Overview of the Soltz geothermal project

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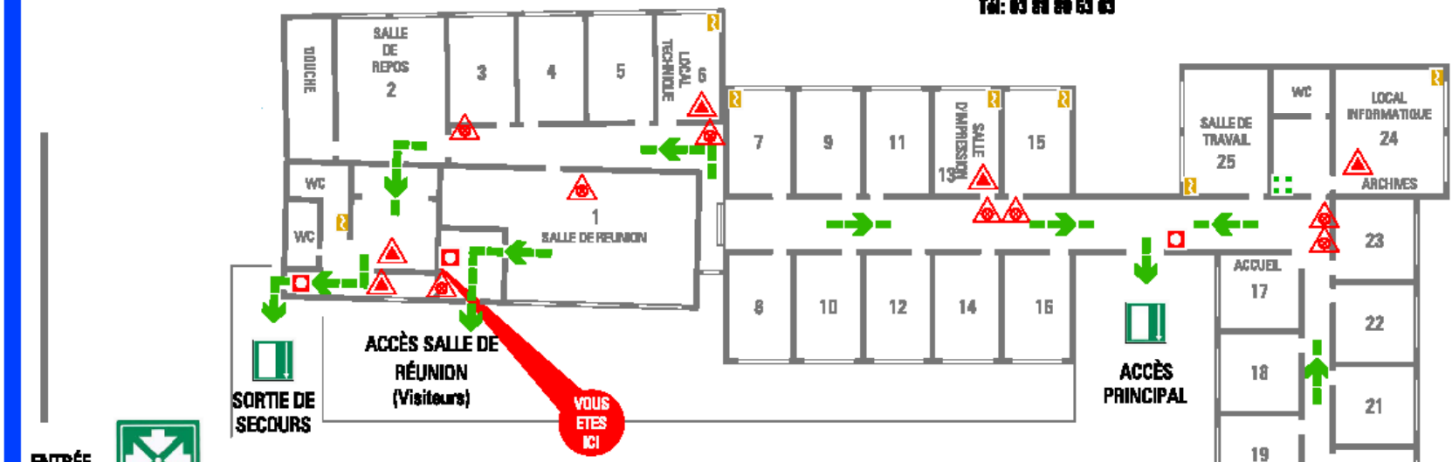
Soultz geothermal power plant

GeoElec Visit

Kutzenhausen, 09th November 2012

Plan d'évacuation

GEIE Exploitation Minière de la Chaleur
Route de Soultz
B.P. 38
67250 KUTZENHAUSEN
Tél: 03 88 80 53 03



Légende :

- Extincteur portatif à dioxyde de carbone CO_2
- Extincteur portatif à eau
- Chemin d'évacuation, direction à suivre
- Chemin d'évacuation, sortie finale
- Coffret électrique
- Armoire à pharmacie
- Alarme incendie

Co-Gérant: J.J.GRAFF / 04-12-2007

OUTLINE

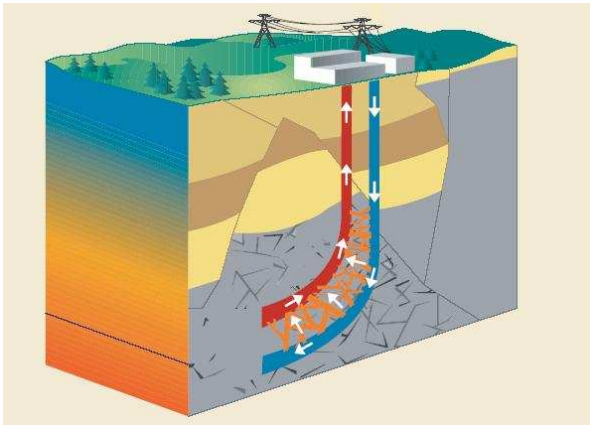
- Project organization
- Scientific achievements
- Technical achievements
- On-going activities on site
- Geothermal activity and dissemination
  - Other EGS projects in the URG
  - Dissemination

Soultz Drilling Rig

The Soultz geothermal concept

Hot Dry Rock

- Acronym HDR
- Heat exploitation from deep hard rocks
- High temperatures at great depth
- Not dependent from the location
- Create artificially a heat exchanger at depth
- Closed system



Artificial heat exchanger

EGS

- Enhanced Geothermal System
- Natural brine 100g/l, NaCl, pH~5
- Naturally Fractured and Altered Granite
- Connection between geothermal well to the reservoir by stimulation
- Forced fluid circulation during exploitation

Geothermal fluid

Large reservoir with similar fluid composition: open system

WHO WE ARE?

European Economic Interest Grouping

“Exploitation Minière de la Chaleur” GEIE EMC

Industrial Partners

Public Funding

Scientific Partners

CONTRACTUAL PROJECT PHASES

2001 Phase I 2005

Deep Drilling & Stimulation
29M€

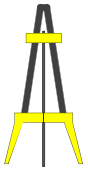
2004 Phase II 2009

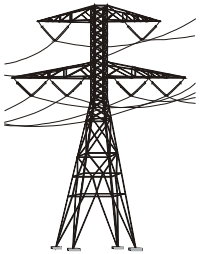
Power plant construction
25M€

2010 Phase III 2012

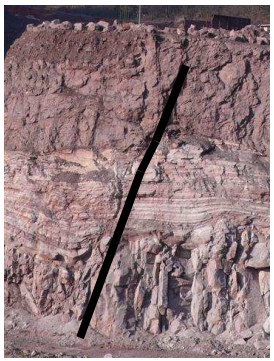
Scientific and Technical monitoring
5M€

Geothermal life cycle

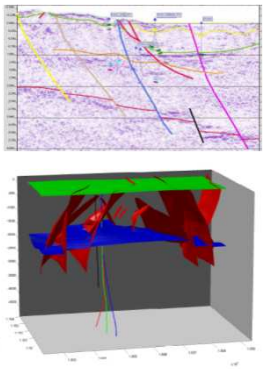




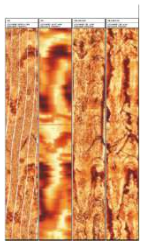
Concept | Site Selection | Drilling | Stimulation Testing | Build & test power plant | Operate and circulation | Site abandonment



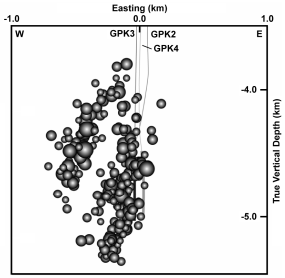
Fracture on outcrops



Concessional scale



Borehole Image



Micro-seismic cloud structure

Power plant exploitation

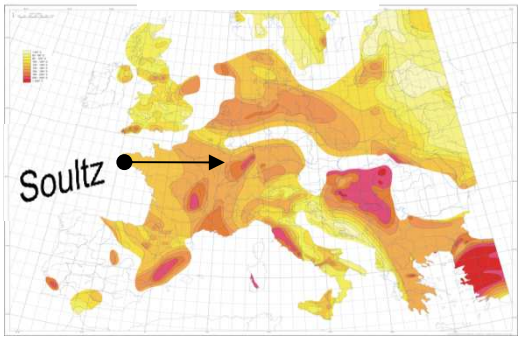
Power plant dismantlement

Geothermal Development

Soultz Project presentation

Location

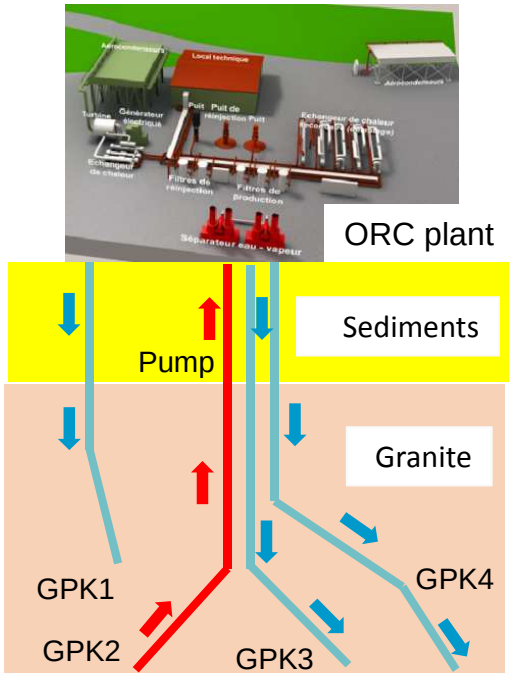
- Geothermal anomaly in the Upper Rhine Graben (URG)



Technology

- 4 deep geothermal wells (3,6 and 5 km): 200°C @ 5 km depth
- 1st binary geothermal plant in France
- Organic Rankine Cycle (ORC) technology: 1.5 MWe
- Down-hole pump tests: Long Shaft Pump (LSP)

