Regional Workshop 3
05/12/2011, Milan, Italy

Geothermal electricity in France: Data, studies and production An overview by BRGM

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BRGM, France
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BRGM French Geological Survey

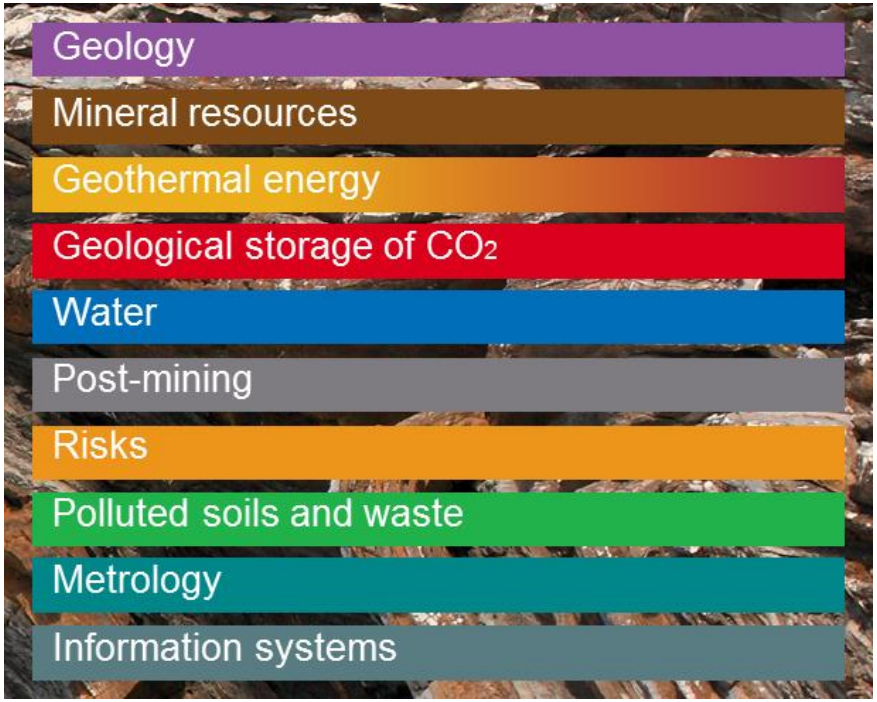
3 key roles:

- Scientific research
- Support to public policy-making
- International cooperation

Staff : 1000 (engineers & technicians)

Income 2010 : 140 M€

10 topics:



Contents

> France geological context

> Geothermal electricity production in France

> General data available in France

> Hot sedimentary aquifers

> EGS

> Volcanic context

> On-going exploration licences in France

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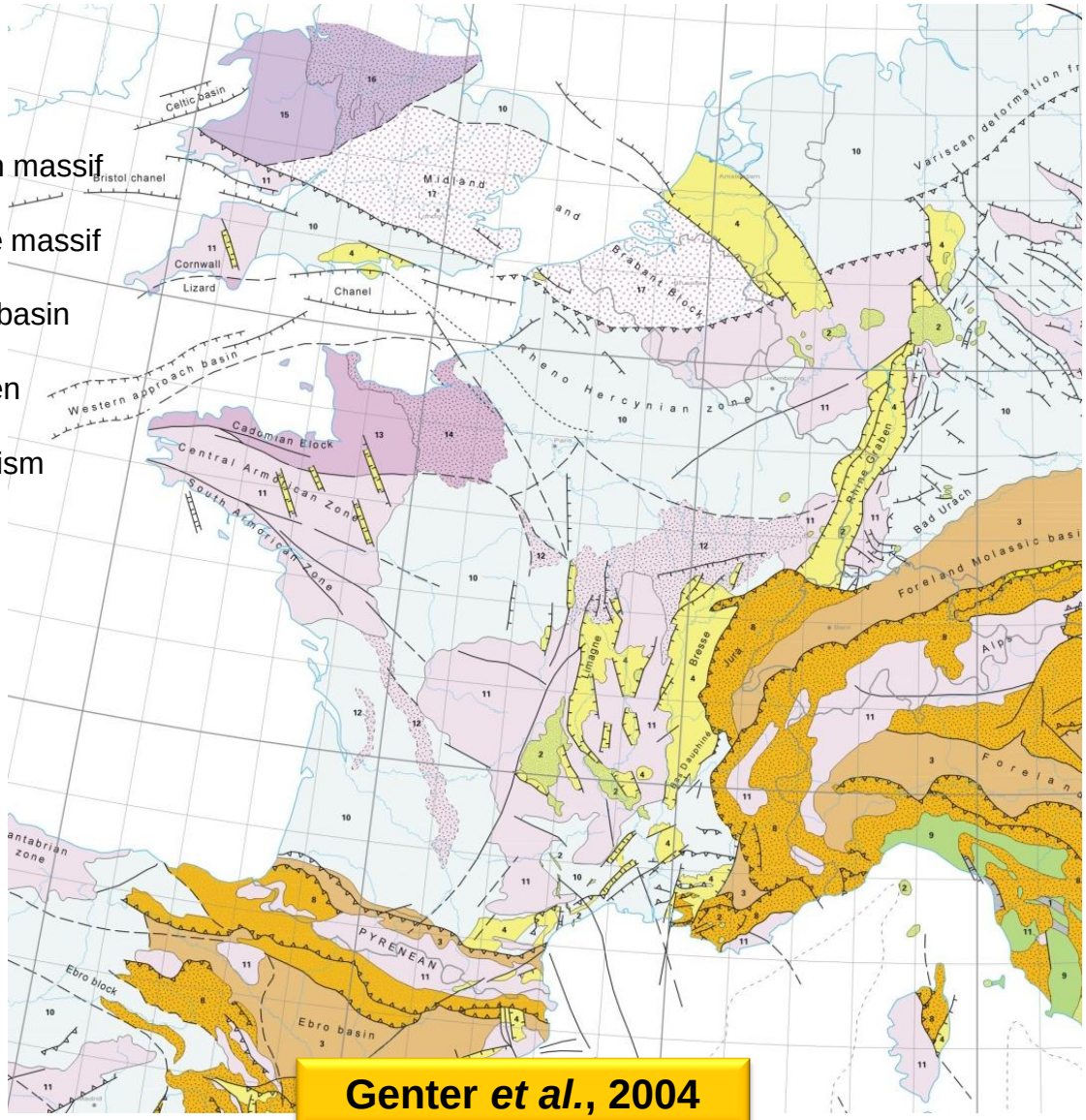
France geological context

- Old hercynian massif
- Recent alpine massif
- Sedimentary basin
- Tertiary graben
- Active volcanism

Oversea territories



Genter *et al.*, 2004

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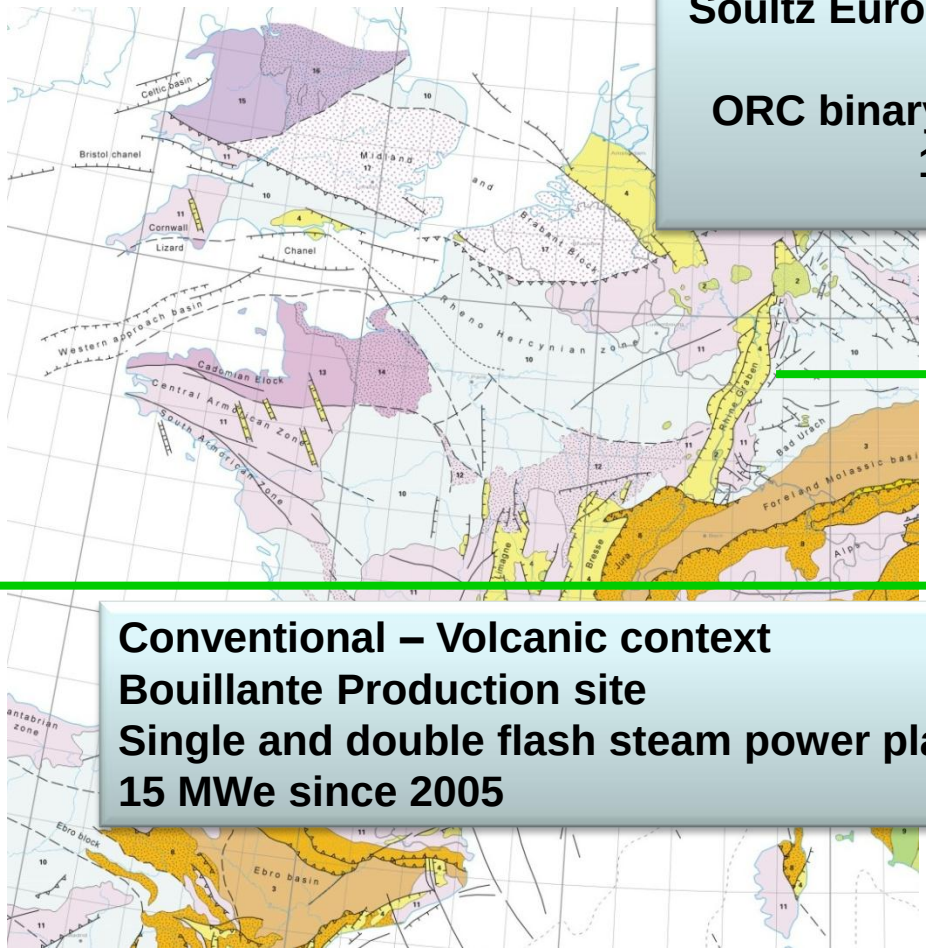
Geothermal electricity production in France

EGS – Rhine graben
Soultz European research pilot site
ORC binary cycle power plant
1.5 MWe since 2008



Conventional – Volcanic context
Bouillante Production site
Single and double flash steam power plant
15 MWe since 2005

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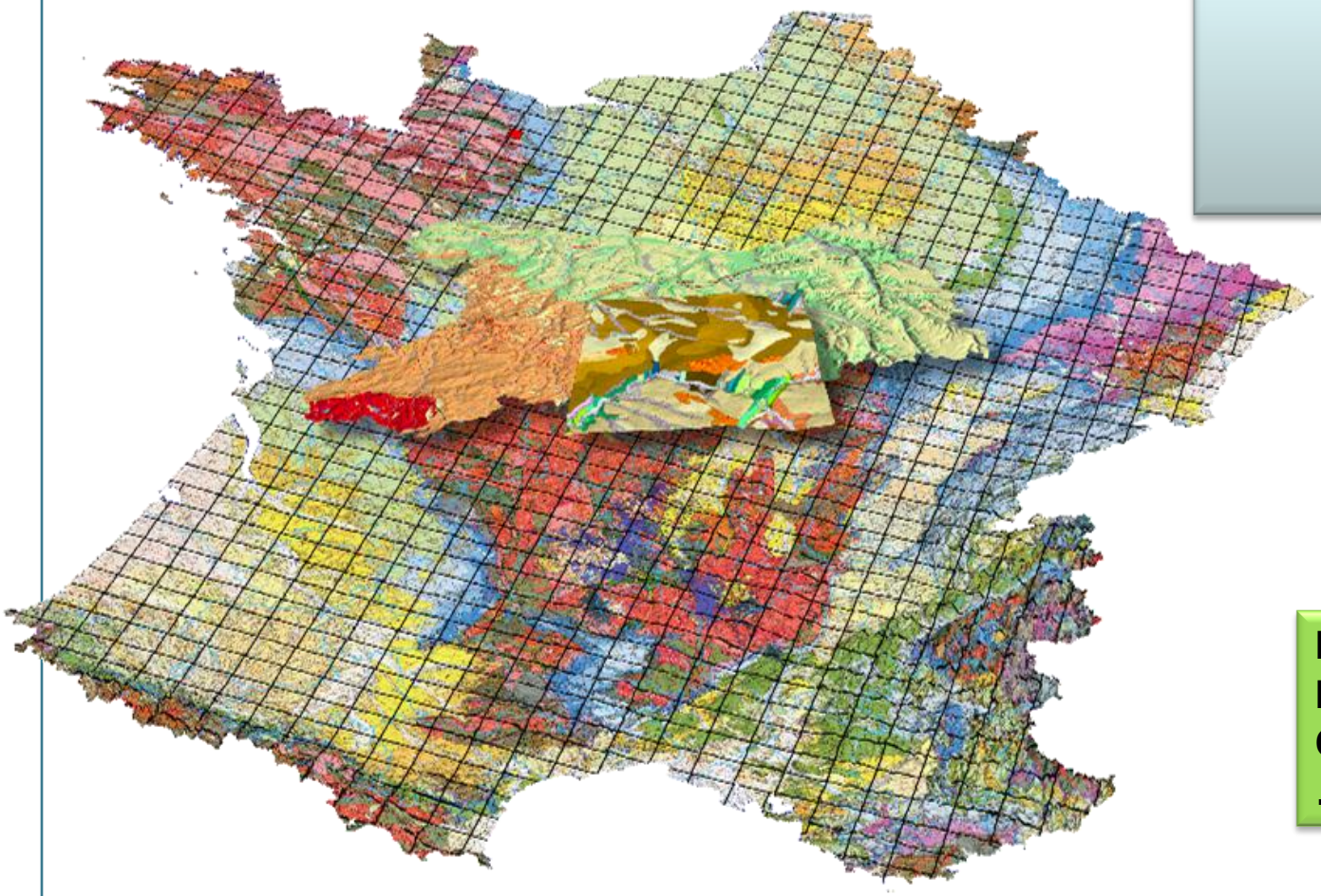
Geological maps

More than 1 000 maps
Various scales:
1:1 000 000
1:50 000
1:25 000
Harmonized areas

