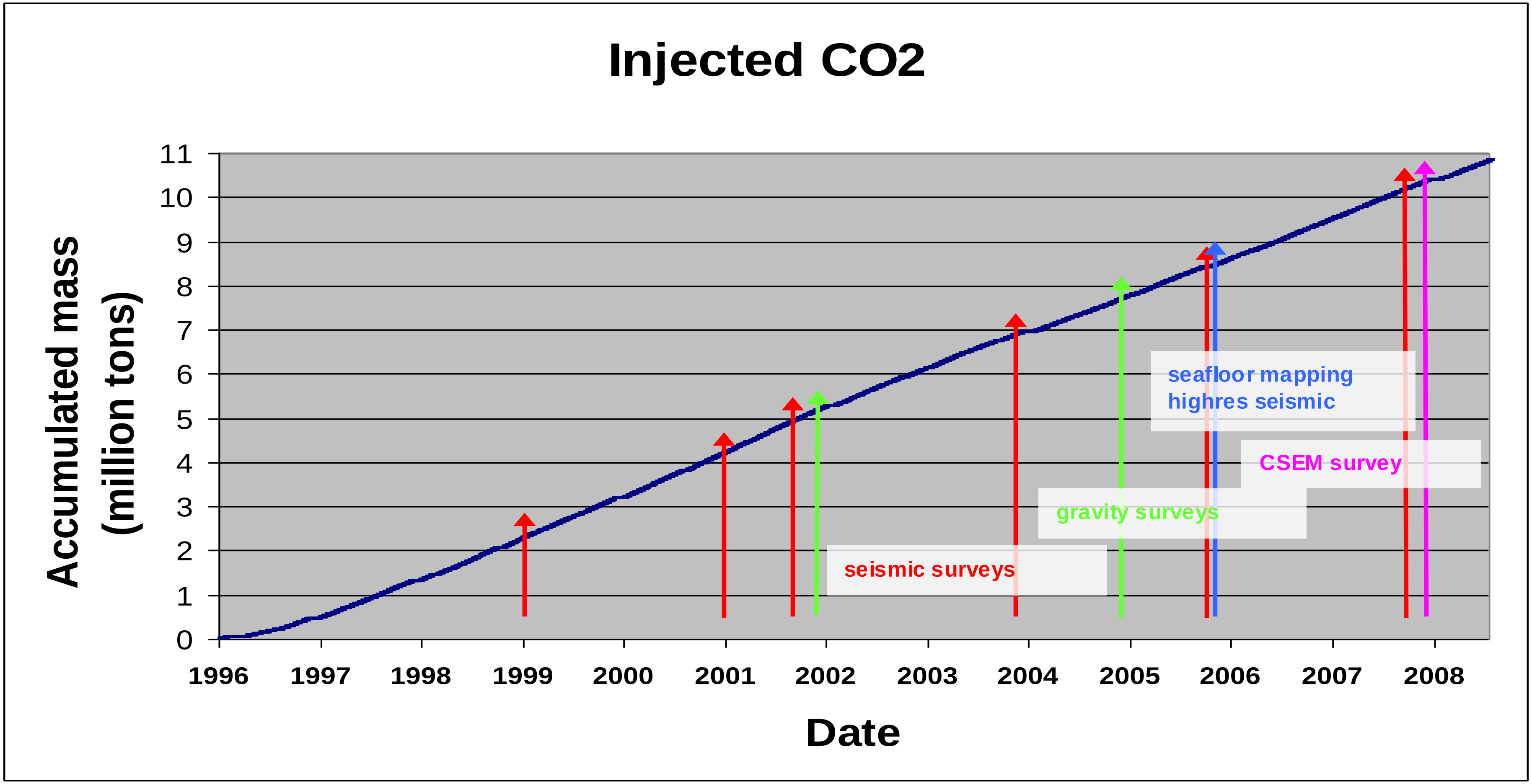
Monitoring is required in order to see whether:

