

France Nord Project

> Joint Industry Project

- Funded by ADEME (French Environment and Energy Management Agency)
- 4 public research institutes
- 7 industrial partners



> Main goals

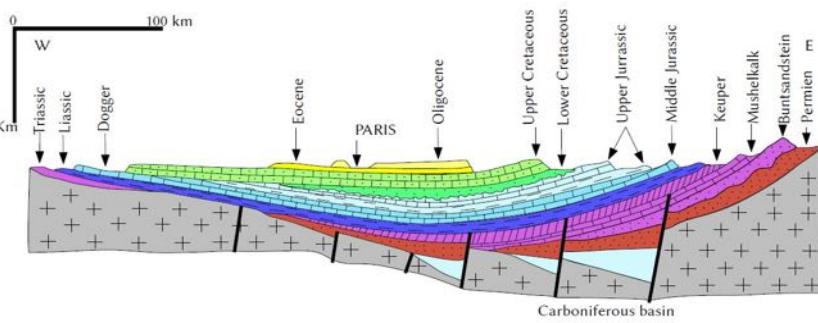
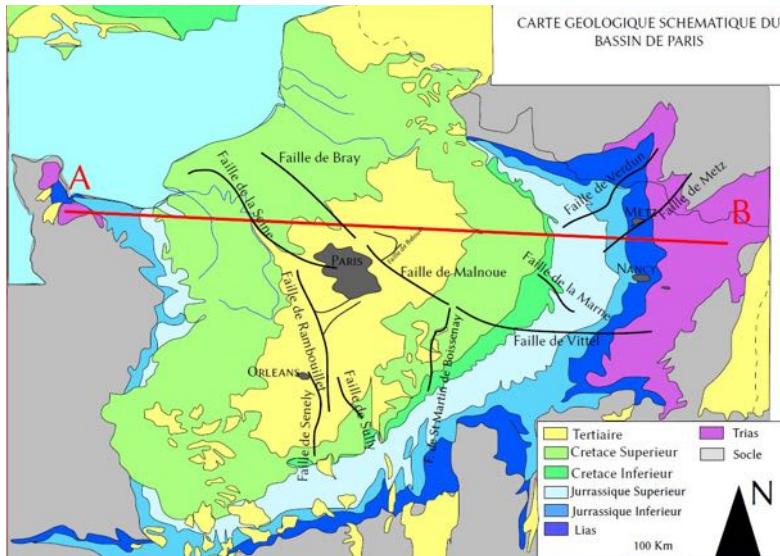
- Feasibility of CCS in the Northern part of France (Paris Basin)
- This presentation is reviewing the main findings concerning the CO₂ storage evaluations.

Qualify, on the basis of available data one site to store at least 200Mt of CO₂ during 40 years of injection in the deep saline aquifers of the Paris Basin.



Criteria for aquifer selection

> In the Paris Basin



3 stratigraphic targets :

- Buntsandstein sandstones
- Keuper fm. (Donnemarie, Chaunoy, Boissy)
- Dogger limestones (Bathonian + Callovian)

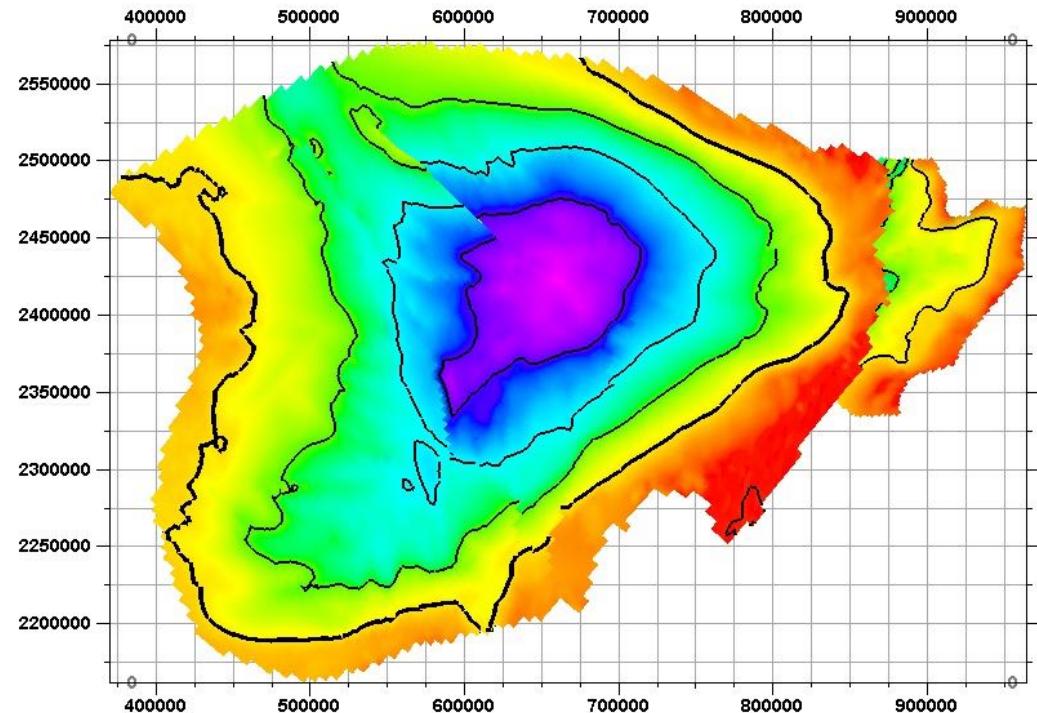
Regional modeling (basin scale)

> **Objectives** : Select storage site(s) with at least a capacity of 200Mt CO₂.

