GÉOTHERMIE
Alsace du Nord
Terre d'énergies par es

Induced seismicity during operation of the Rittershoffen geothermal plant

Vincent Maurer[1], **Francesca De Santis**[2], **Olivier Lengline**[3], **Clara Wilmes**[1], **Clément Baujard**[1]

1 ES-Géothermie, France;
2 INERIS, France;
3 EOST/ITES, France

és géothermie

INERIS
maîtriser le risque pour un développement durable

Ecole et Observatoire des Sciences de la Terre

ÉS is operating 2 geothermal plants in the Upper Rhine Graben

GEIE EMC - Soultz-sous-Forêts

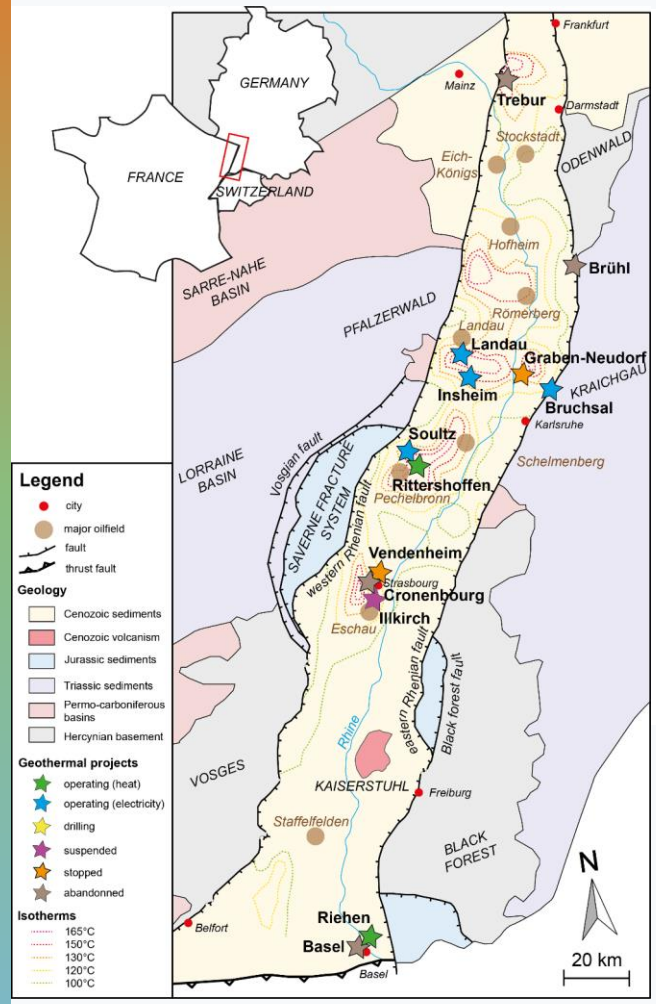
Electricity production since 2016
3 wells in operation at 5 km deep
Reservoir: fractured granite
Temperature: production 130°C / reinjection : 70-80°C
Flow rate : 30 L/s ; P_{WH}=20 bar
ORC installed capacity: 1.7 MW electric
2,200 tons CO_2 saved / year

ECOGI - Rittershoffen

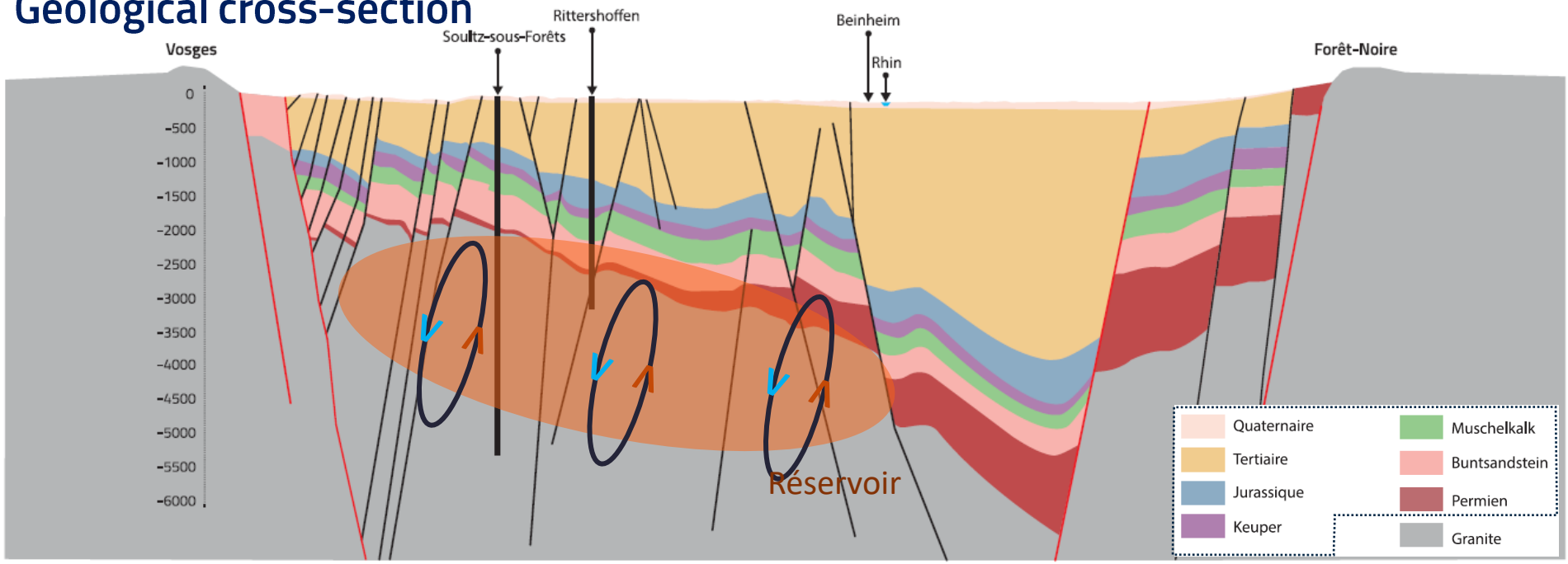
Heat production at high temperature since 2016
2 wells in operation at 2.5 km deep
Reservoir: sandstone and fractured granite
Production temperature: 168°C / reinjection : 85°C
Flow rate 80 L/s; P_{WH}=14 bar
Installed capacity: 24 MW thermal
43,000 tons CO_2 saved / year