Down-hole Pump



Feed-in tariff

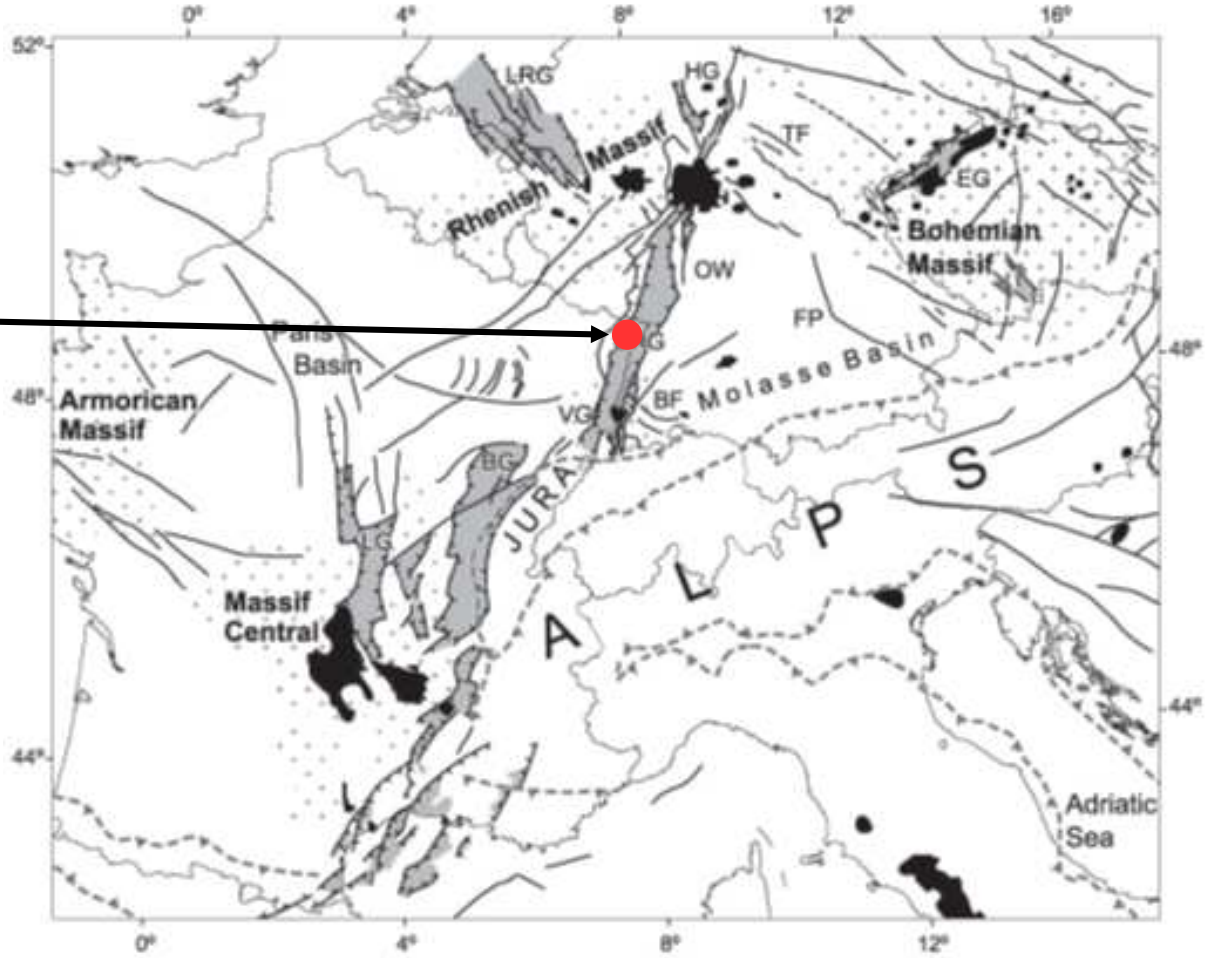
- New decree 23 July 2010 in France
- Geothermal electricity 20 c€ per kWh
- Bonus for heat of 8 c€ per kWh
- At Soultz, selling of electricity started early 2011
- No heat application on site

One of the highest geothermal anomaly in Western Europe

SCIENTIFIC ACHIEVEMENTS

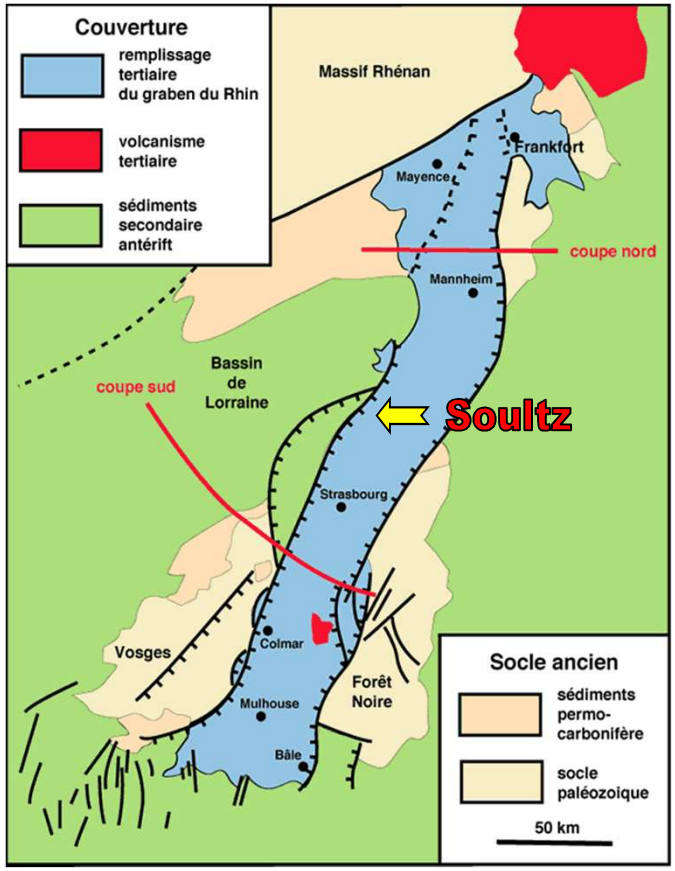
WEST RIFT EUROPEAN SYSTEM

Soltz

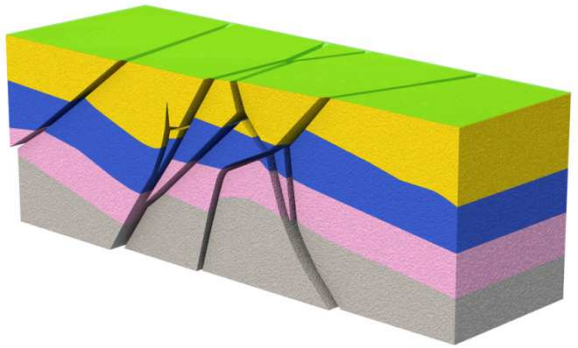


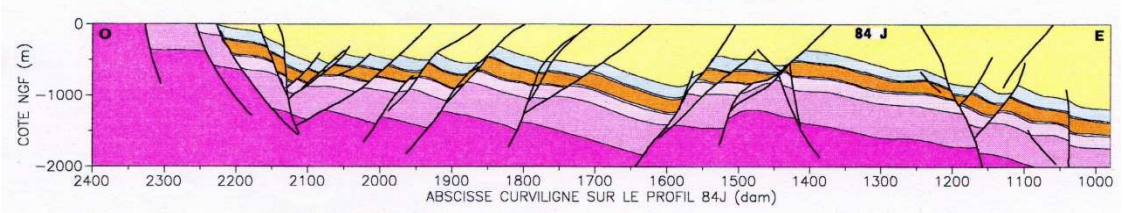
Dèzes et al., 2004

UPPER RHINE GRABEN (URG)