> **3 regional models**

- Buntsandstein (BRGM)
- Keuper (IFP-EN)
- Dogger (BRGM)

- with a common structural scheme,
- from available data (common dataset),
- petrophysical filling at basin scale
- definition of the boundary conditions of aquifers
- selection of suitable injection sites



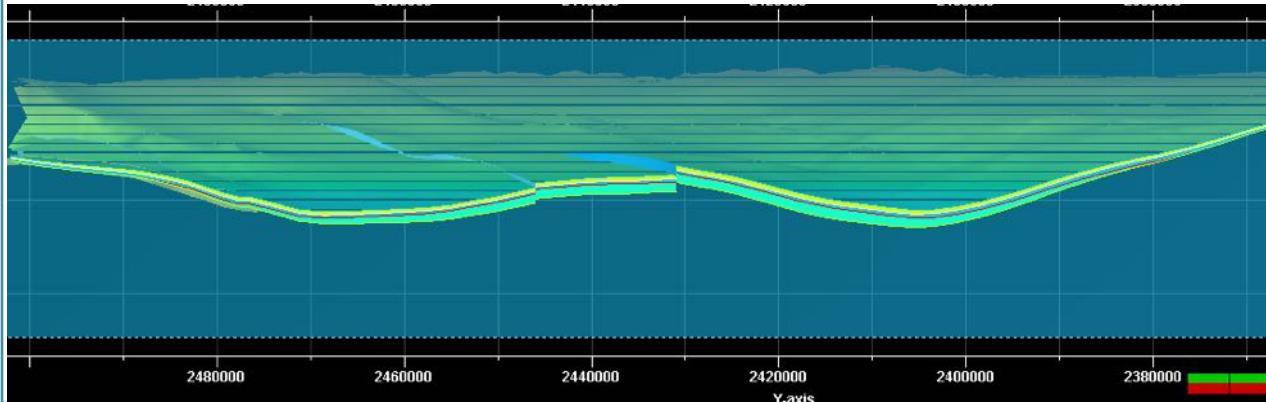
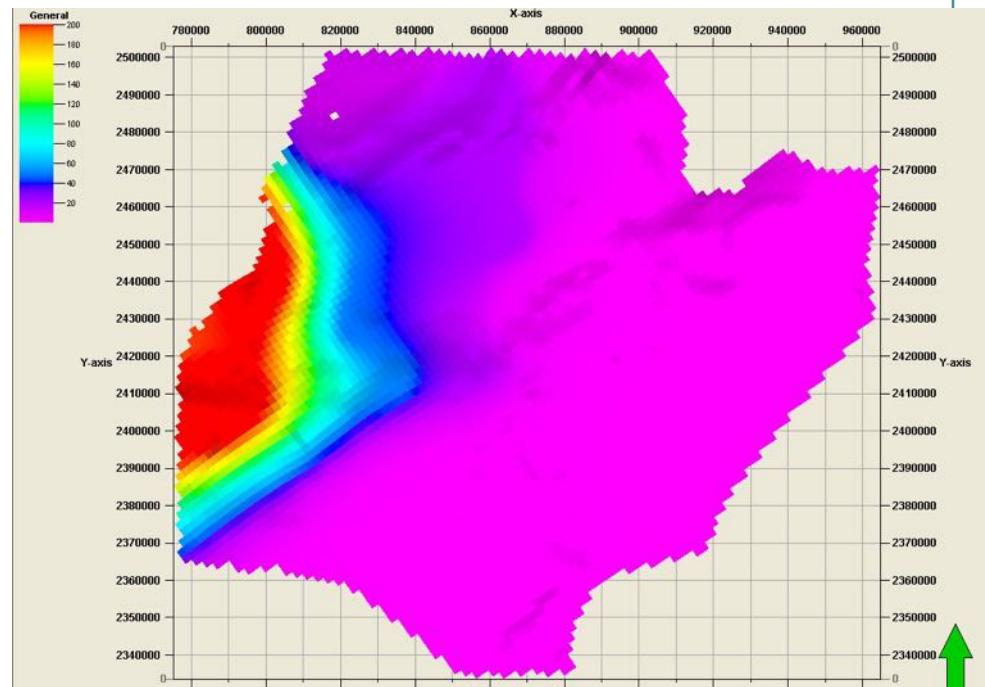
During this phase of the project, 5 sites with a 200 Mt CO₂ potential storage capacity were identified.
3 site were subject to a more detailed modeling (Storengy)

Buntsandstein – Regional modeling

> Static modeling

model size : 200 km x 200 km
3 zones / 10 layers
cells size : 2km x 2km
100 000 cells

4 properties : Porosity
Permeability
Temperature
Salinity



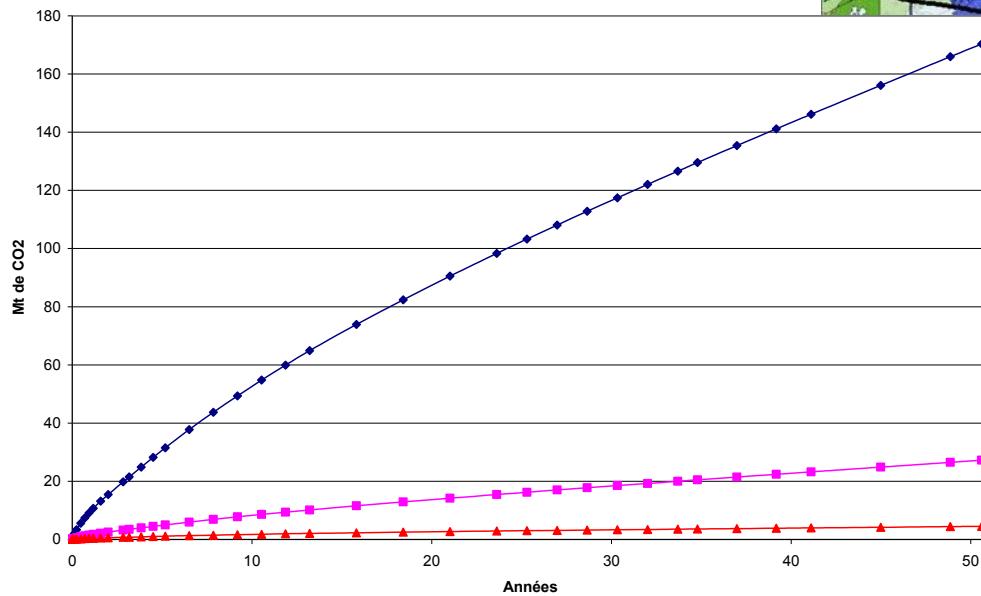
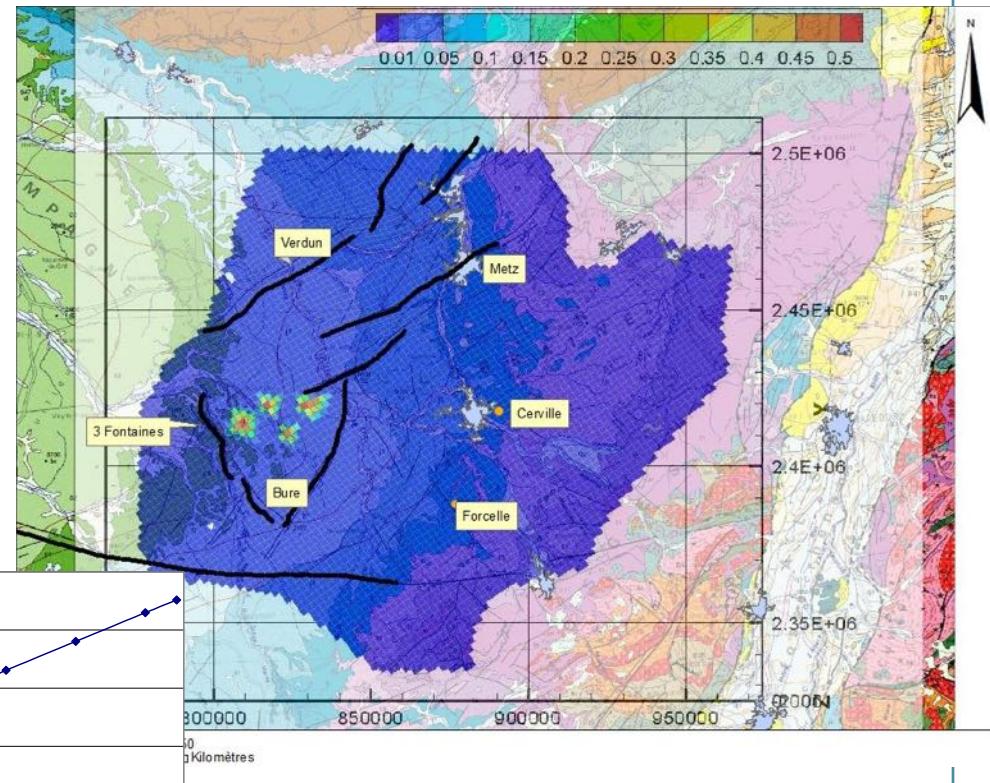
Buntsandstein – Regional modeling

