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Preliminary regional screening for CCS in Switzerland

SCCER SoE Annual Conference, November 2, 2020

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Swiss Confederation

Innosuisse – Swiss Innovation Agency

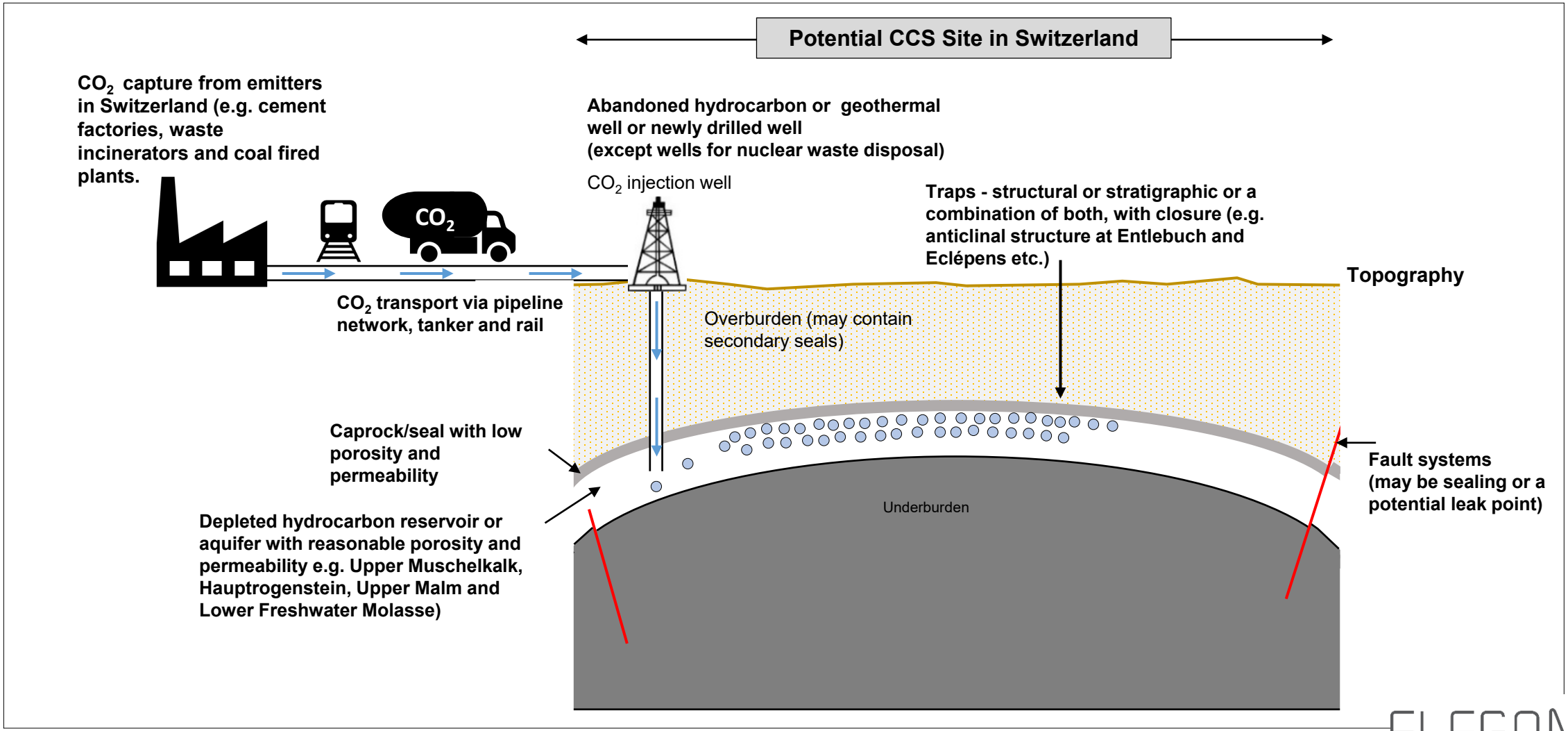
Acknowledgments

- Ovie Emmanuel Eruteya, UNIGE
- Matteo Spada , PSI
- Martin Saar, ETHZ
- Ben Adams, ETHZ
- Larryn Diamond, UniBE
- Gianfranco Guidati, ETHZ

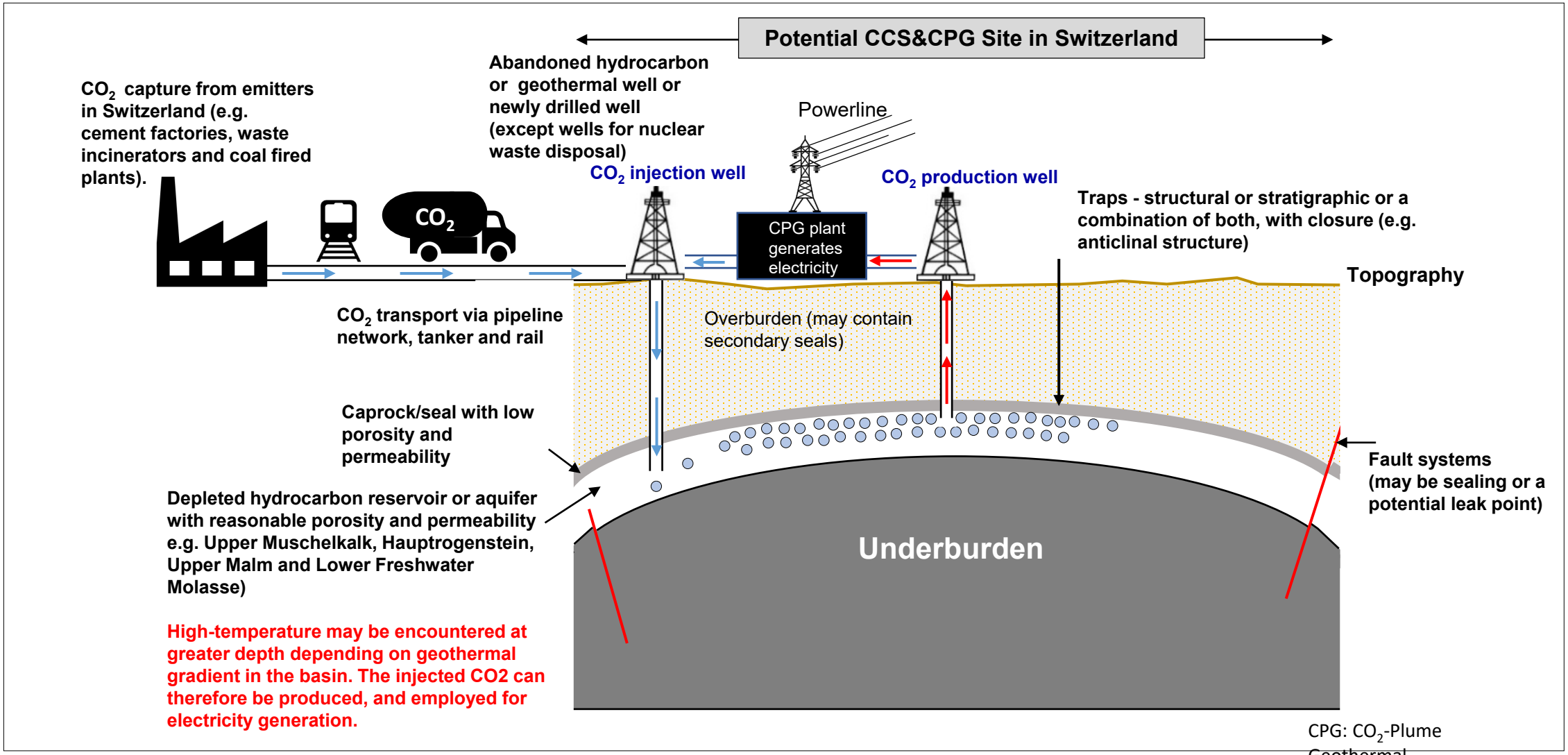
Key Questions

- Where [site(s)] can we store CO_2 in the subsurface in Switzerland?
- What is the storage capacity at the potential sites?
- What is the fate of the injected CO_2 at the potential sites and its associated risks?
- Is storage at the site economically viable? e.g. CO_2-plume-Geothermal