Soultz Horst

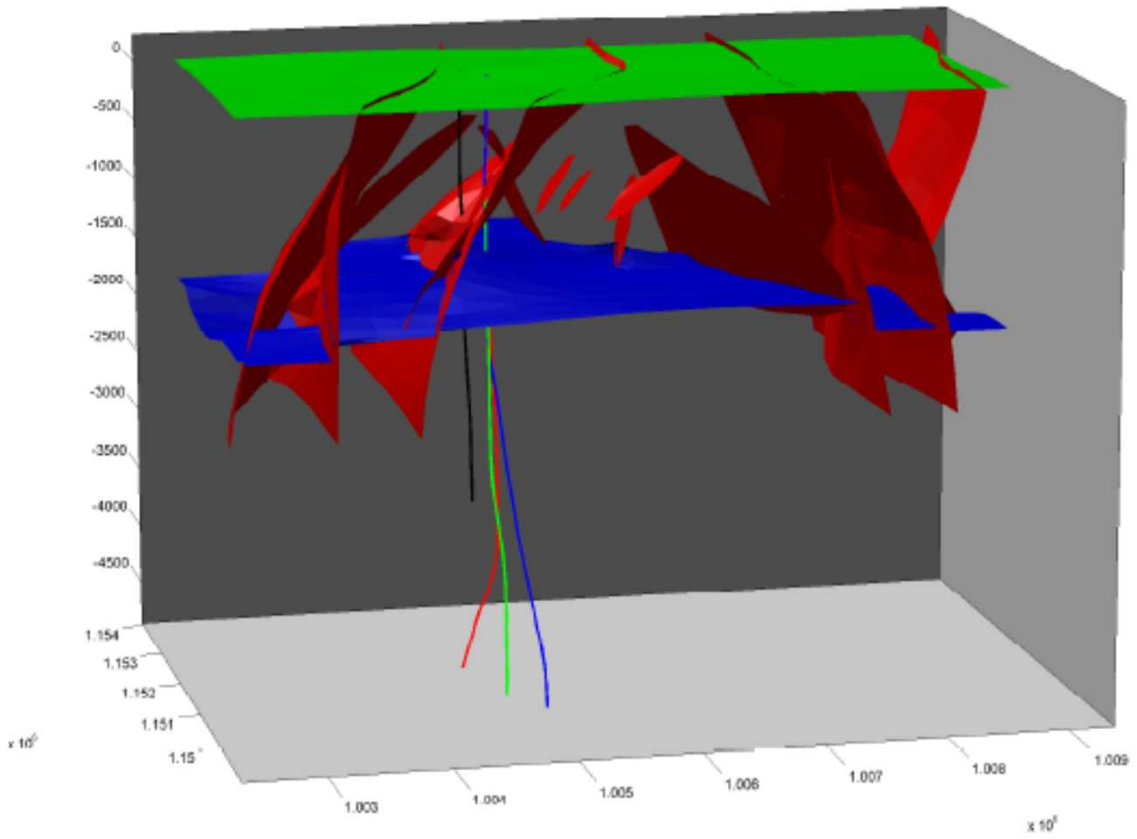




Transverse Seismic line

Geothermal target is a deep crystalline rock

FRACTURE NETWORK BASED ON 2D SEISMIC DATA



Sediments

Granite

Major fault system in the sediments

Need for imaging the deep fractured granite

Renard & Courrioux, 1994; Valley, 2007

The main project steps

1987 – 1991

Exploration phase

- Drilling GPK1 at - 2000 m
- Coring EPS1 at - 2227 m

1991 – 1998

Creation of the 2 wells system GPK1/GPK2 at - 3600 m

- Deepening of GPK1 at - 3600 m and stimulation
- Drilling of GPK2 at - 3880 m and stimulation
- Circulation test between the 2 wells (4 months)

1999 – 2007

Creation of the 3 wells system GPK2/GPK3/GPK4 at - 5000 m

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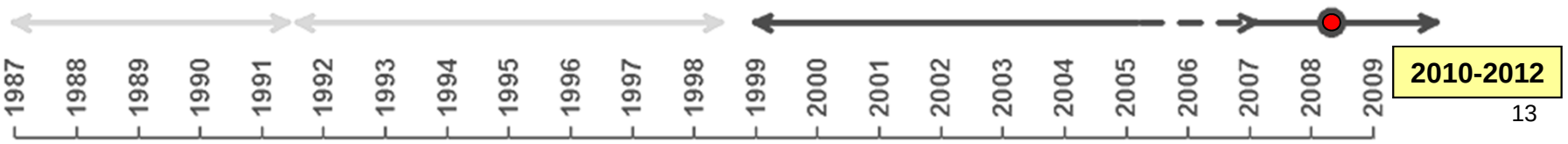
- Drilling of GPK3 at - 5100 m and stimulation
- Drilling of GPK4 at - 5270 m and stimulation
- Circulation test between the 3 wells (5 months)
- Complementary stimulations (chemical)

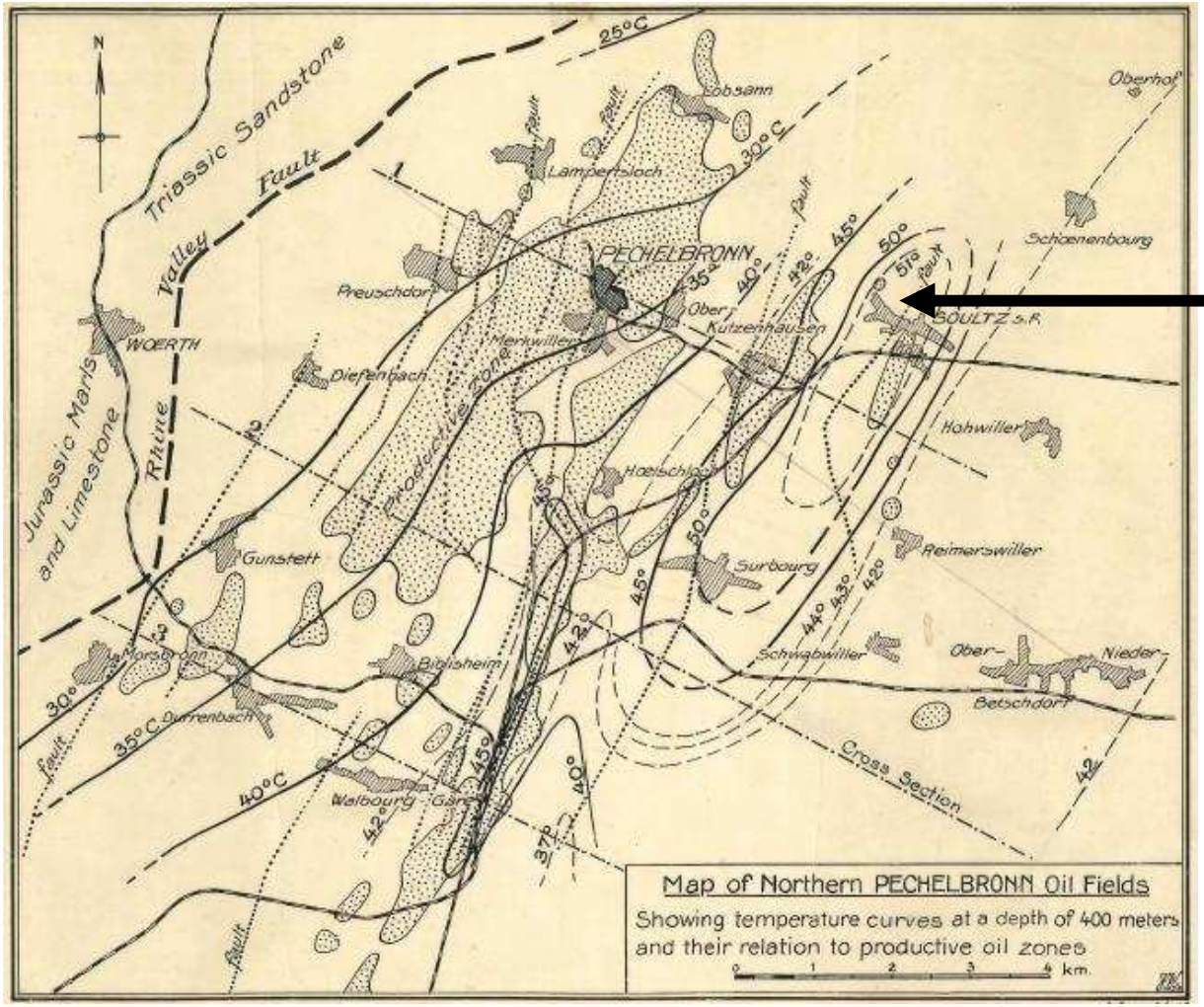
2007 – 2009

Construction of the first production unit ORC - 1.5 MWe

- **Installation of surface equipment (turbine and generator, heat exchangers, cooling systems …)**
- **Installation of the LSP in GPK2 at - 350 m**
- **Inauguration of the power plant 13.06.2008**
- **Installation of the ESP in GPK4 at - 500m**



GEOTHERMAL MAP (1929)



50℃ at 400 m depth

STANDARD GRANITE

7 cm

Core K21, GPK-1 (3510 m)