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

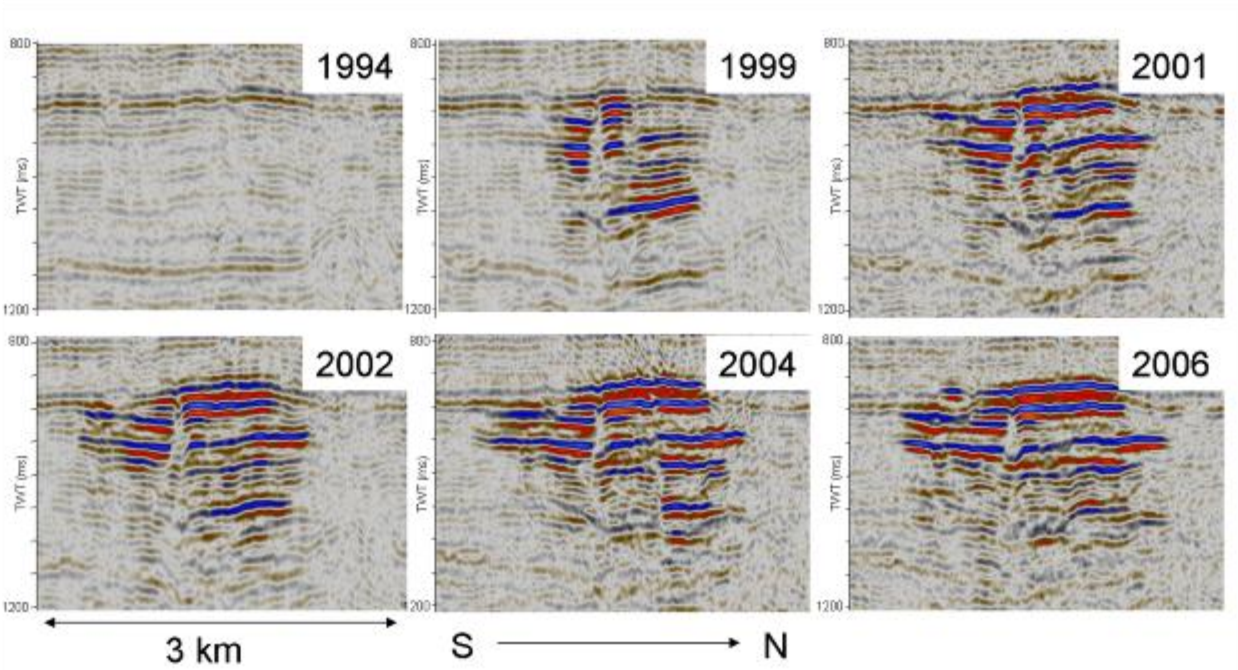
Monitoring of storage site

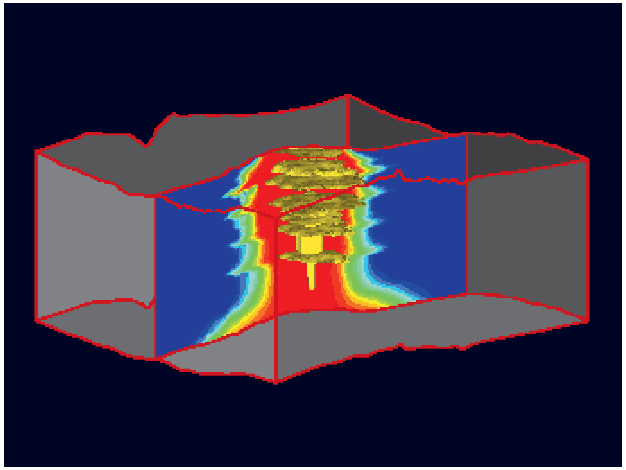


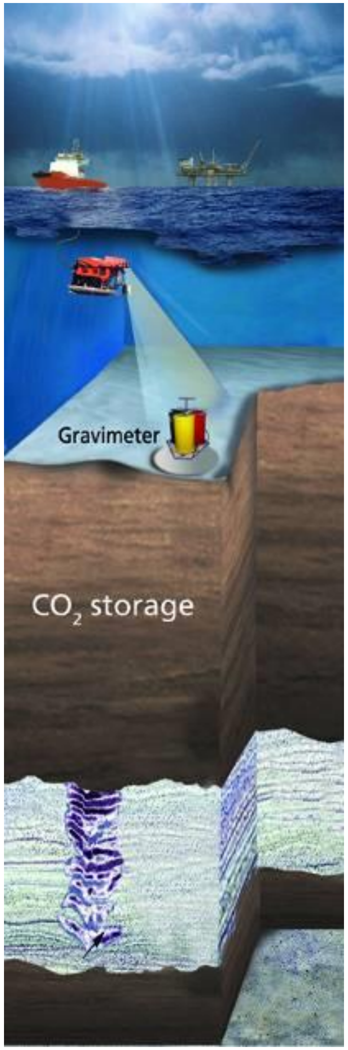
SELECTION OF MONITORING TECHNIQUES DURING INJECTION OF CO_2



IDENTIFICATION AND MONITORING OF CO_2 BEHAVIOUR AFTER INJECTION

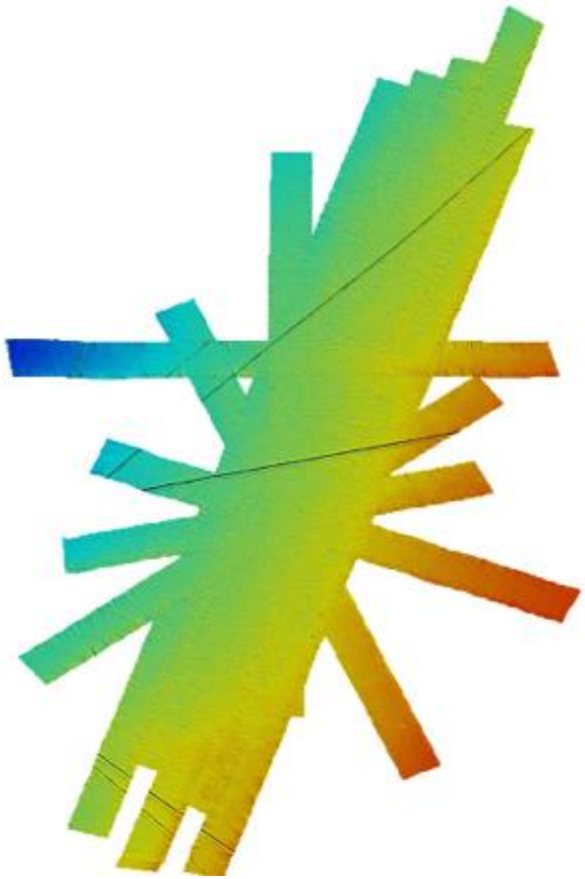




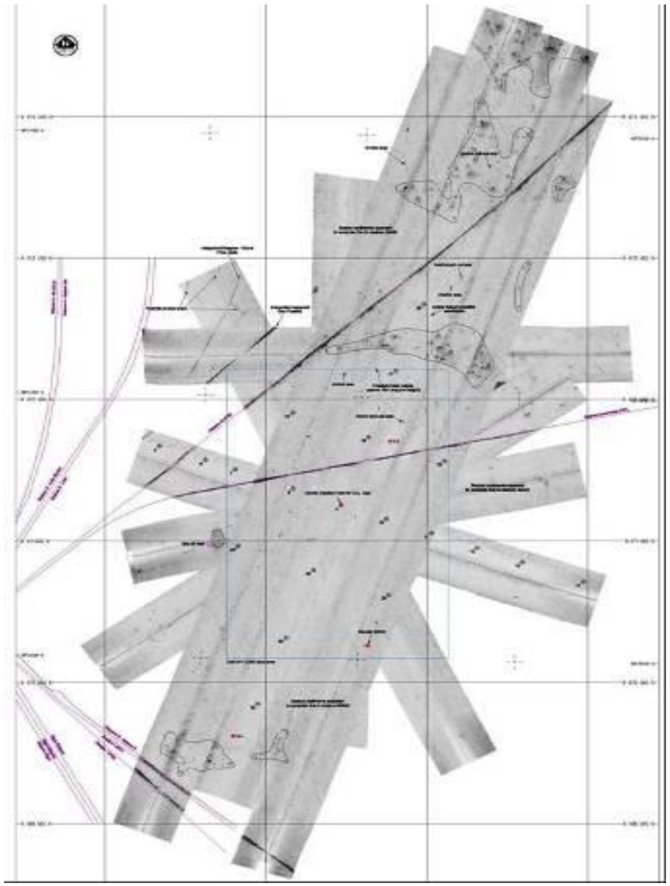


Courtesy Statoil/CO2STORE project

HIGH RESOLUTION SEAFLOOR CHARACTERIZATION FOR THE IDENTIFICATION OF GAS SEEPAGE RELATED FEATURES

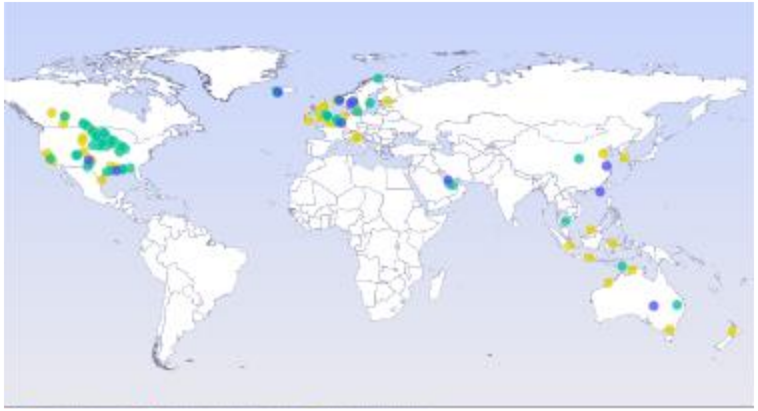


Seafloor morphology, from multibeam echo sounding



Mosaic of side scan sonar data

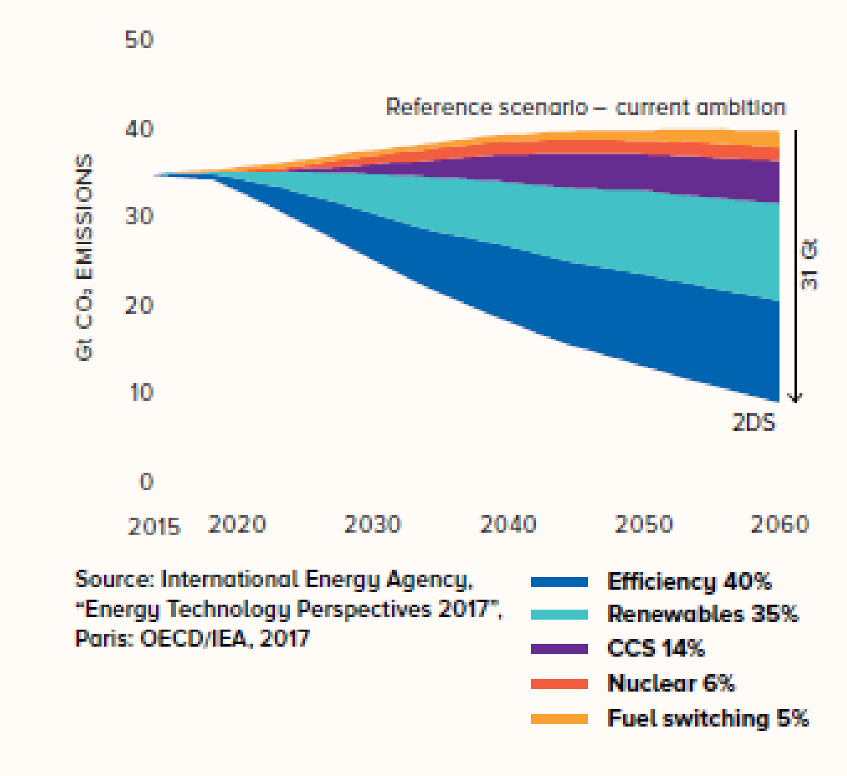
WORLD MAP OF CCS FACILITIES
AT VARIOUS STAGES OF DEVELOPMENT UPDATE 2022



	OPERATIONAL	IN CONSTRUCTION	ADVANCED DEVELOPMENT	EARLY DEVELOPMENT	OPERATION SUSPENDED	TOTAL
NUMBER OF FACILITIES	30	11	78	75	2	196
CAPTURE CAPACITY	42.58	9.63	97.6	91.86	2.3	243.97

30 active plants → **around 40 Mton/year of CO_2 are captured today**

Global CCS Institute, 2022. The Global Status of CCS: 2022. https://status22.globalccsinstitute.com/



CCS IS CRITICAL to achieve the limit average global warming to well below 2°C above pre-industrial times, with the aspiration of limiting warming to 1.5°C (Paris Agreement, December 2015)

Unit 1.5b – Energy storage

Docente: **Erika Barison**

<u>Outline:</u>

- Main concepts on energy storage
- Underground hydrogen and gas storage
  - geological-structural setting
  - monitoring

ENERGY STORAGE

Energy storage is the capture of energy produced at one time for use at a later time to reduce imbalances between energy demand and energy production

↓

UNDERGROUND ENERGY STORAGE

UNDERGROUND ENERGY STORAGE

- Pumped Hydro Energy Storage: a type storage; it is a configuration of two wate elevations that can generate power as to the other (discharge), passing throu

- Underground Thermal Energy Storage: heat pump schemes applied to single boreholes or arrays of boreholes suitably drilled in the subsurface, in which heated or chilled fluid is injected and extracted

- Compressed Air Energy Storage: is a way to store energy for later use using compressed air

- Underground Hydrogen Storage

- Underground Gas Storage

HYDROGEN

Among the many elements that make up matter, hydrogen is the lightest and most abundant. It makes up almost 90% of the visible mass of the universe, mostly in its gaseous form, made up of a simple two-atom molecule (H_2).

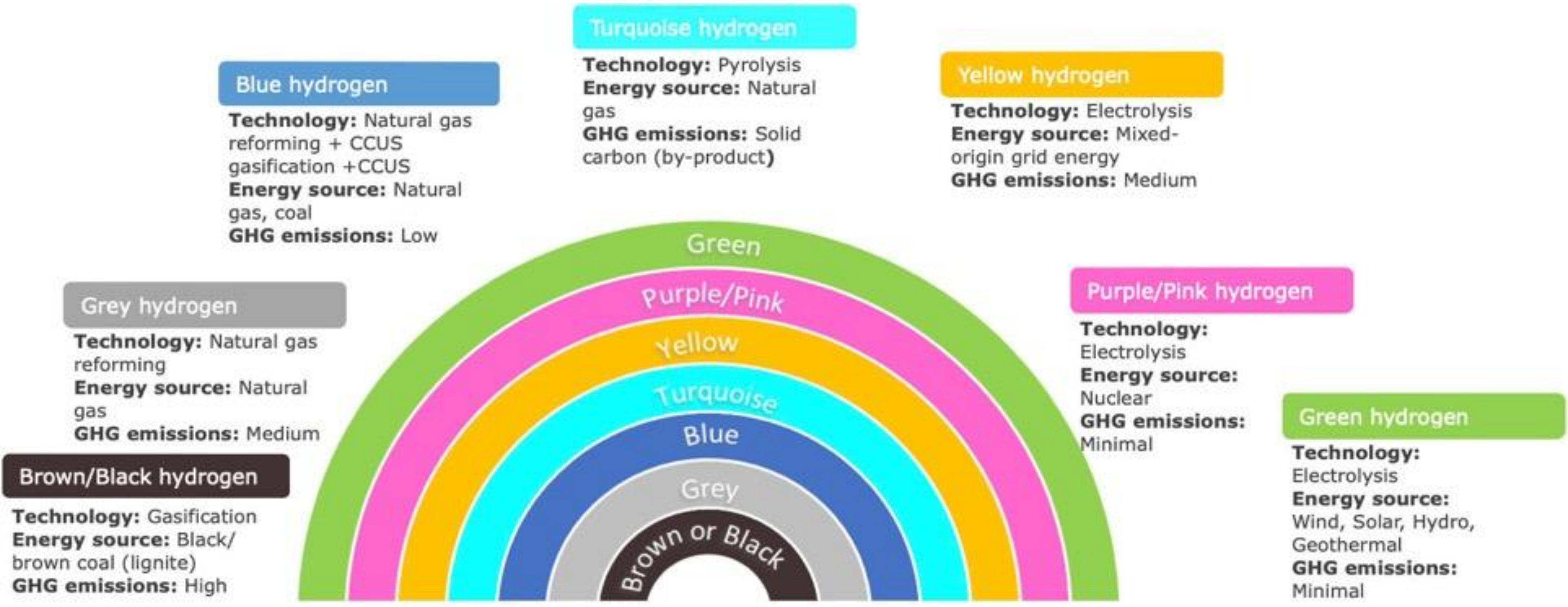
Hydrogen is the fuel of the stars, that is, the propellant that fuels the nuclear fusion reactions with which the stars burn.

Among conventional fuels, it is the one with the highest energy content per unit of weight, three times higher than that of petrol.

It can play a decisive role in the decarbonisation of energy-intensive industries, such as air and maritime transport, steel or chemicals, and is therefore considered one of the pillars of the future energy system

SOMETHING ABOUT HYDROGEN

- **H_2** could play a significant role as a fuel substitute to **limit global warming** and contributing to the transformation to a **low carbon economy** by 2050.



https://www.tecnicasreunidas.es/articulo/hydrogen-present-and-future-part-2/

GREEN HYDROGEN

- **Green hydrogen** is produced by splitting water into hydrogen and oxygen by electrolysis, powered by renewable energy sources, such as wind or solar. We can vent the oxygen to the atmosphere with no negative impact.

It is still a very expensive process, which need huge amount of energy, but the development of renewable energy and the increase in production of electrolyzers could change this scenario, making hydrogen-based energy competitive by 2030-2050.

UNDER GROUND HYDROGEN STORAGE

Energy storage has acquired fundamental importance for energy security, with a view to a progressive energy transition from fossil fuels to renewable sources such as solar and wind energy.

The storage of hydrogen for energy supply can also be done through the injection and storage in deep geological formations, as happens for natural gas and carbon dioxide (CCS), and from them it can subsequently be extracted for use in peaks in energy demand.

To alleviate the main drawbacks of renewable energy generation:

- intermittency
- seasonal constraints
- geographical constraints.