> Injection simulations

4 wells

distance between wells : 30km

202 Mt injected in 40 years
mainly in the upper zone (Grès à Voltzia)



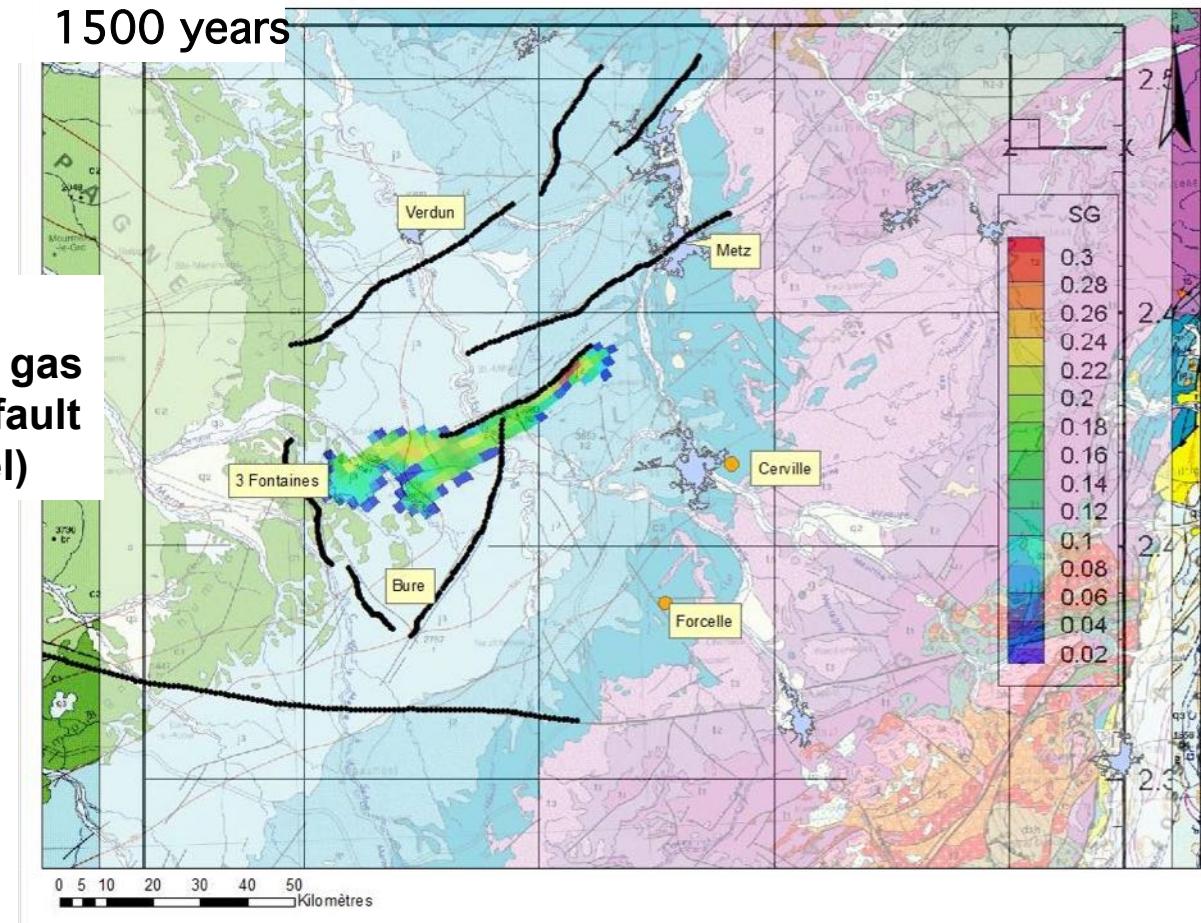
Buntsandstein – Regional modeling

> Post injection

overpressure

gas saturation

after 1500 years,
lateral migration of gas
along Seycheprey fault
(in the storage level)