1st TWh of heat produced in 2022

The Upper Rhine Graben

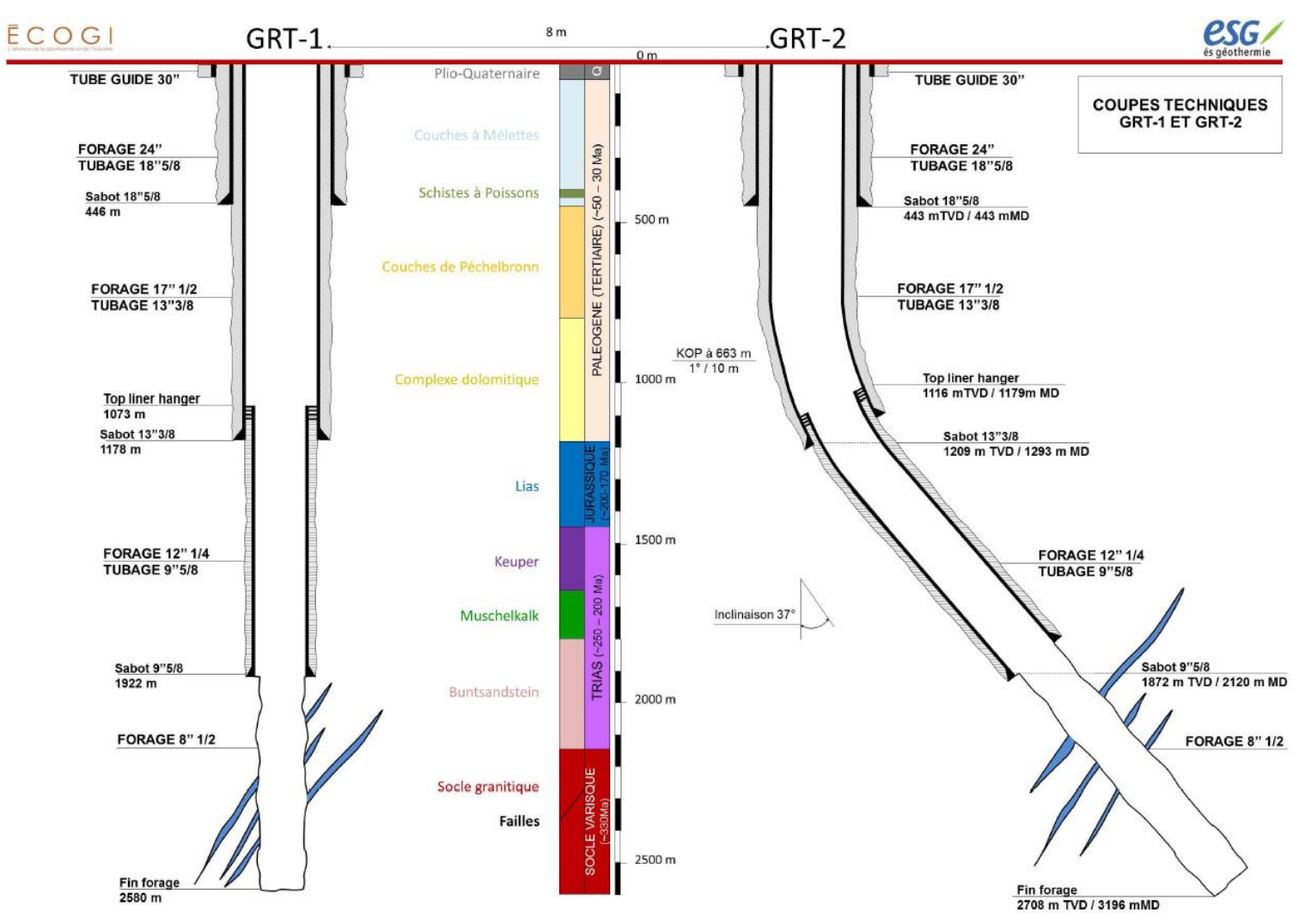


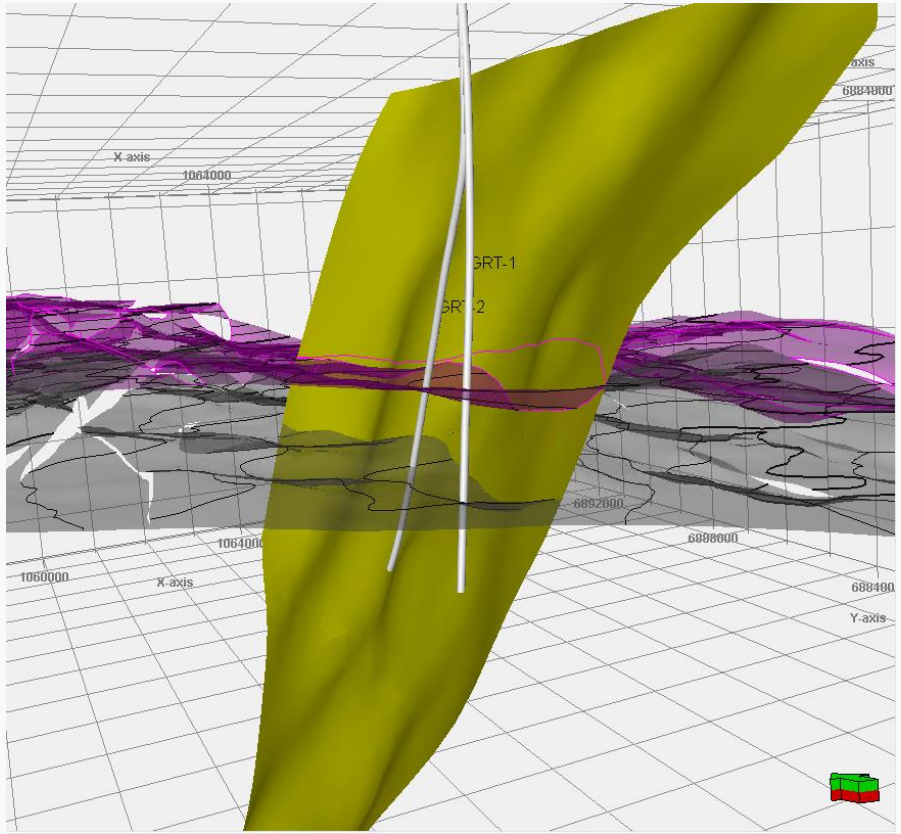
Geological cross-section