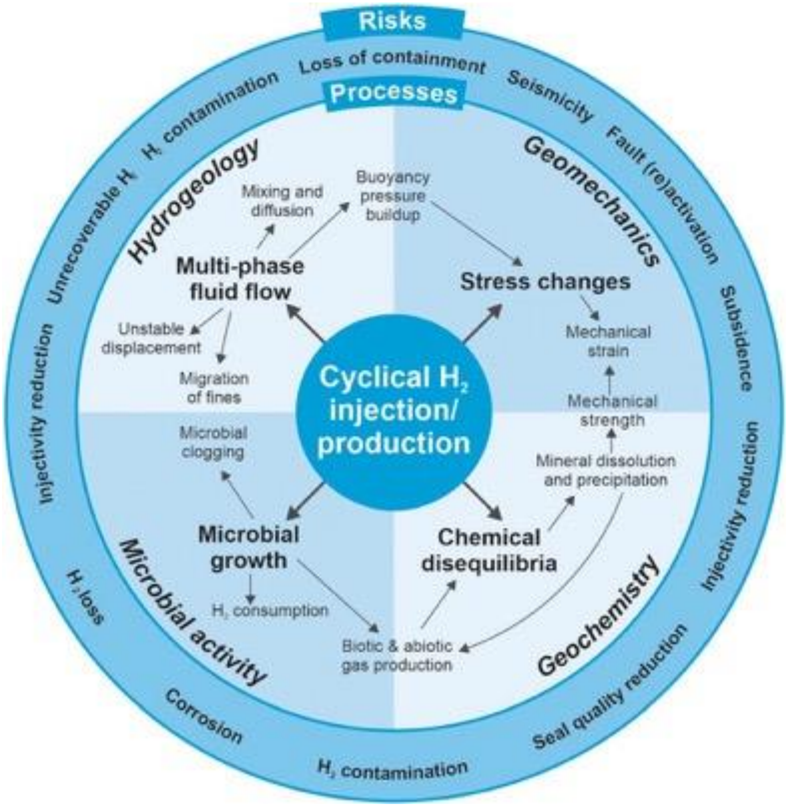
Bigger stored volumes

UNDERGROUND HYDROGEN STORAGE

- Salt caverns (since the 70's in Europe)

- **Deep saline aquifers**
- **Depleted hydrocarbon (gas) reservoirs**

New frontiers and challenging!



from Heinemann et al., 2021

Horizon 2020
European Union funding
for Research & Innovation

HyStorIES
HYDROGEN STORAGE IN EUROPEAN SUBSURFACE

- Call: H2020 FCH-02-5-2020 “Underground storage of renewable hydrogen in depleted gas fields and other geological stores”

- Duration: 24 months (2021-2023)
- Budget: 2,5 M€

Coordinator: GeoStock SAS (France)

OGS: CO2GeoNet third party

HyStorIES Hydrogen Storage In European Subsurface

CONCEPT

- **Renewable hydrogen**, when combined with large scale underground storage, balances out the impacts of **variable energy production** from renewable energy sources;

- While storing pure hydrogen in salt caverns has been practiced since the '70s in Europe, **hydrogen storage has not yet been carried out anywhere in depleted fields or aquifers**;

- Technical developments are still needed to validate this solution, i.e. **bio- and geo- chemical impacts** on the subsurface and **quality of hydrogen** extracted from the store.

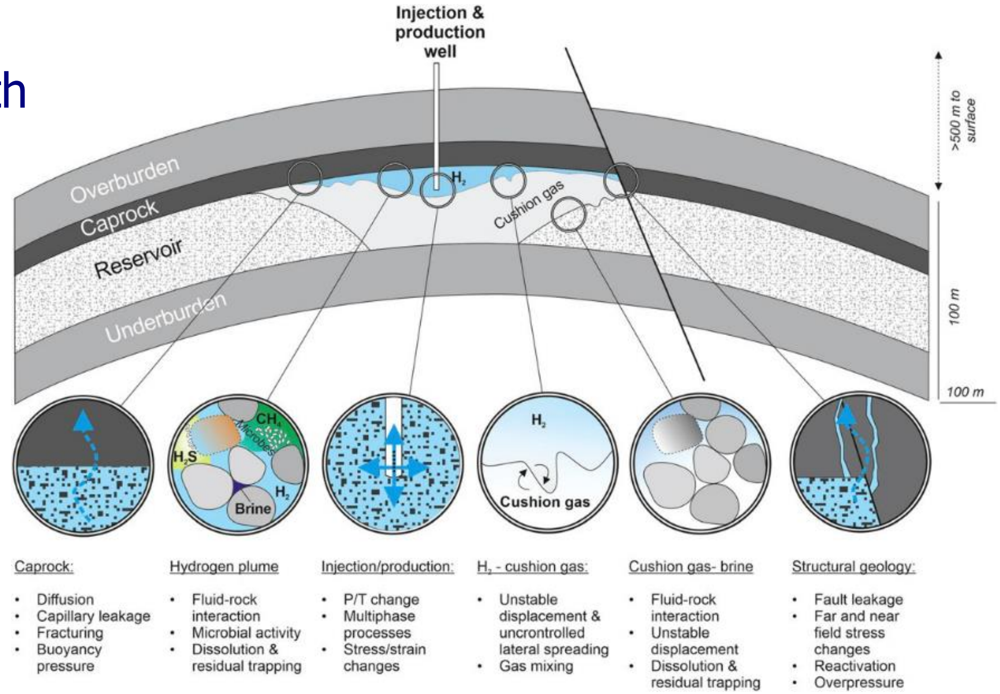
HyStorIES** proposes to address the **main technical feasibility questions and to assess the techno-economical potential of underground large-scale storage of renewable hydrogen by 2050

<u>Main target</u>:
to identify suitable UHS sites in depleted hydrocarbon fields and saline aquifers both onshore and offshore

<u>Criteria</u>

- Idoneous caprock/reservoir systems
- Top reservoir depth 500 - 2500 m
- Net reservoir thickness of 30 - 100 m
- Reservoir extent 0.3 - 60 km^2
- Not overlay with seismogenic sources

(for Italy: Database of Individual Seismogenic Sources - DISS M > 5.5 - INGV)



da Heinemann et al., 2021

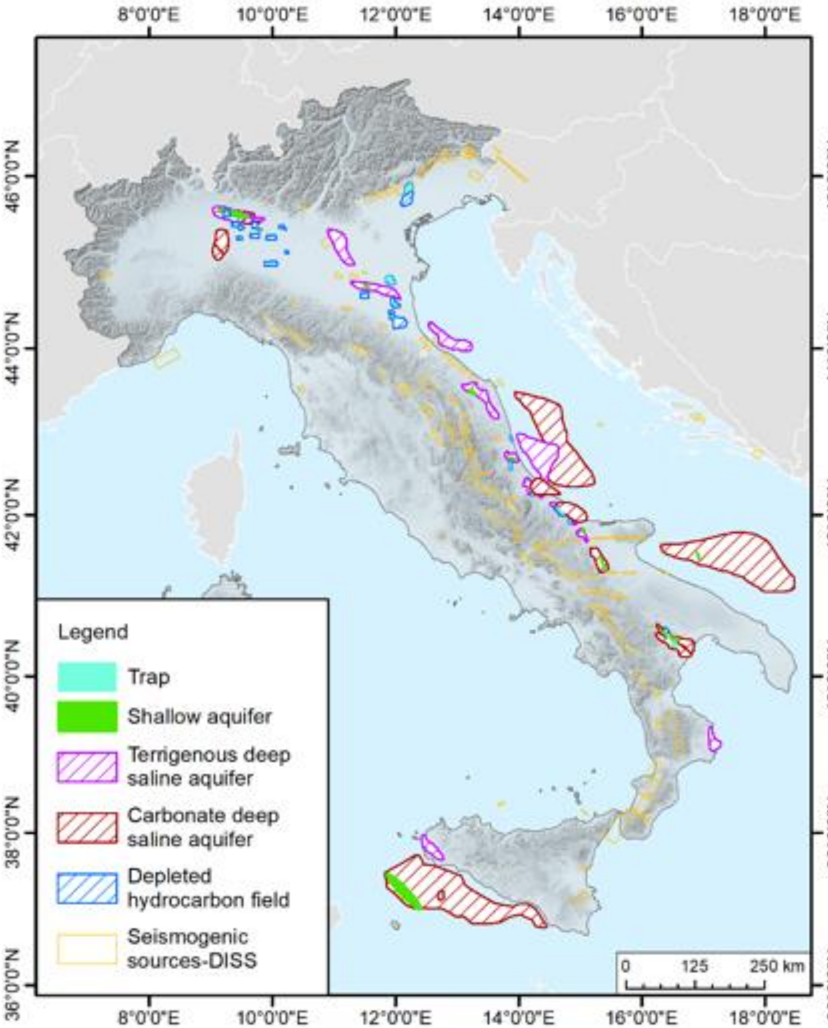
All the data and information used for the characterization of the H_2 storage sites are public and freely available

OGS in HYSTORIES PROJECT

1. Deep carbonate and terrigenous saline aquifers already identified as possible CO_2 storage sites (Civile et al., 2013; Donda et al., 2011)

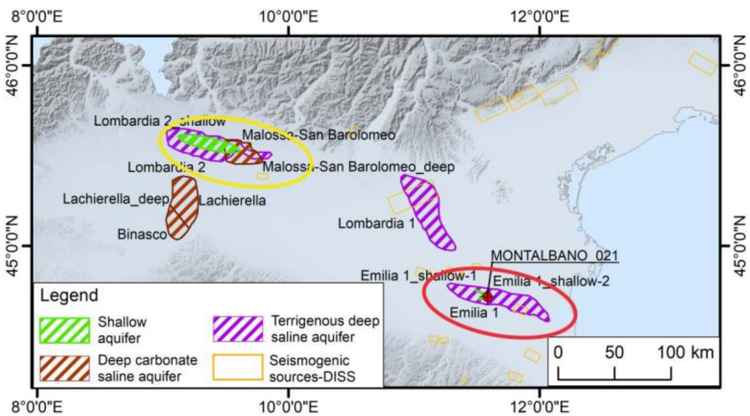
2. Well logs analysis: shallower aquifers identified from well logs available at the ViDEPI (Visibility of Petroleum Exploration Data in Italy) database (https://www.videpi.com/)

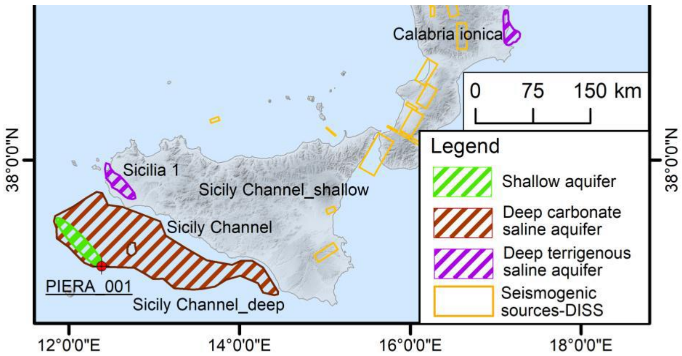
3. Hydrocarbon depleted fields (some of these sites are currently used for CH4 temporary storage, but could be considered for UHS in future9 (*https://unmig.mise.gov.it/index.php/it/dati/stoccaggio-del-gas-naturale*)