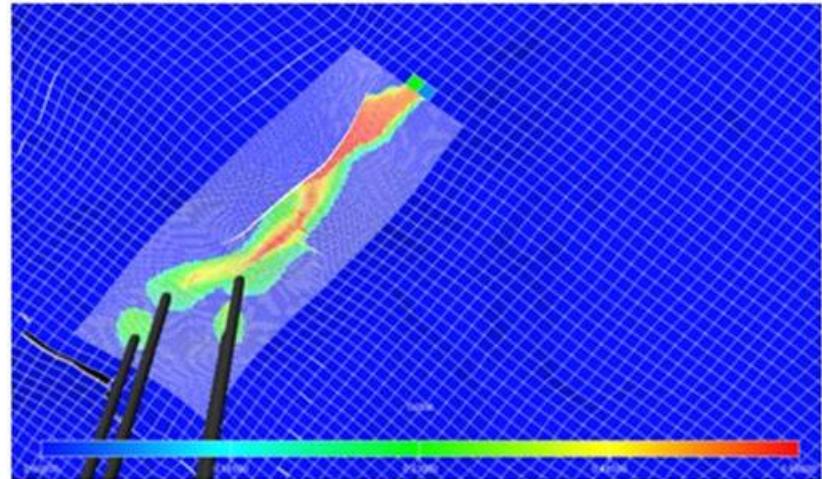


Buntsandstein – Site modeling

> Optimisation of the gridding

around injection wells

along the Secheprey fault



> Review of the petrophysics

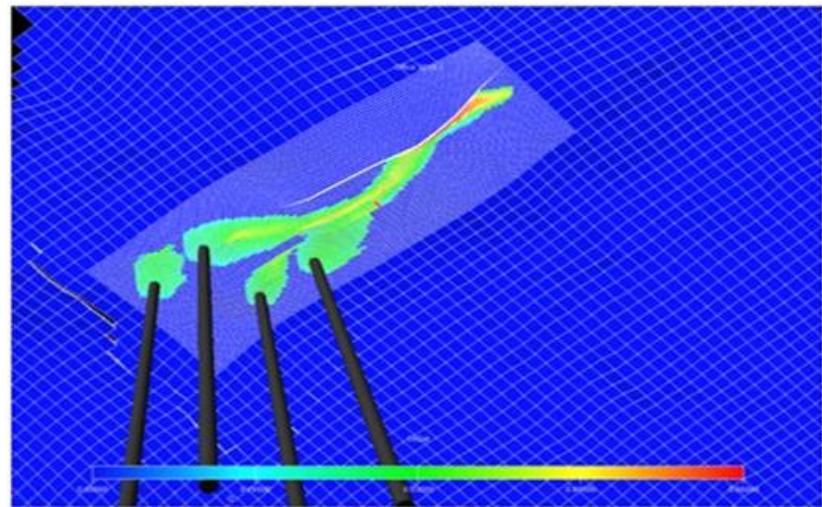
permeability

capillary pressure (Pc)

> Optimisation of the wells location

→ Storage potential reassessed to 133Mt

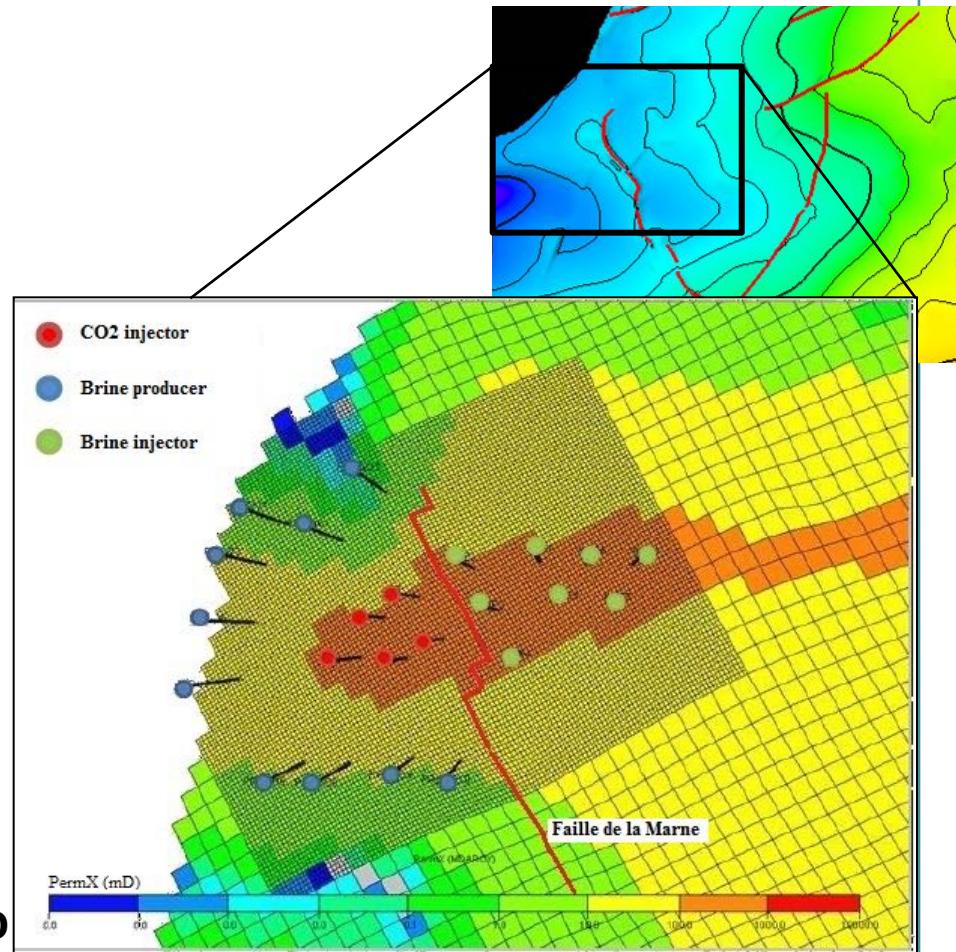
Confirmation of CO₂ migration along the fault



Buntsandstein – Site modeling

> Alternative case

- Injection west of the Marne fault in a zone where reservoir properties are significantly less favorable.
- Water injection east of the fault
- 23 wells (5 CO₂ injectors, 10 brine producers and 8 brine injectors)



→ Storage potential : 87.5 Mt

Necessity to produce brine to keep reasonable pressure in the reservoir.