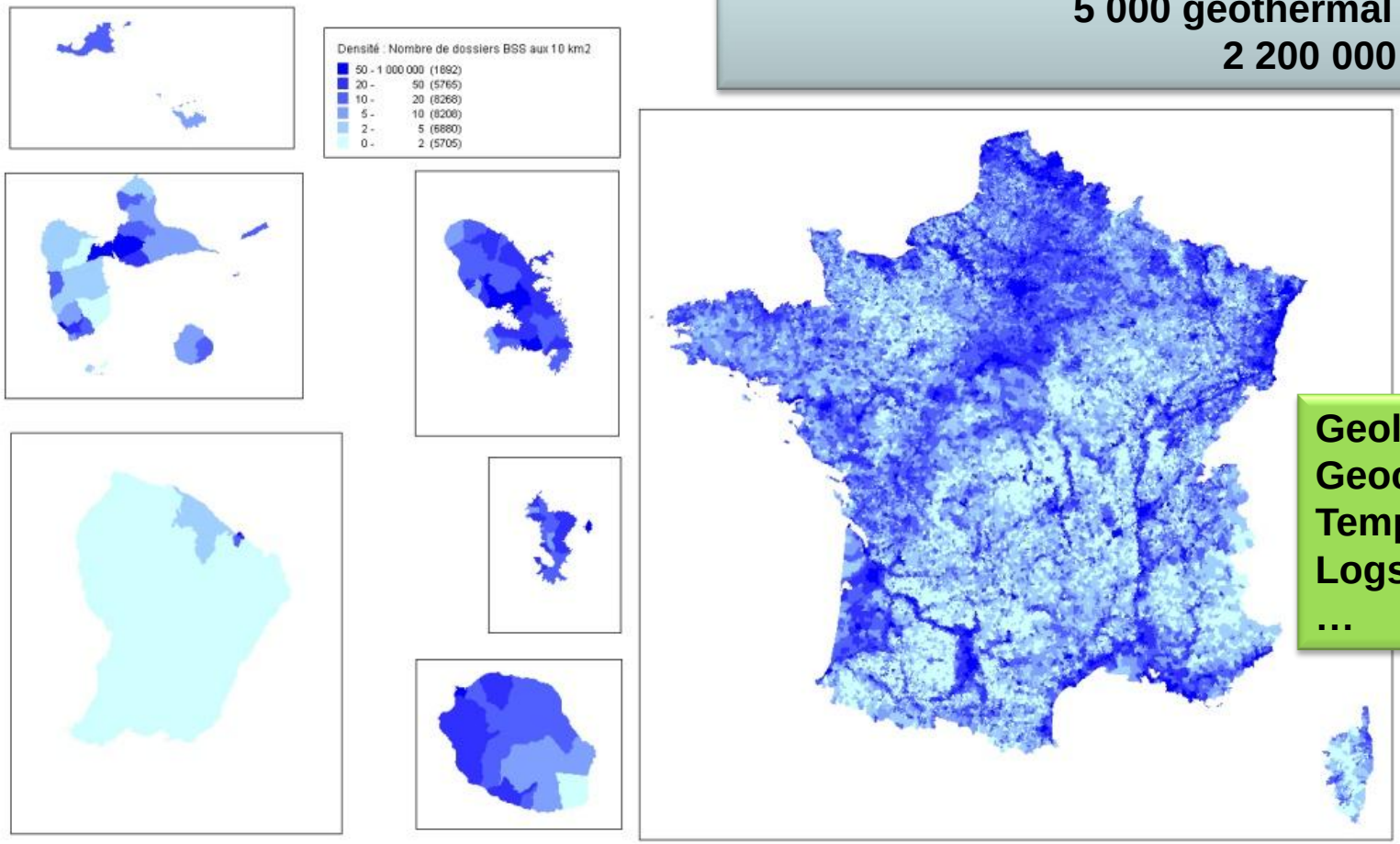


Basins borders
Faults location
GIS layers
…

www.infoterre.fr

Boreholes databases

BSS (Database of the underground)
380 000 boreholes
57 000 springs
5 000 geothermal works
2 200 000 scans



Geology
Geochemistry
Temperatures
Logs
…

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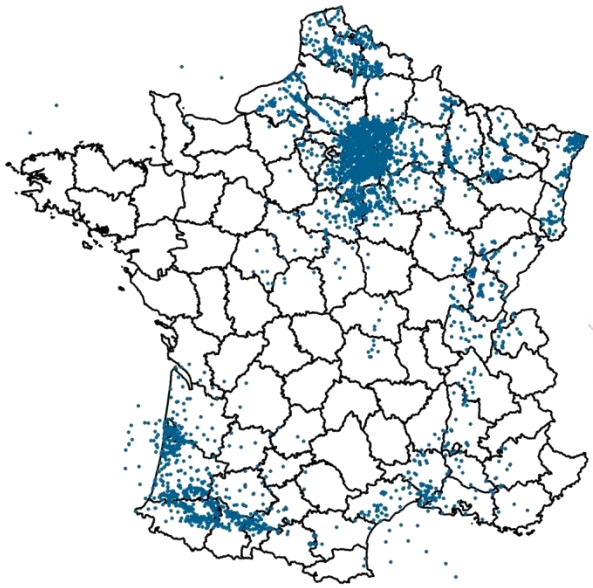
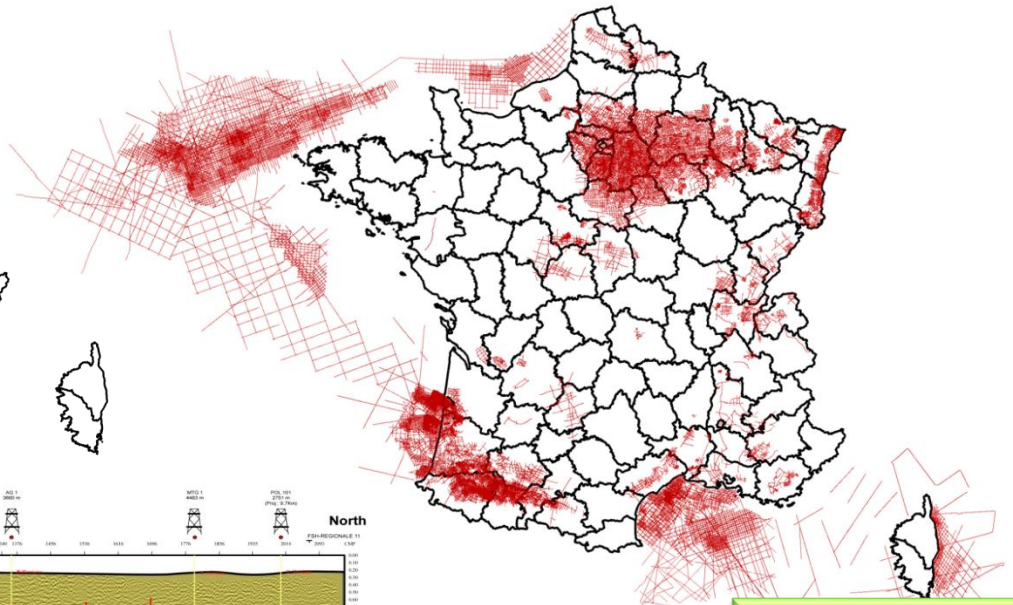
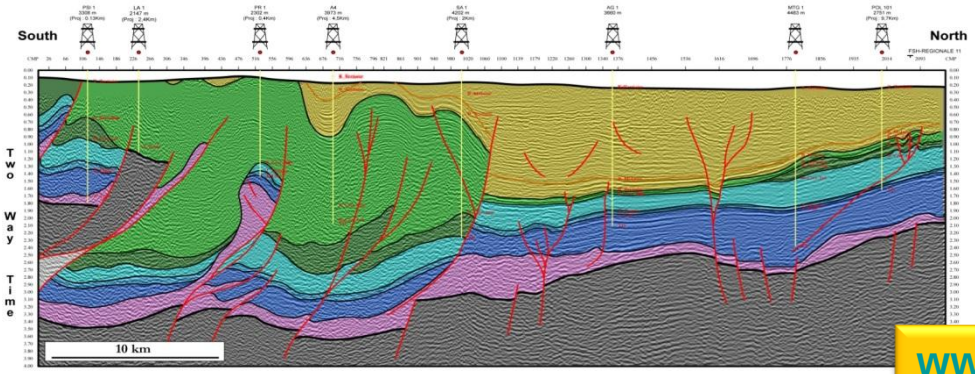
French National oil & gas data



Guichet-H
5 685 boreholes
225 055 km seismic profiles (>1970)





Geology
Temperatures
Logs
…

www.beph.net

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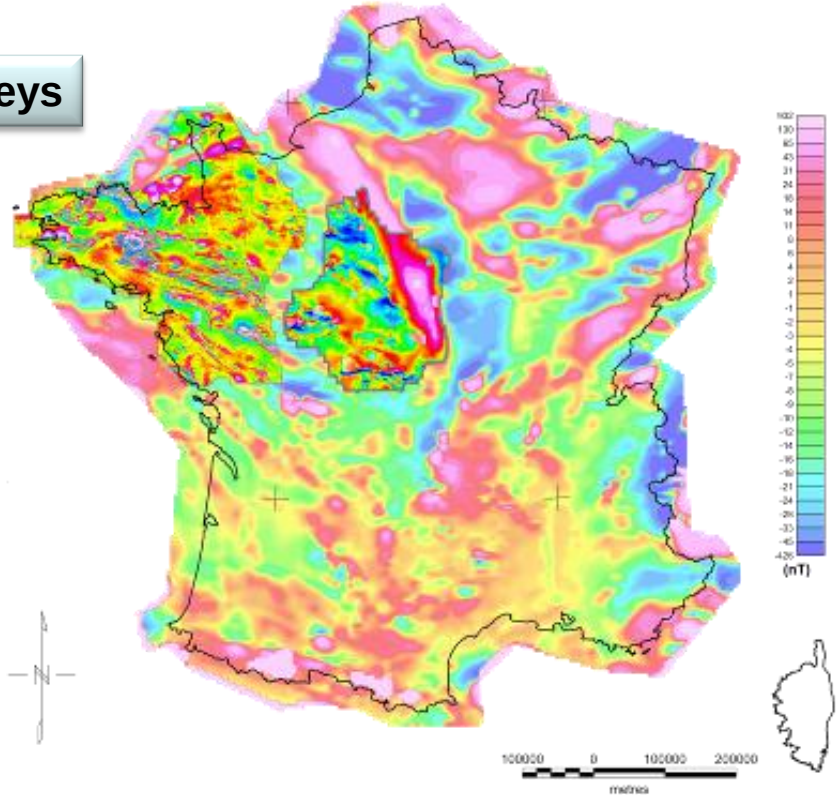
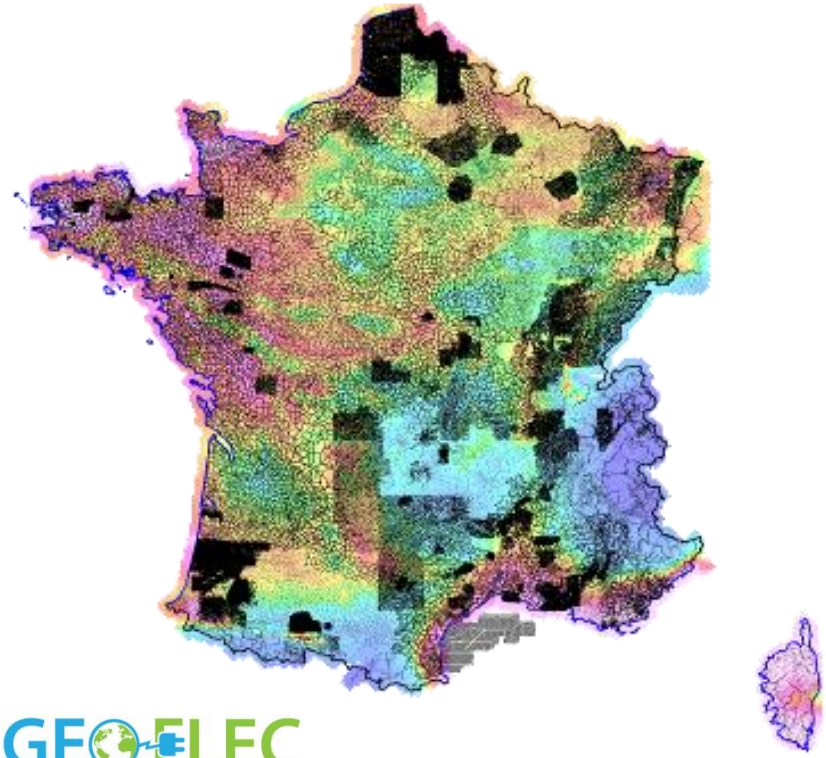
General data – More geophysics

Airborne surveys



More than 417 000 ground gravimetric stations



Gravimetry
Electromagnetism
Spectral radiometry
…

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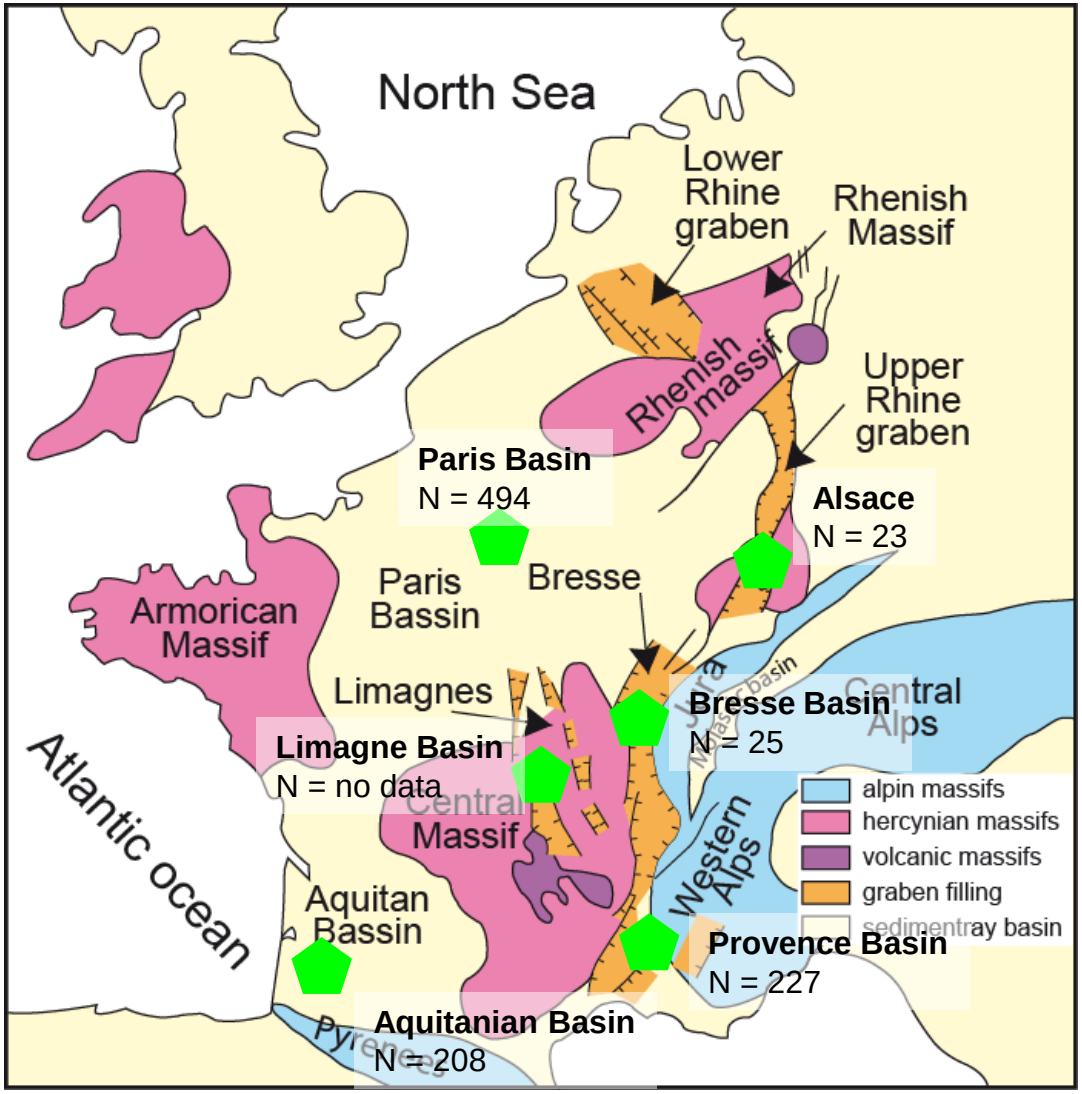
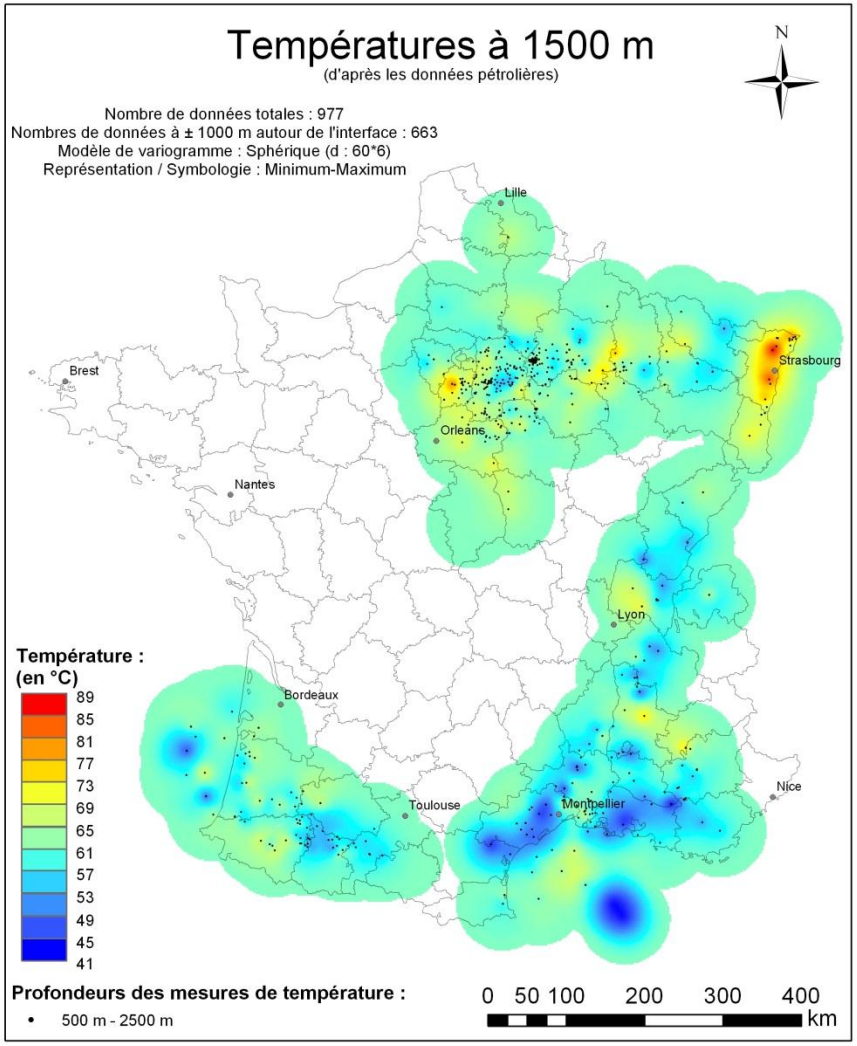
Temperatures on metropolitan territory