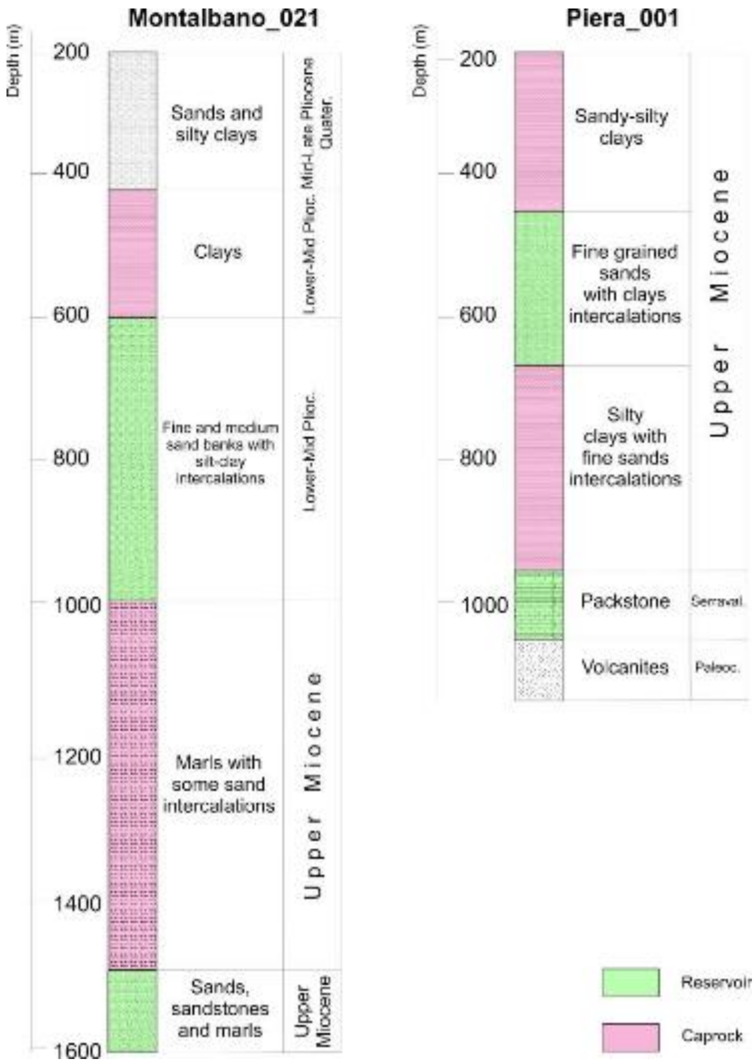


Modified after Barison et al., 2023

2) Well log analysis





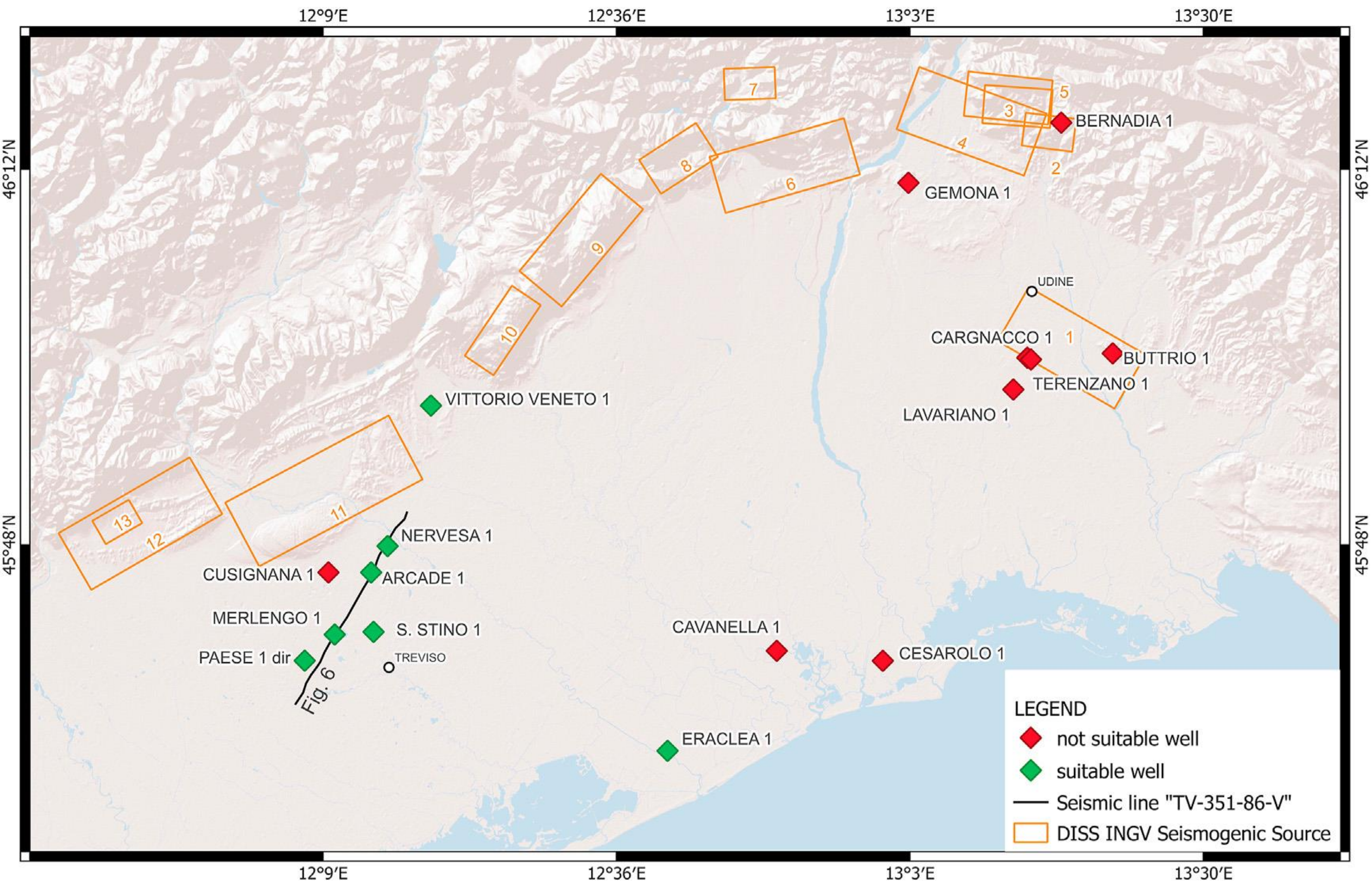


Modified after Barison et al., 2023

SITES POTENTIALLY SUITABLE FOR HYDROGEN STORAGE IN THE **VENETO-FRIULI PLAIN REGION**

The study area has been chosen in light of some key initiatives that have been undertaken in the northern Adriatic region concerning hydrogen-related technologies: on April 2022, the "**North Adriatic Hydrogen Valley**" initiative was officially launched with the aim of building the **first cross-border hydrogen valley**. This initiative brings together Friuli Venezia Giulia district, Slovenia and Croatia through a cooperation agreement that has been finalized to pursue the **Hydrogen Strategy** for a climate-neutral Europe which was launched in 2020 by the European Commission.

SITES POTENTIALLY SUITABLE FOR HYDROGEN STORAGE IN THE VENETO-FRIULI PLAIN REGION



17 boreholes available from the «Visibility of petroleum exploration data in Italy (Videpi)» database

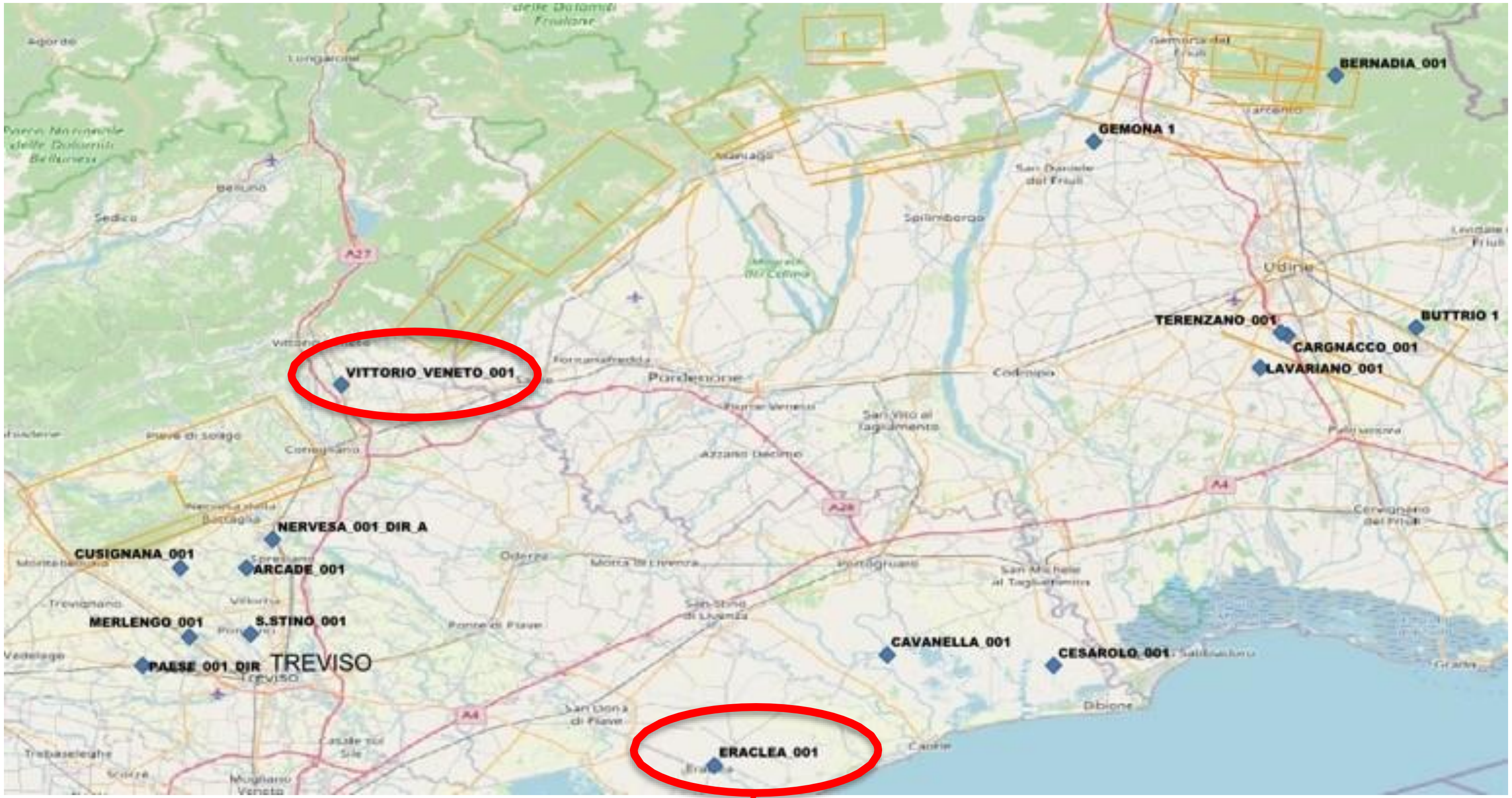
NOT SUITABLE AREAS

- None or non adeguate caprock/reservoir system (Cesarolo 1, Cavanella 1 e Cusignana 1)