Keuper – Regional modeling

> Static modeling

model size : 400km x 520 km

8 zones

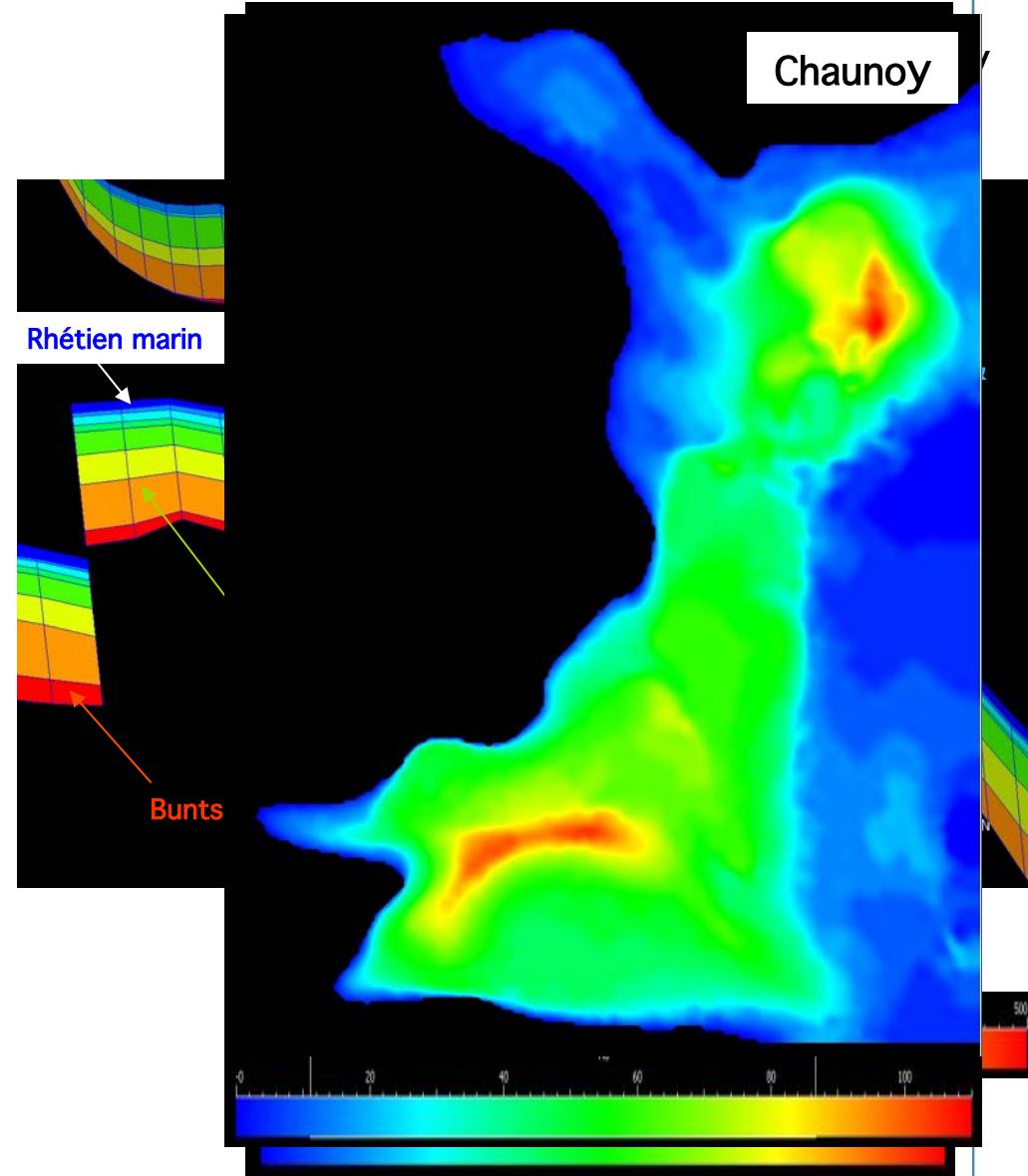
cells size : 4km x 4km

100 000 cells

3 properties : Porosity

Permeability

Effective thickness



Keuper– Regional modeling

> Injection simulations

2 area of interest :

Keuper Nord

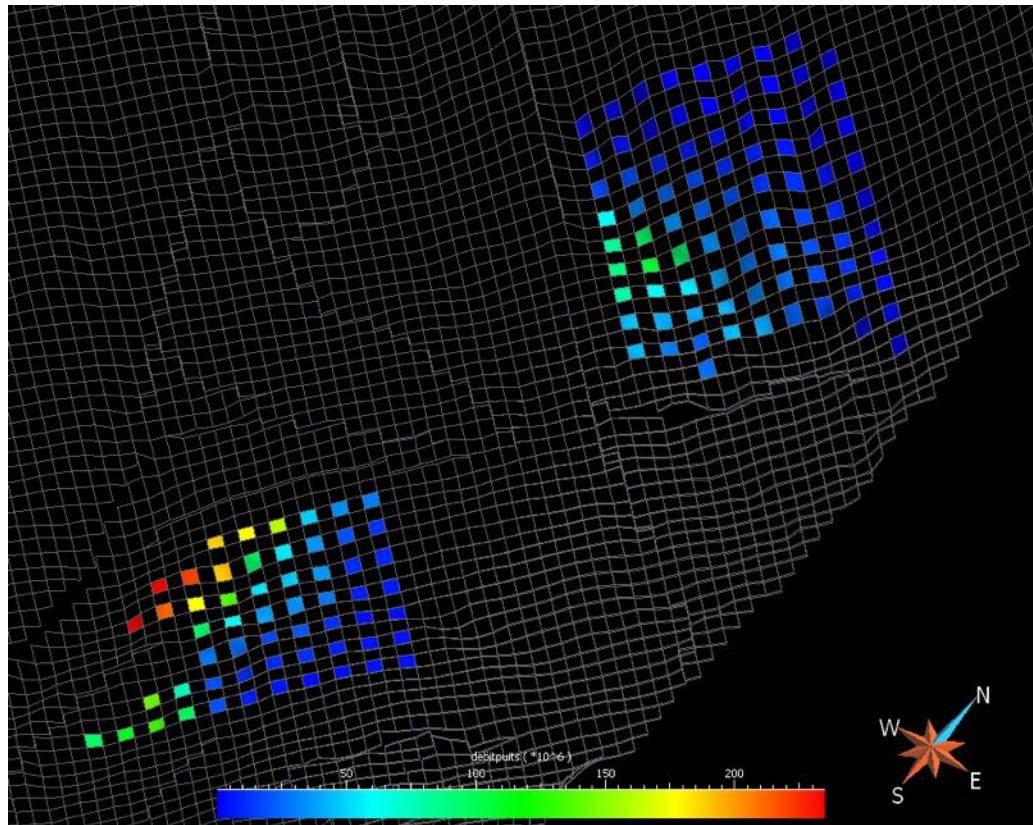
Keuper Sud

Keuper Nord :

6 wells necessary to inject 200 Mt of CO₂ in 40 years.