Geostatistical interpolation with uncertainties

Bonté *et al.*, 2010

Temperatures on metropolitan territory



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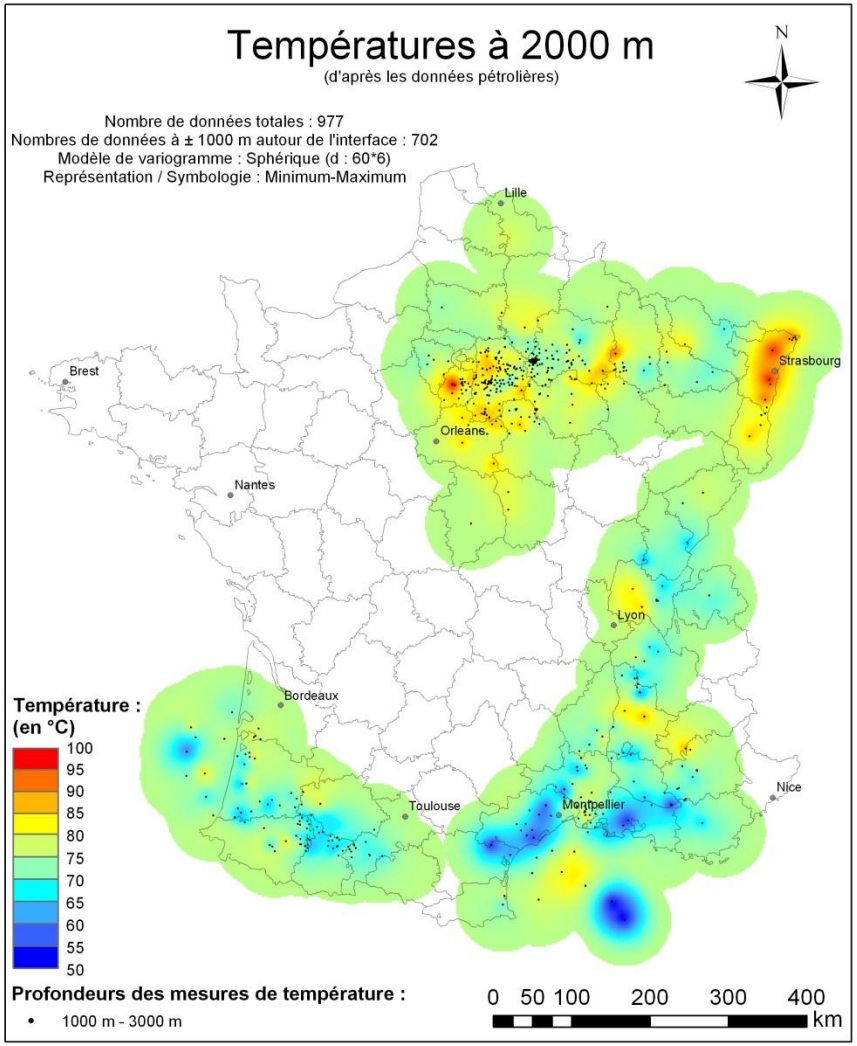

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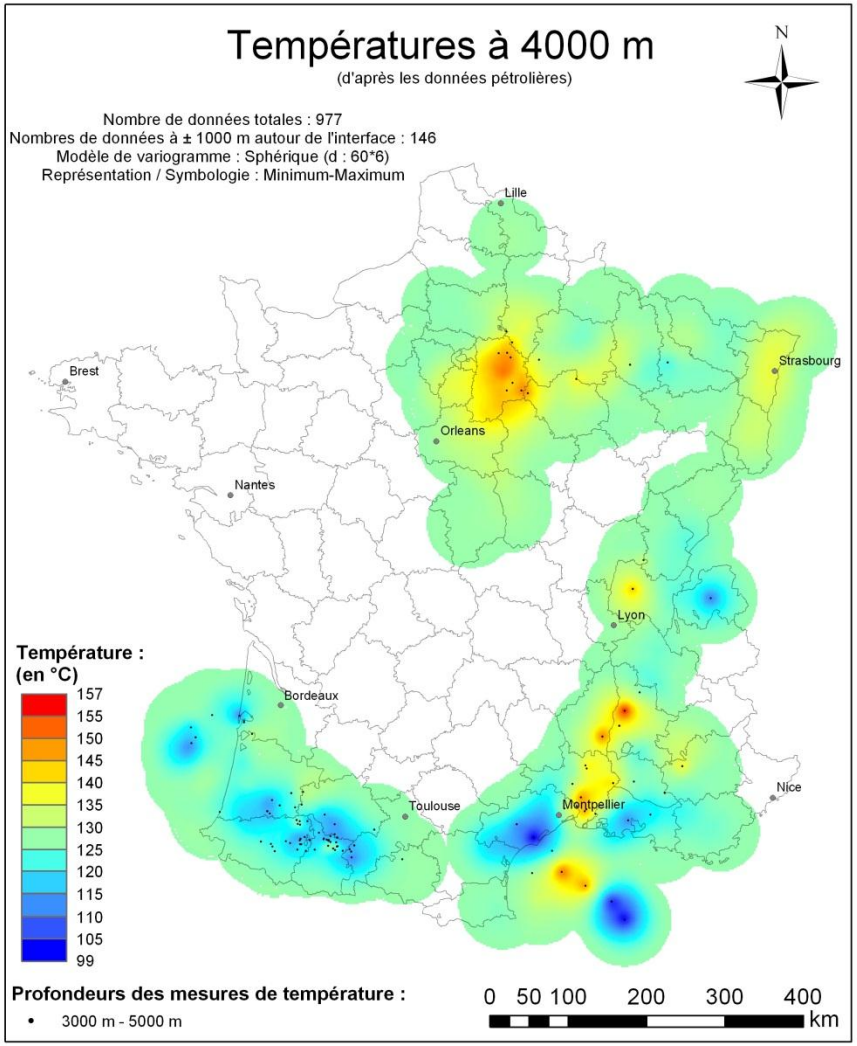

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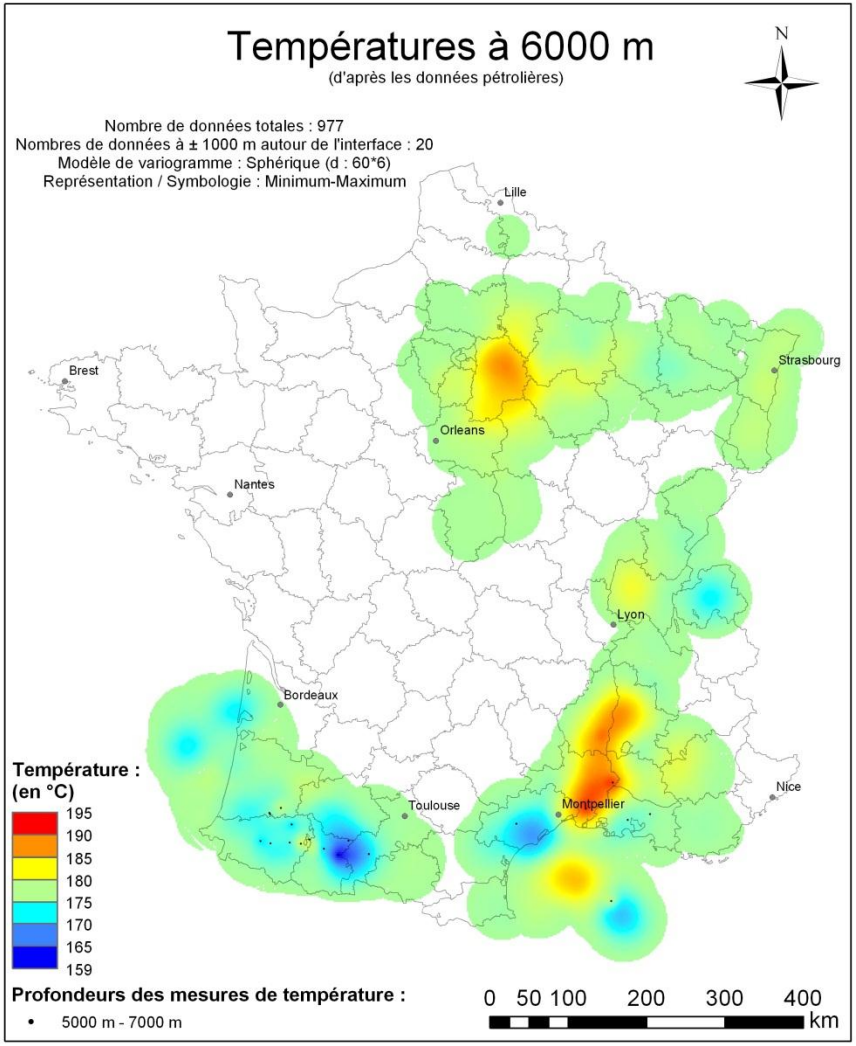
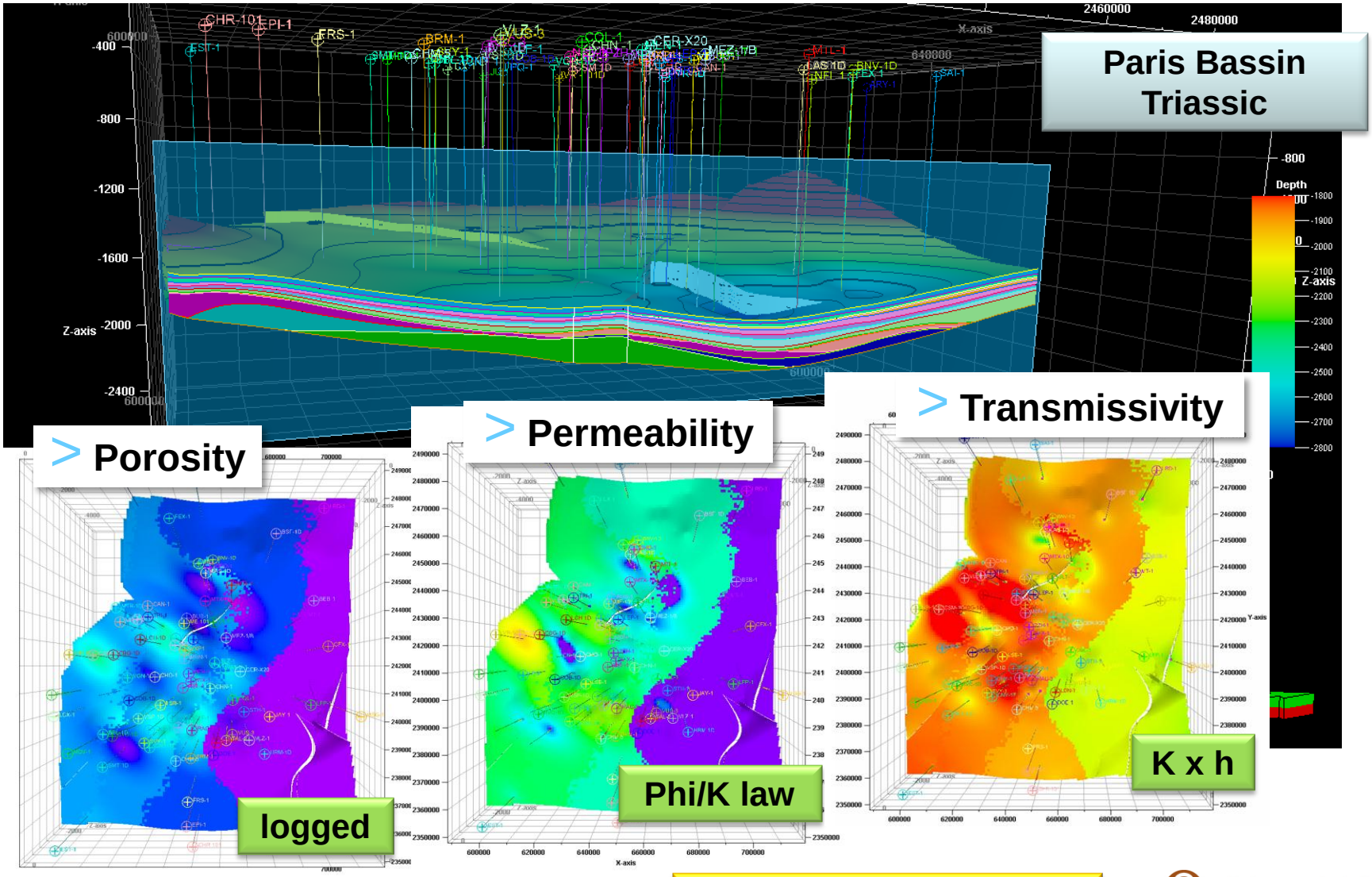