Swiss model - CCS



Swiss model - CCS/CPG

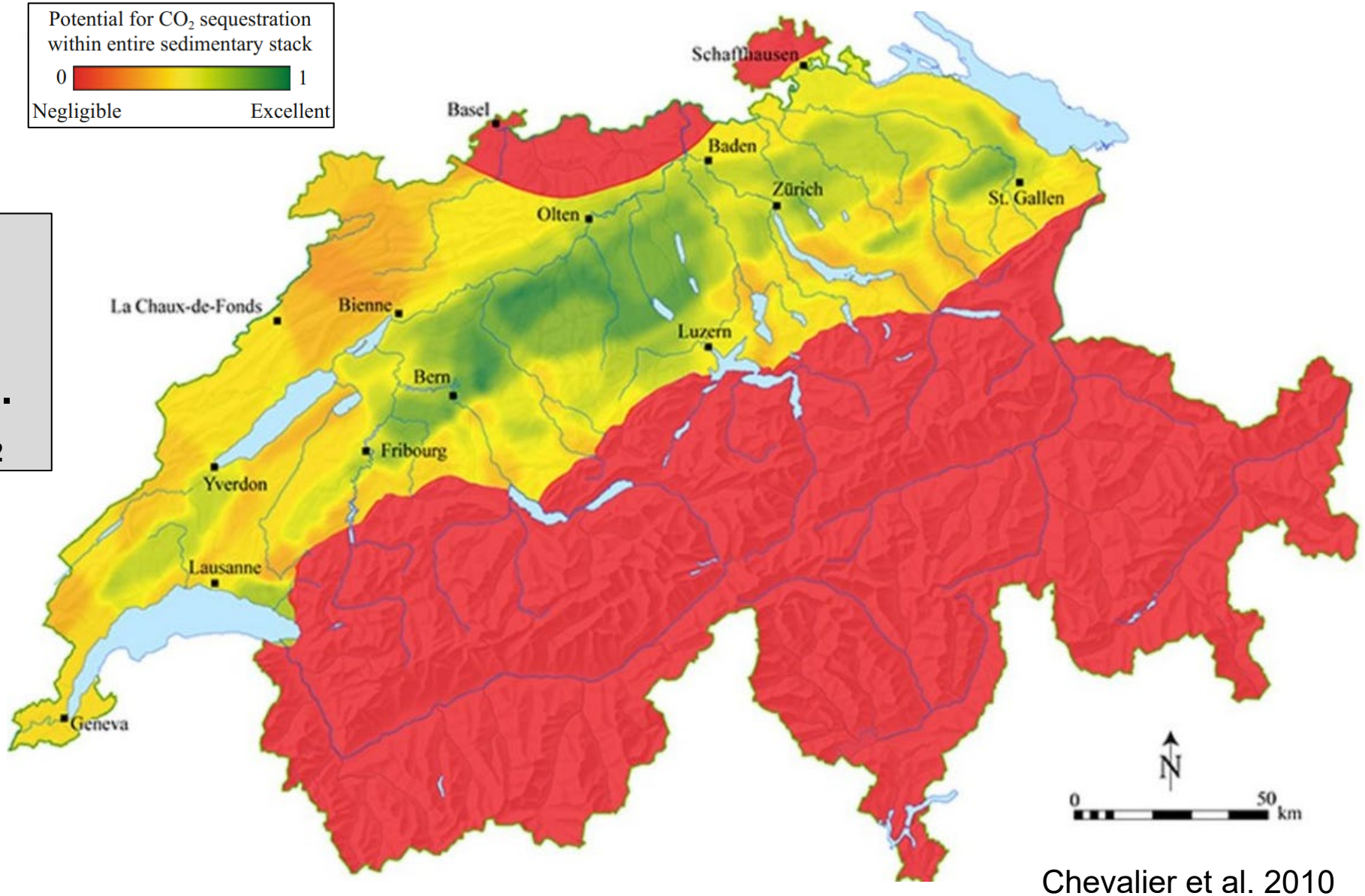


CPG: CO_2-Plume Geothermal

Where we stand ?: Theoretical storage capacity

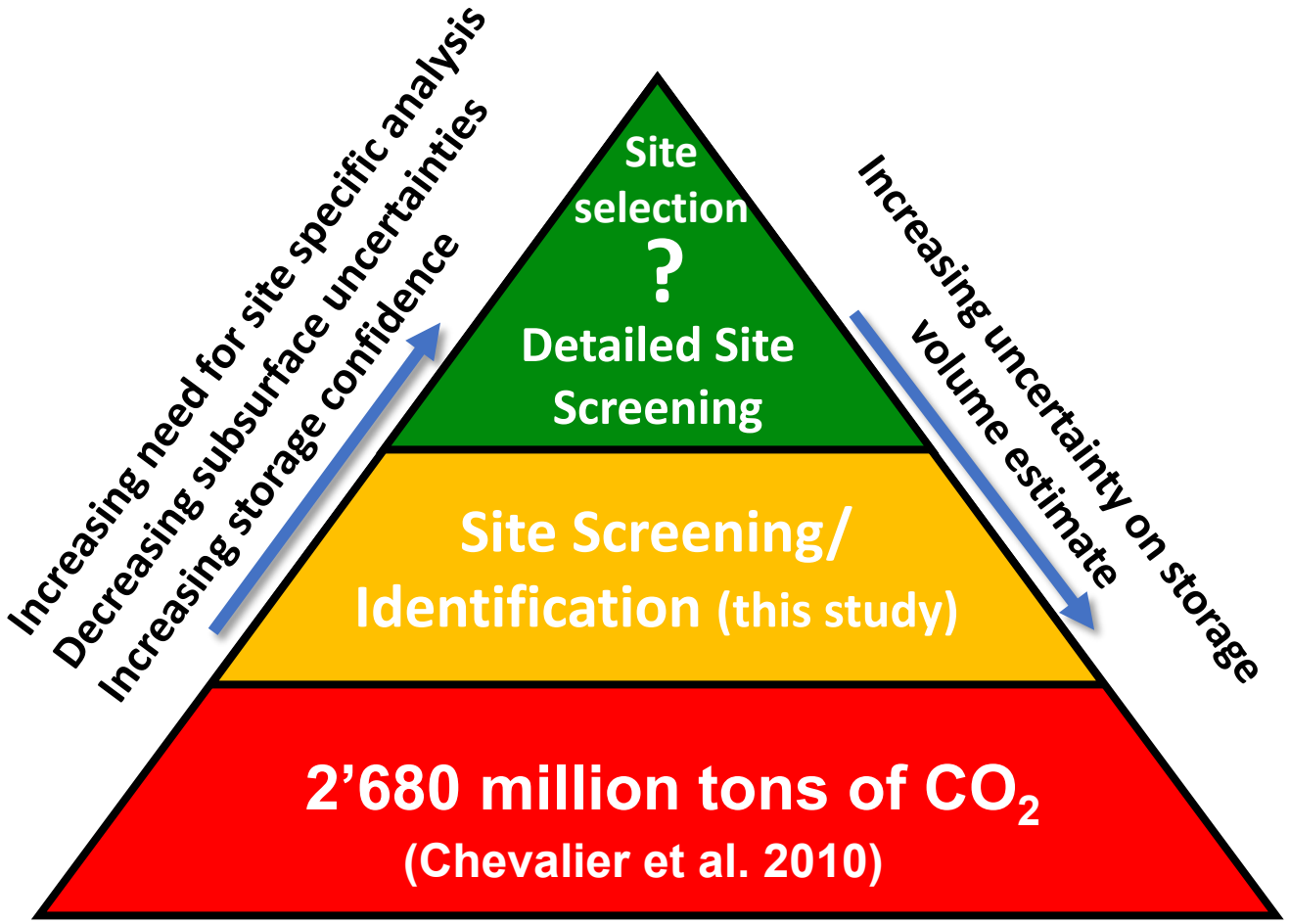
Theoretical storage capacity under area

- **0.6 Pot. of Seq.**
- **~2'680 Mt CO_2**



Chevalier et al. 2010

Estimation of storage capacity for CO_2 in Switzerland



- **Quantified capacity** for CO_2 storage in conformity with regulatory framework based on large-scale paired emitters and sinks (storage sites).
- Highest precision of storage efficiency factor usually quantified from reservoir simulations and injectivity test

- **Assessed capacity** for CO_2 storage controlled by geological and technical constrains.
- Requirement for establishing specific site identification and selection assessment criteria.

- **Theoretical capacity** estimate of CO_2 storage in the Swiss Molasse Basin. CO_2 storage volume estimate are based on low-resolution data and hence prone to large uncertainties, leading to most likely unrealistic values.

* 50 Million tons storage capacity have been estimated for parts of the Upper Muschelkalk (https://nfp-energie.ch/en/projects/960/) see previous slide.

Site screening workflow developed for CCS/CPG in Switzerland

Typically, the viability of large industry project depends on a large number of TECOPES aspects, often intertwined and inter-dependent.

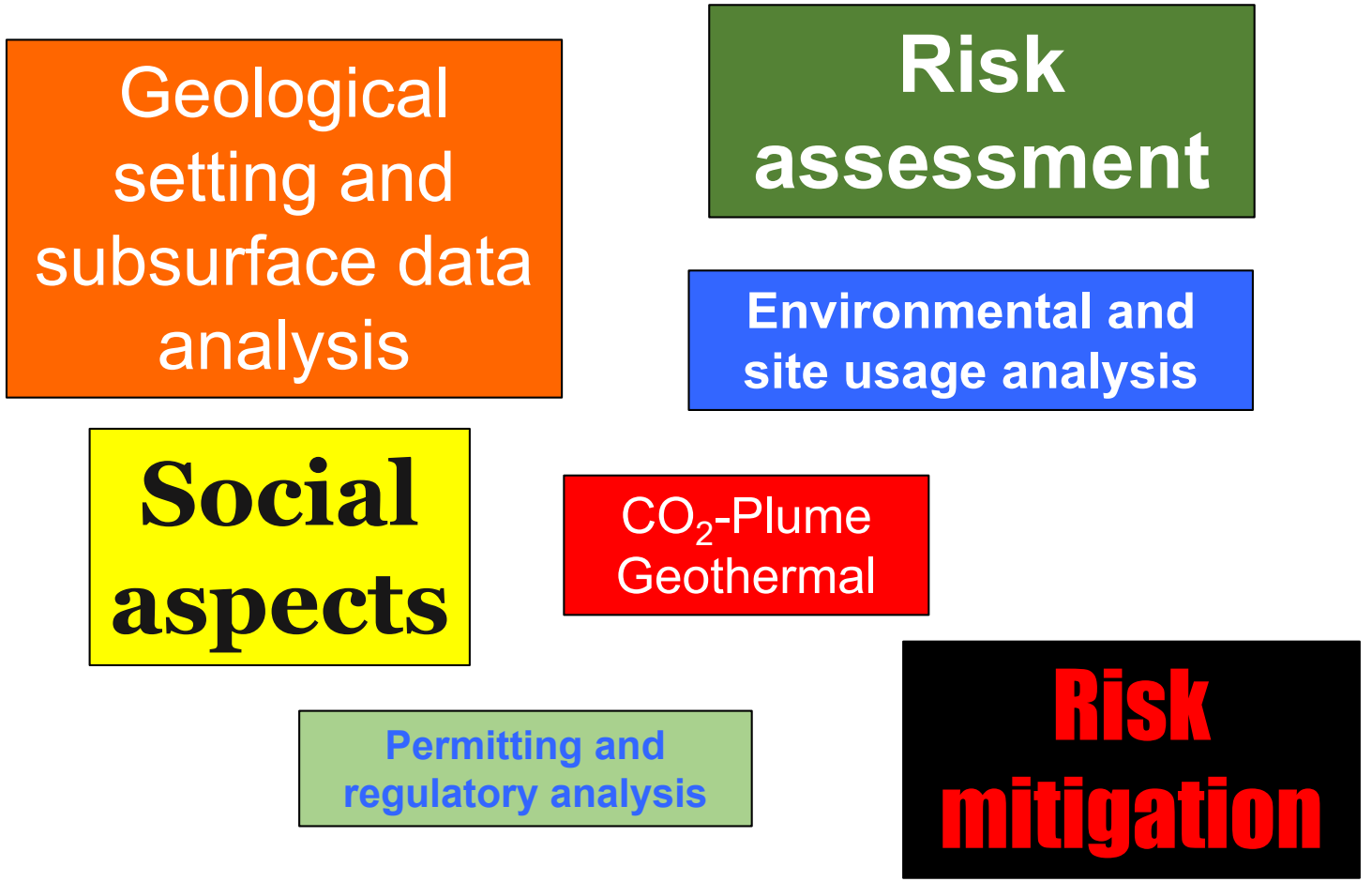
This work focused primarily on identifying the critical aspects for the following aspects:

Subsurface

Environmental

Social

Legal Framework



TECOPES: Technical, Economic, Commercial, Political, Environmental, Safety

Site screening workflow developed for CCS/CPG in Switzerland

Geological setting and subsurface data analysis

Existing geological model e.g. GEOMOL, various aquifer and reservoir models

Geological, geophysical, geomechanical and geochemical data
- Seismic (2D & 3D).
- Well logs
- Petrophysical data
- Pressure data
- Production history
- Leak-off test
- Temperature data
- …

Identify candidate storage formation (reservoir or aquifer)

Adequate storage depth (> 800 m below ground level)

Confining zone or structures (trap)

Storage capacity

Seal integrity

Injectivity (CCS) and Transmissivity

Develop models
- Geological model
- Static model
- Dynamic model

Risk assessment

Storage Integrity
- Cap rock
- Overburden
- Seismicity (natural & induced)
- Landslide

Potential plumbing and leakage pathways
- Faults
- Well bore failure

Storage Quality
- Connected volume
- Injectivity

Subsurface fluids
- Hot water flow
- Hydrocarbons

Environmental and site usage analysis

Site accessibility

Distance to CO_2 source

Existing surface facility

Proximity to existing population centers

Environmentally protected areas

Underground usage
- Existing geo-energy projects or existing resource development
- Nuclear waste repository

Environmental impact assessment
- Baseline environmental surveys for: Groundwater, soil and near-surface gas.

Social aspect

Demographic trend

Land usage

Social and political acceptance

Permitting and regulatory analysis

Local Government laws

Cantonal laws and regulations

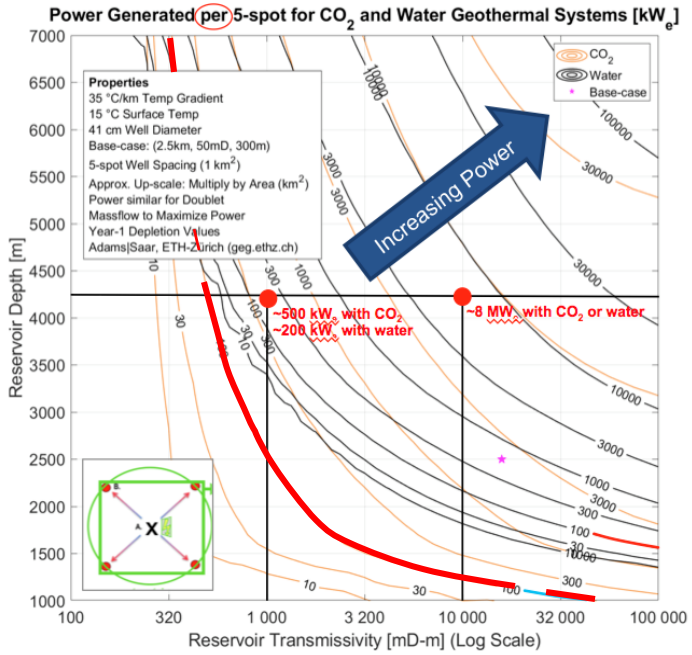
Federal laws and regulations

Environmental constraints

Assessment of conflict of existing surface and underground usage

CO_2-Plume Geothermal

➢ 100 Kwe From the contour plot



Risk mitigation*

Seal / Caprock Integrity - Core analysis of seal rock samples. Assess faults geometry, sealing or leaking potential. Acquire dedicated 2D/3D seismic data. Use quantitative analogue data sets () from lab tests and drilling parameters (i.e. leak-off test) from off-set wells to condition detailed geological/ geomechanical models of selected site. Assess feasibility of 4D seismic (due to small volumes of CO_2 injected). Check for additional sealing units in the overburden. Determine magnitude of pressure build-ups and rate of injection and tests effects of different injection strategy by fit-for-purpose modelling approaches.

Reservoir injectivity/ transmissivity – Estimate uncertainties ranges of reservoir permeability values based on analogue long term well tests. Quantify effects of a realistic number of subsurface models (e.g. reservoir connectivity and fault/fracture geometry and density) and development scenarios (e.g. injectors, pressure parameters etc.).