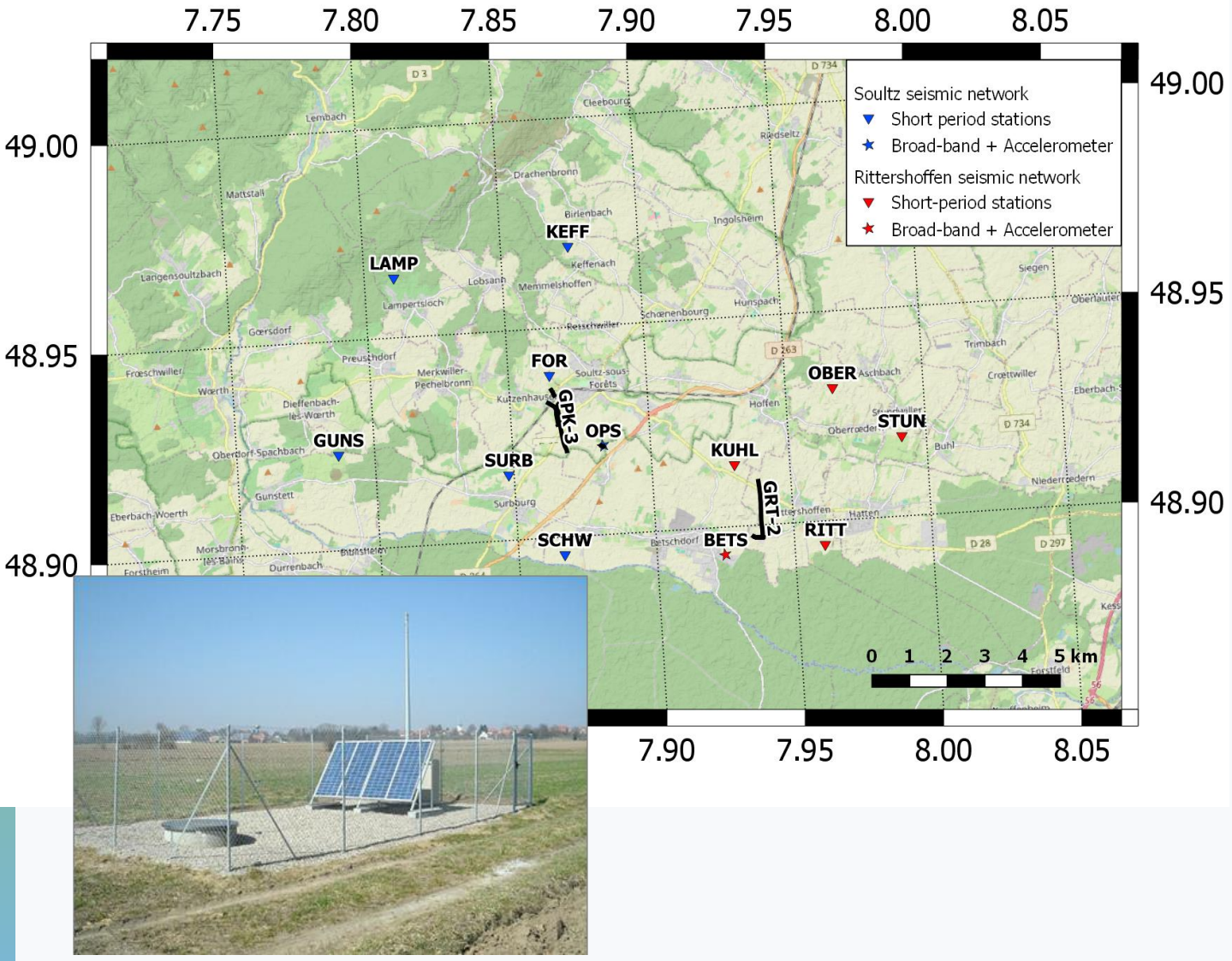
- A geological history: faults and natural fractures
- Geothermal fluid circulating in these structures
- High temperatures at accessible depths