Geostatistical interpolation with uncertainties

Bonté *et al.*, 2010

Aquifer Parameters in Paris Basin

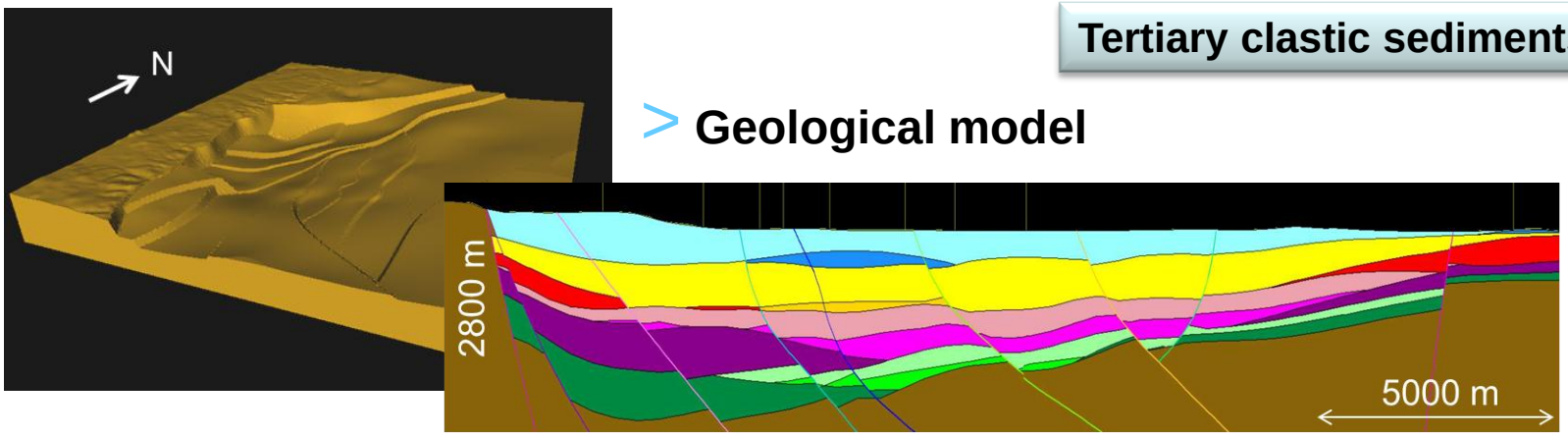


CLASTIQ-2 project, 2011

Geothermal potential in Limagne

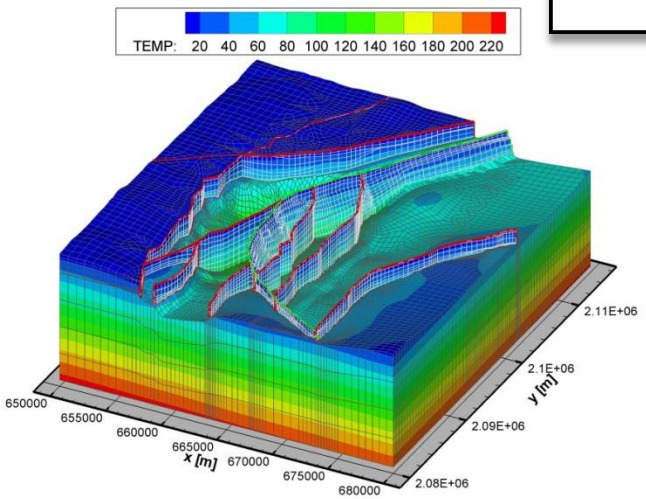
Tertiary clastic sediments

> **Geological model**

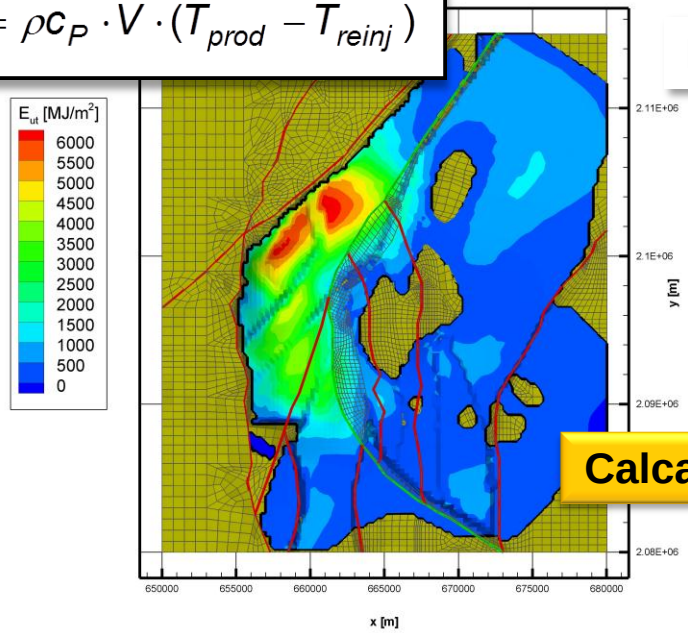


> **Temperature**

$$E_{HIP} = \rho c_P \cdot V \cdot (T_{prod} - T_{reinj})$$



Recovery factor



> **Recoverable energy**

Calcagno *et al.*, 2009

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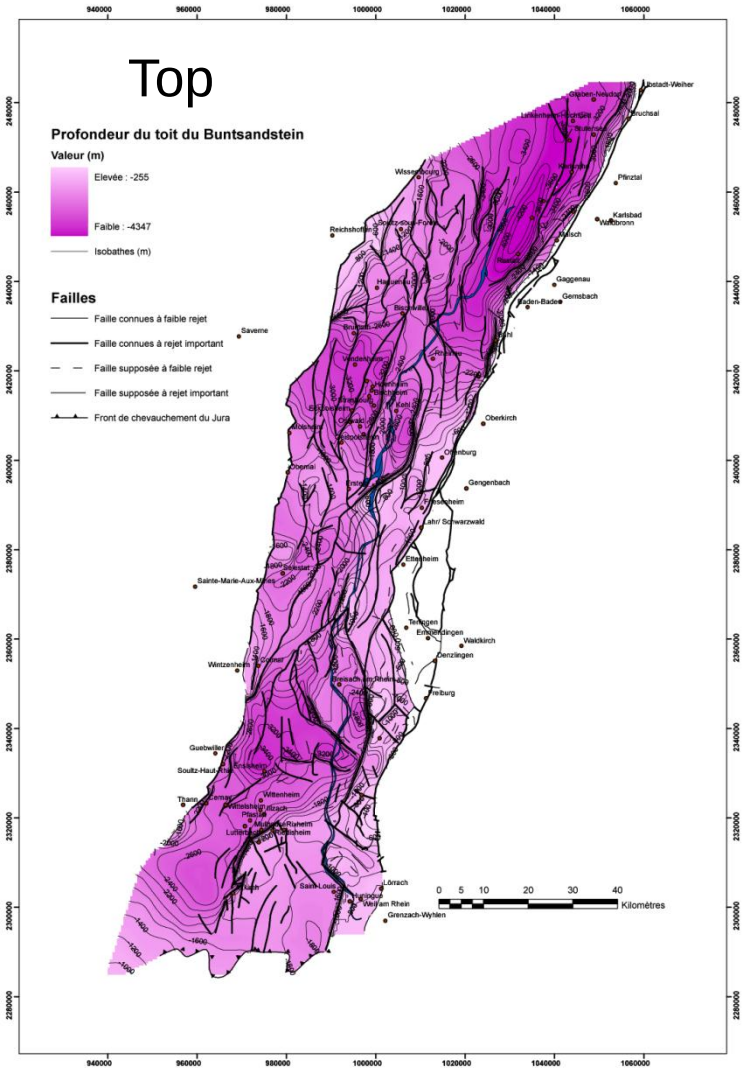
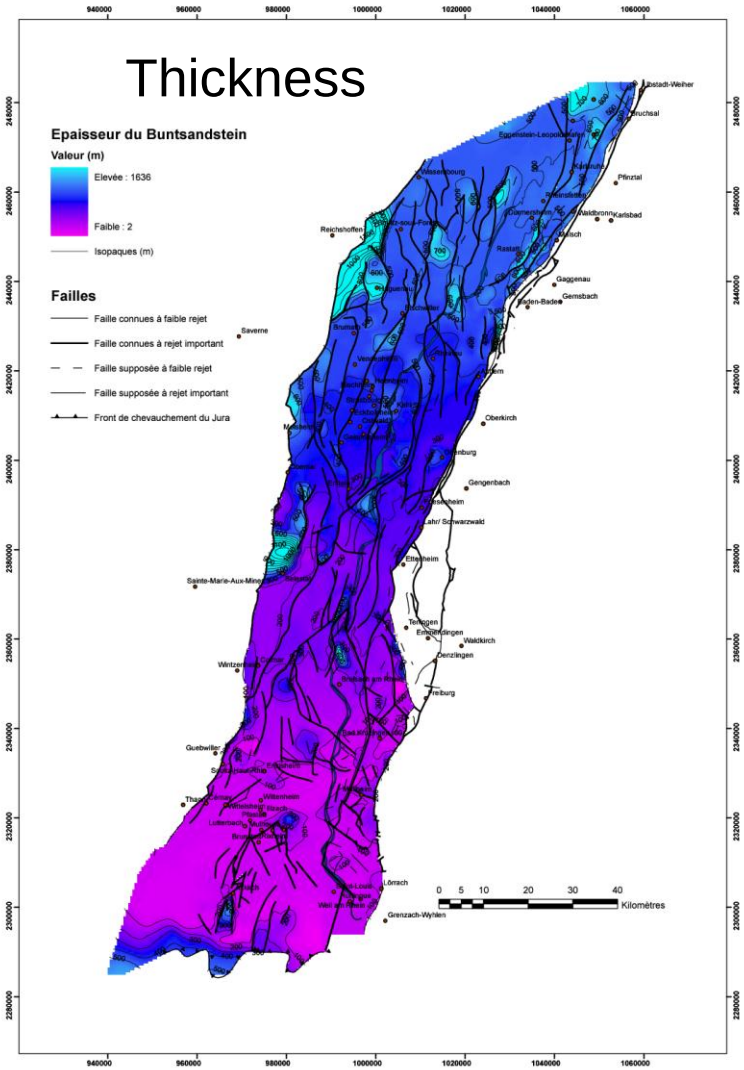
Geothermal potential in Alsace



Lower Triassic (Buntsandstein) clastic sediments

Dezayes *et al.*, 2007, 2008, 2010

Geothermal potential in Alsace



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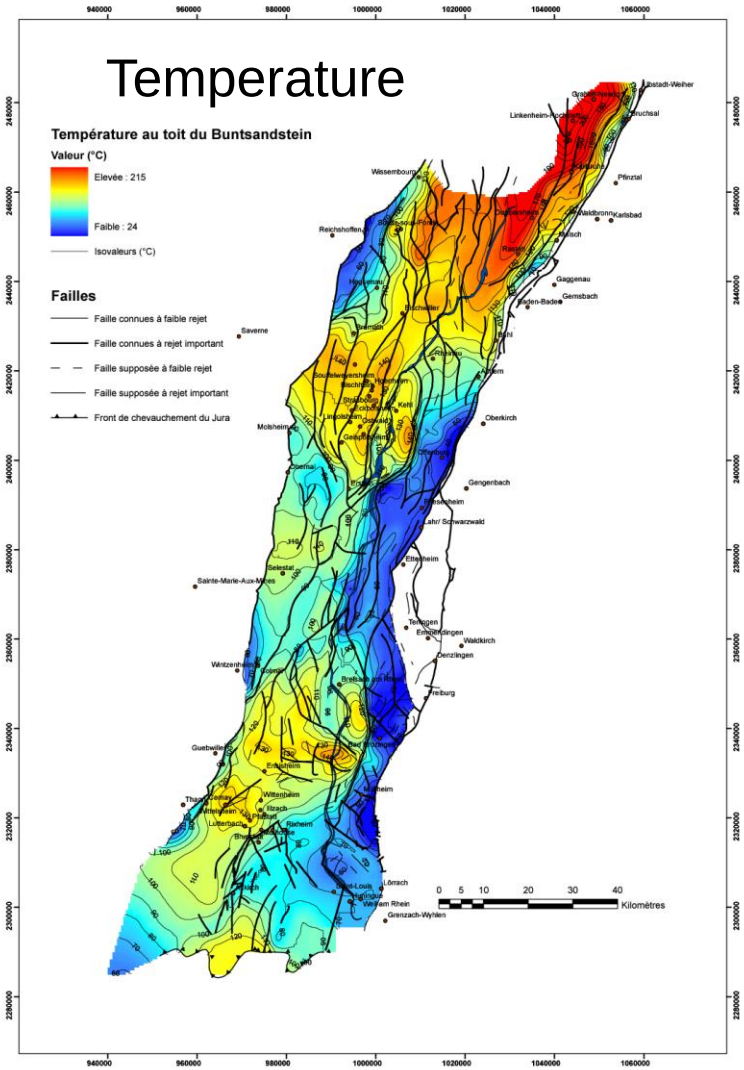