Keuper Sud:

SW of the area, 1 well can be sufficient to inject 200 Mt of CO₂ in 40 years.



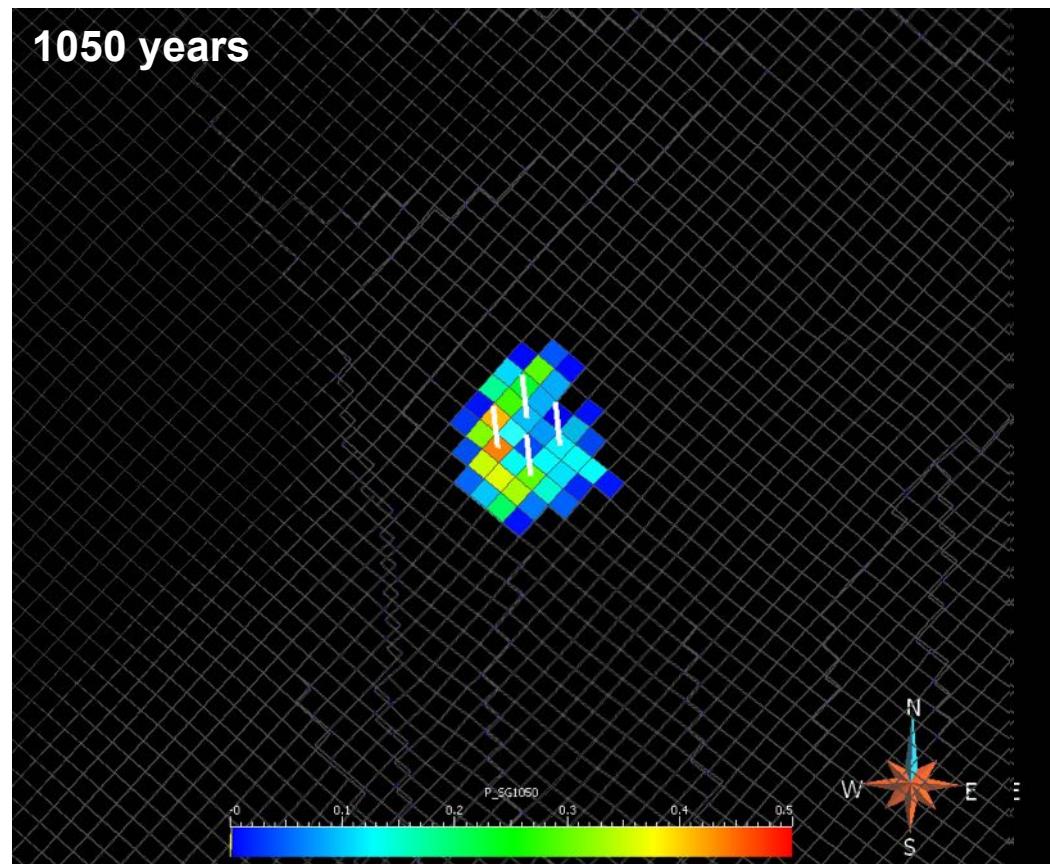
Keuper – Regional modeling

> Post injection,

Example of Keuper Sud
with 4 wells

overpressure

gas saturation



Keuper Sud – Site modeling

> Refinement of the model

- Vertical layering from 8 to 28 layers,
- New constraints on the structural scheme,
- Petrophysical analysis from cores, logs and production test.

→ Reduction of the net thickness estimation for all layers (~2.5 factor)

This can be explained by a very heterogeneous reservoir (fluvial deposits – horizontally and vertically unconnected channels).

Modèle IFP Unités v #1	STORENGY
Rhétien marin	modèle local argiles supérieurs (couverture)
Boissy sup.	Chalain Supérieur (Argiles et chenaux mal connectés)
Boissy inf.	Chalain Moyen sup (Argiles et chenaux mal connectés) Chalain Moyen inf (Argiles)
Chalain inf.	Chalain Inférieur (Argiles et chenaux mal connectés) Chalain Couv. Dolomie (réservoir)
Chaunoy Marnes IS	Couverture CCS ou absence couverture Chailly chaunoy Sup (réservoir) Couverture CCM Chailly chaunoy moyen sup (réservoir) CCMCI CCM inf Couverture CCI Chailly chaunoy inf. (réservoir) Arg. Interm. Sup.
Argiles et Grès intermédiaires	AI R1 (argiles et grés) AI R2 (argiles et grés) Arg. Interm. Inf
Donnemarie	Donnemarie Sommital (réservoir) Couv. Sup. Donnemarie Sup. (réservoir) Couv. Moy Donnemarie Moy. (réservoir) Couv. Inf Donnemarie Inf. (réservoir) Couv.
Bunt	Buntsandstein (réservoir)
	Socle