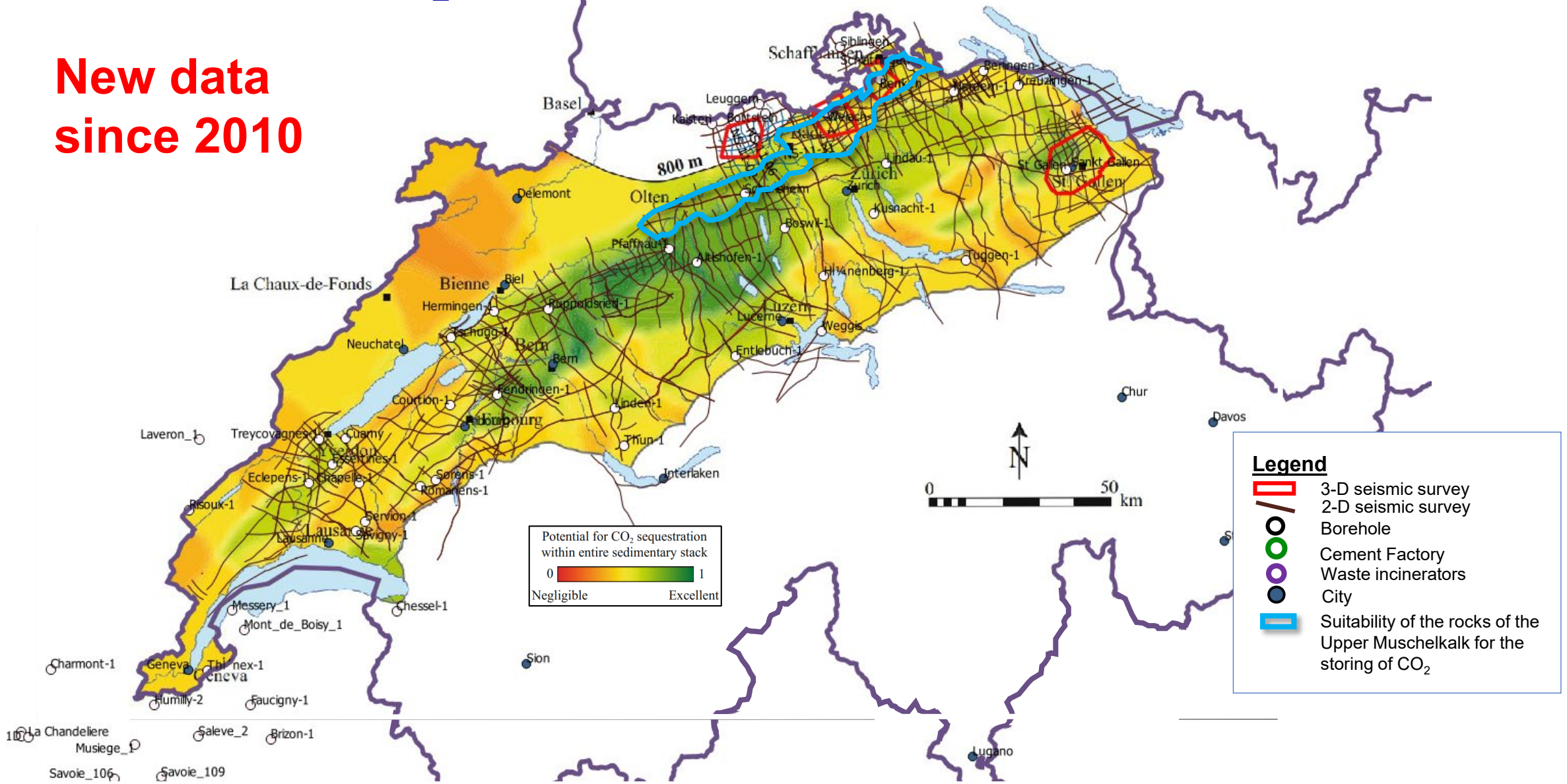
Fault reactivation – Perform geomechanical simulations to look at local/regional stress regime. Establish regional seismicity baseline and monitor seismicity. Fluid injection/leak-off tests. Keep injection pressures well below cap-rock failure pressure.

Contamination of protected groundwater with CO_2/brine/gas – Perform a baseline survey on groundwater (water chemistry, connectivity) and establish a monitor and surveillance strategy (e.g. repeated surveys at regular intervals). Establish permanent network of soil gas probes for near-surface gas detection and monitoring (e.g. scanning lasers). Address these items in the Environmental Impact Assessment (EIA).

* input from BGS

Potential for CO_2 Storage

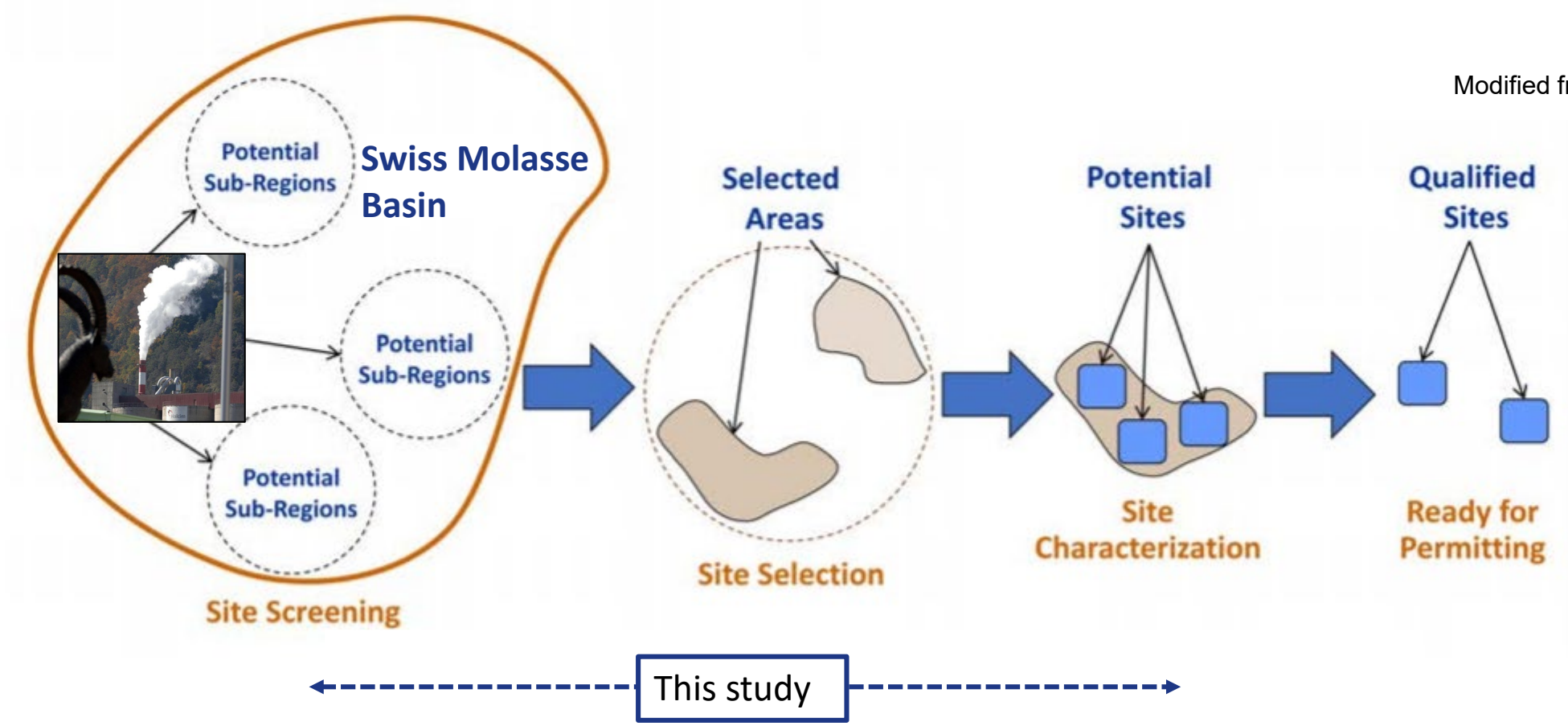
New data since 2010



Modified from Chevalier et al., (2010) and https://nfp-energie.ch/en/projects/960/

Scale of Investigation and Major Steps in Process of Finding Qualified Sites for geological sequestration of CO_2

Modified from NETL, 2017



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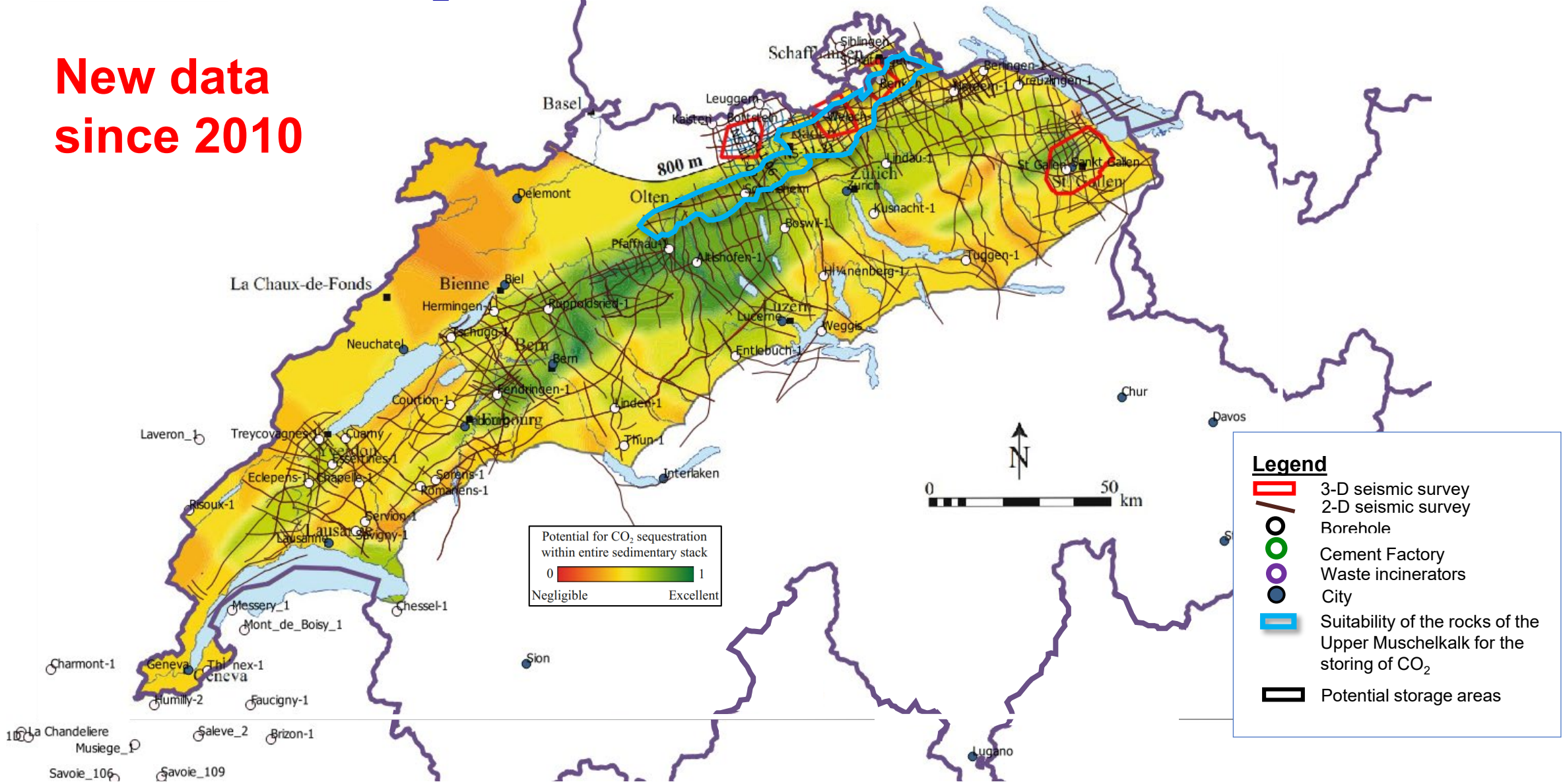