- Seismogenetic sources (Bernadia 1, Buttrio 1, Cargnacco 1, Gemona 1, Lavariano 1, Terenzano 1)

Mattera et al., under review

INDIVIDUAL SUITABLE WELLS



Mattera et al., 2023

Reservoir: Late Cretaceous/Eocene limestones
thickness: ca. 180 m
Caprock: Eocene marls
thickness: ca. 860 m

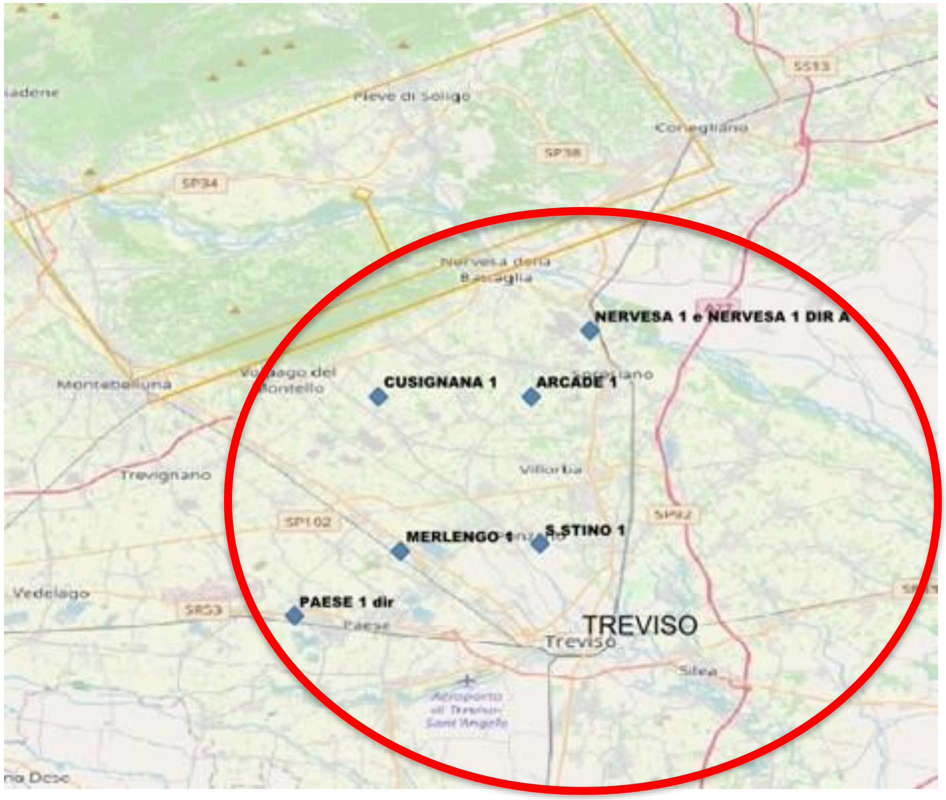
THE «TREVISO SITE»

- 7 boreholes
- 5 suitable boreholes

Reservoir: early Miocene sandstones (Glauconie di Cavanella)
Thickness: min 115 m, max 290 m

Caprock: Tortonian Marls (Marne di San Donà)
Thickness: min 160 m, max 950 m

Porosity evaluation from geophysical logs: 10-28%



Mattera et al., 2023

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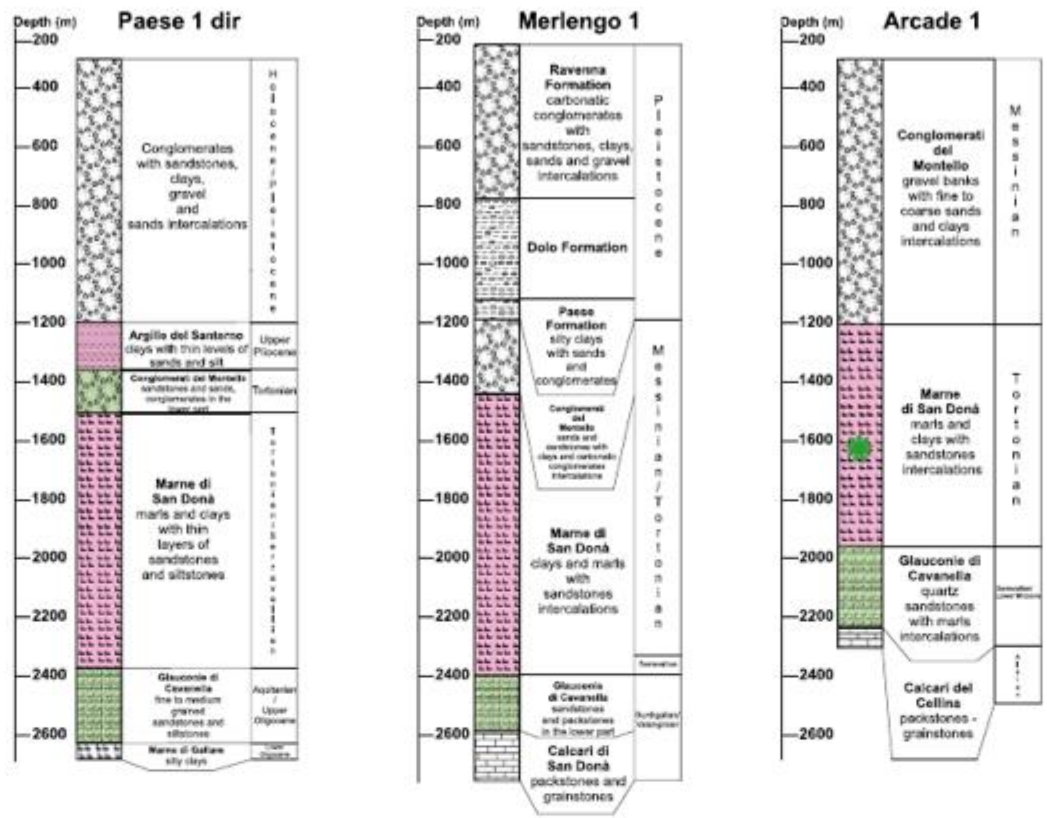
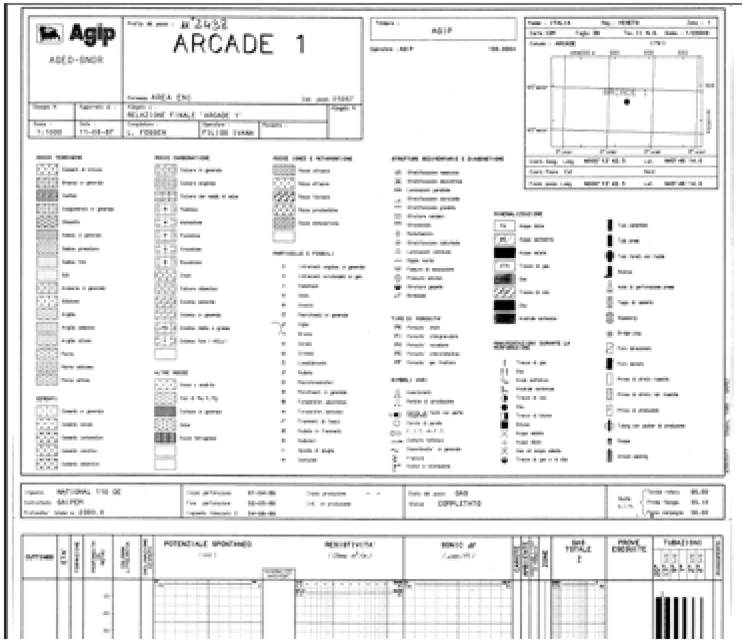
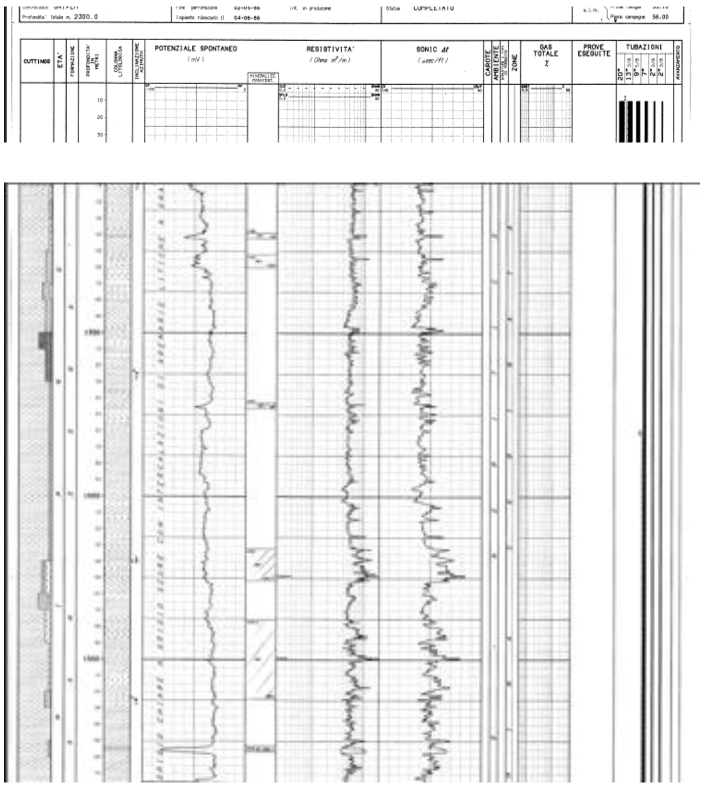


Mattera et al., 2023

THE «TREVISO SITE»





THE «TREVISO SITE»