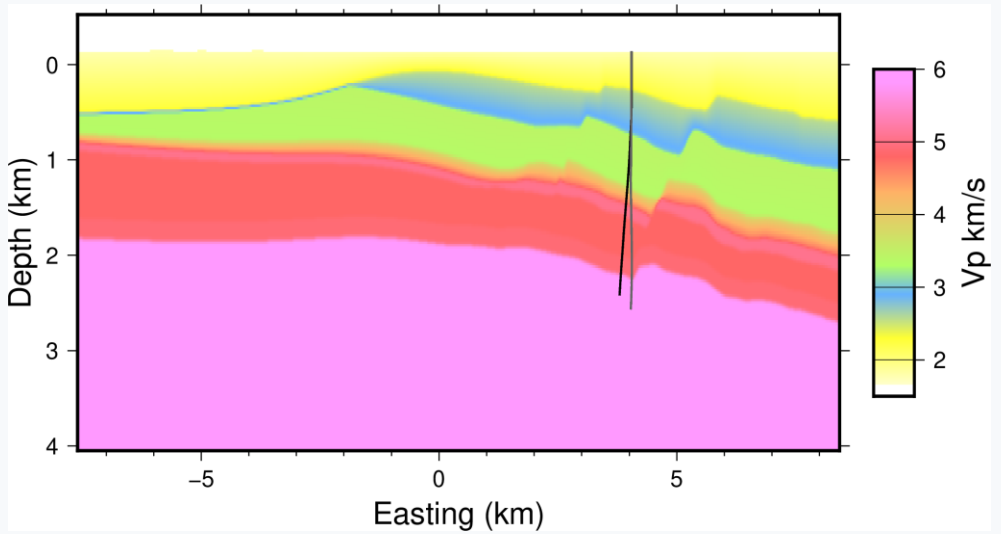
The wells: a deviated productor well & a vertical injection well