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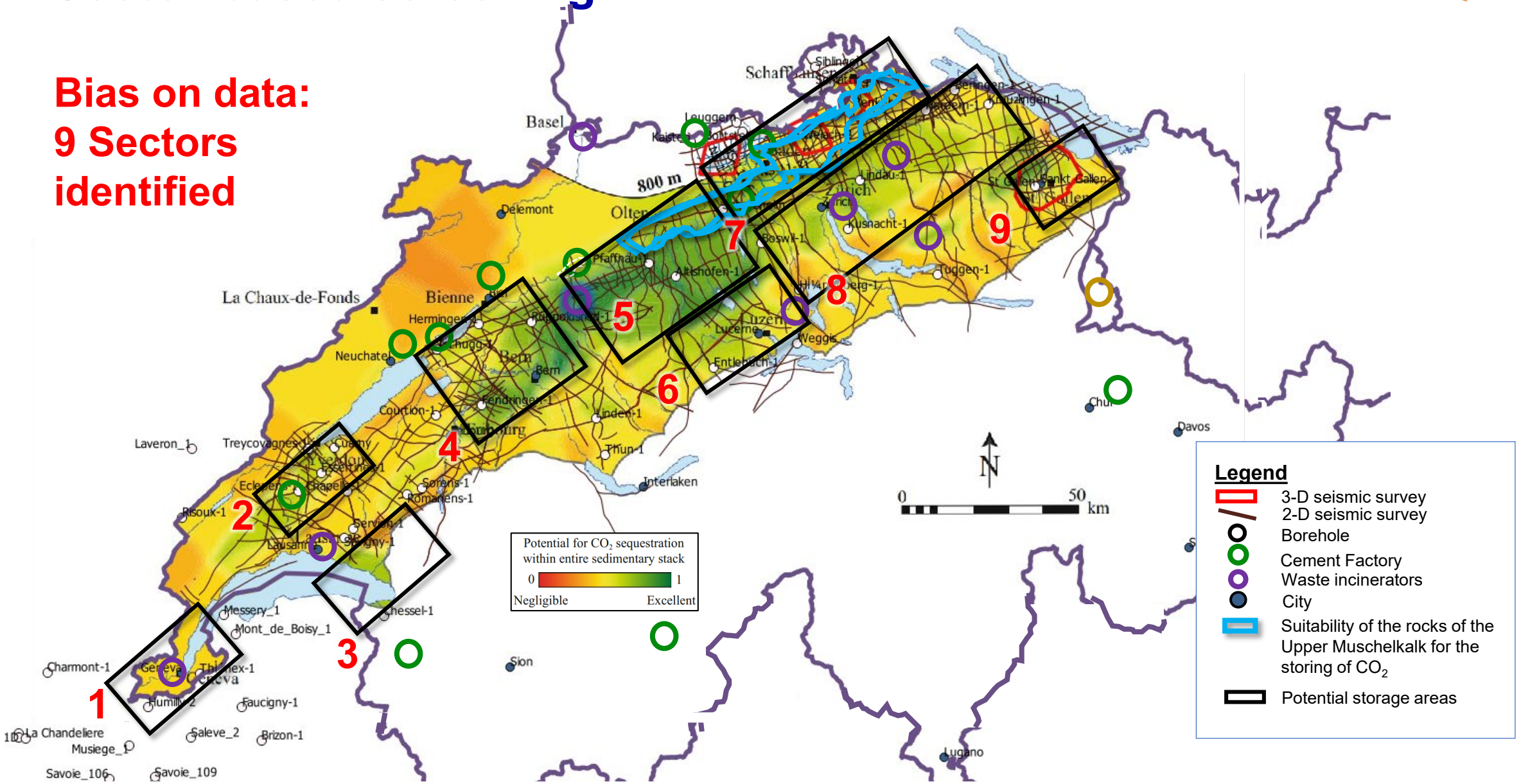
Sector-based screening

Bias on data:
9 Sectors identified



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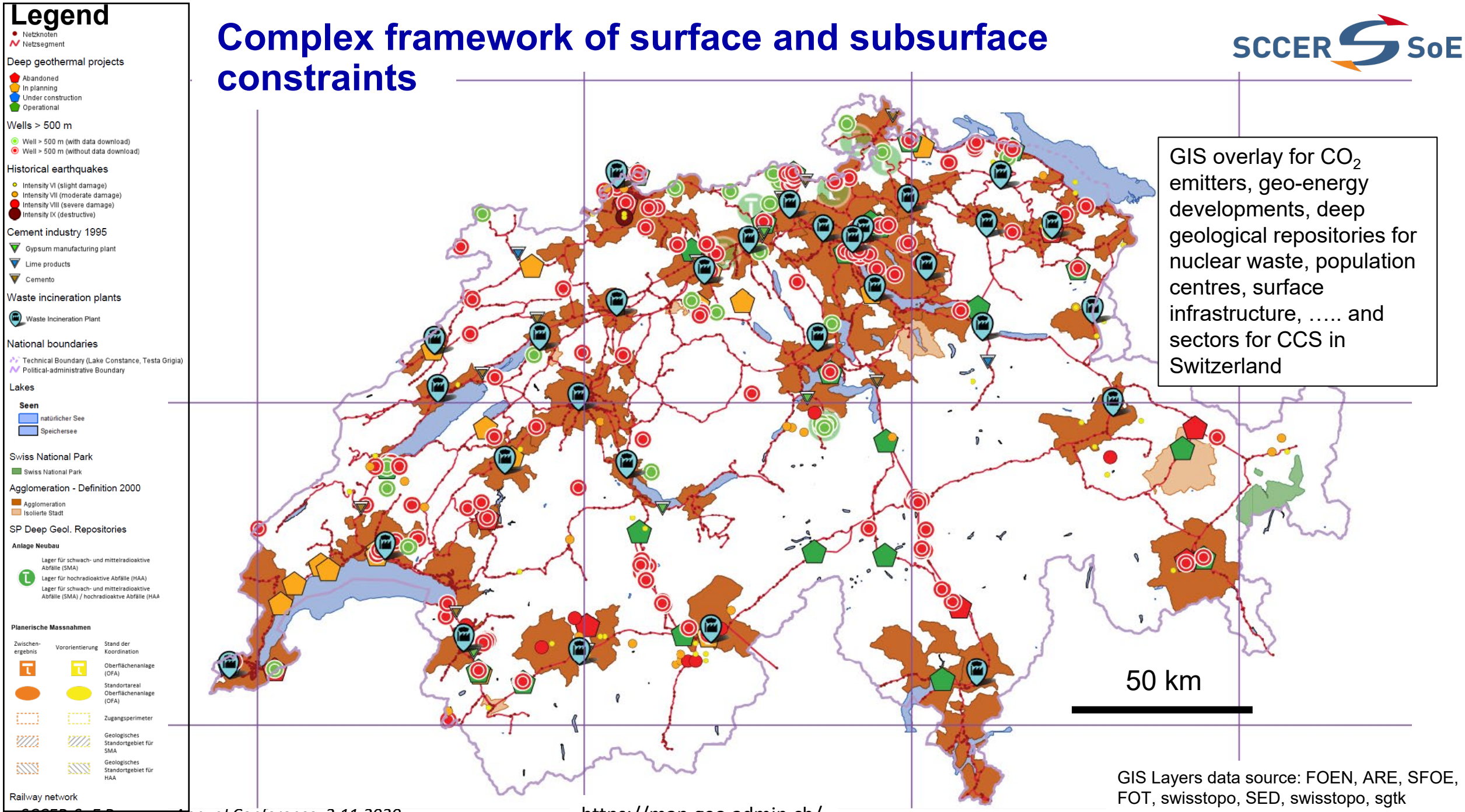
Complex framework of surface and subsurface constraints



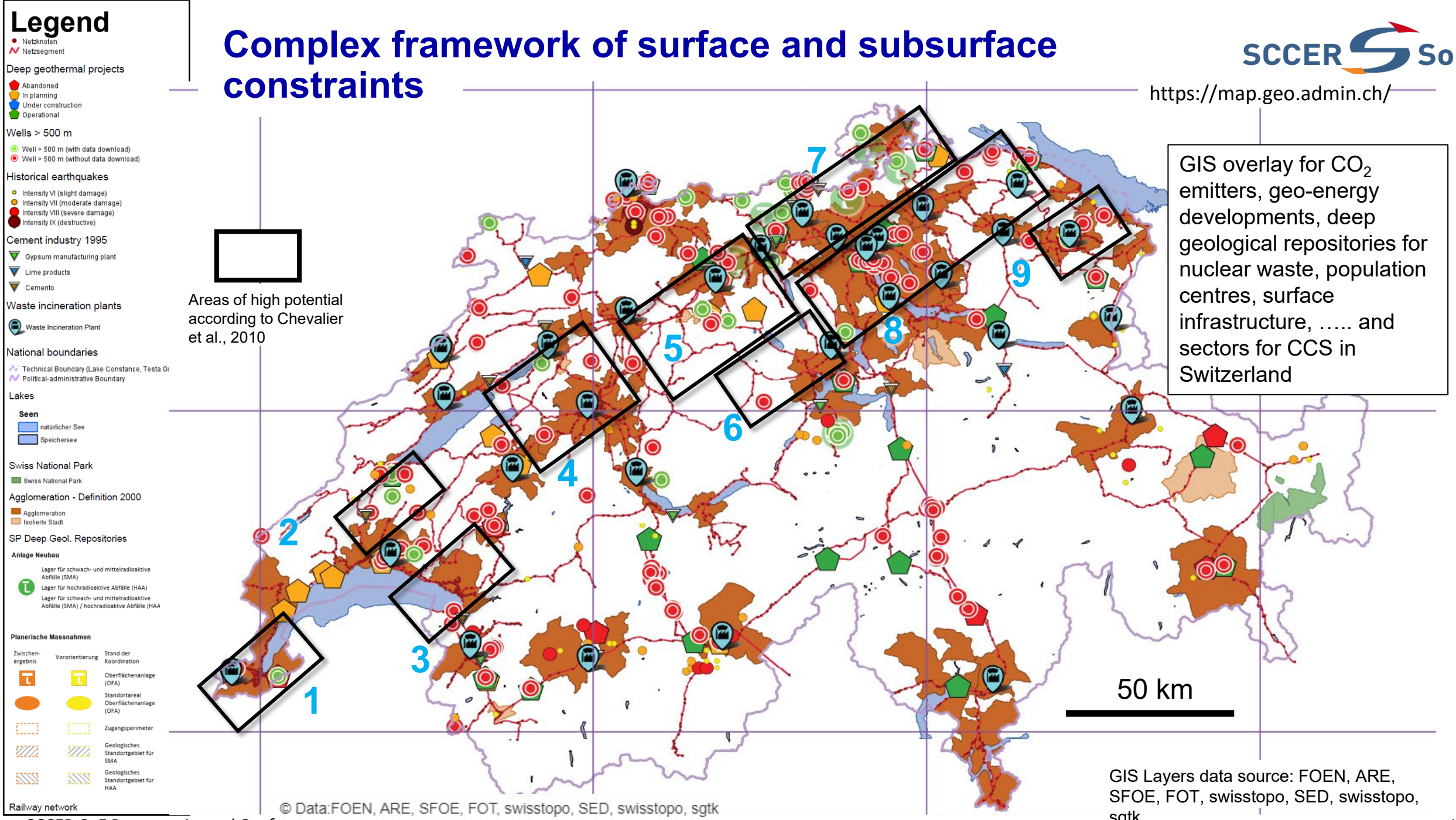
GIS overlay for CO_2 emitters, geo-energy developments, deep geological repositories for nuclear waste, population centres, surface infrastructure, ….. and sectors for CCS in Switzerland