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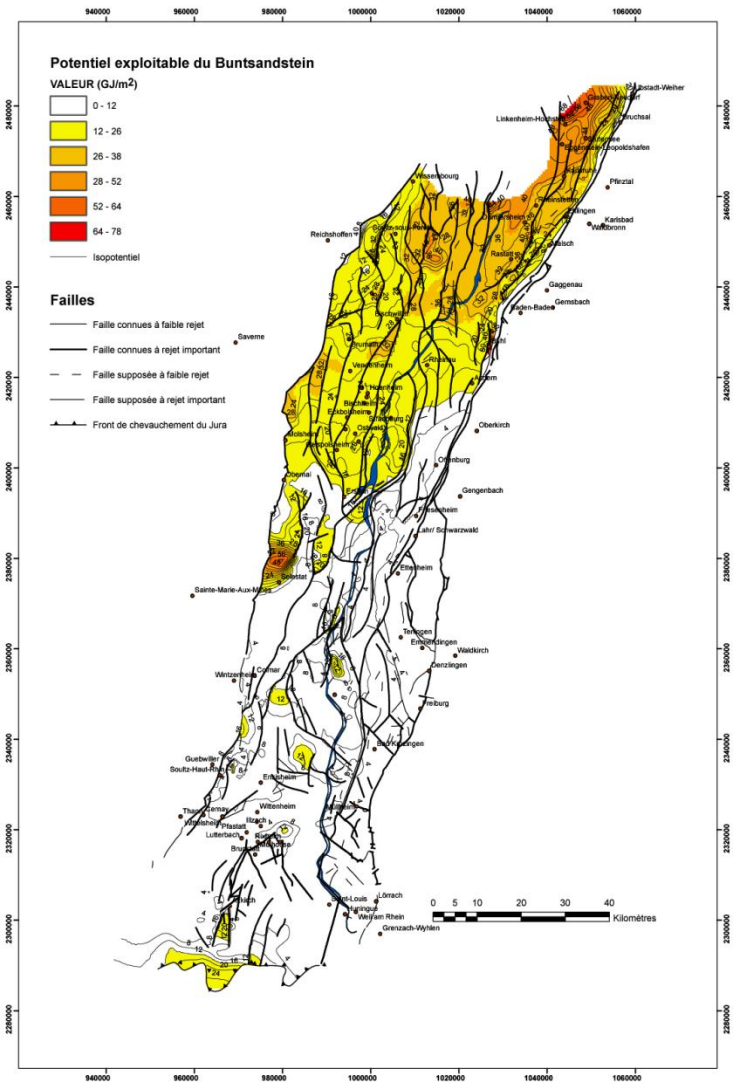
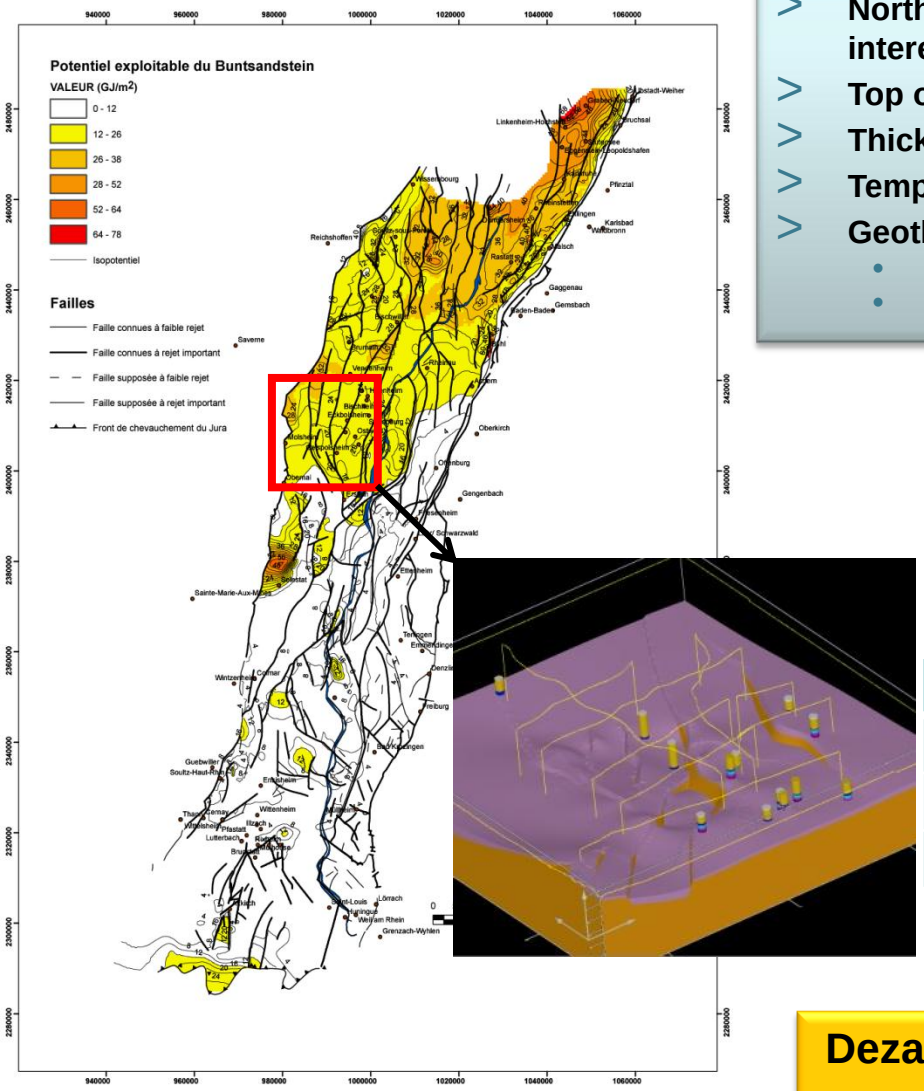


- **Northern part of the Rhine Graben shows more interesting values of geothermal potential;**
- **Top of Buntsandstein: 2000-3000m;**
- **Thickness: 500-600m;**
- **Temperature: 140-150°C;**
- **Geothermal potential : 15-30 GJ/m²**
  - Dogger of Paris Basin : 7 GJ/m²
  - Trias of Paris Basin : 15 GJ/m²

Dezayes *et al.*, 2007, 2008, 2010

Geothermal potential in Alsace



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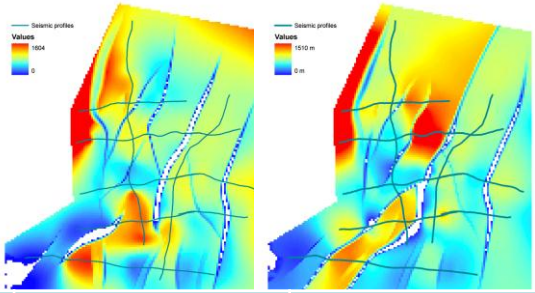

	Model A	Model B
Volume	275 km³	302 km³
Q	1224 GW.yr$_{th}$	1346 GW.yr$_{th}$
Q expl	337 GW.yr$_{th}$	370 GW.yr$_{th}$

Good knowledge of geological condition = best geothermal potential calculation

Dezayes *et al.*, 2007, 2008, 2010

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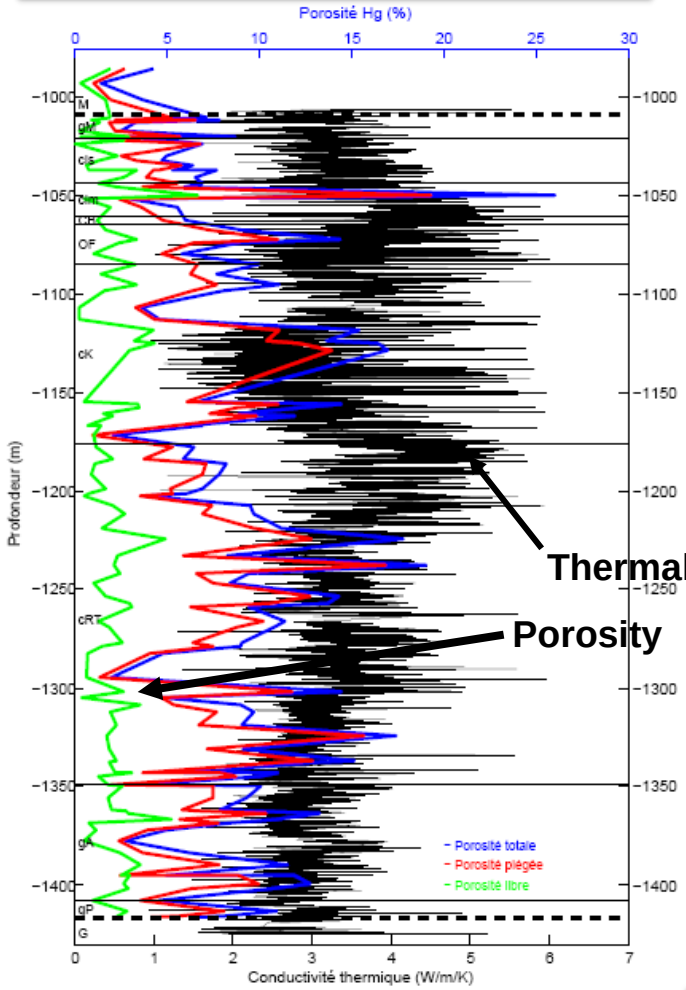
Reservoir characteristic of the Buntsandstein

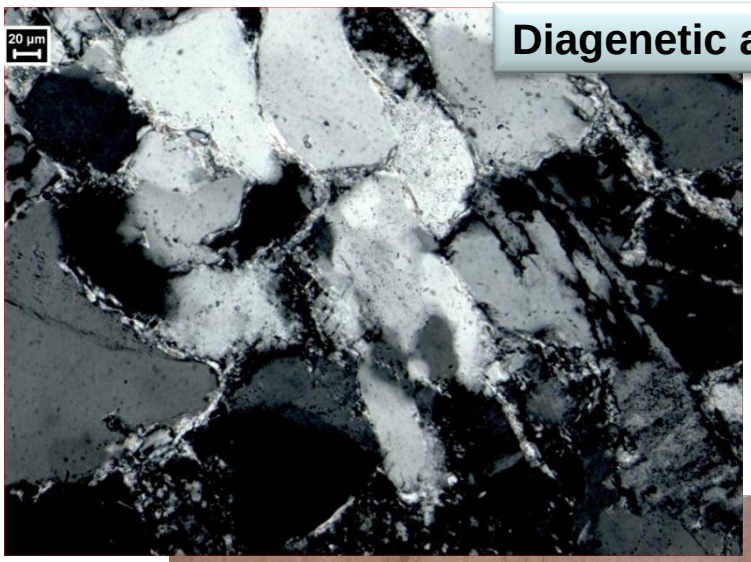
Petrophysical measurements

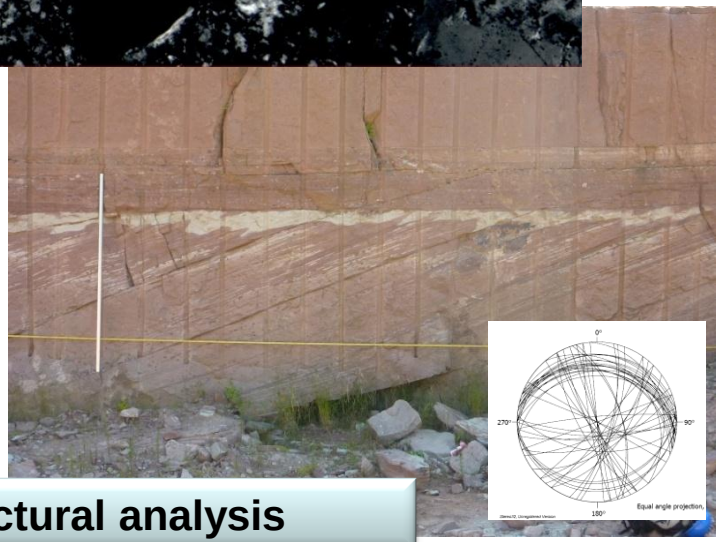


Thermal conductivity

Porosity

Diagenetic analysis



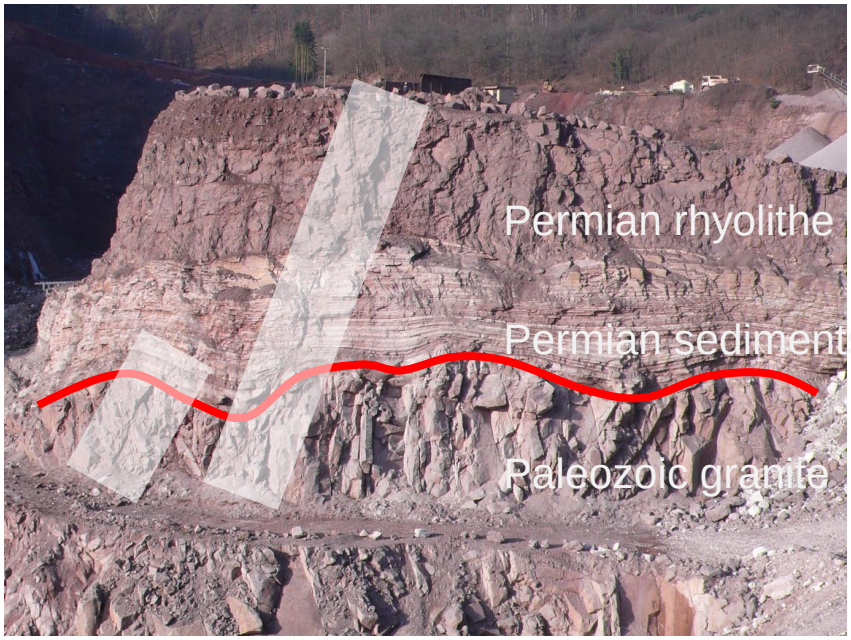


Structural analysis

Thesis of S. Haffen

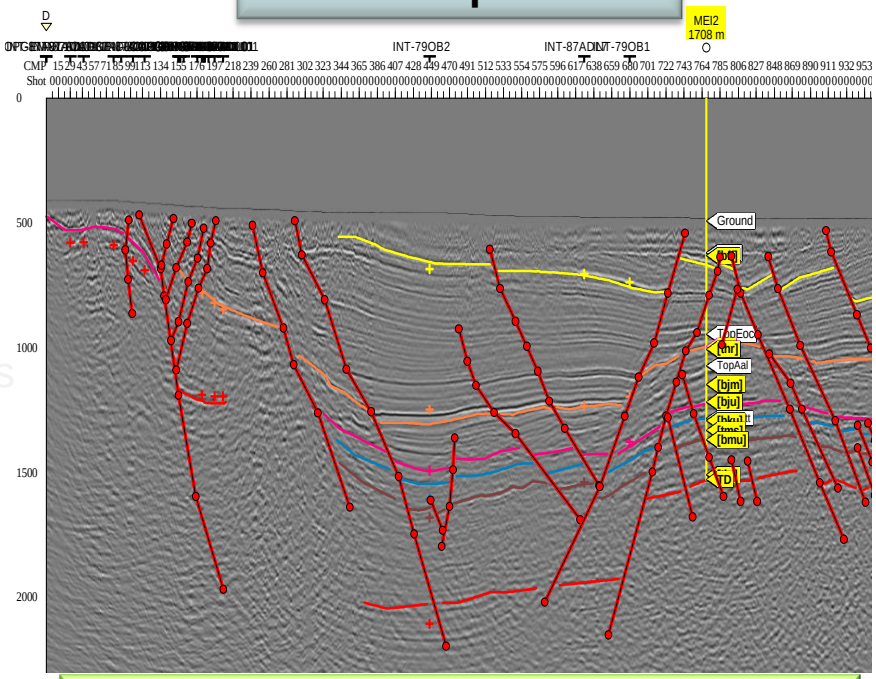
Fractured basement/cover unconformity in the Rhine Graben