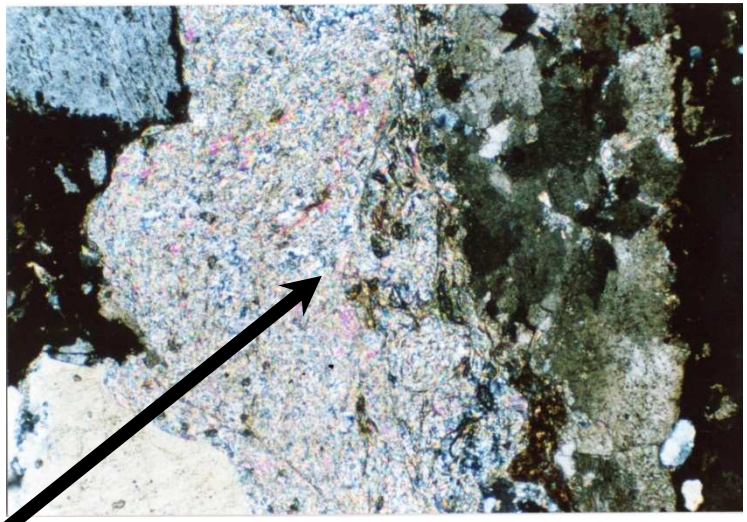
Monzogranite

Crystals of FK (1 to 4 cm)

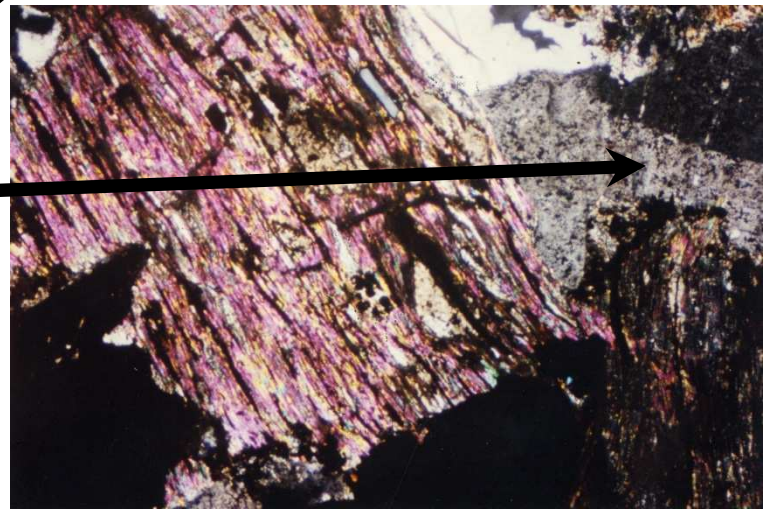
Granite matrix:
plagioclase, quartz, biotite and hornblende

Accessory minerals: magnetite, zircon, apatite, titanite, hematite, leucoxene,

ILLITE AND CALCITE WITHIN FRACTURED GRANITE



GPK1 well
K5-20



GPK1 well
K19-12

1mm

THE MAIN PROJECT STEPS

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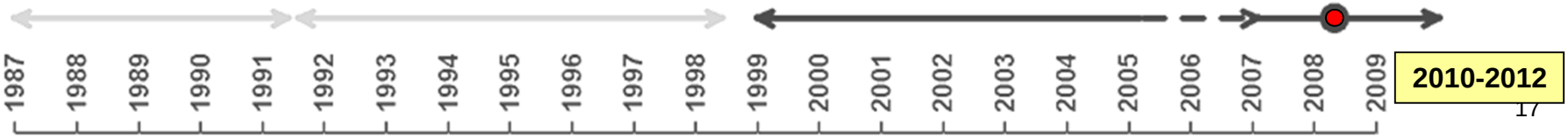
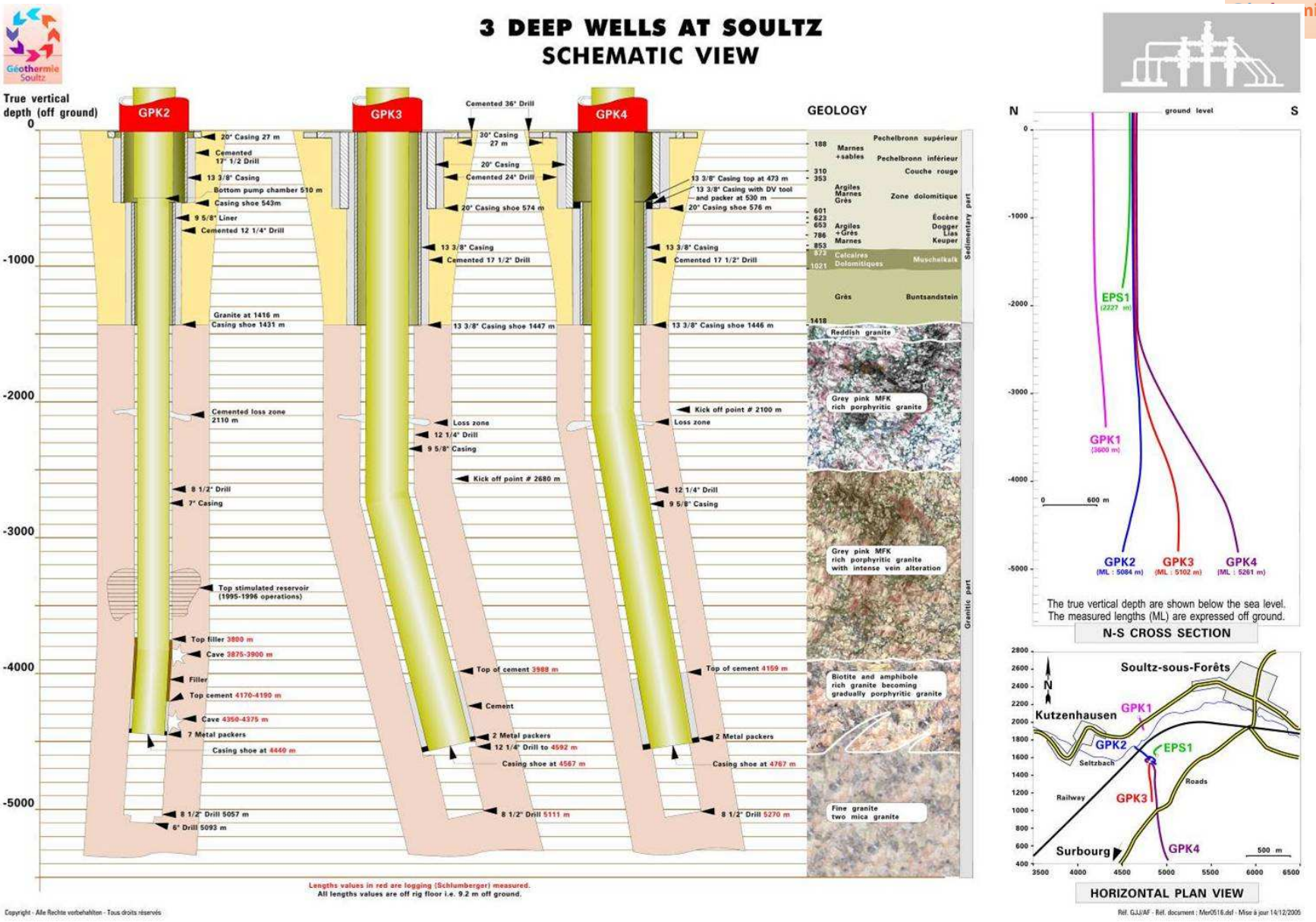