GIS Layers data source: FOEN, ARE, SFOE, FOT, swisstopo, SED, swisstopo, sgtk

https://map.geo.admin.ch/

Complex framework of surface and subsurface constraints

https://map.geo.admin.ch/



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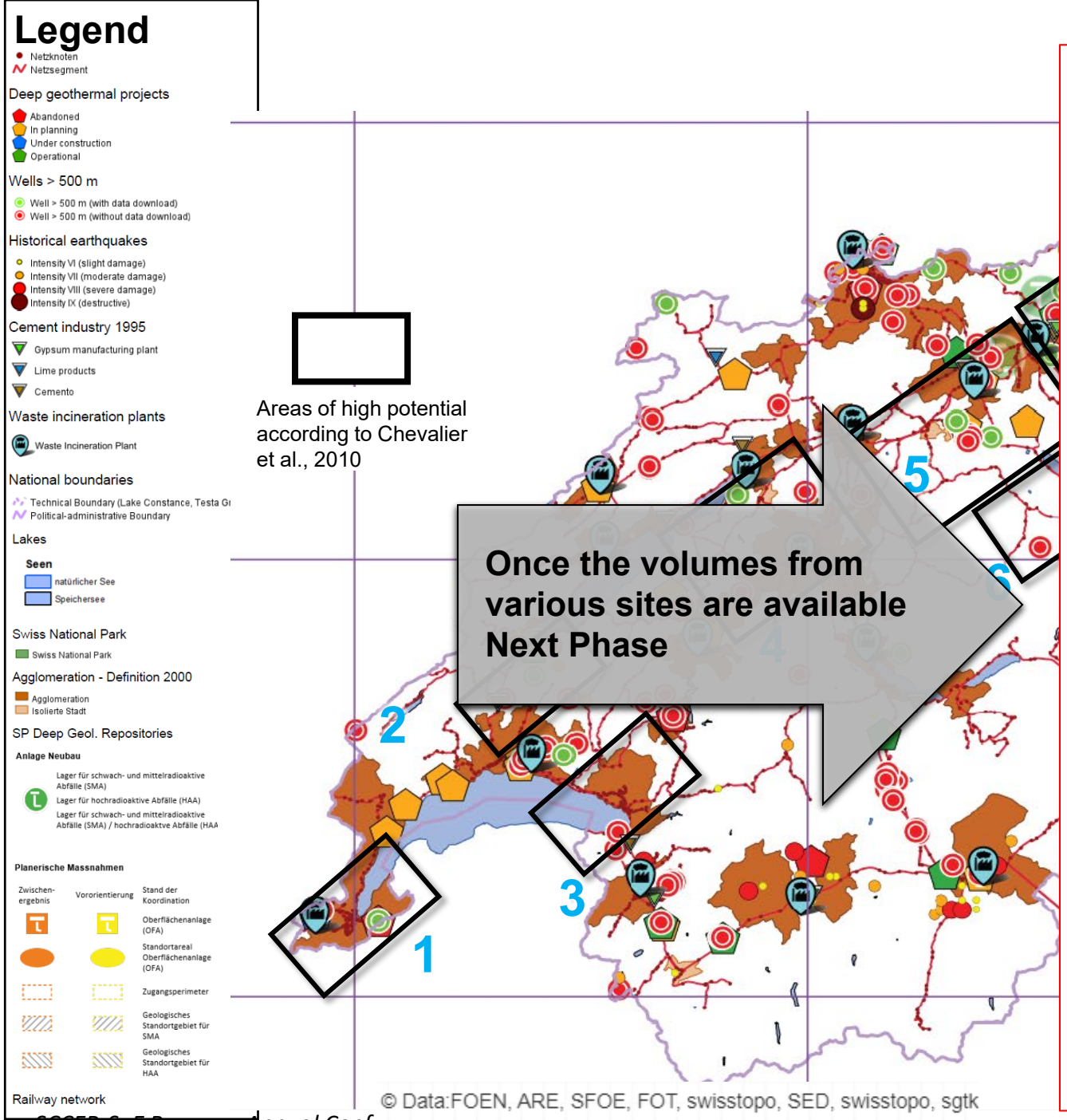
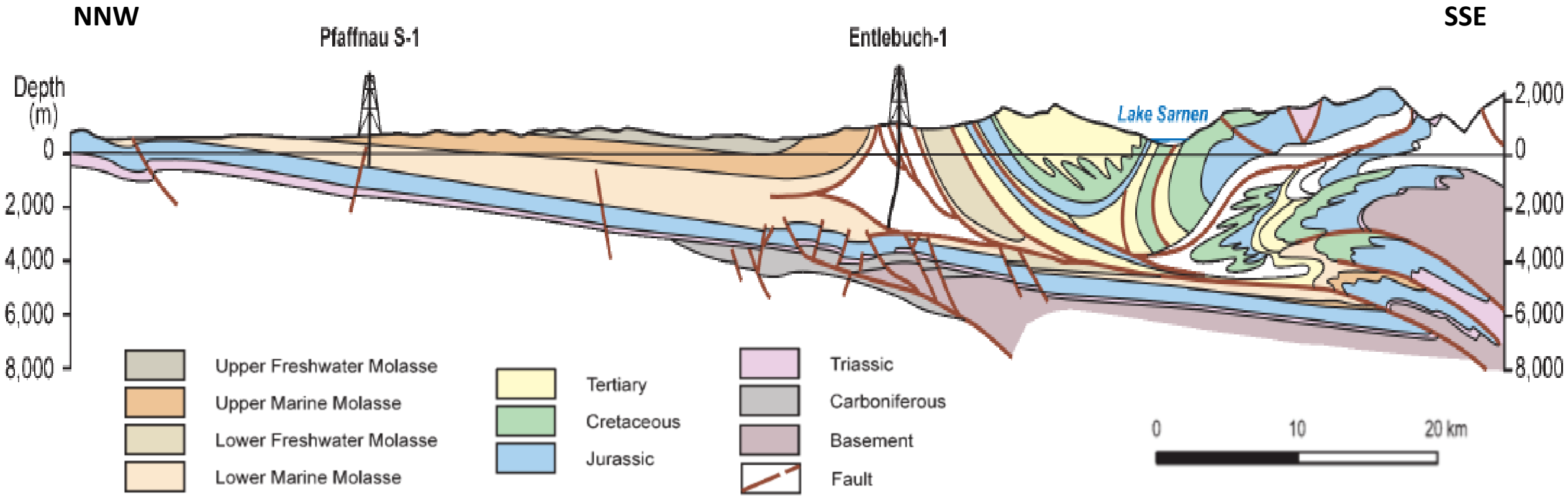


Multi-criteria decision analysis

- Geological Suitable Regions
  - Depleted hydrocarbon field
  - Other regions with storage capacity
  - Evidences of hydrocarbon seepage
- Deep geological repository (Nuclear waste exploration wells and planning perimeter)
- Existing and future Geothermal Project
- Environmentally protected areas
- CO_2 emitters (size and proximity)
- Population centers/ distribution)
- Land use (e.g. Agriculture,EPAs)
- Co_2 transport
  - Pipeline network
  - Rail network
  - Road network
- Important surface infrastructure (e.g. nuclear power stations)

Subsurface conceptual subsurface models for the Swiss Molasse Basin



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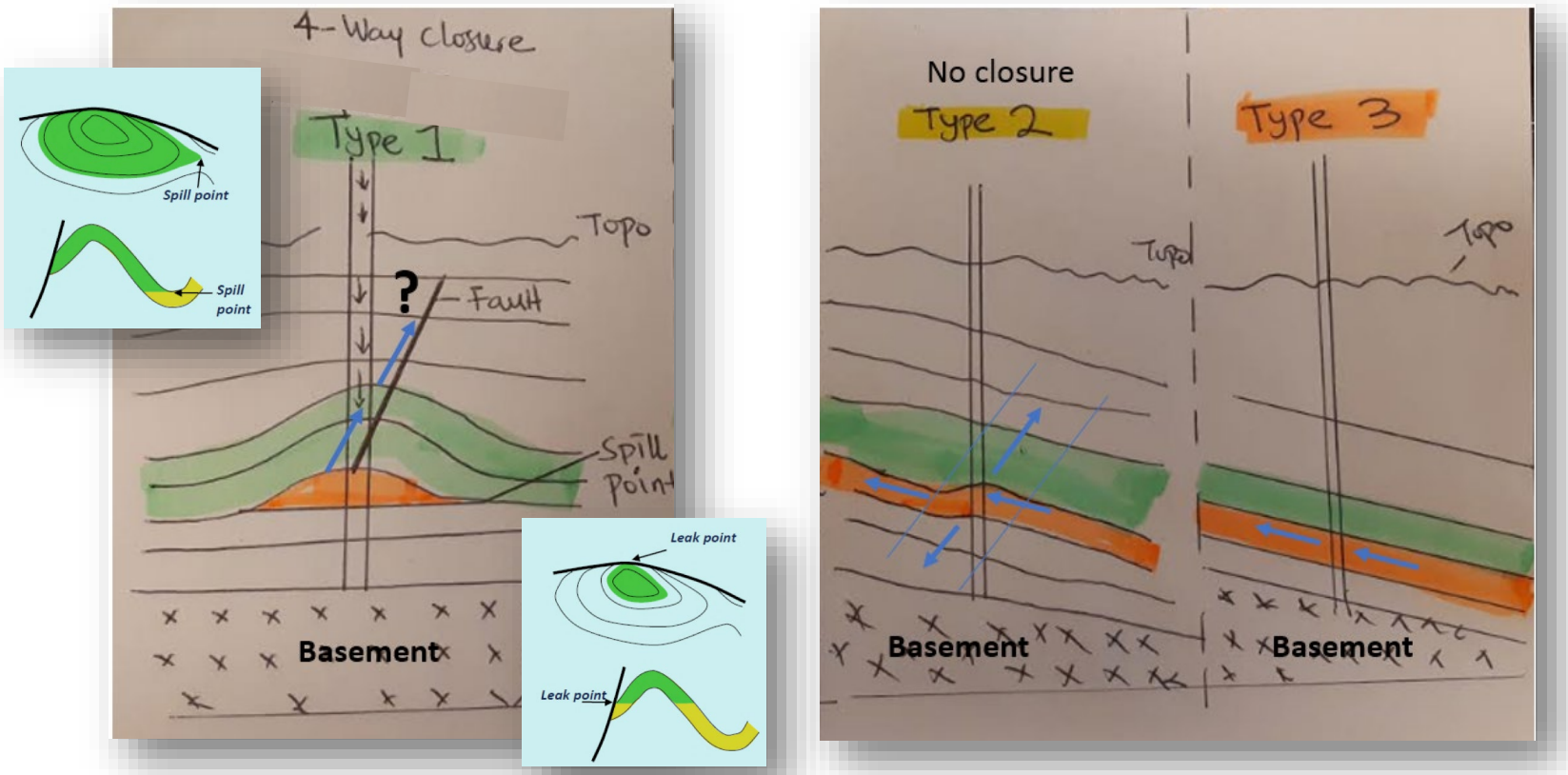
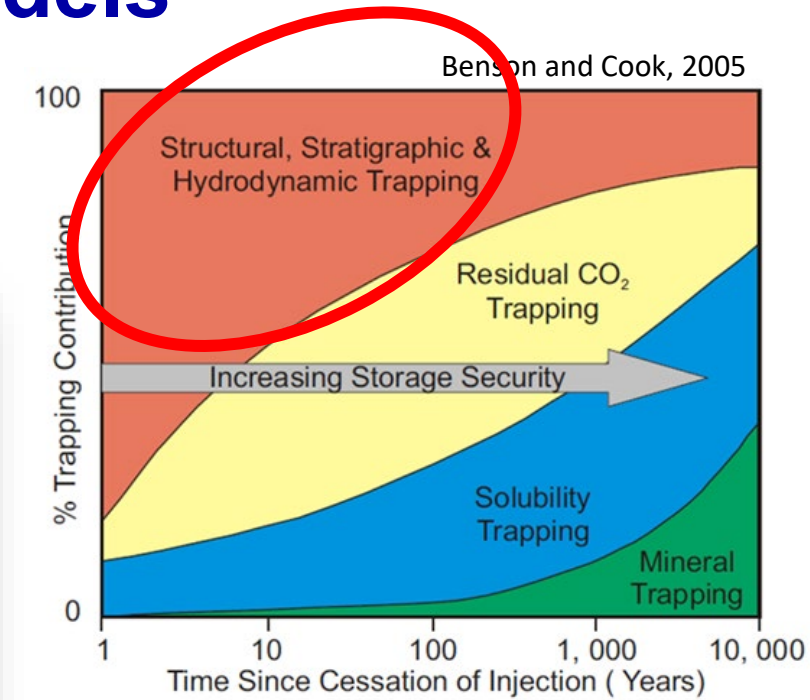
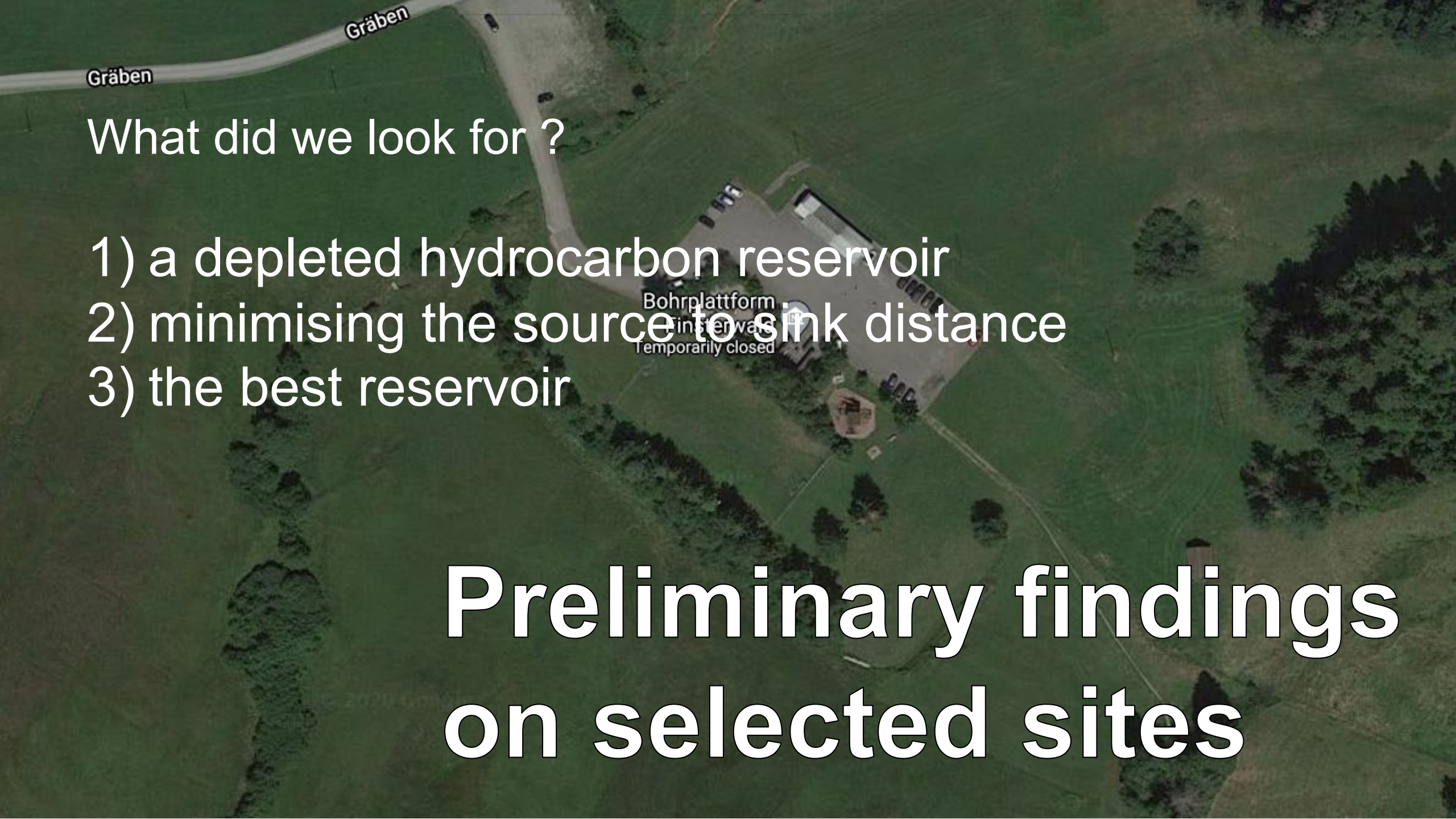