Seismic monitoring network and velocity model



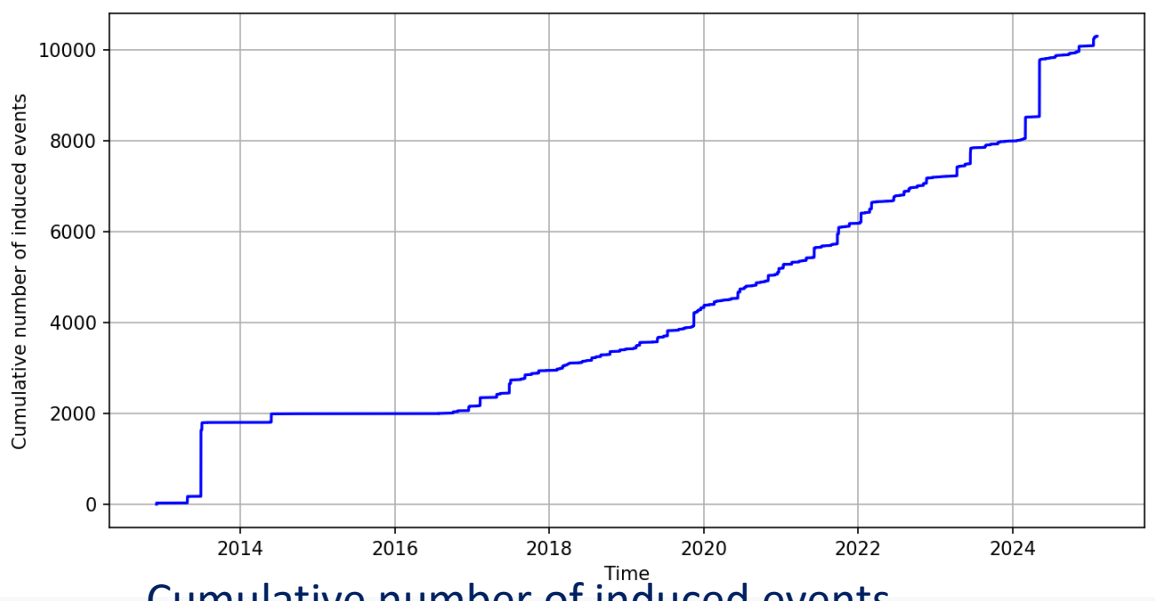


- 12 permanent stations operating since 2012
- Densification of the network during key operations (stimulations, commissioning,…)
- All events repicked and relocated into a 3D local velocity model

Seismic monitoring

Summary at date (2012-2025):

- 10 300 induced events repicked:
  - 2000 during drilling & stimulations
  - 8300 during exploitation
- > 500 natural events in a range of 20 km
- Magnitude max : 2.3 (2024-05 and 2024-07)
- PGV max : 3.2 mm/s (2024-07-24)