WELL COMPLETION



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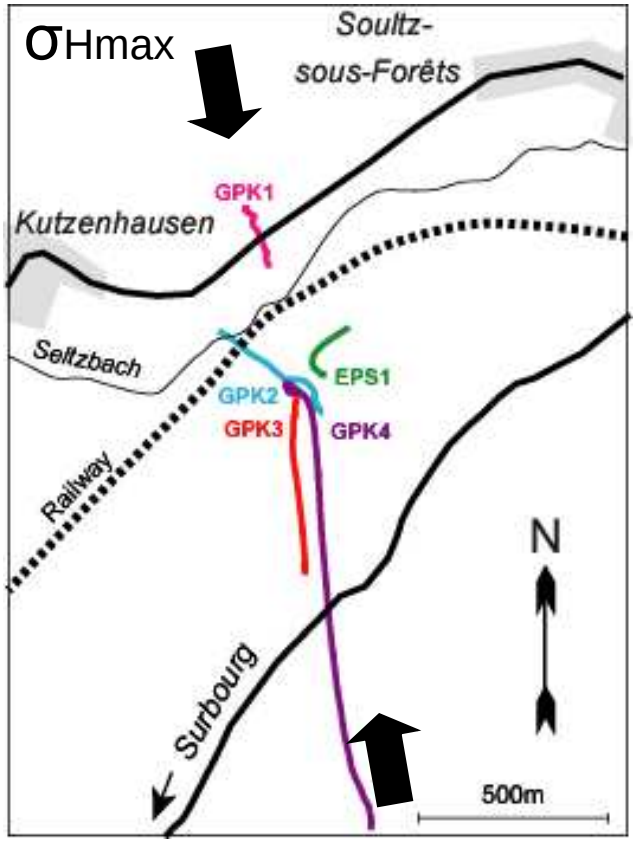
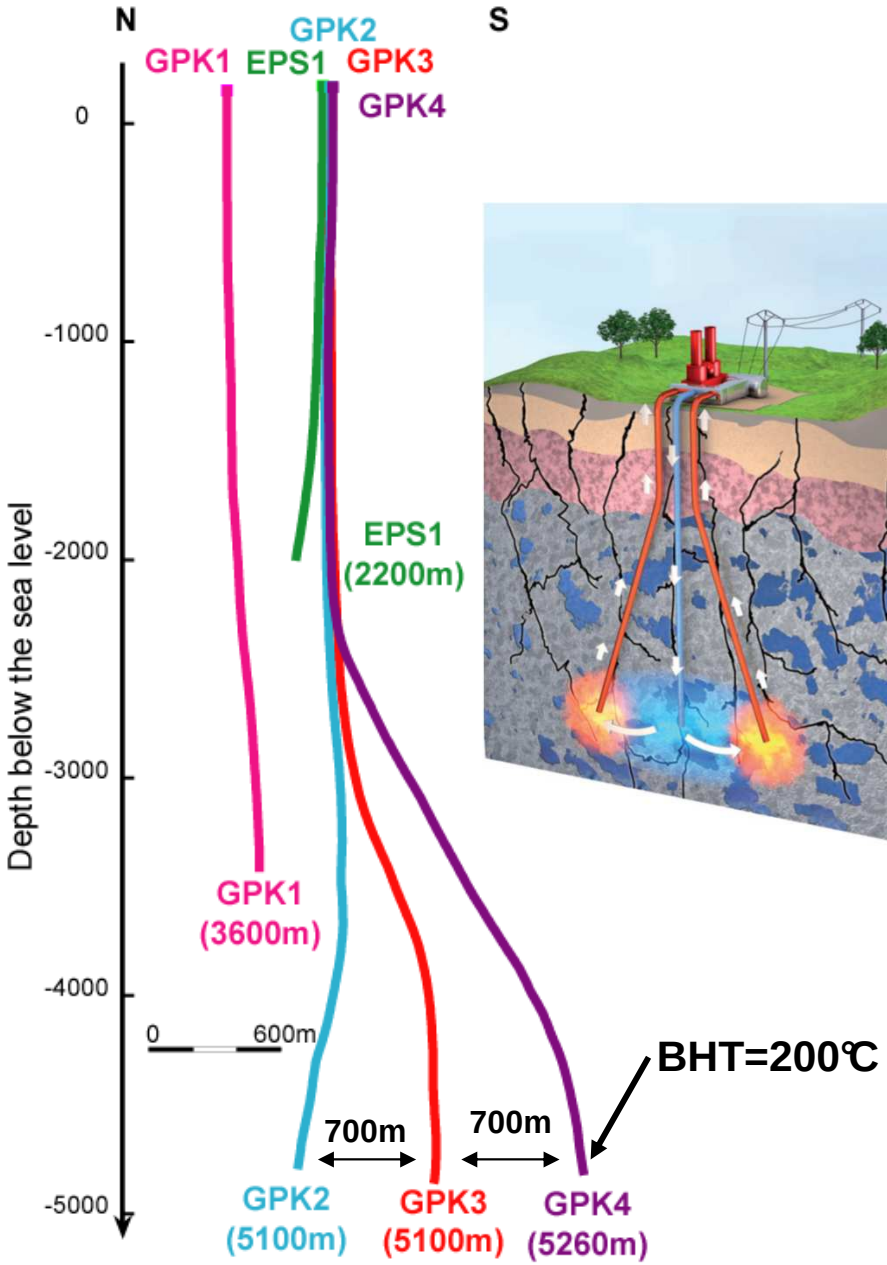
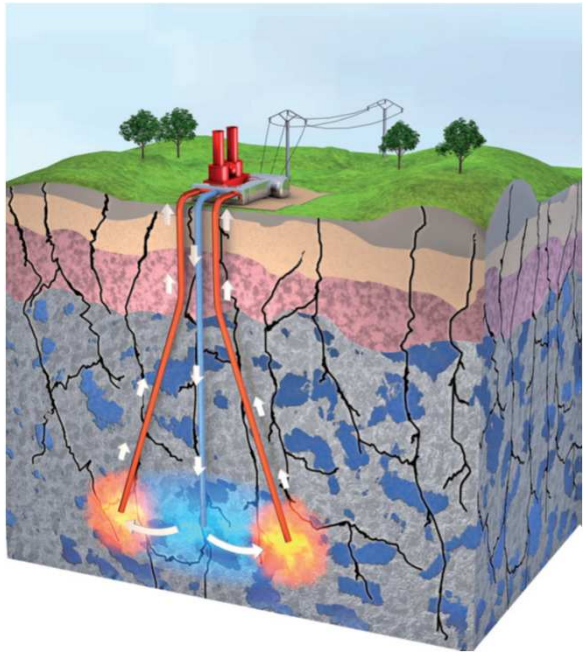
SITE MAP



Since 1987:

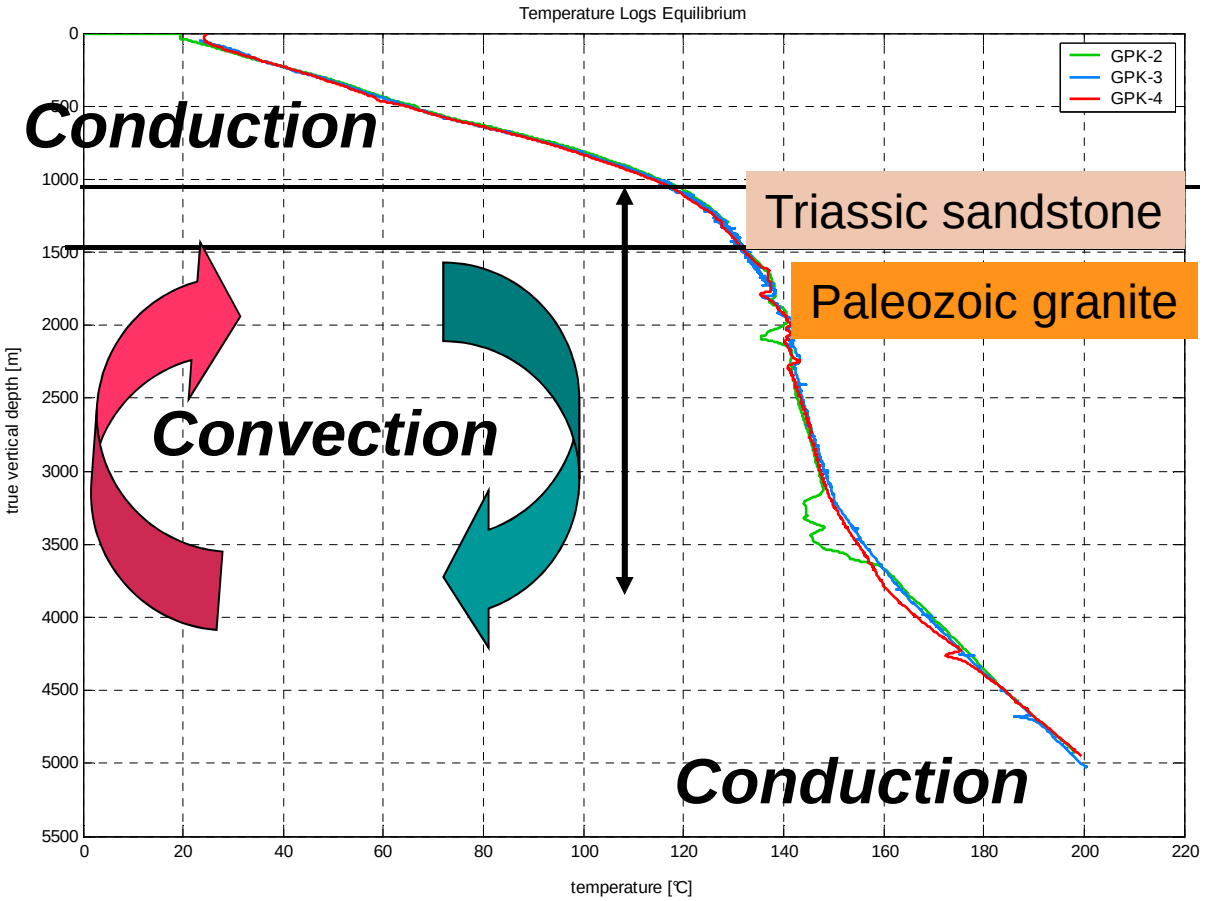
- EPS1 fully cored ➡ exploration well
- GPK1 ➡ Injection well
- GPK3 ➡ Injection well
- GPK2 & GPK4 ➡ Production wells