While CO_2 can be stored in porous and permeable units in the subsurface a trap and effective seal are needed to maintain storage security at a given location over a considerable geological time.

Risk of long term storage security



What did we look for ?

1) a depleted hydrocarbon reservoir
2) minimising the source to sink distance
3) the best reservoir

Preliminary findings on selected sites

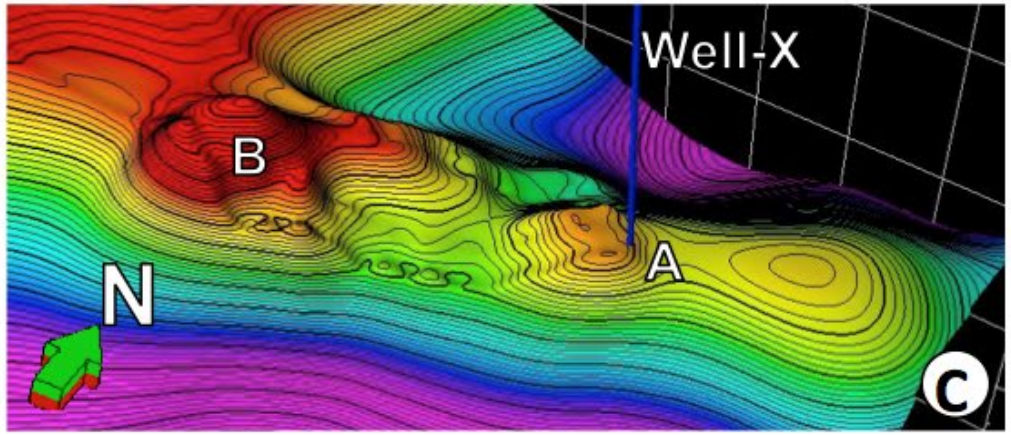
Location 1: Looking for a depleted hydrocarbon reservoir

Why store CO_2 in a depleted hydrocarbon reservoir ?

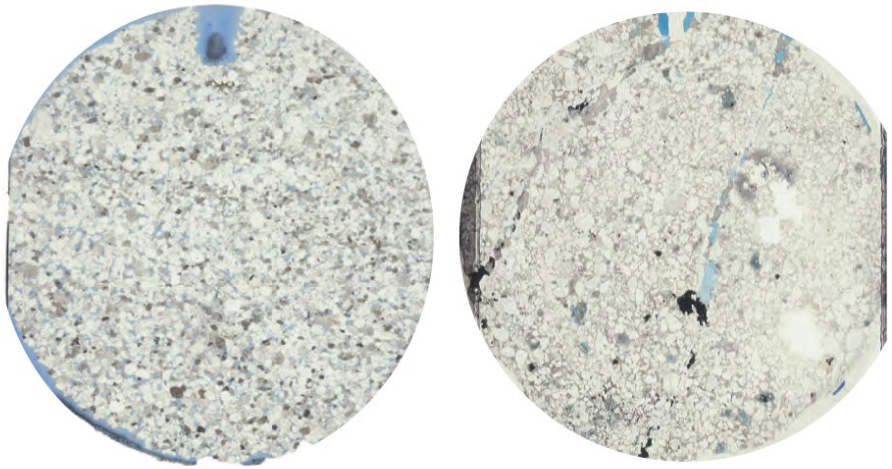
Depleted hydrocarbon reservoirs are suitable for carbon dioxide (CO_2) sequestration based on their **storage capacity**, **proven seal**, **reservoir characterization knowledge and existing infrastructure** (Hoteit et al., 2019).

Where these reservoirs are characterized by adequate temperature and permeability CO_2 can be used to exploit geothermal energy via a process described as **CO_2-plume geothermal (CPG)** system (Randolph and Saar, 2011; Adams et al., 2015).

Location 2: looking for the source to sink shortest distance

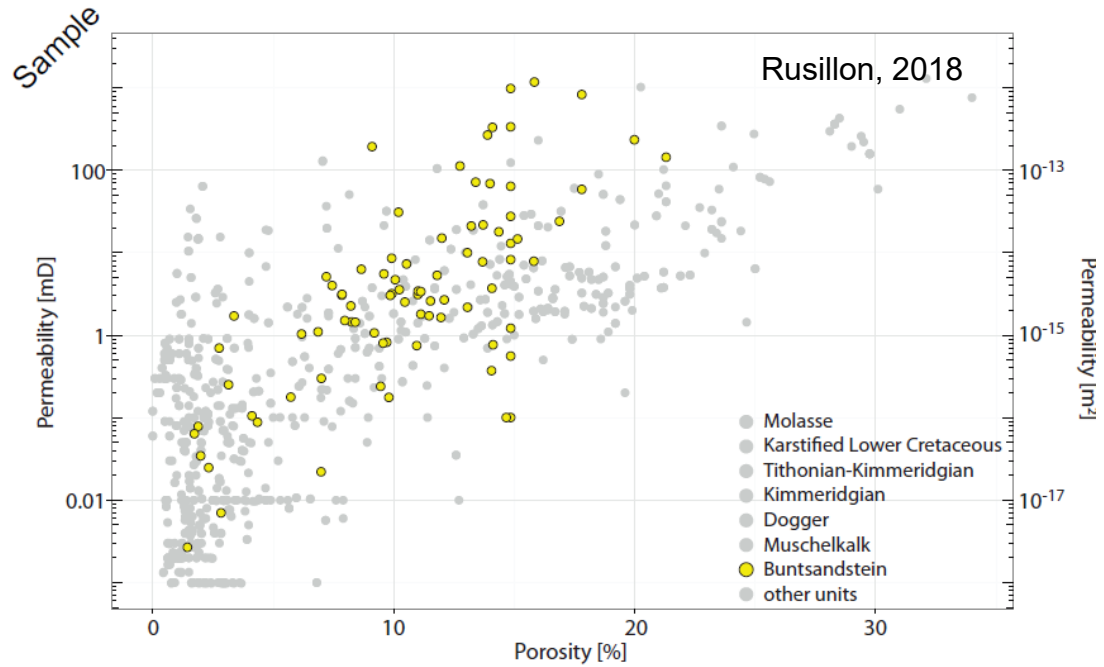


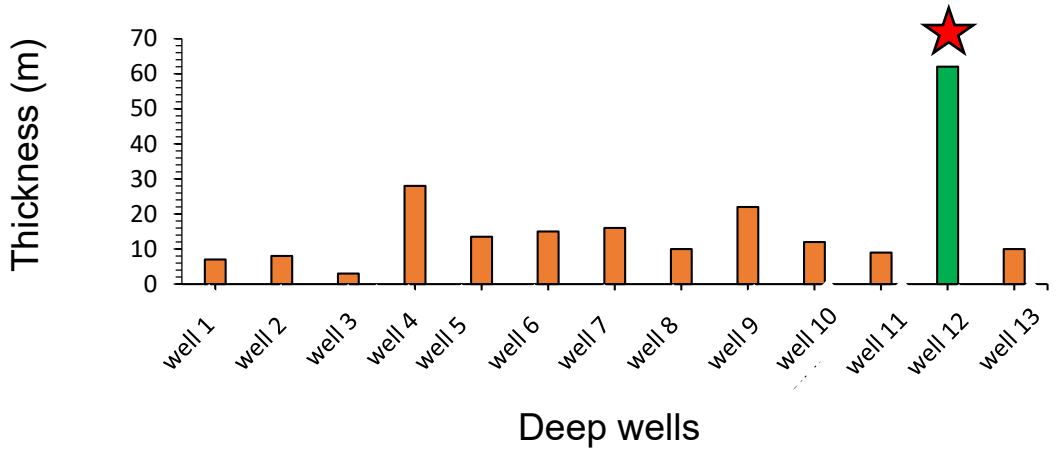
Location 3: looking for a good reservoir



Buntsandstein (core from Humilly-2)