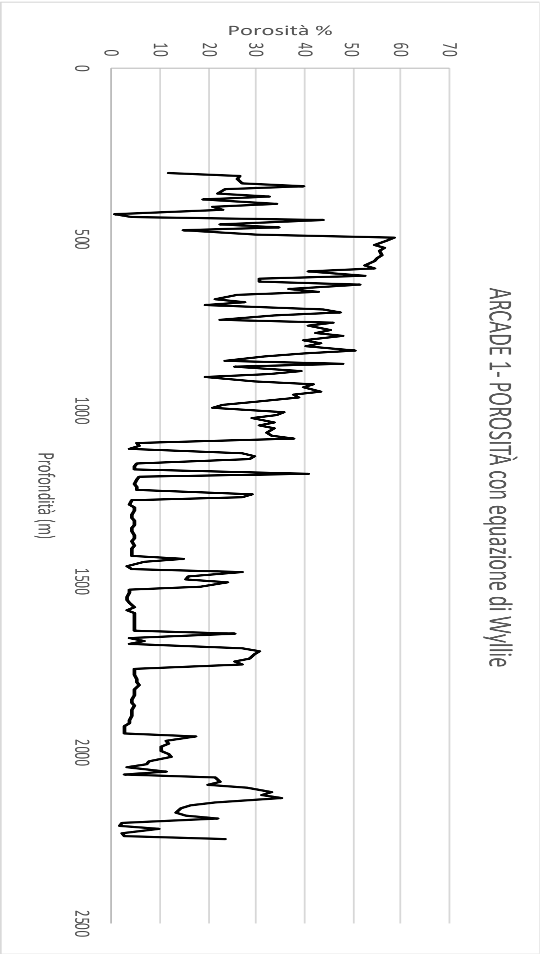
Archie's law

$$\phi = \left(\frac{R_w}{R_t} S_w^{-n}\right)^{\frac{1}{m}}$$

Willyes's law

$$\phi = \frac{\Delta t_p - \Delta t_{p,ma}}{\Delta t_{fl} - \Delta t_{p,ma}}$$

Porosity evaluation from geophysical logs: 10-28%



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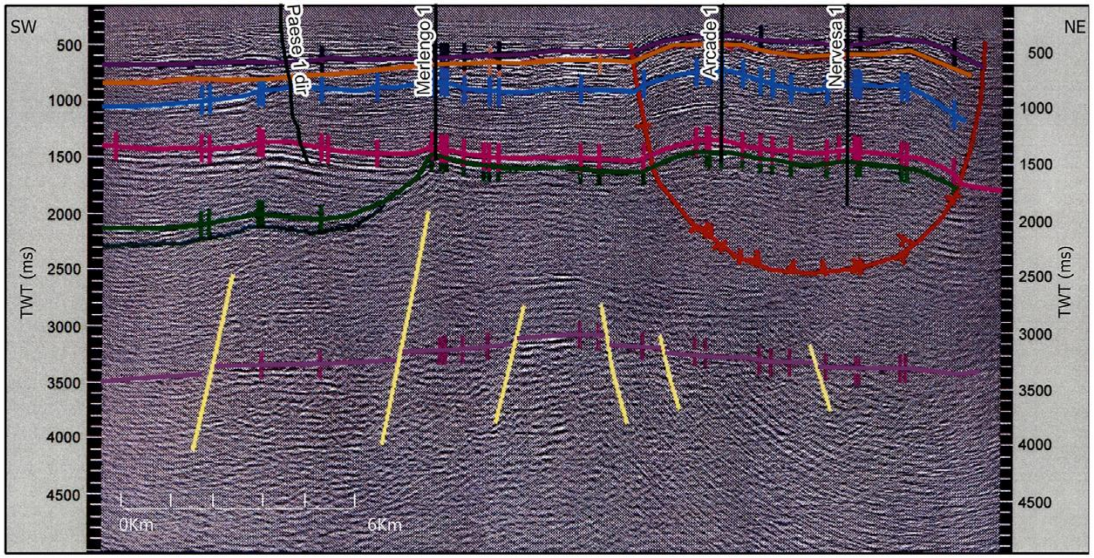
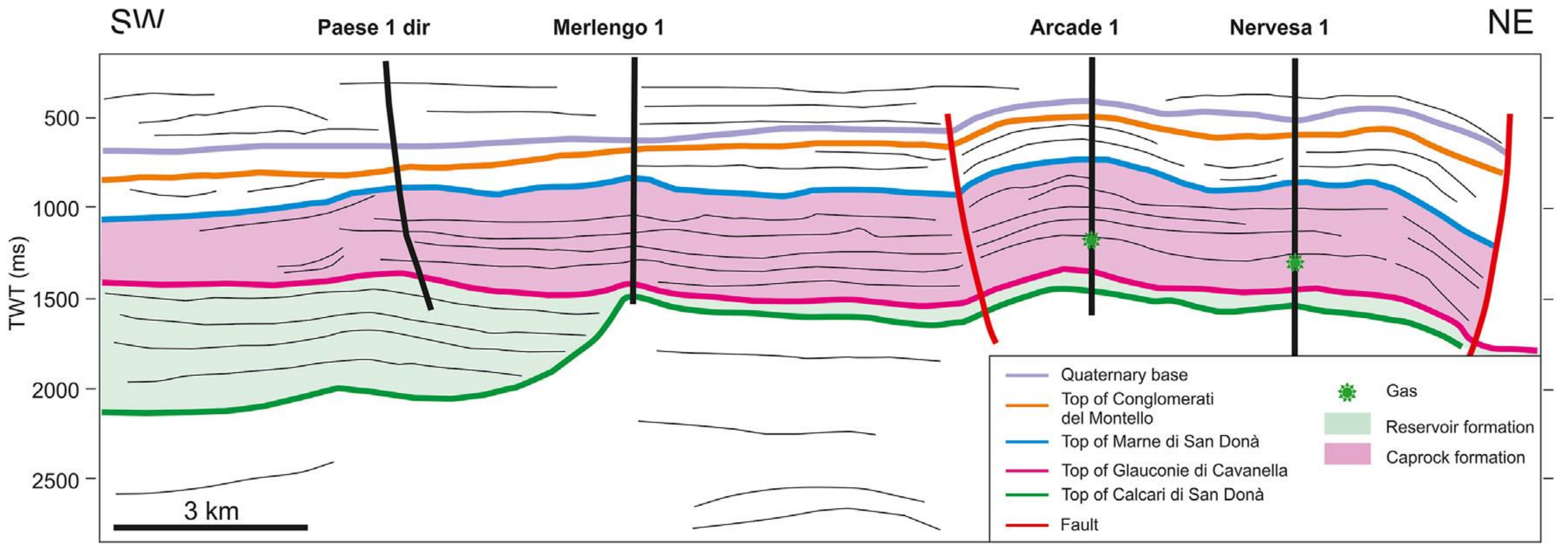
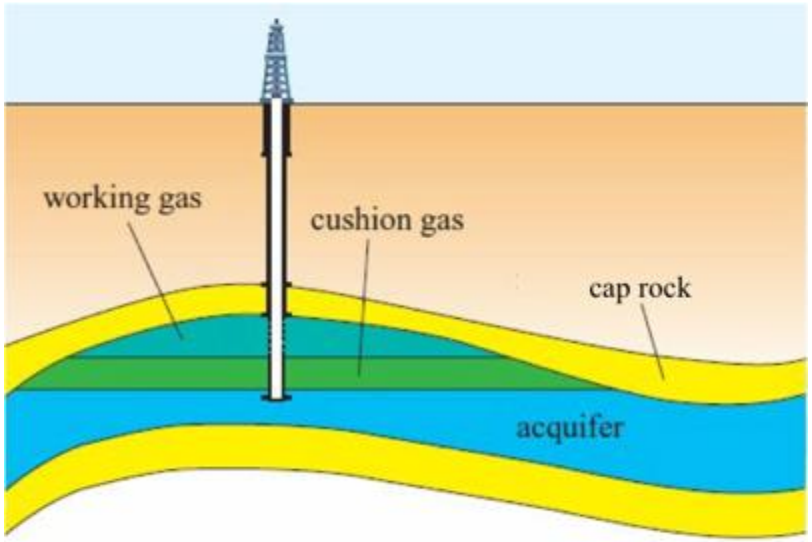




UNDERGROUND GAS STORAGE

Depleted gas-reservoirs are one of the safest types of underground gas storage. As gas has been trapped inside at the confining pressure for millions of years.

The reservoir is a geological trap with porous and permeable rock layers, tens to hundreds of meters thick, sealed by impermeable formations.



EXAMPLES

Italy has 15 active underground gas storage, all in depleted gas reservoirs. No evidence of induced seismicity, ever.

Hutubi (China) is one of the biggest underground gas storage (WGV ≈10 billion Sm^3). First case of weak earthquake (M ≈2.8-3) hypothesized to have been induced by UGS, by poro- elastic stress diffusion *(Qiao et al, 2018; Zhou et al, 2019).*

Underground gas stroage in **depleted oil-reservoirs** is much **less safe**; e.g., the Castor Project (Spain)

Slide kindly provided by E. Priolo-OGS

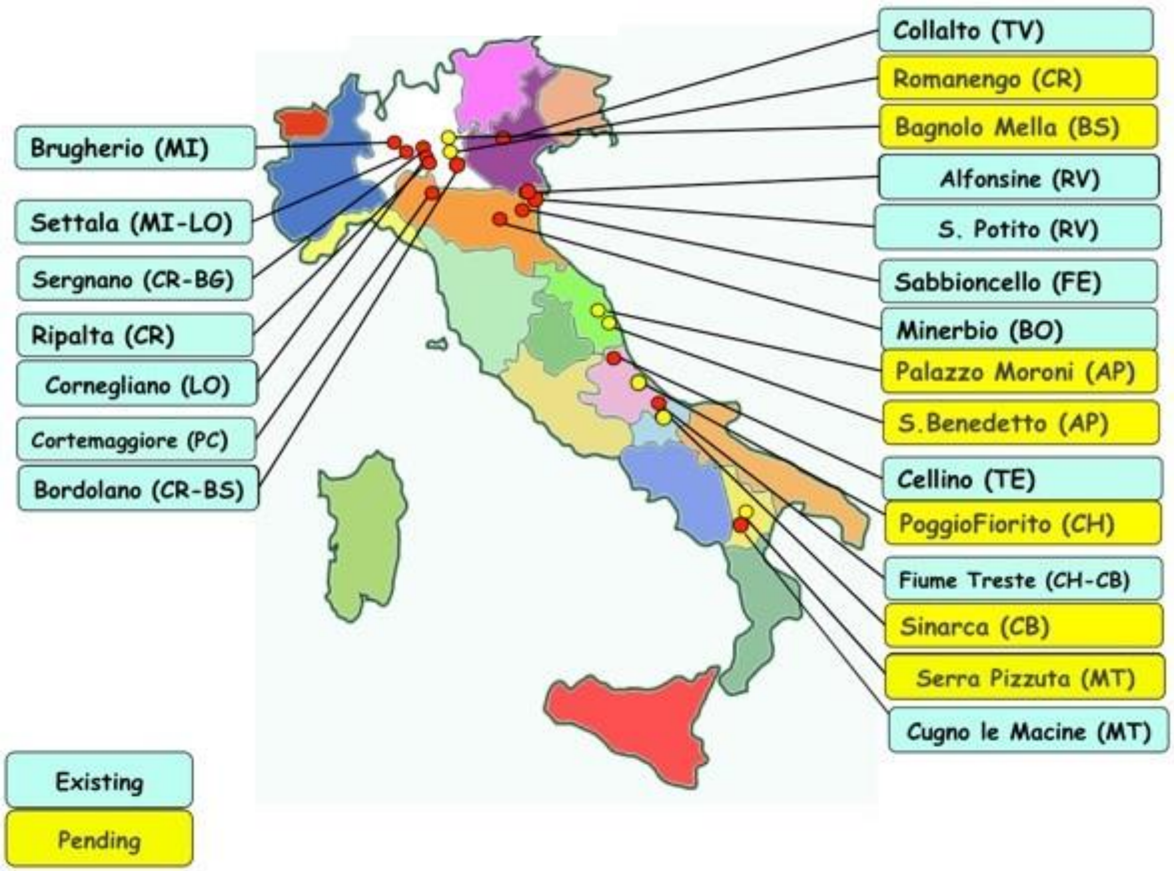
UNDERGROUND GAS STORAGE

- 15 campi attivi
- 7 richieste pendenti

Capacità totale di stoccaggio:
16.5 Miliardi Sm^3, di cui
4.6 di riserva strategica

Pressione max di esercizio:
130-230 bar

(Sm^3 = metro cubo standard)



In Italia sono utilizzati esclusivamente depositi depleti; per nessun caso si ha notizia di sismicità indotta o innescata.