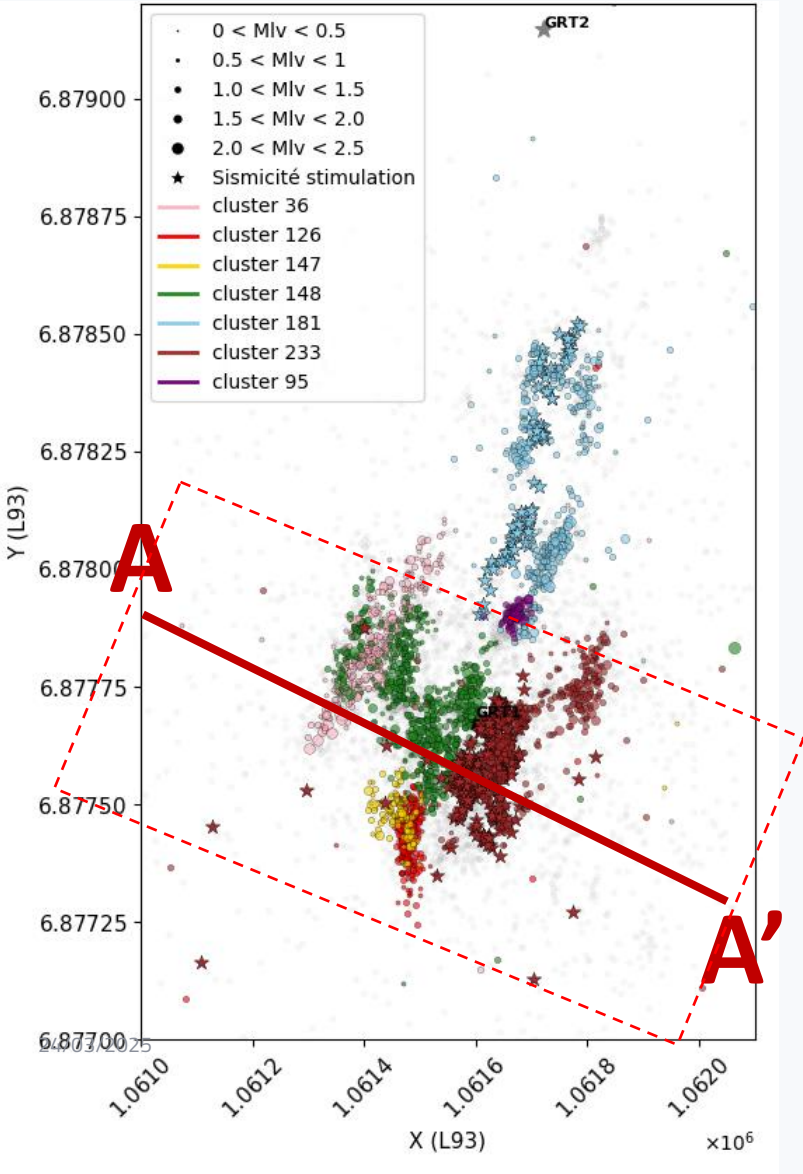


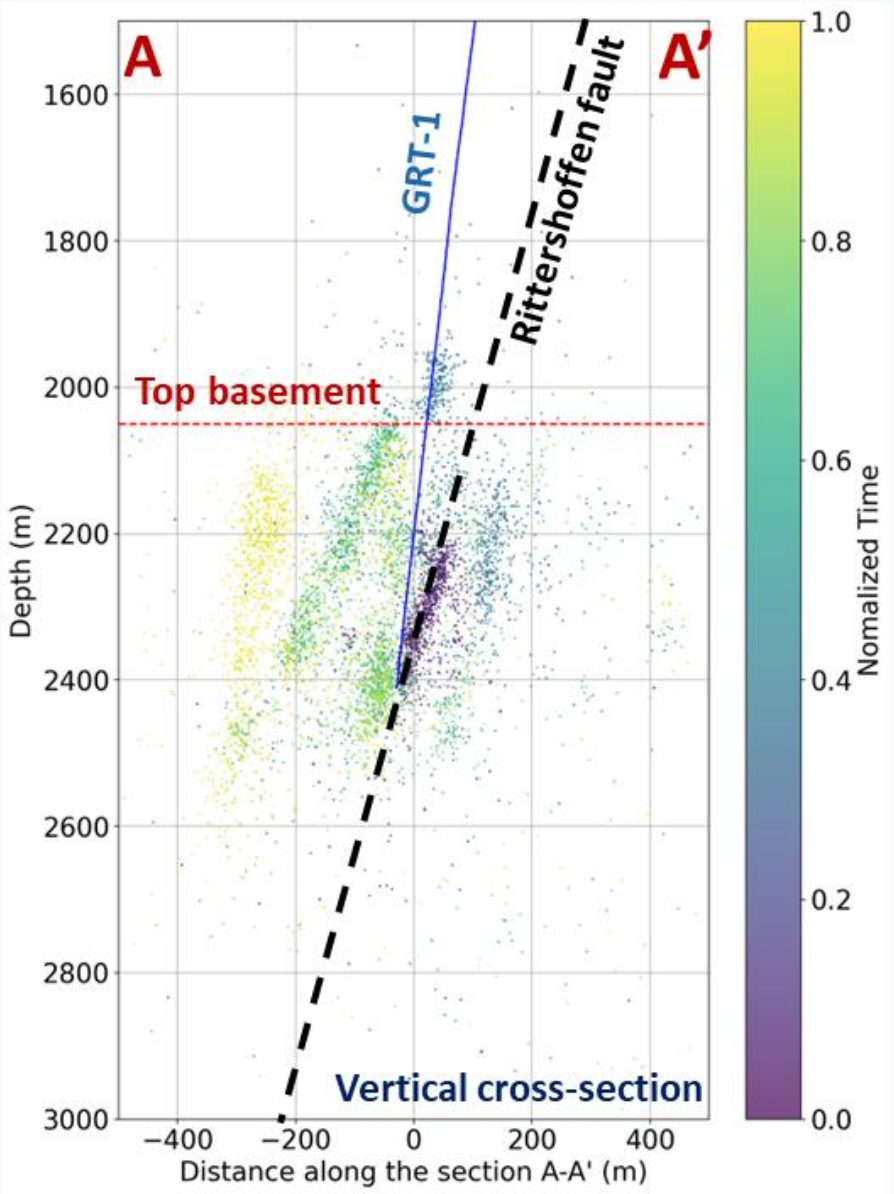
Cumulative number of induced events

Year	Number of IE
2012	26
2013	1773
2014	193
2016	166
2017	786
2018	468
2019	913
2020	864
2021	990
2022	1018
2023	795
2024	2096
2025	207