Phi (%): 12 (14)
K (mD): 66 (0.42)
Dens (g/cm3)2.67(2.65)
Vp (m/s): 4765





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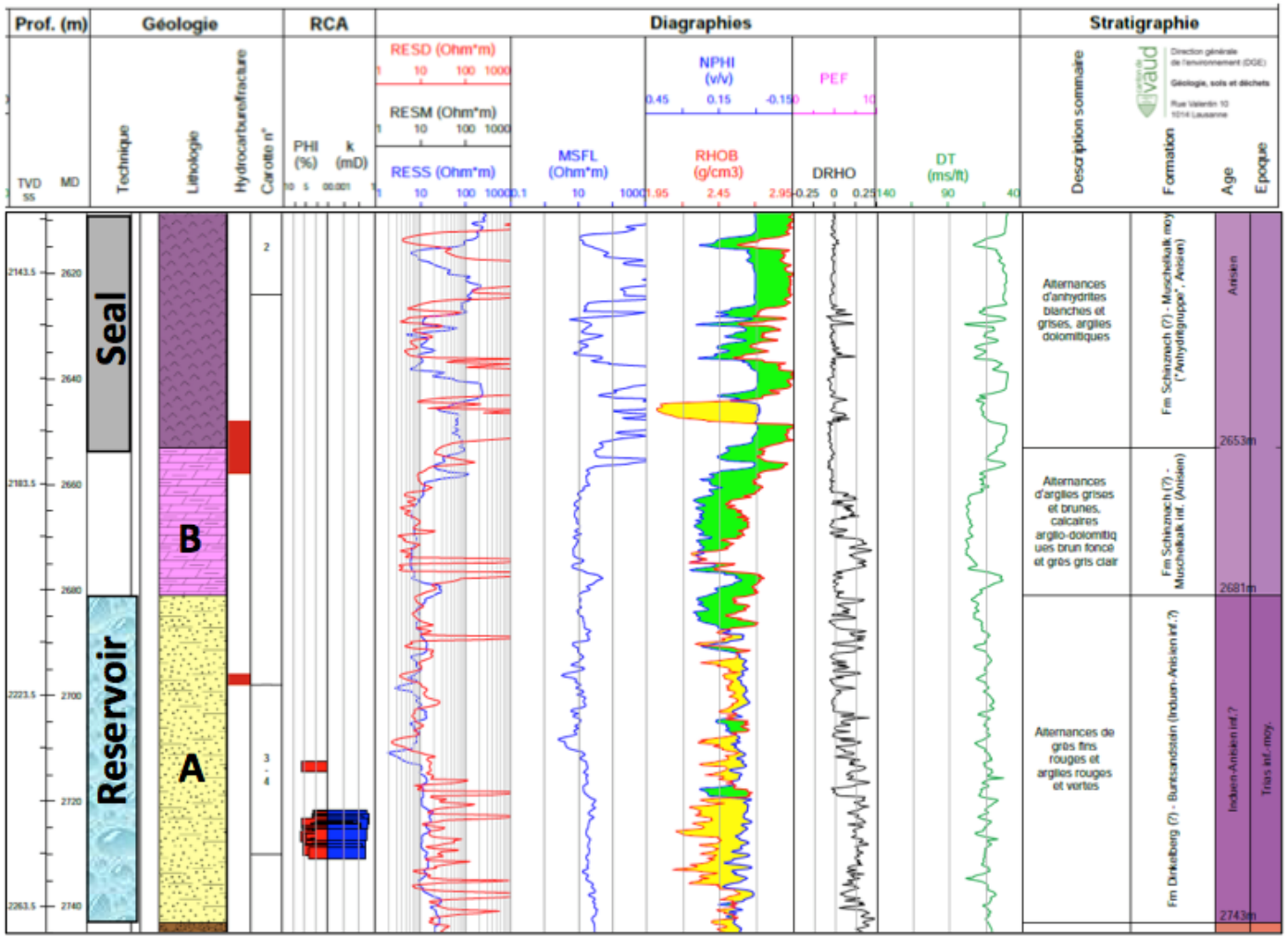
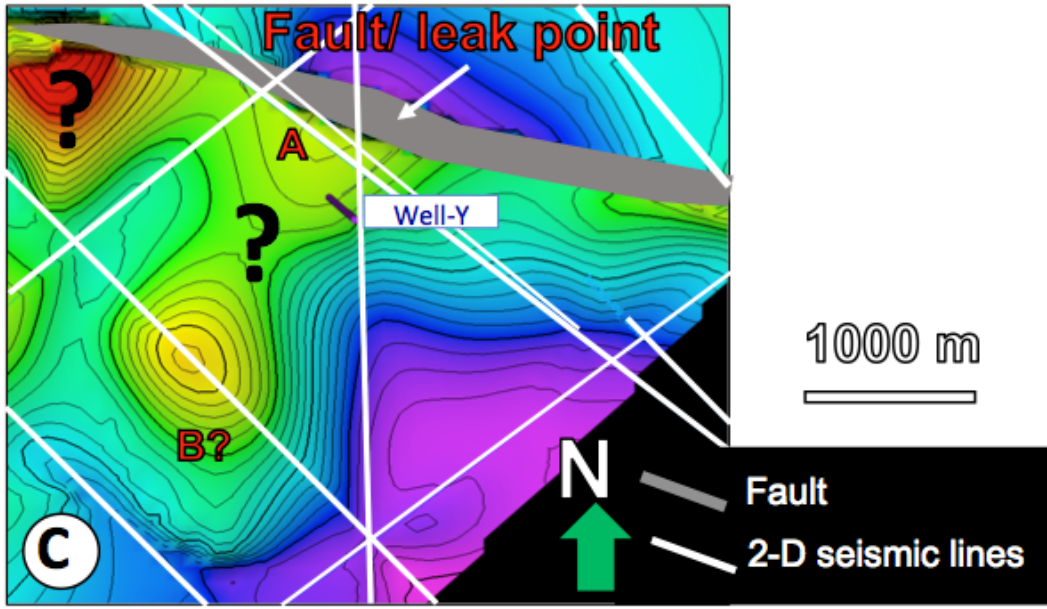




Structural Trap	Anticline		
Depth of reservoir/ aquifer (MD – m)	Top = 2'681	Base = 2'743	
Area of reservoir (m^2) Above spill point	Anticline A= $0.4\ 10^6$	Anticline B= $0.58\ 10^6$	
Porosity (%)	Min= 2%	Mean=3.5%	Max=6%
Thickness (m)	62		

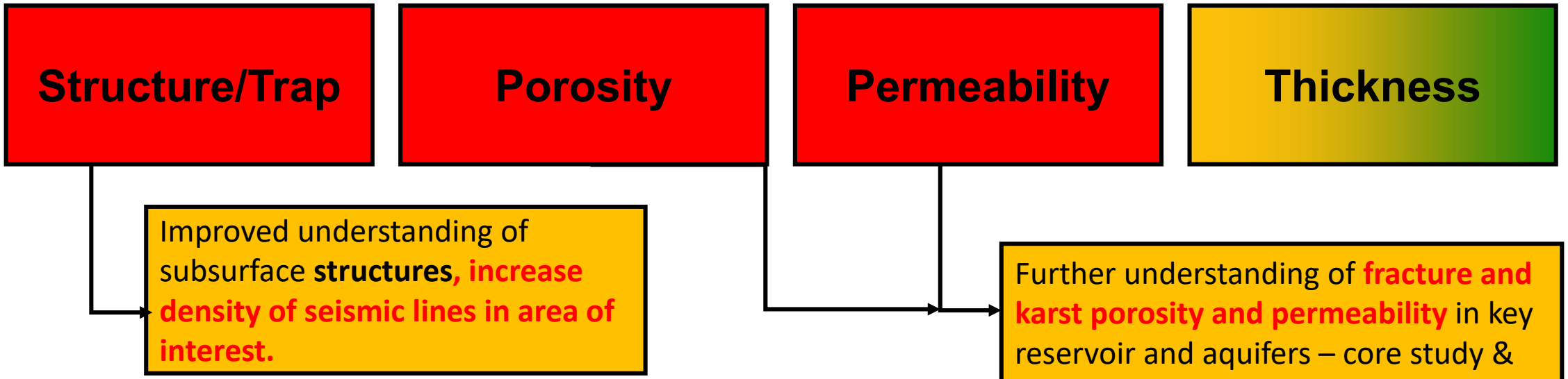
Site qualifying & delimiting factors

No	Criterion	Global best practice Positive indicators (e.g Chadwick et al., 2008; NETL, 2017)	Location A	Location B	Location C	Reference / remark
1	Storage capacity	> Planned CO_2 injection amount	Injection rate yet to be defined			Overall low storage capacity less than 1Mt may be suitable for a pilot project
2	Proximity to CO_2 source	Close to site	< 30 km	< 5 km	< 20 km	This study
3	Depth to reservoir/aquifer	> 800 m	4300 m	2042 m	2681 m	
4	Reservoir Area	m^2	No data	3.7 10^6 m	0.97 10^6 m	
5	Porosity	> 10%		1-7.5%	2-6%	
6	Permeability	> 300 mD		< 2 mD	<1 mD	
7	Reservoir thickness	> 20 m	20 m	62.5 m	62 m	
8	Caprock thickness	> 10 m	> 10 m	> 10 m	> 10 m	
9	Faulting and Fracturing	Limited to moderate				
10	Seismicity	Limited-moderate				SED
11	Hydrocarbon resource	Absent or small				
12	Site accessibility	Road, well head				This study- Google Earth
13	Socio-environ. concerns	Protected areas	UNESCO	NPA		This study
14	STORAGE VOLUME	Million Tons	0.2	0.07-0.32	0.03-0.05	

Uncertainty -> Risk

Low
Medium
High

CO_2 storage in the Swiss Molasse Basin
Preliminary conclusions



Uncertainty -> Risk

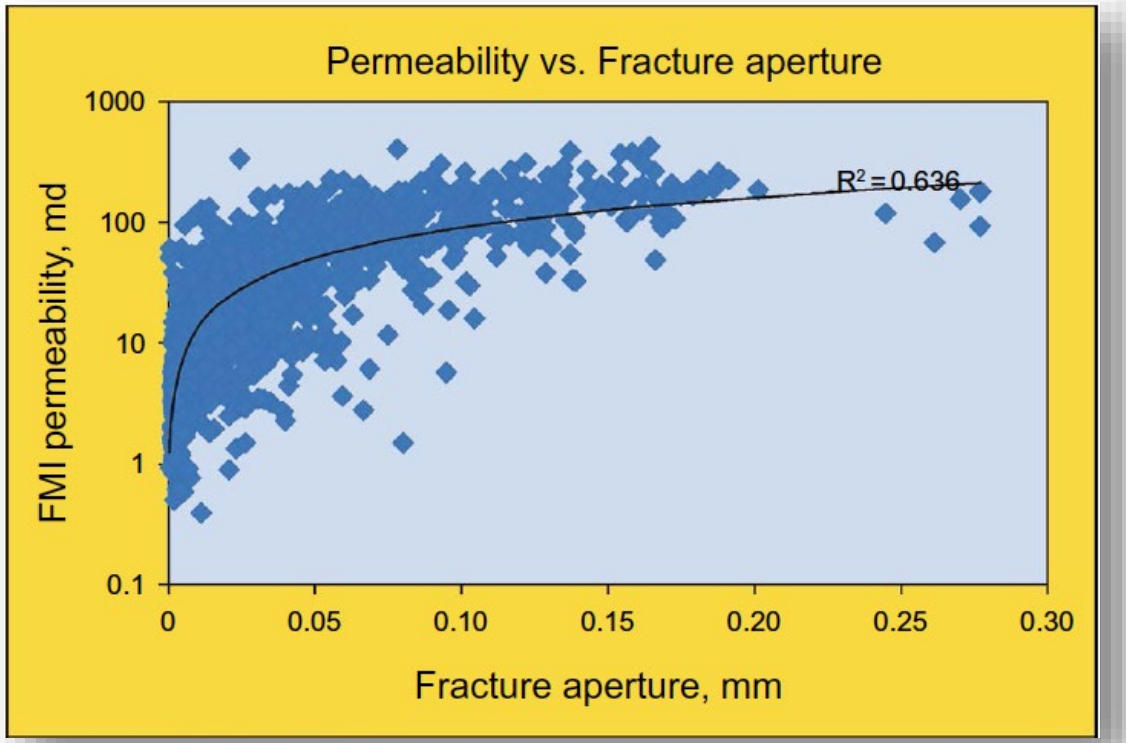
Low
Medium
High

The way forward?