THERMAL PROFILES IN THE SOULTZ WELLS

Fractured Altered Granite



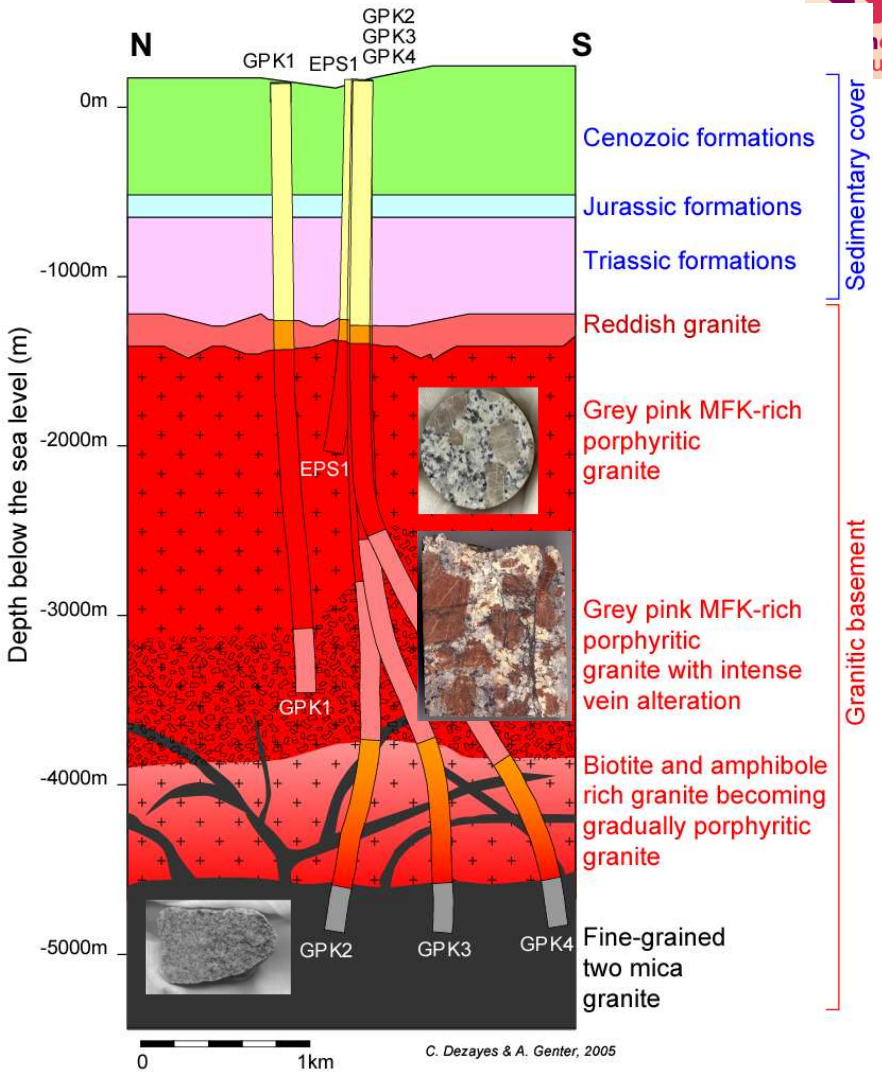
Fractured Sandstone

Natural circulation within hydrothermally altered and fractured zones

DEEP GEOLOGY

- Methodology:
  - **Fracture network with borehole image logs**
  - **Petrography and hydrothermal alterations with cuttings, cores and geophysical logs analyses**

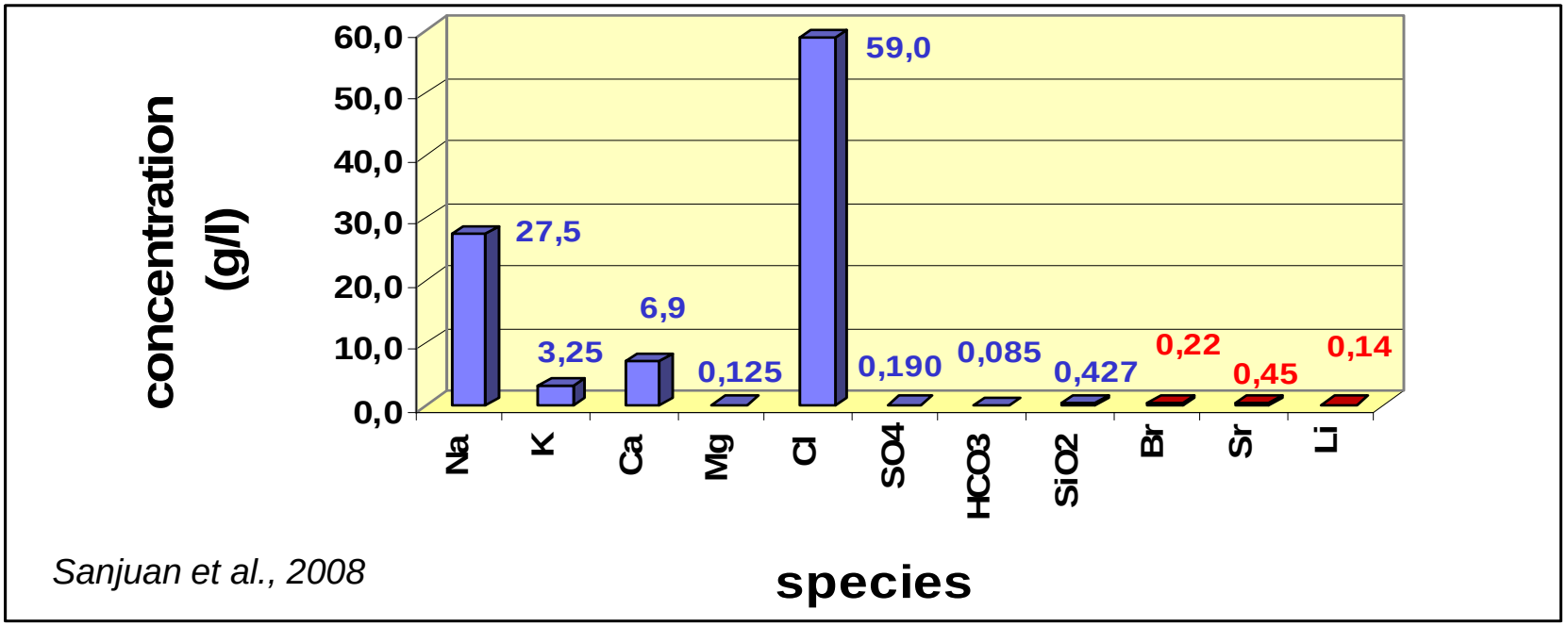
- Geological model:
  - **2 granites (U/Pb dating)**
  - **Normal faults, graben**
  - **Fracture zones with low natural permeability**



Dezayes et al., 2004

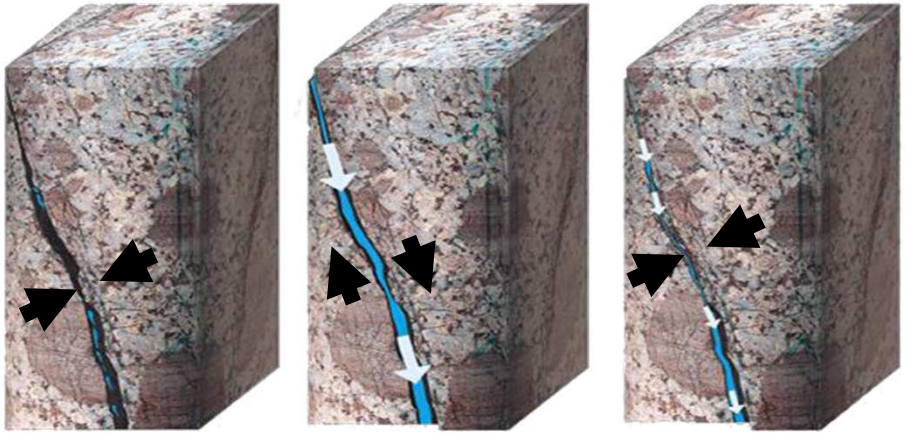
GEOCHEMICAL CHARACTERISTICS OF THE BRINE