Dati del Ministero dello Sviluppo Economico (MiSE) Ultimo aggiornamento: febbraio 2021

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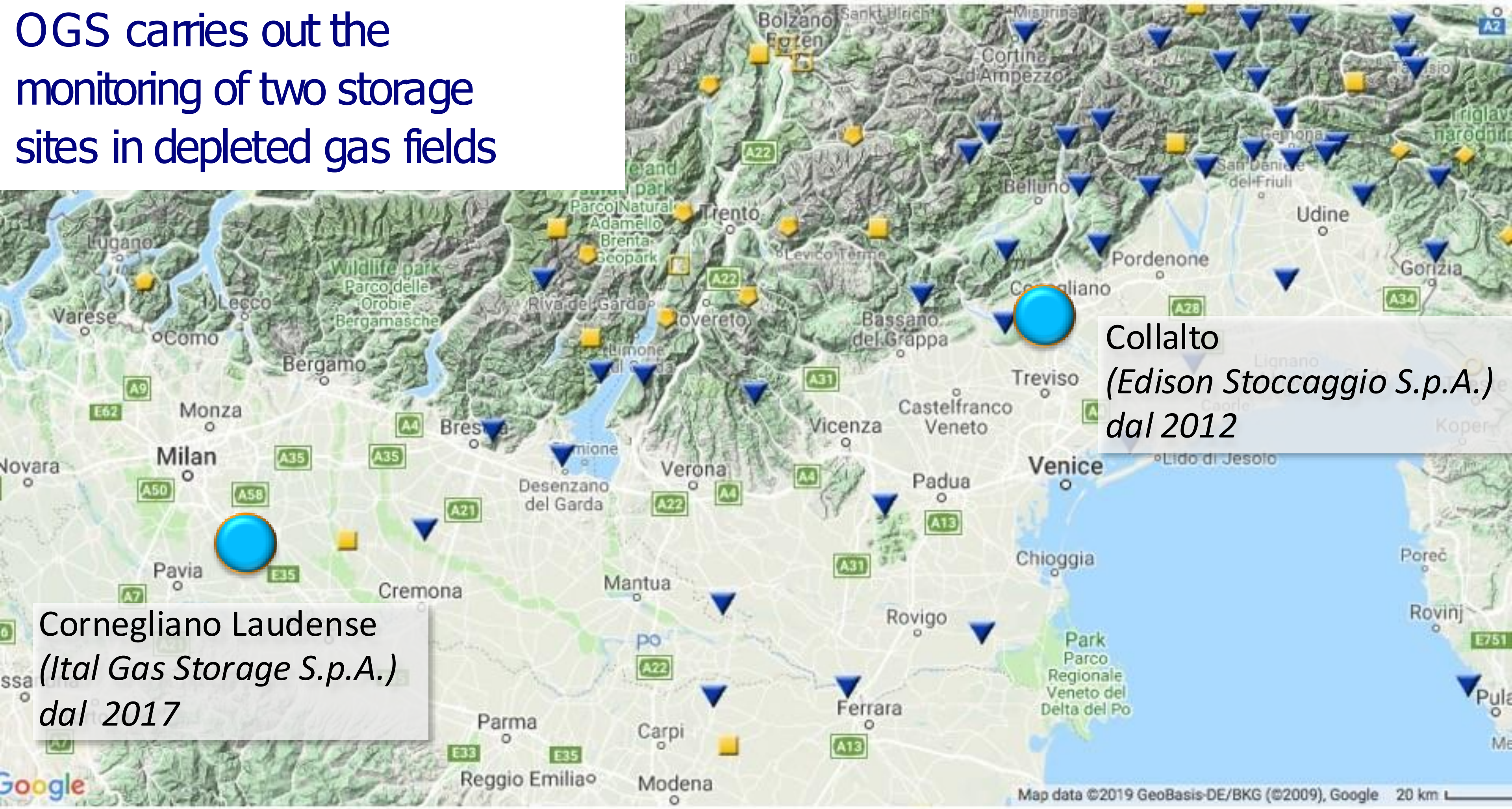
OGS GAS STORAGE MONITORING

OGS carries out the monitoring of two storage sites in depleted gas fields



Slide kindly provided by E. Priolo-OGS

OGS GAS STORAGE MONITORING

Stazione sismica + GPS

Strumentazione Guralp:

- Minimus
- Radian
- Fortis

Bocca pozzo + accelerometro (Fortis)

Sismometro da pozzo (Radian)

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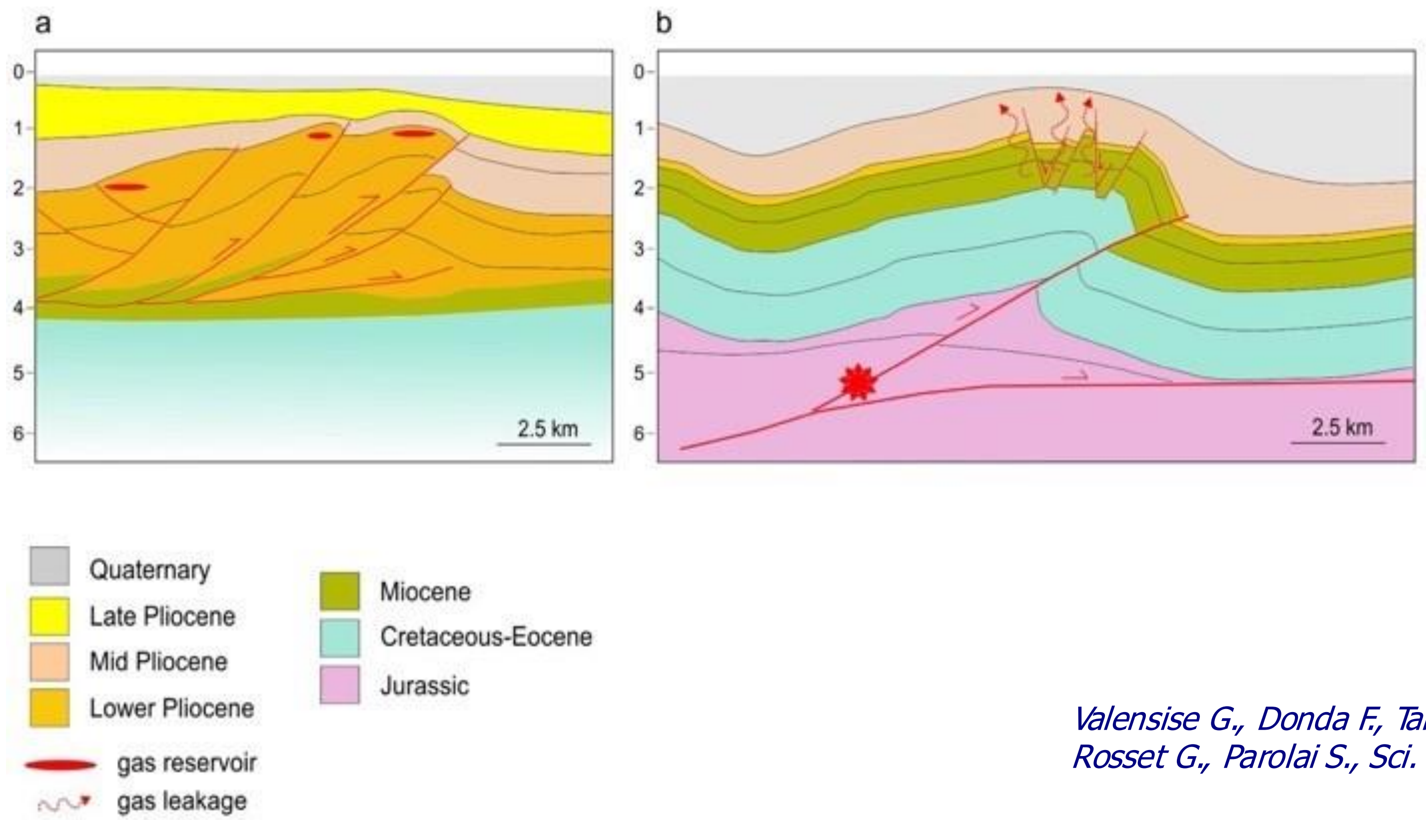
THE ROLE OF THE GEOLOGICAL-STRUCTURAL SETTING



Valensise G., Donda F., Tamaro A., Rosset G., Parolai S., Sci. Rep., 2022

The most **productive reservoirs** are hosted in **small-scale anticlines** (Figure a-left), generated by faults that are shorter and narrower with respect to the **deep and large faults** driving long-wavelength folds that may generate significant **earthquakes** and where **gas is generally not found** (Figure b-right)

THE ROLE OF THE GEOLOGICAL-STRUCTURAL SETTING

- In a fold and thrust hydrocarbon province the lack of productive gas reservoirs is likely to be controlled by seismogenic faulting
- Conversely, the presence of significant reservoirs is in itself an indication of a predominantly aseismic behavior of the underlying faults

Our findings indicate that the best option for planning such facilities is to **stay away from large seismogenic faults** and opt for a depleted gas reservoir

Valensise G., Donda F., Tamaro A., Rosset G., Parolai S., Sci. Rep.,2022

INDUCED AND TRIGGERED SEISMICITY

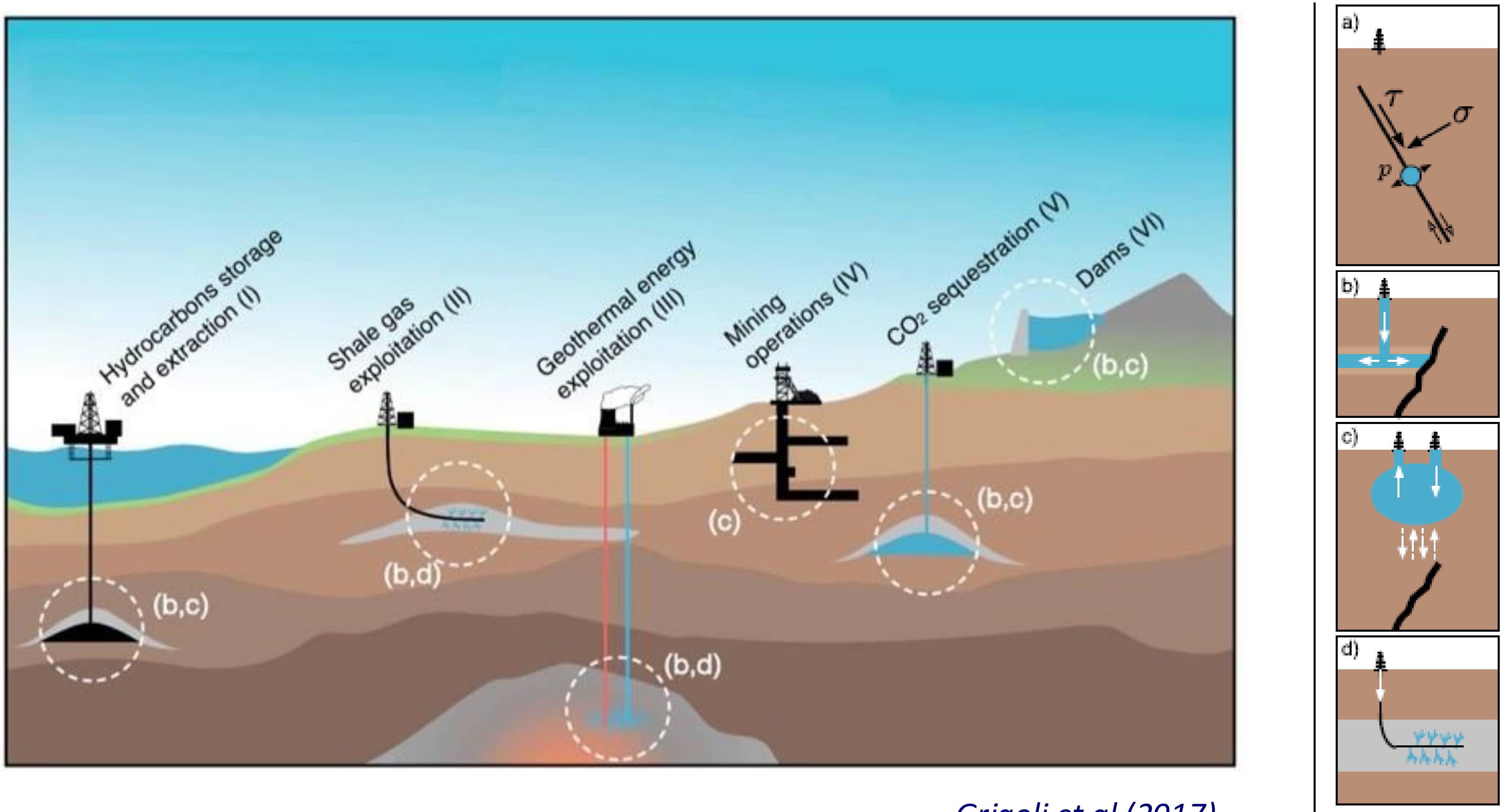
In the case of **induced earthquakes**, the nucleation, growth, and rupture process are determined by human-related stress perturbations.