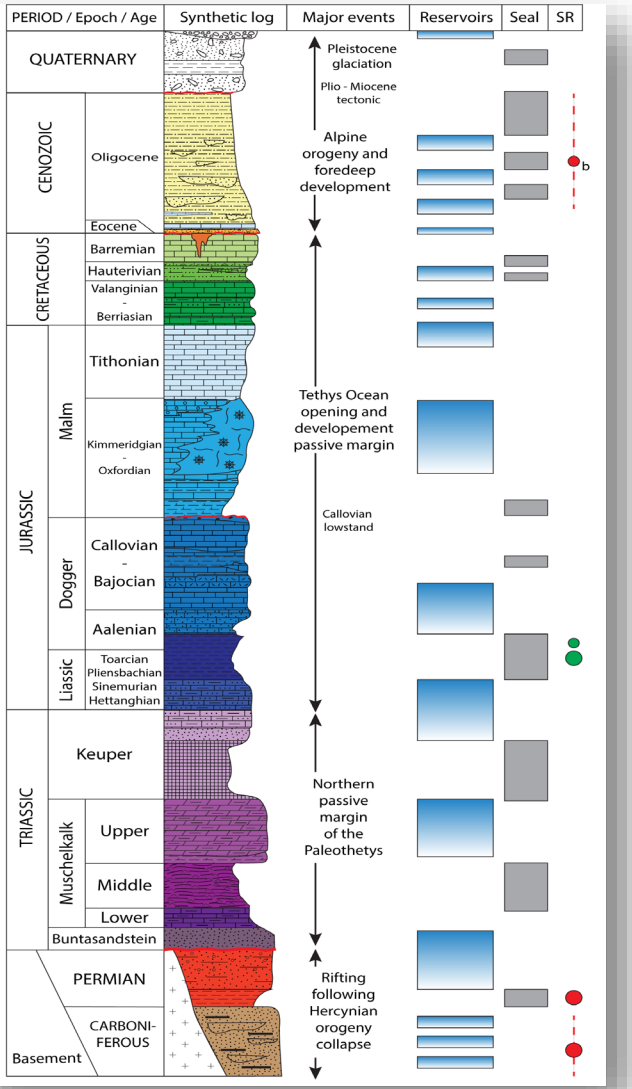
Outlook

- Site screening and selection activities are ongoing for other promising sites in other segments of the Swiss Molasse Basin characterized by geological structure capable of trapping injected.
- During the next phase, multiple realizations of **3D geological models** will be developed for the identified sites which will be populated with **realistic porosity and permeability** values representative of aquifer/reservoir interval and **fracture/karstic network** if their presence is envisaged.
- 3D static model allowing the **probabilistic-based volumetric assessment** of storage capacity will then be used as input for **dynamic simulation to understand the fate of the CO_2 plume** and will serve a basis for geomechanical modelling to predict induced seismicity associated with injectivity tests and the behavior of the faults.
- Multi-criteria decision analysis will be performed encapsulating all the sites to identify the best option.

Outlook: looking for Fractured Reservoirs & Effective Seals



Aghli et al., 2020

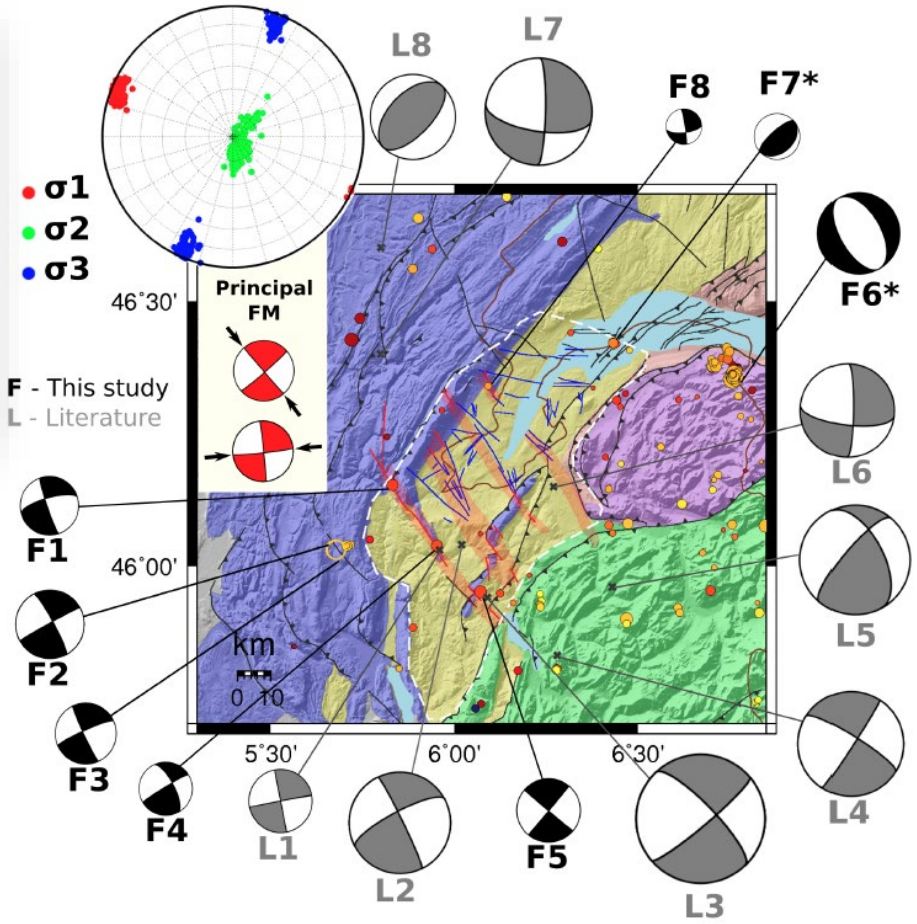


Moscariello, 2019

High dense network of fracture with a aperture between 0.1-0.2 mm can provide the required permeability to make CO2 injection viable, provided that seal integrity is ascertained.

Outlook: Does Switzerland have Effective Seals ?

Leu, 2011

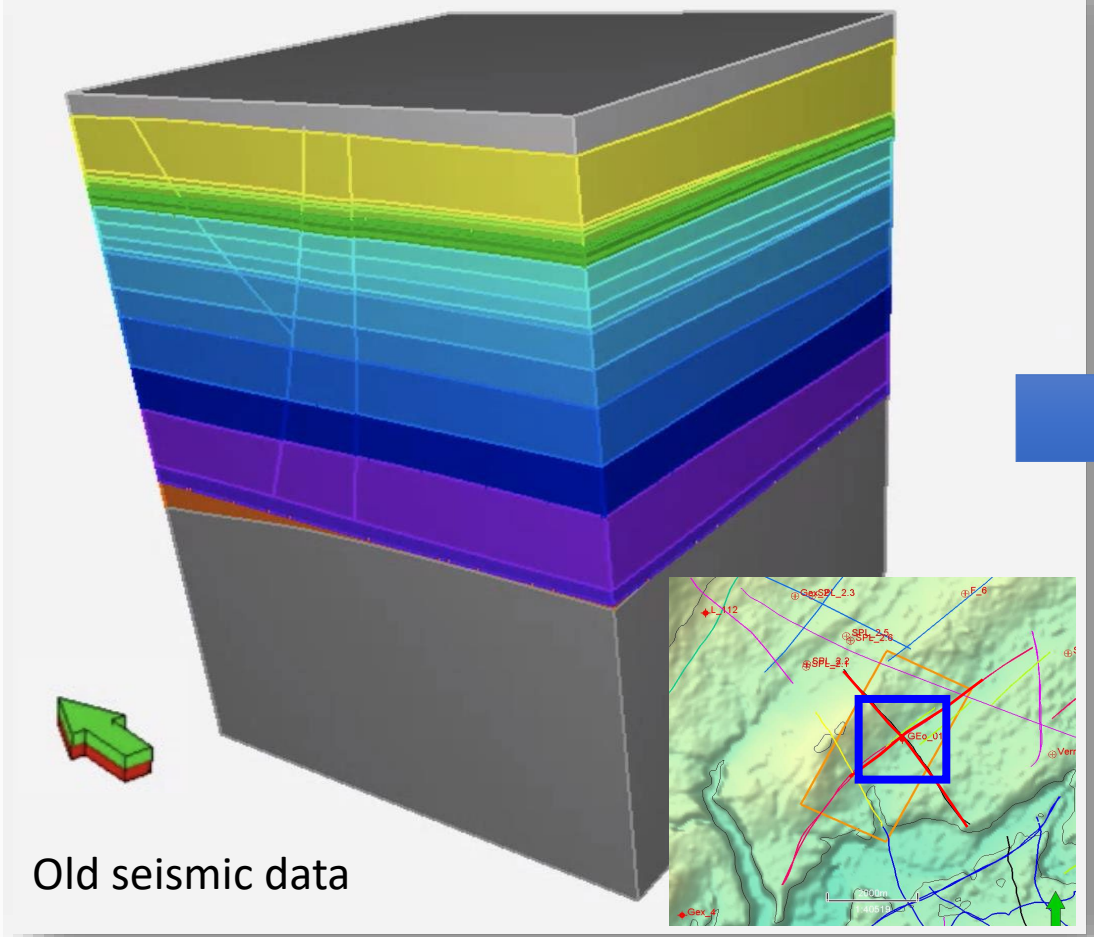


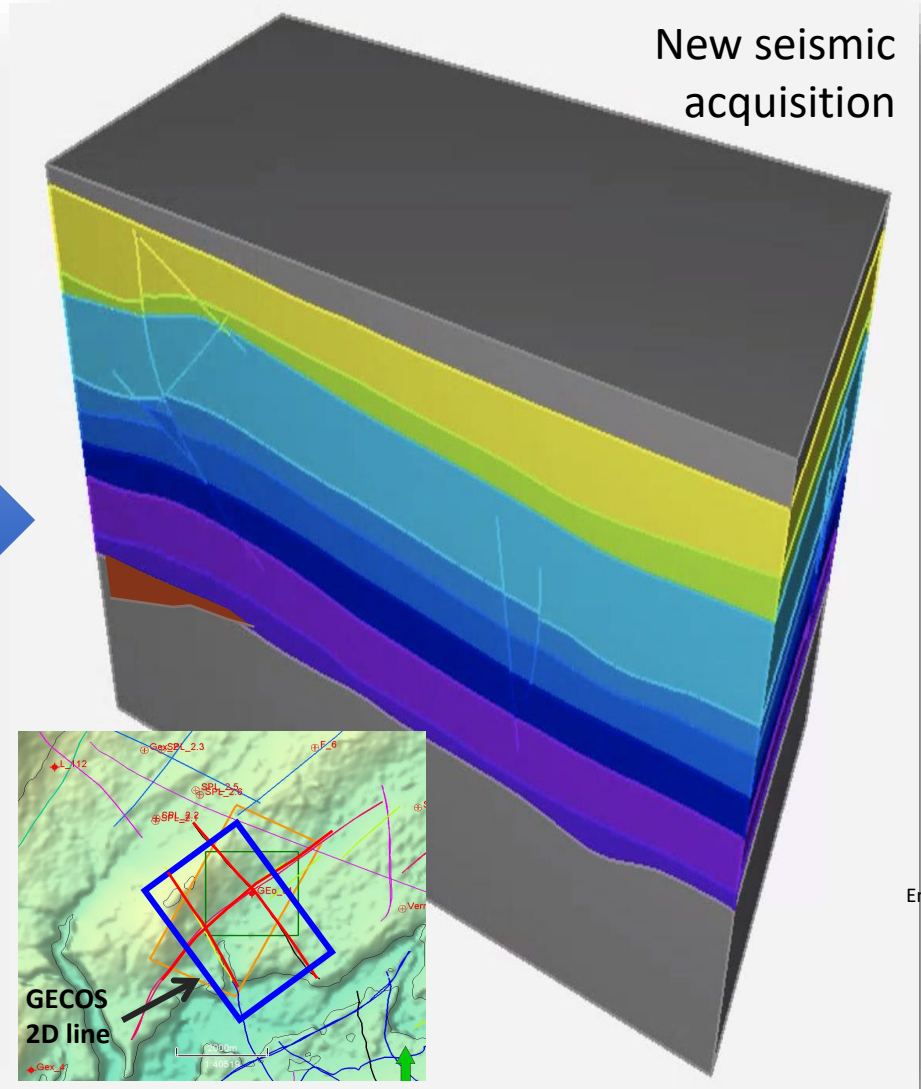
Antunes et al., 2020

Effective seals exists as few hydrocarbon discoveries have demonstrated (i.e. Eclepens, Essertines, Enthlebuch, Noville)

Recent kinematics of large strike-slips systems across the Swiss Molasse Basin must be better evaluated to assess the sealing potential of these systems

Outlook: looking for structural closure





Large impact on 3D reservoir modelling

GECOS
Geothermal Energy Chance of Success

heatstore
High Temperature Underground Thermal Energy Storage

https://www.current-news.co.uk/news/ofgems-decarbonisation-plan-begins-to-scratch-the-surface-says-sta-but-omissions-remain

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21 Feb / 2020 16:55

Molly Lempriere
Deputy Editor, Current±

SWISS decarbonisation plan begins to 'scratch the surface', but omissions remain

The Plan is lacking in incentives for decentralised renewable energy technologies says STA.

The Solar Trade Association (STA) has released its reaction to Ofgem's Decarbonisation Programme Action Plan, criticising "gaps" and providing ten recommendations.

In its response, the STA highlighted the regulatory instability caused by reforms such as the Targeted Charging Review (TCR) and the insufficient recognition for the challenges involved in gaining a grid connection for onshore renewables.

The plan is not sufficiently clear, the STA continued, and should have a longer term focus, stating "an 18-month framework is insufficient to provide the overarching, holistic approach toward decarbonisation that is needed".

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Thank you for listening