Keuper Sud – Site modeling

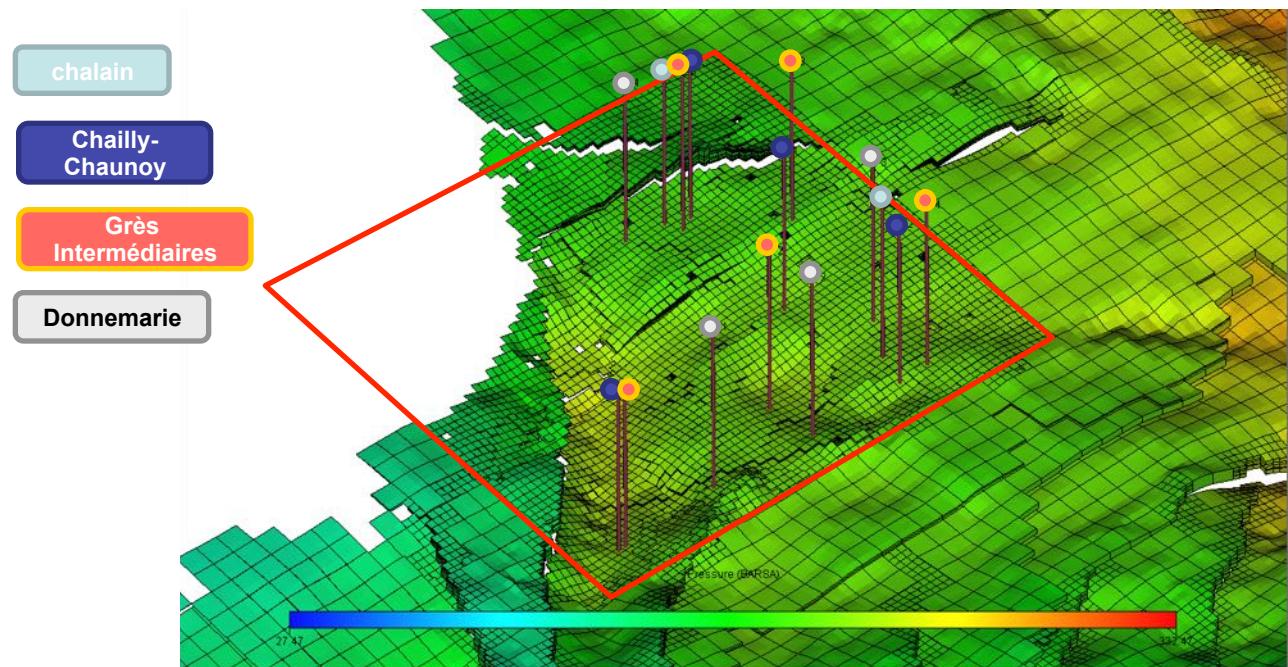
> Injection simulation with the new petrophysical models

- 1 model with K/Phi laws computed by layers but no facies modeling

→ **Storage potential : 140 Mt with 15 wells**

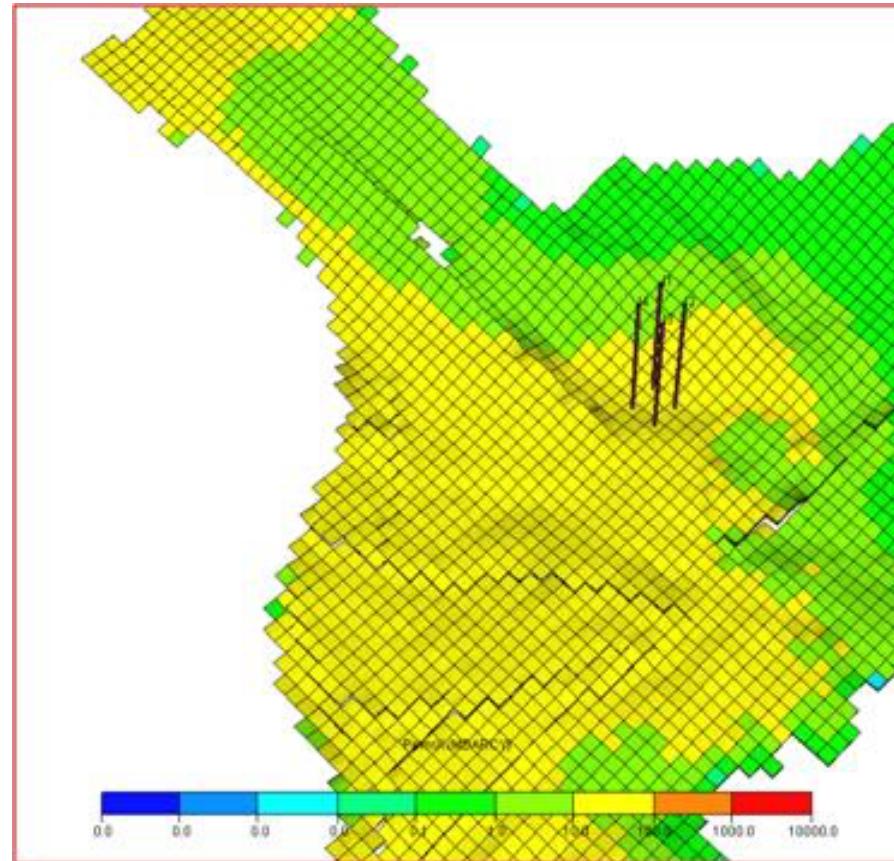
- 1 model with facies integration. K/Phi relationships computed for each facies in each layer.

→ **Storage potential : 54 Mt with 15 wells**



Keuper Nord – Site modeling

- > **Refinement of the model**
 - Net thickness revisited
 - No advanced geological studies
- > **Injection simulations**
- **Storage potential : 40 Mt with 20 wells**