In the case of **triggered seismicity**, the background stress field plays a more important role, and human activities are only responsible for the earthquake nucleation, while the rupture evolution is controlled by the background stresses (Dahm et al., 2013)

Strictly speaking, human activities CANNOT "induce" huge and devastating events, whereas they can trigger them.

Slide kindly provided by E. Priolo-OGS

INDUSTRIAL ACTIVITIES INDUCING EARTHQUAKES

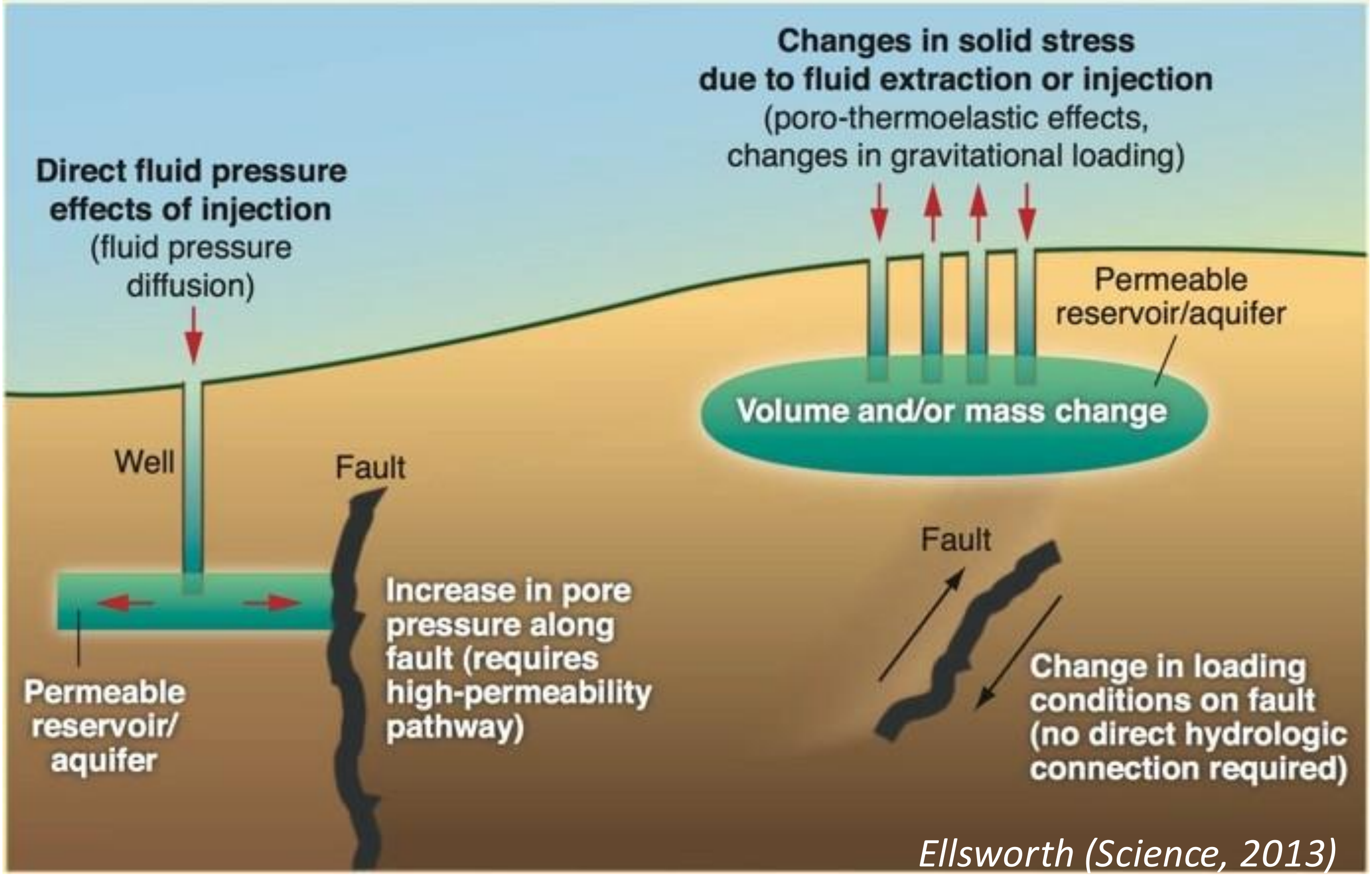


Grigoli et al (2017)

Slide kindly provided by E. Priolo-OGS

MAIN MECHANISMS FOR INDUCING EARTHQUAKES

- increasing the pore pressure acting on a fault
- changing the shear and normal stress acting on the fault



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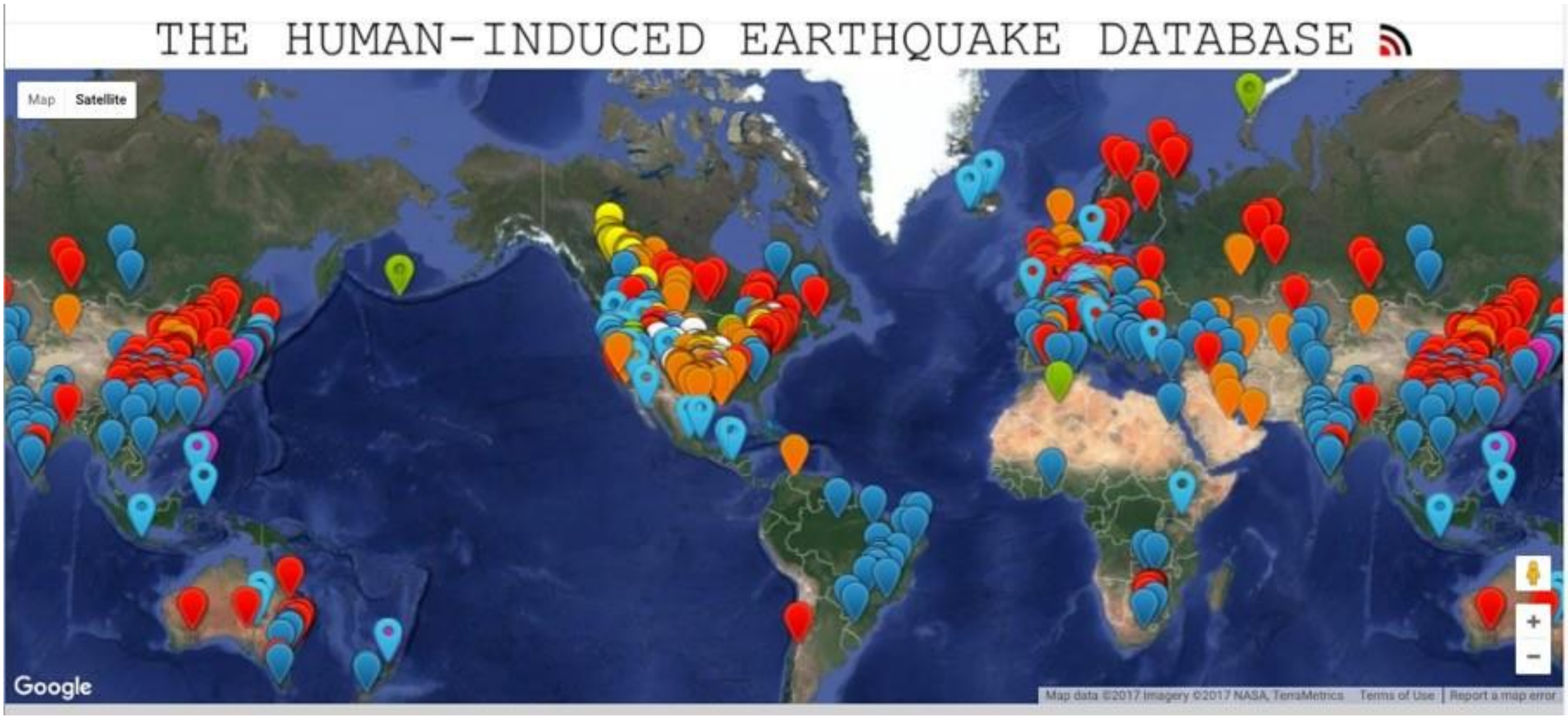
HUMAN-INDUCED EARTHQUAKES IN THE WORLD



To date, about 1200 entries of induced seismicity

http://inducedearthquakes.org/ (Wilson et al, 2017; Foulger et al, 2018)

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Italian monitoring guidelines

Nel 2014 il MiSE-DGRME istituisce il Gruppo di Lavoro per la redazione di **Indirizzi e Linee Guida** (ILG) per i monitoraggi delle attività di coltivazione di idrocarburi, stoccaggio sotterraneo di gas naturale e reiniezione di fluidi nel sottosuolo svolte on-shore.

Composizione del gruppo:

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Dott. Claudio Chiarabba (INGV, Roma)

Dott.ssa Daniela Di Bucci (DPC, Roma)

Prof. Carlo Doglioni (Univ. La Sapienza, Roma)

Prof. Paolo Gasparini (Univ. "Federico II", Napoli)

Ing. Riccardo Lanari (CNR–IREA, Napoli)

Dott. Enrico Priolo (OGS, Trieste)

Prof. Aldo Zollo (Univ. "Federico II", Napoli)

MiSE = Ministero per lo Sviluppo Economico

DGRME= Direzione Generale per le Risorse Minerarie ed Energetiche

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