Outcrop scale



> Structural and petrographical characterization at the outcrop scale

Seismic profiles



> Detection of the seismic horizon represented the top of the basement

> Analysis of the continuity of the major faults

> Understand the transistion between the basement and the sedimentary cover

> Identify the potential geotermal reservoir

Dezayes *et al.*, 2011

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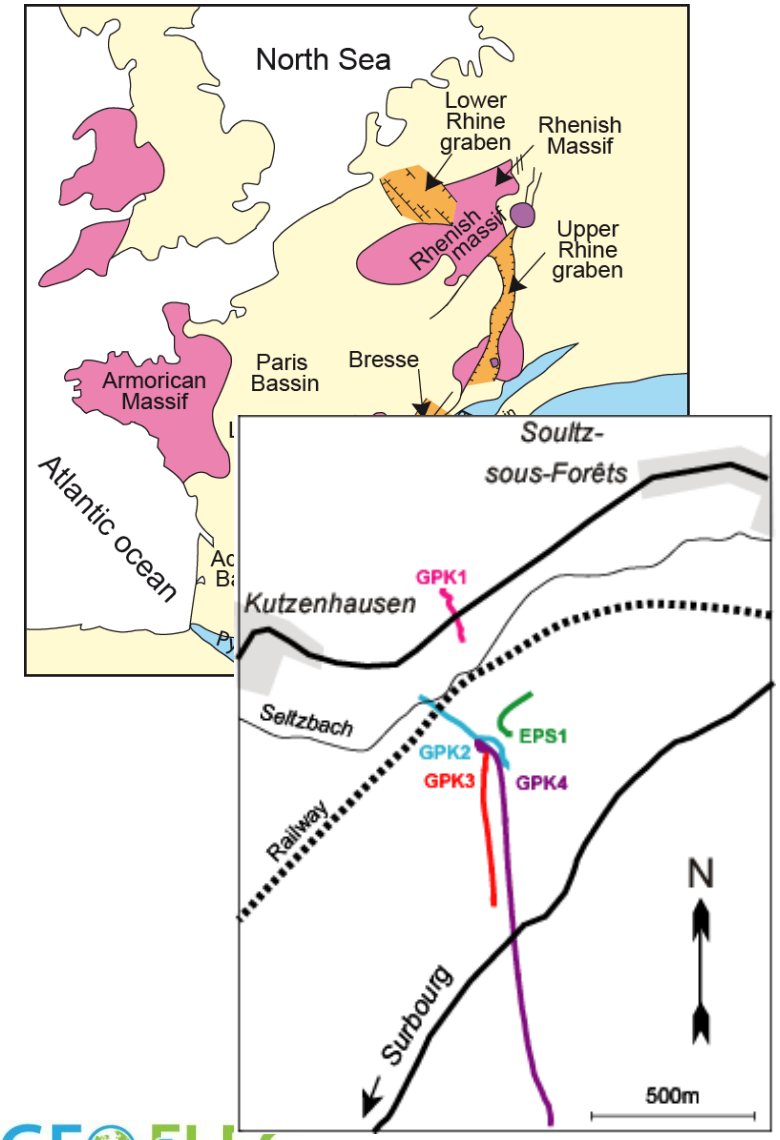
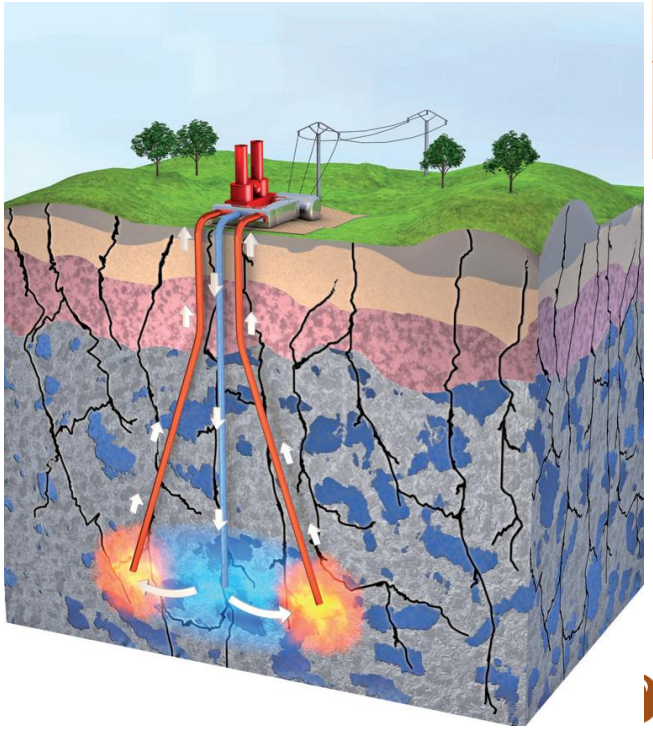
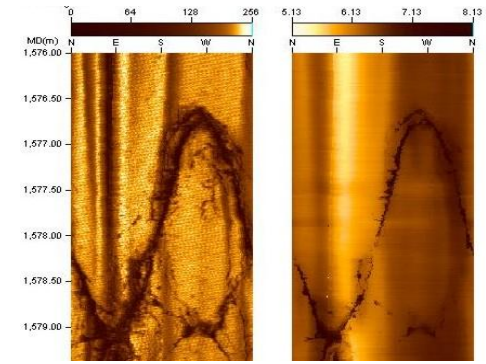
The Soultz project

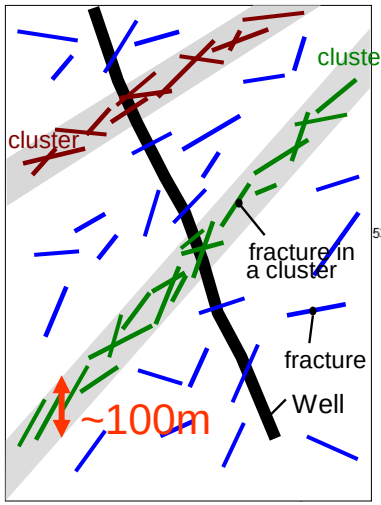


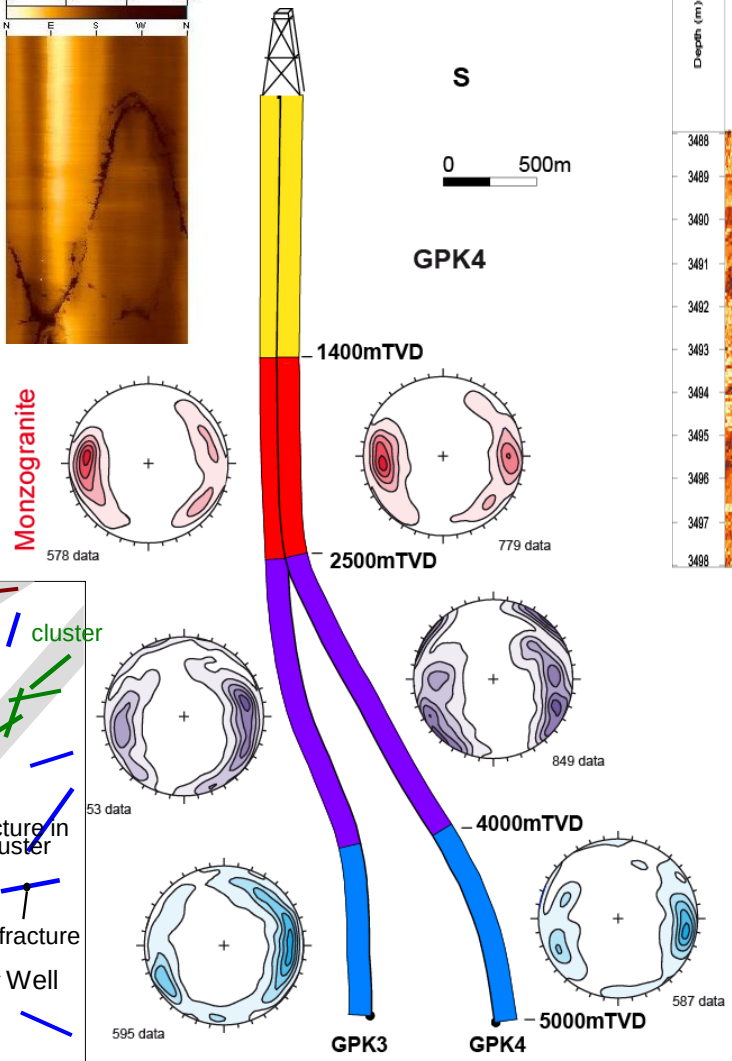
- 24 years of research
- 80M€
- 15 research laboratory
- 1500 scientific publications
- 40 students

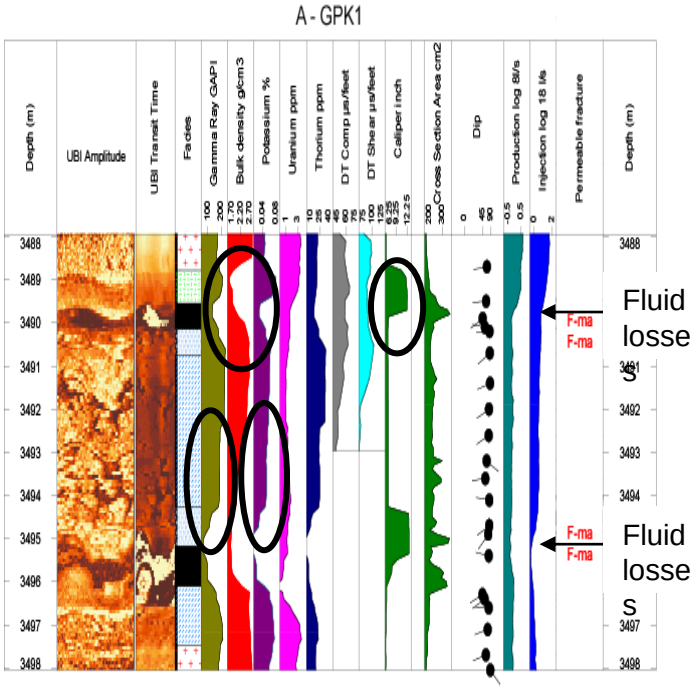


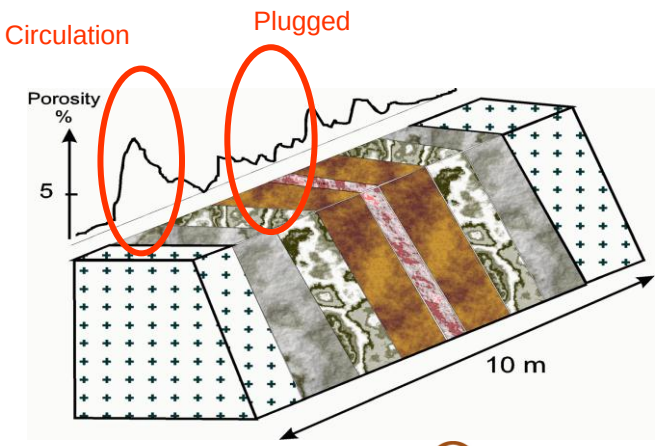
Structural study











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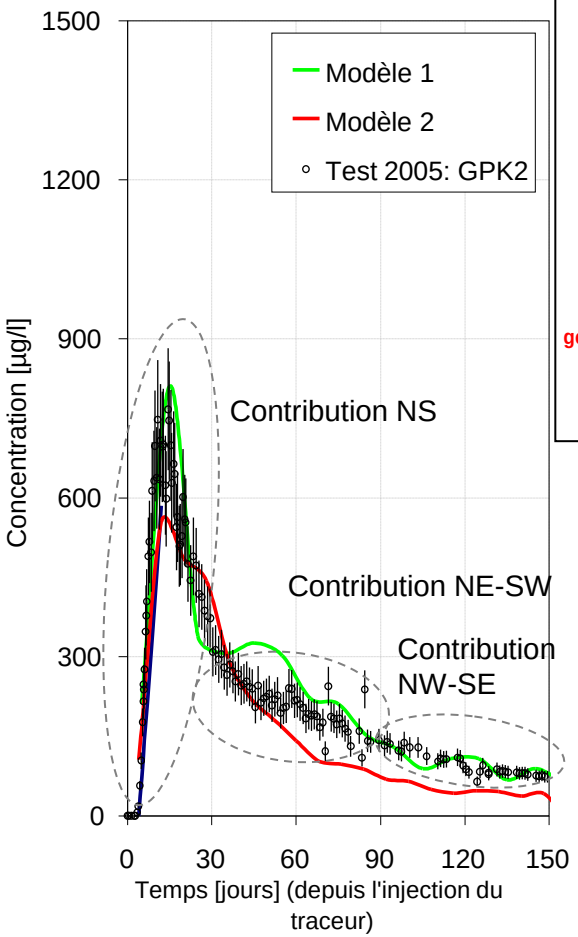
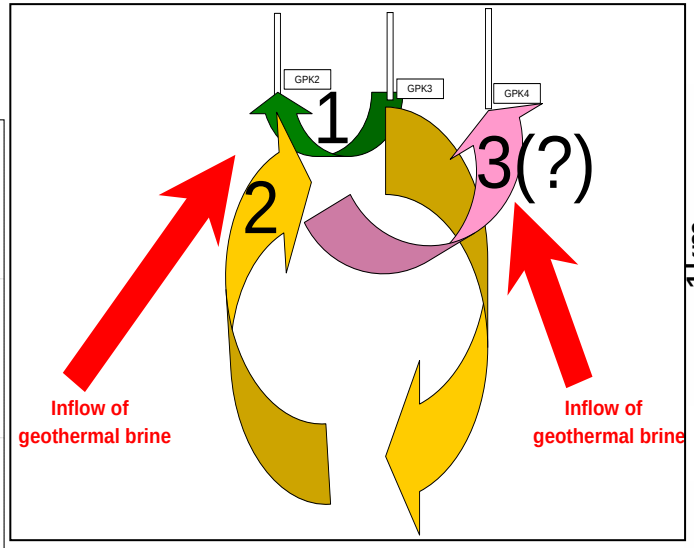
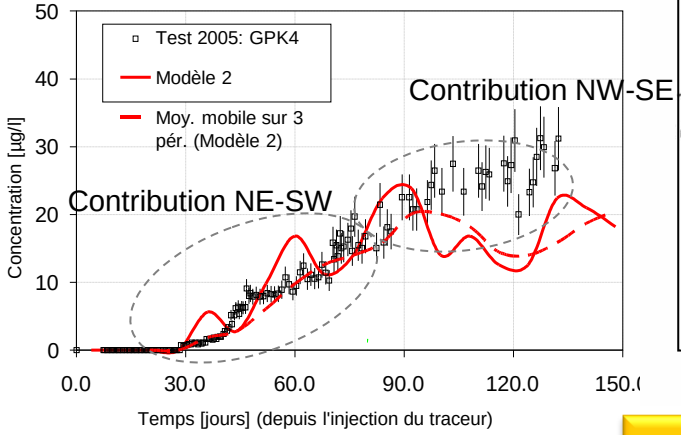
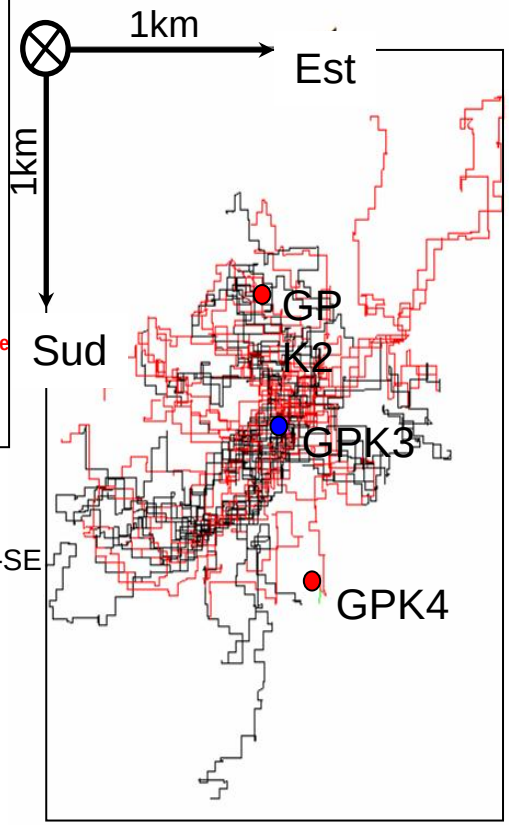
Tracer tests and hydraulical simulation