Dogger – Regional modeling

> Static modeling

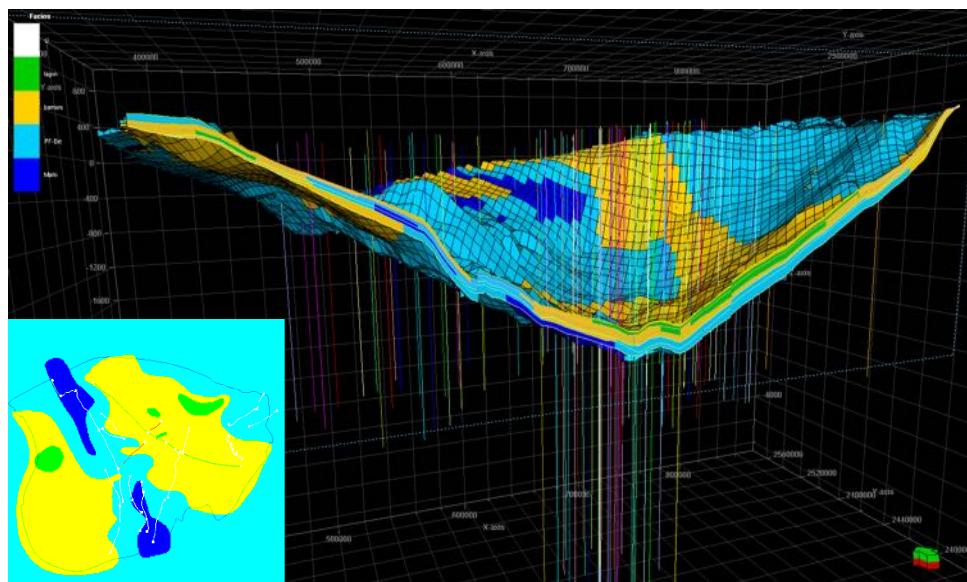
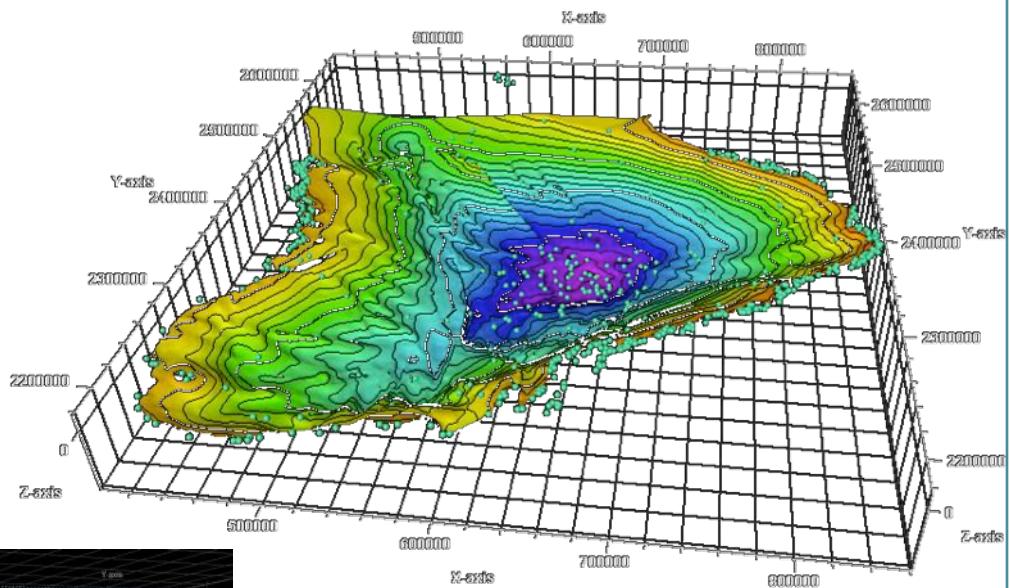
model size : 500km x 700 km

7 zones

cells size : 5km x 5km

75 000 cells

facies modeling



Dogger – Regional modeling

- > 3 K-Phi relationship were investigated
 - > Due to a complex diagenesis history of the Dogger limestones, dual porosity / permeability system occurs (presence of pathways of very high permeability)
 - > As, with the available data, there is no predictive localization of these drains, we are not able to predict the evolution of the CO₂ plume and its migration.
 - > Moreover, there is a risk that injection of 200 Mt of CO₂ in the Dogger would impact the geothermal activity.
- Because of these uncertainties on the Dogger geological properties and the possibility of an interaction with geothermal energy development within this level, this stratigraphic target was discarded.

Storage capacity identified

Site	Potential of injection	# of wells	Comments
Keuper Nord	40 Mt	20 wells	
Keuper Sud	140 Mt	15 wells	Without facies modeling (optimistic case)
Keuper Sud	54 Mt	15 wells	With facies modeling (pessimistic case)
Buntsandstein	157 Mt	21 wells	Injection east of the Faille de la Marne. Risk of CO ₂ migration towards the drinkable part of the aquifer was considered as too important.
Buntsandstein	87 Mt	23 wells	Injection west of the Faille de la Marne Aquifer properties significantly degraded compared to the previous case



All these results are largely under the objectives of the France Nord project

Comparison with previous estimations

	JOULE II (1996)	Projets GESTCO (2003) et EU GEOCAPACITY (2009)			France Nord (2009-2011)
	Traps	Traps	Total	Conservative	Flow models
Dogger	189 Mt (E=0.18%)	9 Mt (E=0.01%)	4320 Mt (E=6%)	1440 Mt (E=2%)	Potential Conflict with geothermal resources
Keuper	529 Mt (E=0.18%)	130 Mt (E=0.18%)	4331 Mt (E=6%)	72 Mt (E=0.1%)	90-180 Mt
Buntsandstein	Conflict with fresh water	529 Mt (E=0.18%)	17640 Mt (E=6%)	5880 Mt (E=2%)	~ 90 Mt
Other fm.	91 Mt	-	845 Mt	530 Mt	-
TOTAL	809 Mt	668 Mt	27136 Mt	7922 Mt	180-270 Mt

Conclusions

- > The assessment phase of the project has shown that it was not possible to identify a single site to store 200 Mt CO₂.
- > The constraint of the acceptable overpressure (1.5 x Pi) limits drastically the capacity evaluation.
- > Do not take into account this phenomenon leads to an overestimation of storage capacity as shown in comparison with previous capacity estimates.

Is CO₂ storage impossible in the Paris Basin?

Capacities identified during the France Nord project are not enough for a very large storage (200Mt in 40 years of injection) as identified at the start of the project.

BUT

- > Volumes identified are important (up to 100Mt).
- > The interest of the Paris Basin for CCS exists but for smaller storages related to different uses than those defined during the France Nord project

→ BRGM is still working on the Paris Basin for CO₂ sequestration.



Thank you

Acknowledgements

This work has been done within the France Nord project funded by ADEME (French Environment and Energy Management Agency) and industrial partners.

The authors also thank all the technical contributors that have enabled to perform this work, namely:

T. Fargetton, D. Dequidt, K. Djaouti, F. Delsante, P. Egermann and R. Nabil from Storengy;
J.-P. Gely, and R. de Lannoy from GDF SUEZ;
S. Gabalda, C. Kervevan C. Chiaberge and M. Gastine from BRGM;
J.C. Lecomte, P. Houel, J.M. Daniel, A. Fornel and F. Roggero from IFPEN;
D. Pourtoy, L. de Marliave and G. Moutet from Total.

You can find the main results of this work in the paper
BADER, A.G. et al., 2014. CO₂ Storage Capacity Evaluation in Deep Saline Aquifers for an Industrial Pilot Selection. Methodology and Results of the France Nord Project. Energy Procedia 63, pp. 2779 – 2788.

ADEME



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