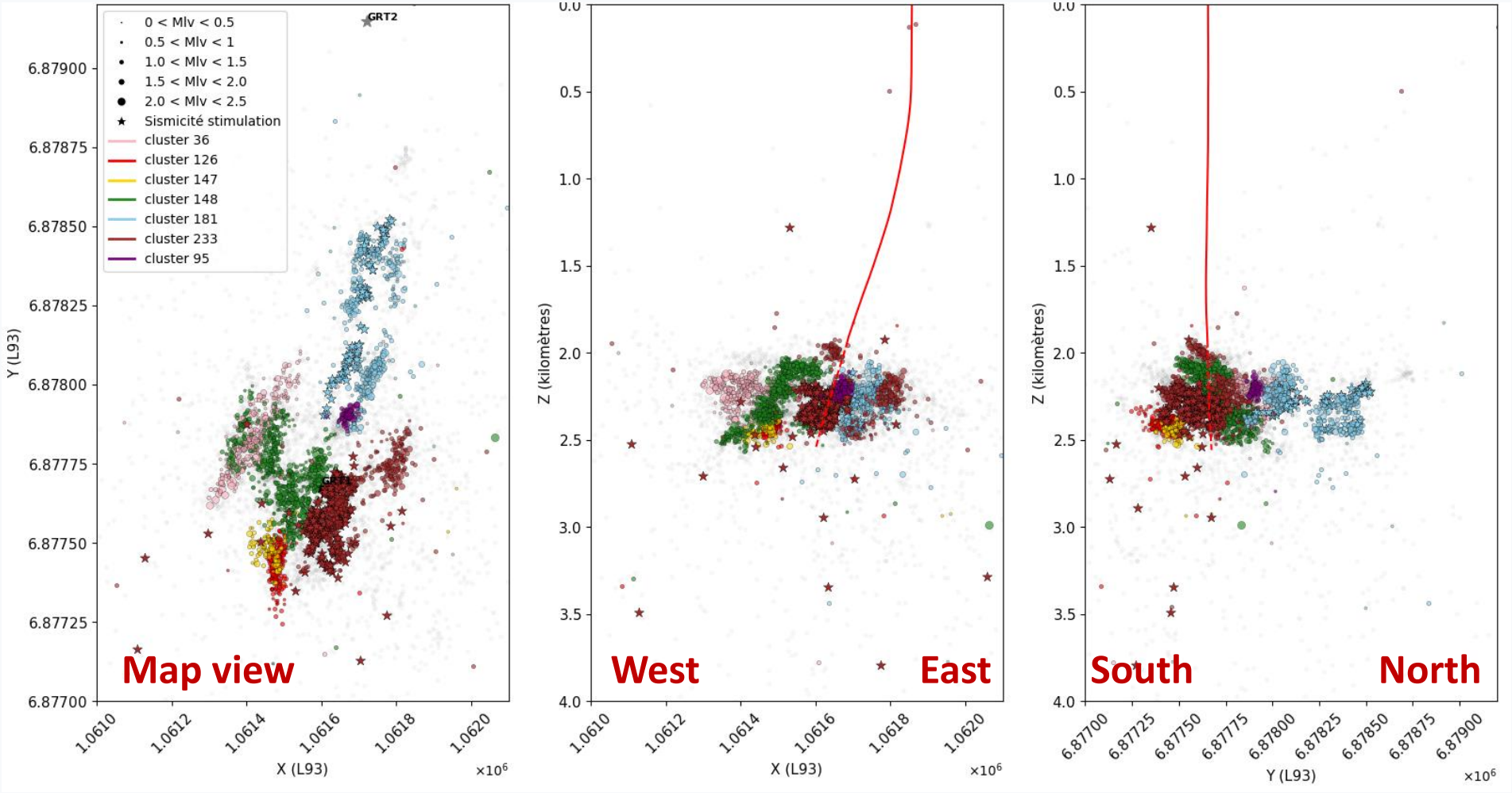
Absolute locations

Long-term migration of the induced seismicity





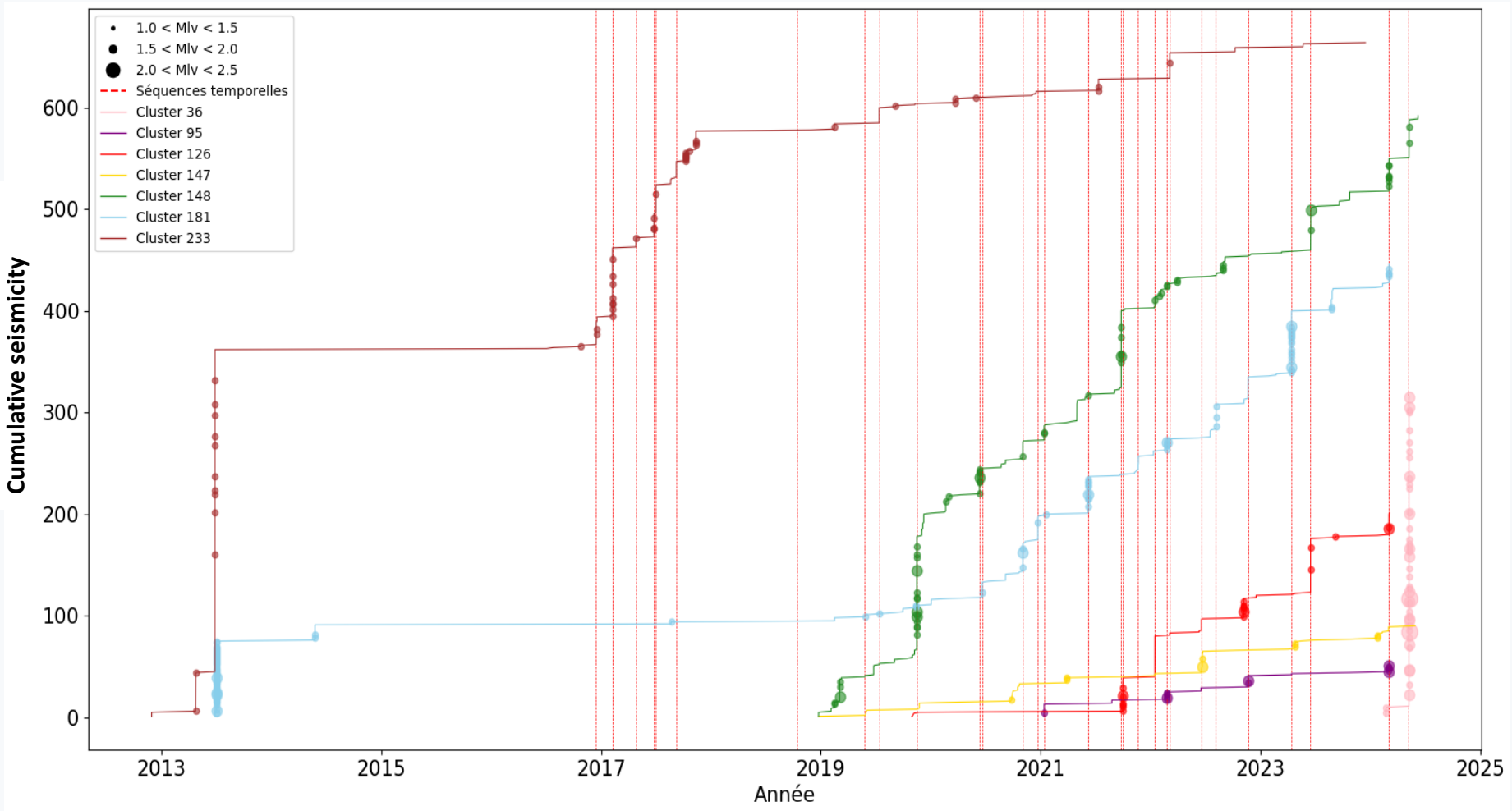
Waveforms correlation clustering



WFs correlation clustering :

- Corr > 0,7
- Based on a single station (BETS)
- Identify different active structures based on the pattern of the seismic signal

Waveforms correlation clustering

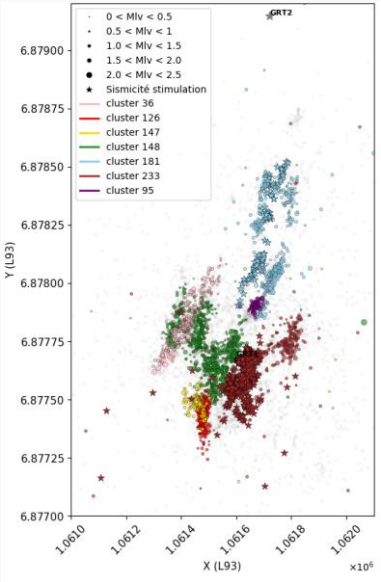


During stimulation:

- Cluster 233 (b-value = 3.1)
- Cluster 181 (b-value = 2.2)

During exploitation

- Cluster 148 (b-value = 1.8)
- Cluster 147 (b-value = 1.4)
- Cluster 126 (b-value = 1.3)
- Cluster 95 (b-value = 1.2)
- Cluster 36 (b-value = 1.1)

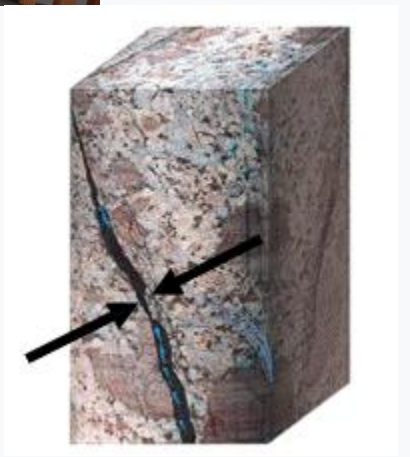


What is triggering the seismic sequences ?

GÉOTHERMIE Alsace du Nord Terre d'énergies par es

Injection pressure?

- The injectivity index of the well was significantly improved during exploitation (Currently P_{inj}<5 bar in the reservoir)
- Direct effect on seismic activity is rather unlikely as pressure is in steady state regime



Injection temperature?

- Propagation of the cold-front could induce seismicity directly by the reduction of the friction coefficient due to the thermal contraction of the rocks
- Variations in thermomechanical stresses favoring the reactivation of pre-existing faults
- May explain the long-term migration

Chemical processes?

- Plug and stimulate phenomena ? Not visible on well-head pressure
- May explain the long-term-migration

Aseismic movements can also be considered

Conclusion

The progressive decrease in b-values is consistent with the progressive alignment of seismicity with an existing structure and allow to consider two scenarios

Scenario 1:

- Activation of new clusters will continue linked to a continuous migration of seismicity (could be associated with an increase of the magnitudes)

Scenario 2:

- A progressive attenuation of the seismicity after relaxation of the critically stressed faults in association with a good injectivity index and a stabilization of the migration of the seismicity

Thank you for your attention !

The authors would like to thank:

This work was carried out within the framework of the AIS project (ANR ANR-22-FAI2-0008-02).

For more information see also Poster Session: Case Studies
P-3: Characterisation of microseismic sequences induced by the Rittershoffen deep geothermal project (Clara Willmes)

See also Lengliné O., Maurer M., Yorillo A. (2025). Intermittent induced seismicity during the multi-year operation of a geothermal reservoir, *submitted to Geophysical Journal International*.