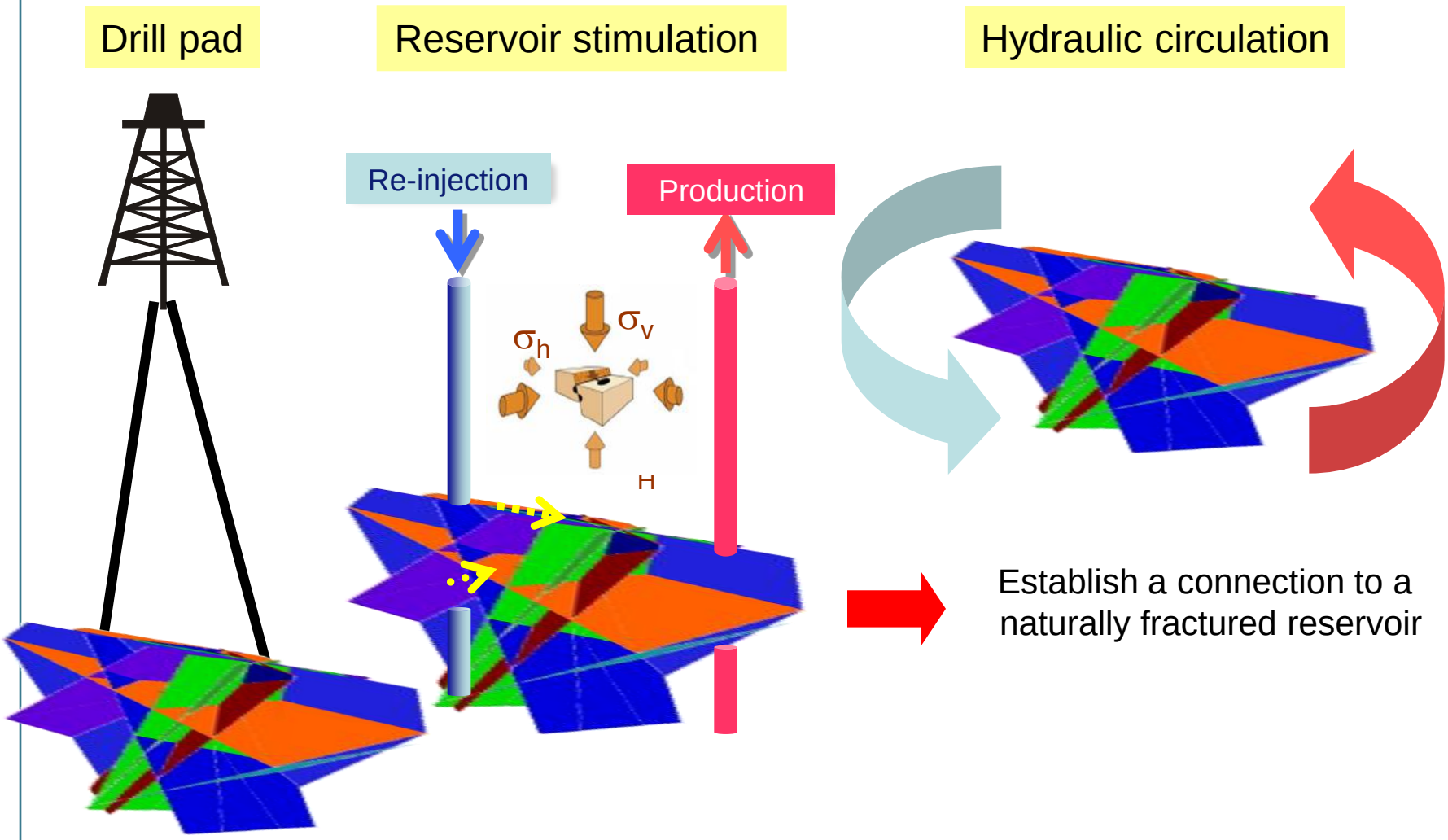






Gentier et al., (2010)

EGS concept


Drill pad
Reservoir stimulation
Hydraulic circulation
Re-injection
Production
σ_h
σ_v
H
Establish a connection to a naturally fractured reservoir

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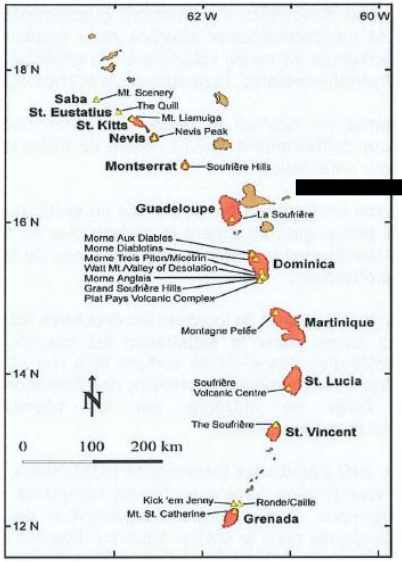
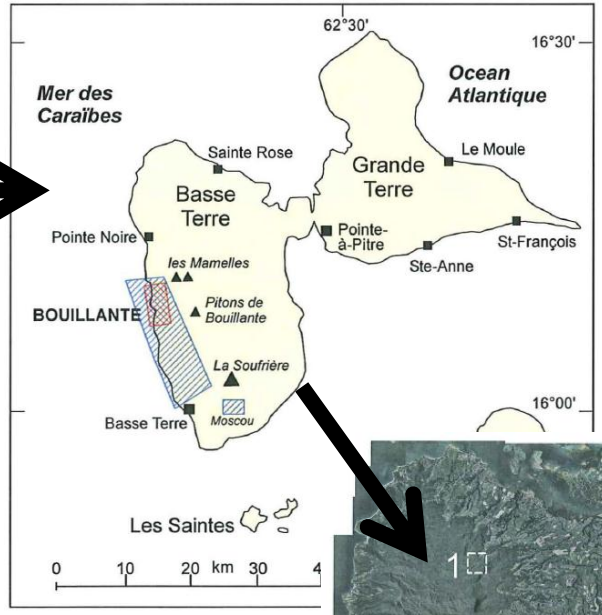
Guadeloupe island

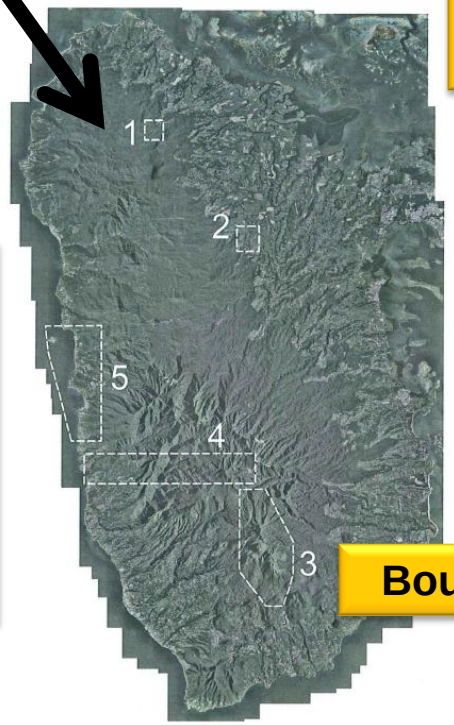


West Indies



Since 1963, numerous works in geology, geochemistry, geophysics and hydrogeology for geothermal exploration

Summary reports before 1999



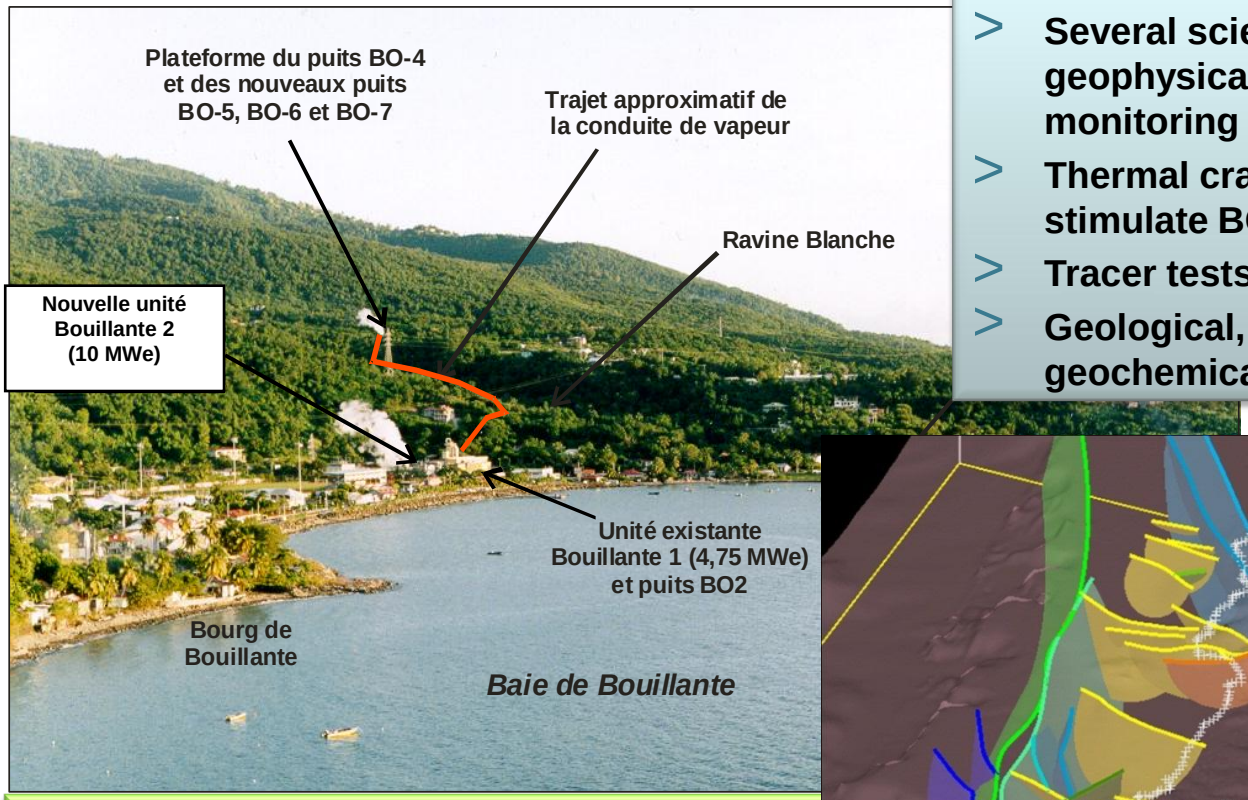
Bourdon et al., 2008

Potential geothermal resources:

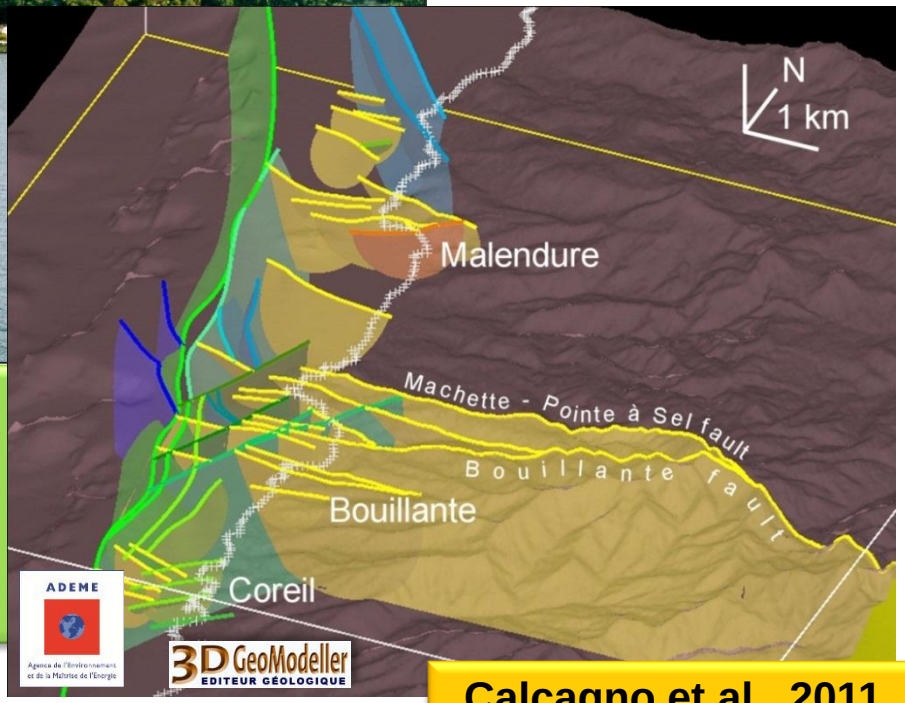
- **Sofaïa**
- **Ravine Chaude**
- **Soufrière**
- **Vieux habitants**
- **Bouillante**

Bouillante geothermal power

- 4 drilling in the 70's and 80's
- Last 3 wells in 2001
- Several scientific activities, geophysical and geochemical monitoring
- Thermal cracking in 1999 to stimulate BO-4
- Tracer tests
- Geological, hydrochemical and geochemical modelling