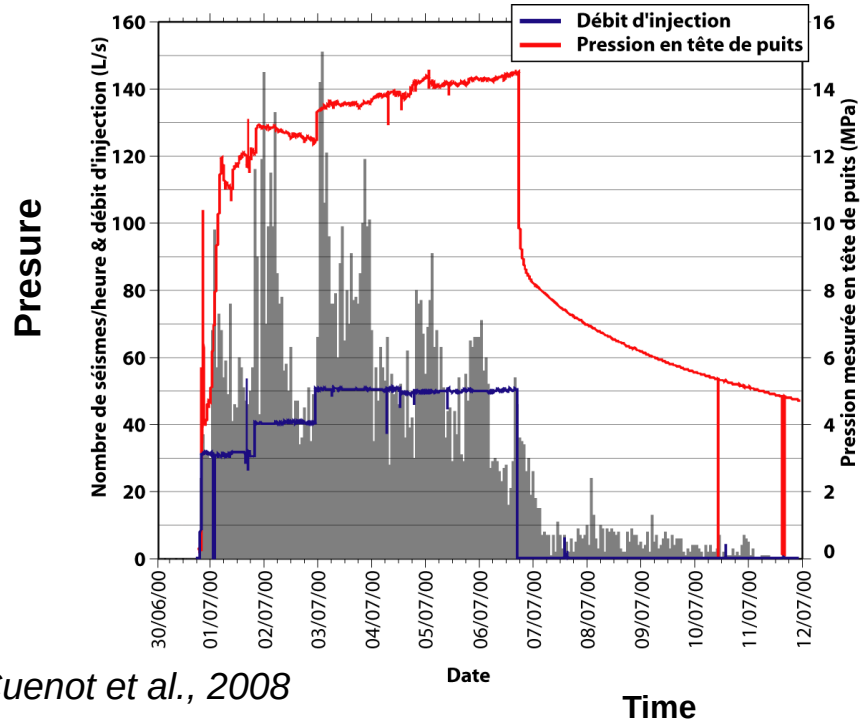
- Representative chemical composition: Na-Cl brine, pH ≈ 4.8-5.0
- TDS ≈ 97 g/l and density = 1.065 g/cm^3 (20°C)