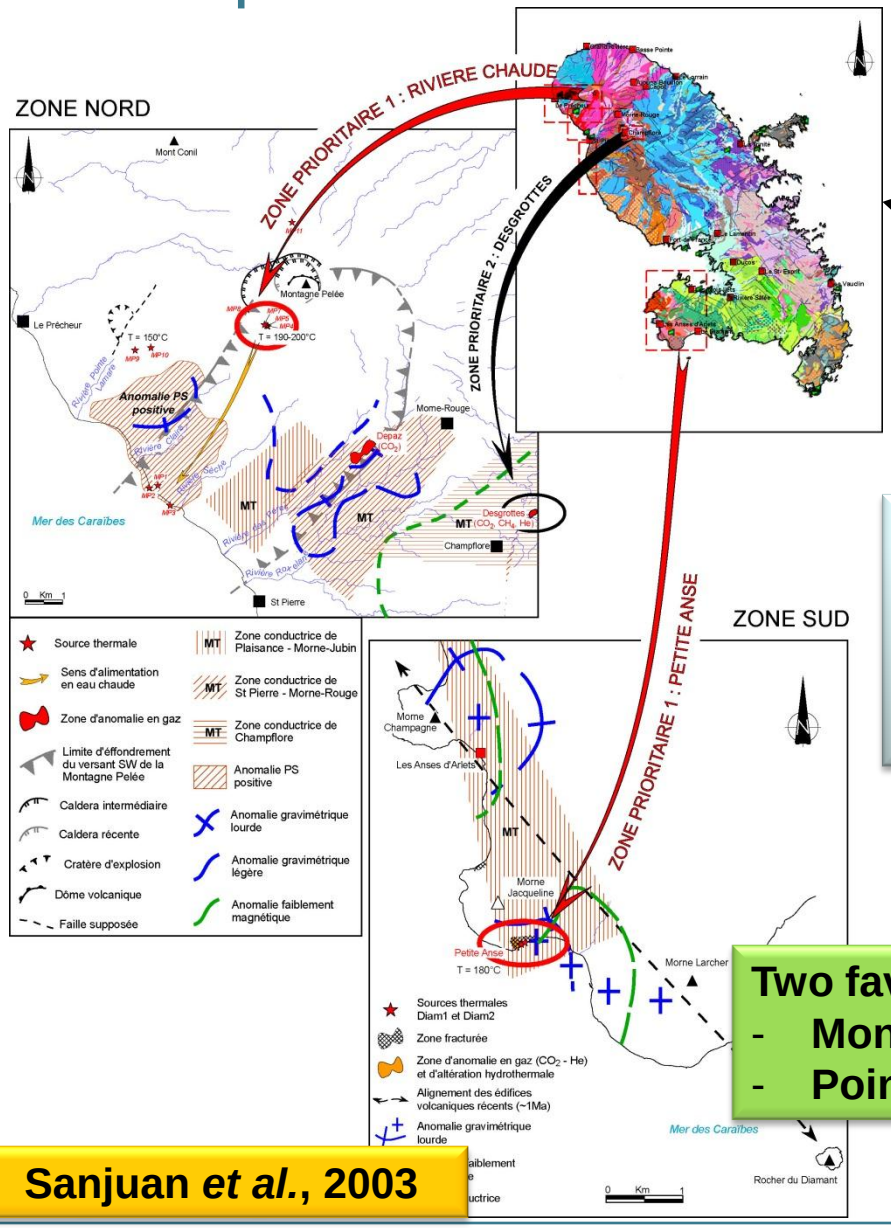


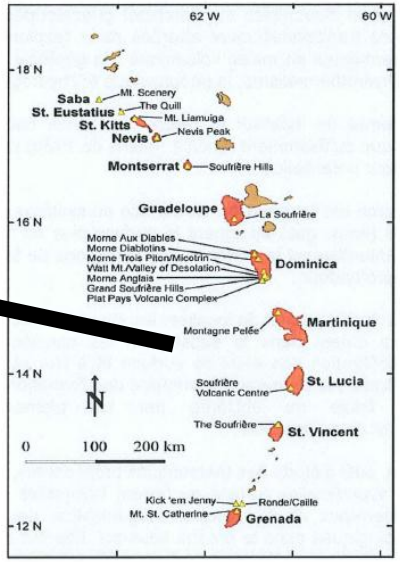
Bouillante 1: 5 MW
Bouillante 2: 10 MW since 2004
-> 6-8% of the electricity of the island (400 000 inhabitants)



Calcagno et al., 2011

Martinique island





West Indies

> **Activities of geothermal exploration in 1967-1970**

> **Geothermal potential reevaluation between 1979 and 1985**

Summary reports

Two favorable areas (180-200°C):
- **Montagne Pelée**
- **Pointe Diamant**

Sanjuan *et al.*, 2003

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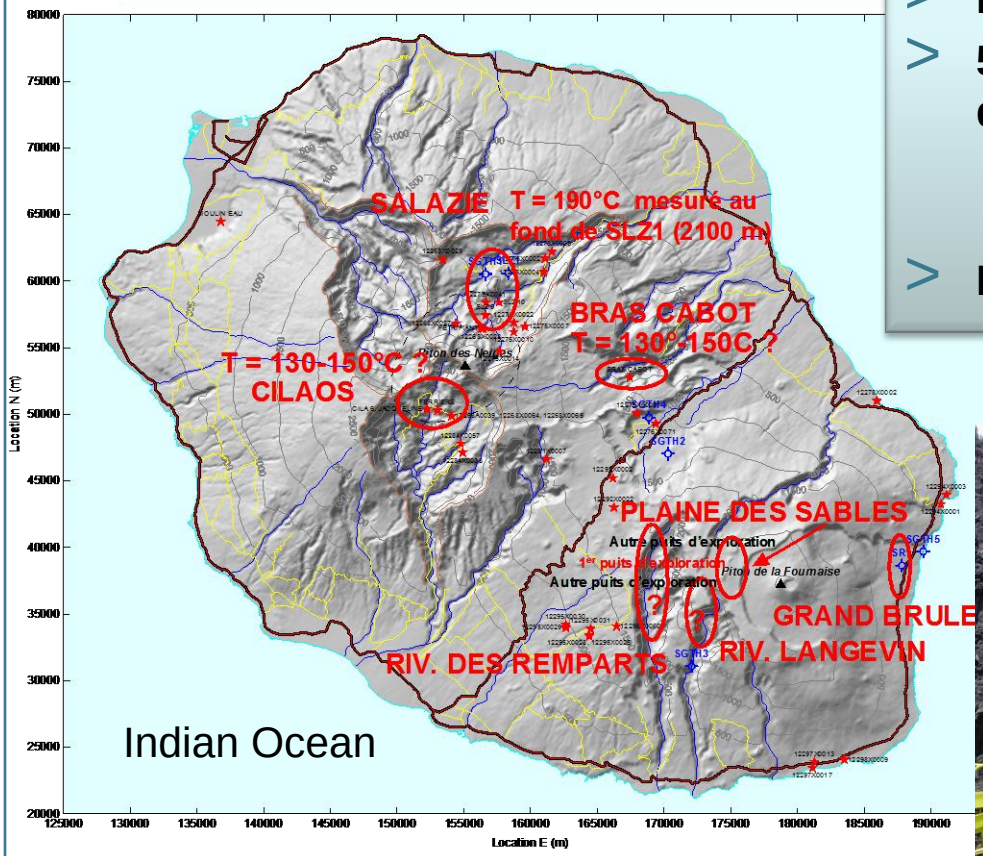
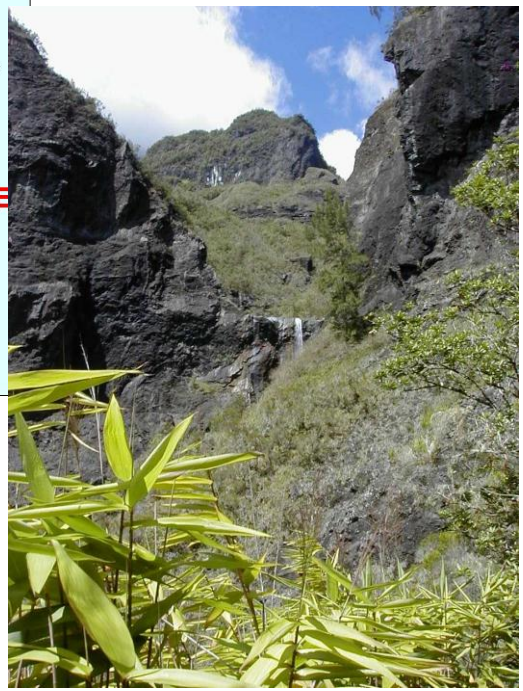
brgm

La Réunion island



- > **Exploration works in the 70's**
- > **5 thermal gradient wells and 2 deep exploration wells in 80's:**
  - Salazie: 185°C @ 2100m
  - Grand Brûlé: ~140°c @ 3000m
- > **Exploration works in the 2000's**



Summary reports
BRGM 2000
GeoPower 2002

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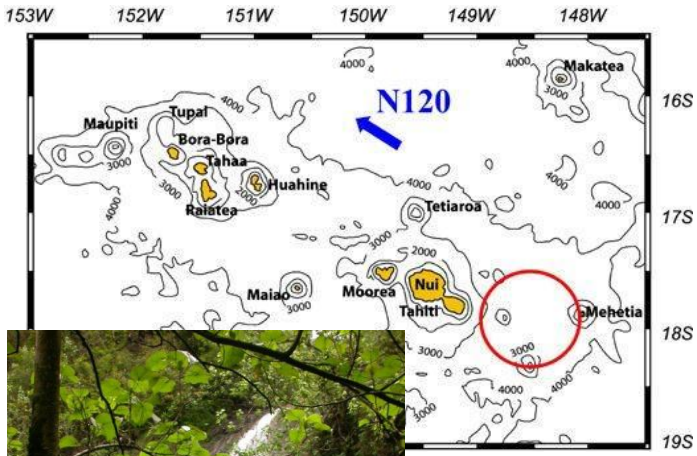
Tahiti and Mayotte islands

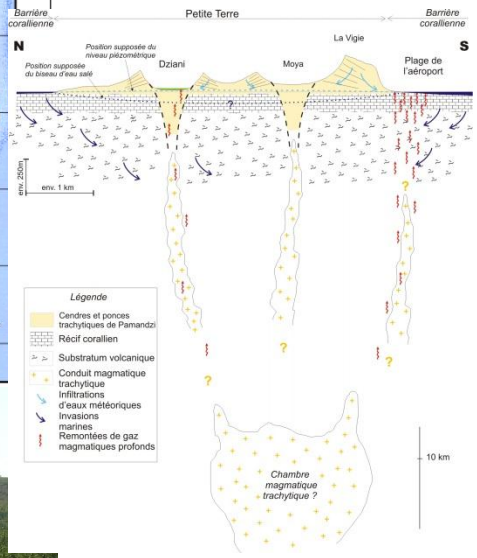
TAHITI

Geothermal exploration works in 2006
(mainly in the Tahiti Nui island)



MAYOTTE

Geothermal exploration works in 2005-2008



- **No trace of hot water**
- **Gas emanations with magmatic origin**

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> General data available in France

> Hot sedimentary aquifers

> EGS

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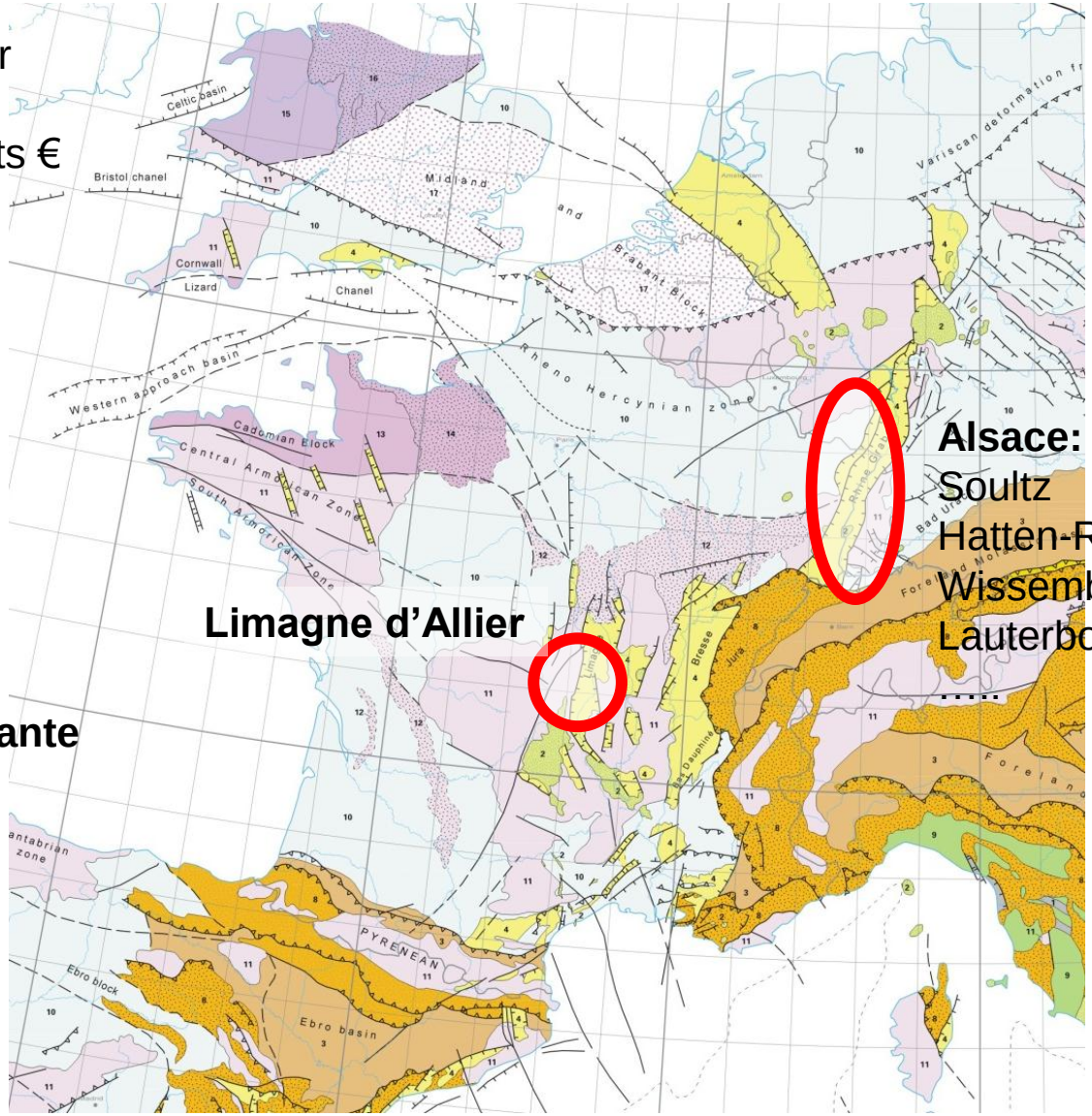
On-going exploration licences in France

Feed-in tariff for geothermal electricity: 20 cts € kWh



Thank for your attention