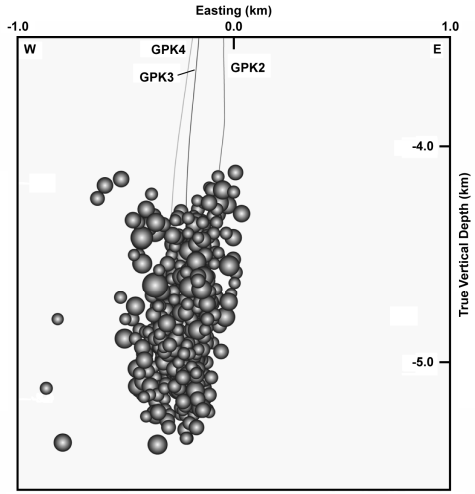
Sanjuan et al., 2008

HYDRAULIC STIMULATION

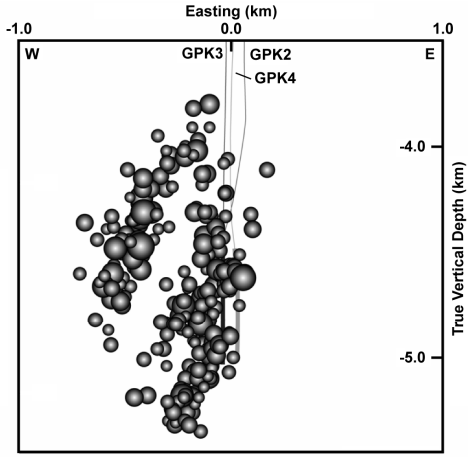




Cuenot et al., 2008



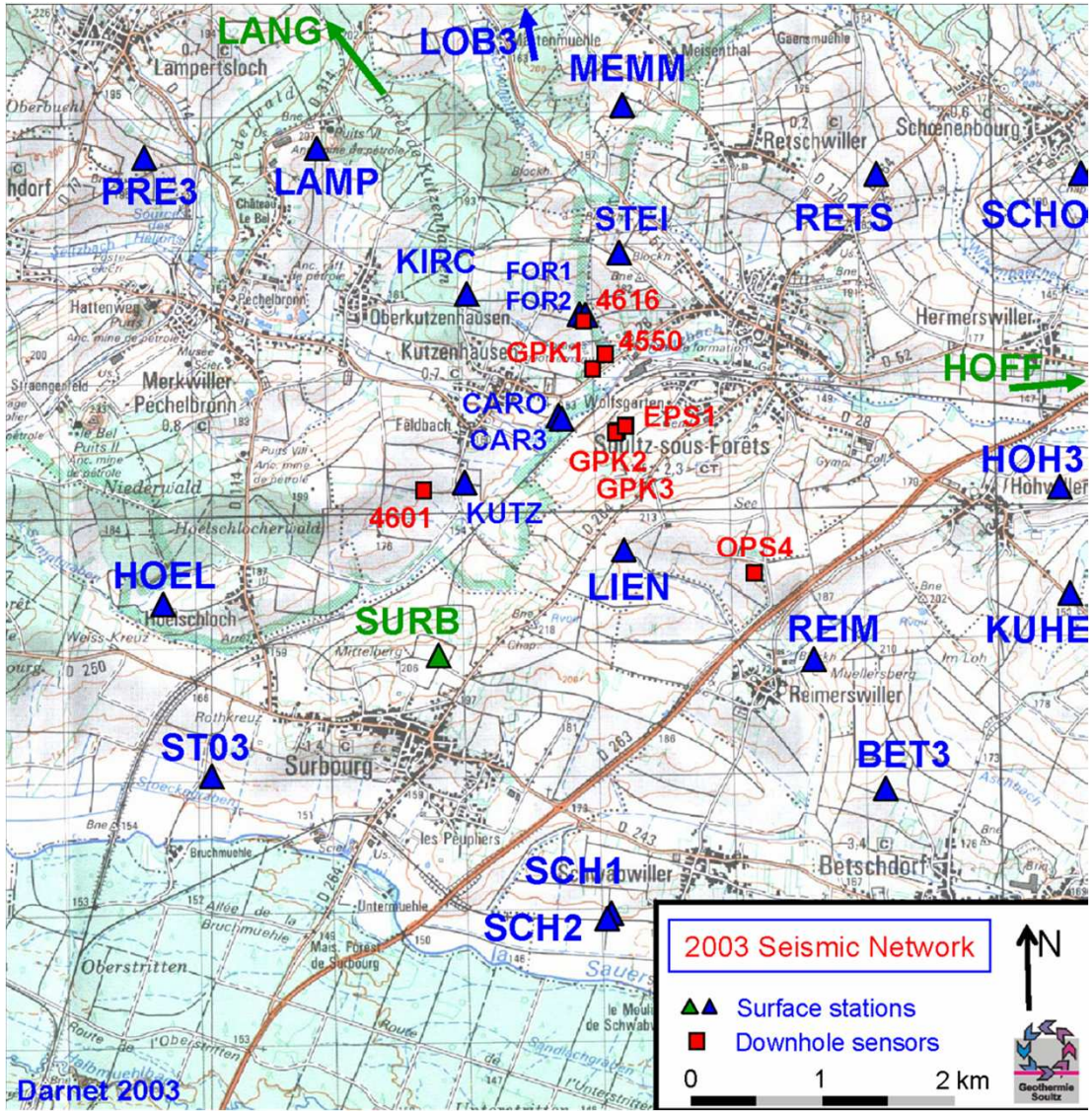
GPK2, 2000
µseismic events M>1



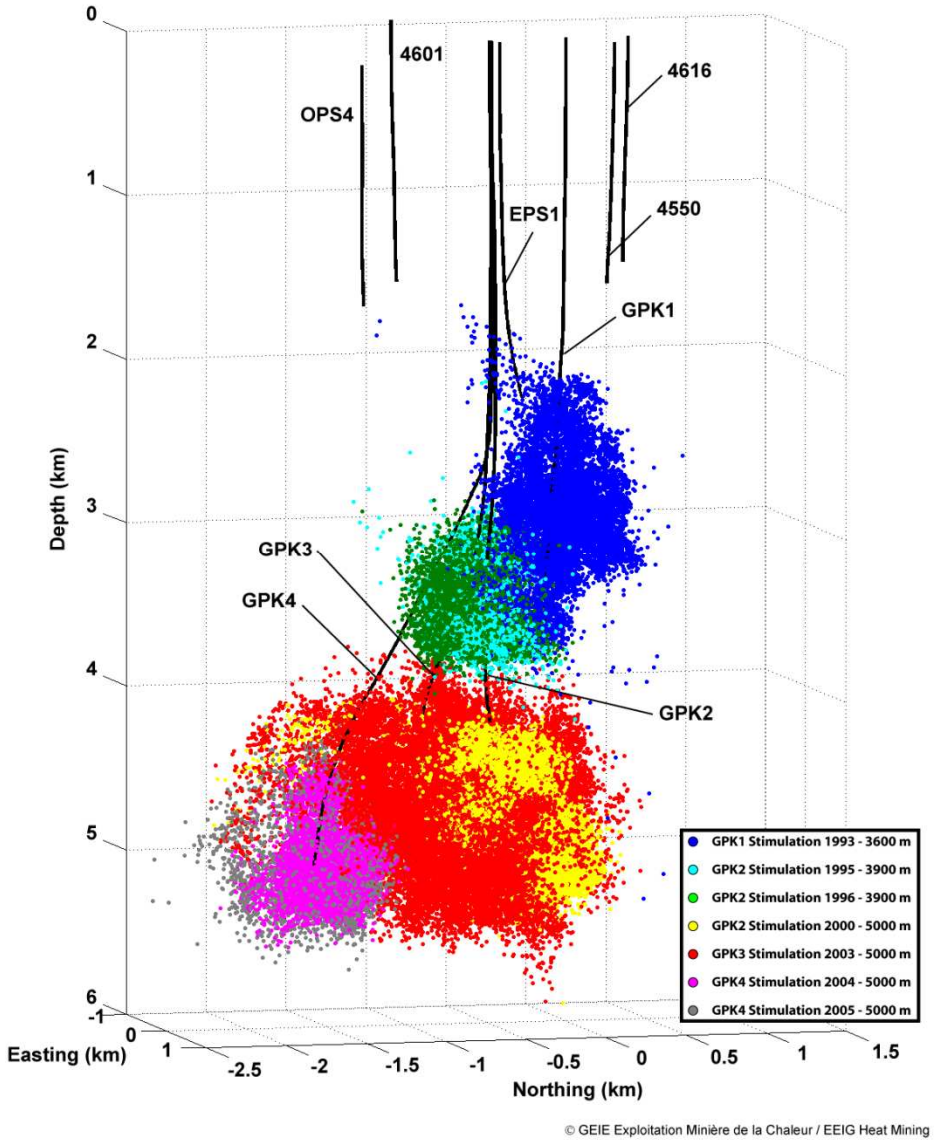
GPK3, 2003
µseismic events M>1

Dorbath et al., 2009

SEISMOLOGICAL NETWORKS



MICROSEISMIC CLOUDS



- **Several thousands of microseismic events during each stimulation test**
- **Several felt earthquakes (M > 2)**
- **Maximum magnitudes**
  - **2000 : 2.6**
  - **2003 : 2.9, 2.7**
  - **2004 : 2.0**
  - **2005 : 2.6**

PUBLIC ACCEPTANCE

- **growing fear due to:**
  - **the largest earthquakes (vibration, sound, moving objects)**
  - **repetition of felt earthquakes (within a short period)**
- **lots of phone calls (complain or ask for information)**
- **complaints to local authorities from individuals or associations**
- **articles in local newspapers**
- **around 70 complaints for presumed damages, which were evaluated by experts from insurance companies**
- **long-term risk of strong opposition to the project**

Soltz-sous-Forêts DNA 12/06/03

Géothermie : la secousse qui inquiète la population

●●● *Nombre d'habitants de la large région de Soultz-sous-Forêts, ont été réveillés en sursaut dans la nuit de mardi à mercredi. Peu avant 1 h, il y a eu une violente secousse, perceptible jusqu'à Haguenau. Une conséquence des essais géothermiques.*

SOULTZ-SOUS-FORETS

La géothermie préoccupe les maires

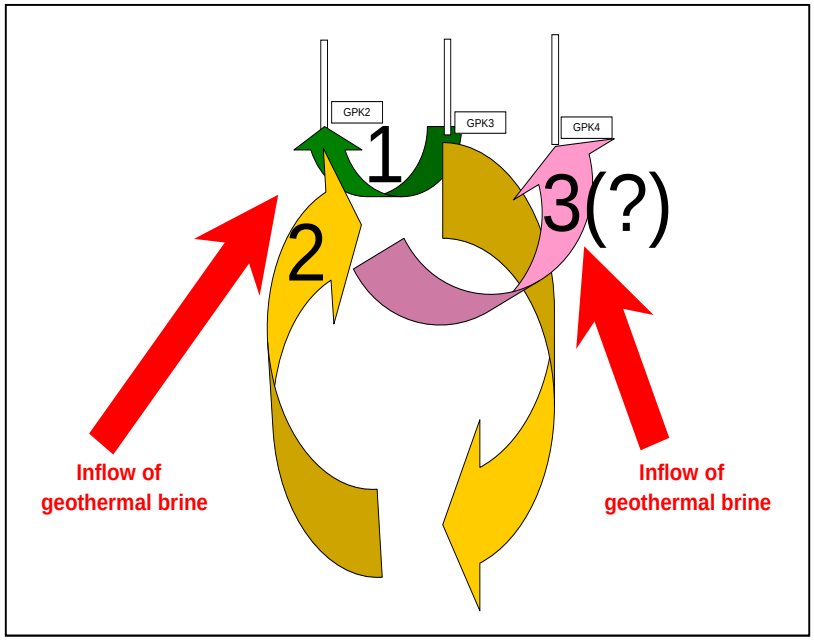
●●● *Suite aux secousses qui se sont succédé récemment dans les environs du site géothermique de Soultz-Kutzenhausen (voir en pages régionales des DNA du 12 juin), les maires du canton de Soultz ont bousculé leur programme pour mettre à l'ordre du jour de leur réunion ce thème d'actualité qui préoccupe une partie de la population depuis quelques jours.*

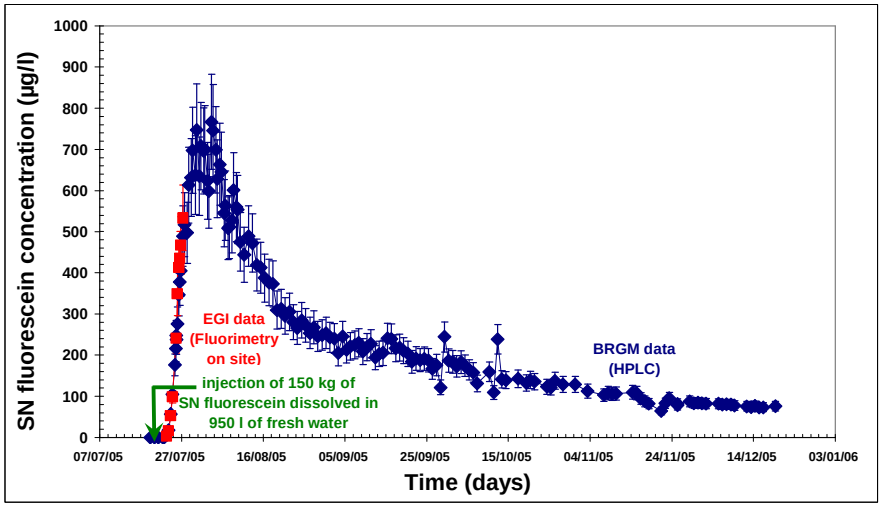
Pour répondre aux questions des élus et dissiper leurs inquiétudes, André Gérard et Pascal Vix, deux des responsables du Groupement d'Intérêt économique «Exploitation minière de la chaleur» présents dans la salle étaient accompagnés de deux experts en sismologie, en l'occurrence Catherine et Louis Dorbath, du Bureau central sismologique français situé à Strasbourg.

Après les explications d'André Gérard, quant à la nature des opérations pratiquées pour élargir les fractures contenues dans le granit à 5000 mètres de profondeur et de leurs conséquences, à savoir des déplacements de roches à peine de l'ordre du millimètre, mais aux effets pour le moins impressionnants, les sismologues ont réitéré leurs propos qui se voulaient rassurants à propos de dégâts éventuels provoqués par ces phénomènes: *«Pour des secousses inférieures à une magnitude de 3,5 sur l'échelle de Richter, nous ne faisons même pas d'enquête, elles n'ont aucune incidence sur les bâtiments».* Or la secousse enregistrée l'autre nuit n'était que de 2,9.

Toutefois, pour les gens qui estiment avoir subi un préjudice causé par ces tremblements répétés, M. Gérard ajoute: *«Ces derniers sont invités à signaler les dégâts. Des experts envoyés par l'assurance se rendront sur place pour constater les faits.»* Une visite prochaine sur le site de la géothermie a été demandée par certains élus; elle leur permettra d'en savoir davantage sur le sujet.

TRACER TEST IN 2005
PRODUCTION GPK2 & INJECTION GPK3





Strong hydraulic dissymetry between GPK3/GPK2 & GPK3/GPK4

70% of external water: open system

Sanjuan et al., 2006

THE MAIN PROJECT STEPS

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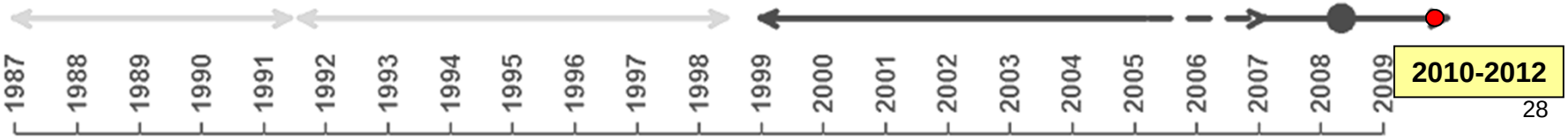
2007 – 2009

Construction of the first production unit ORC - 1.5 MWe

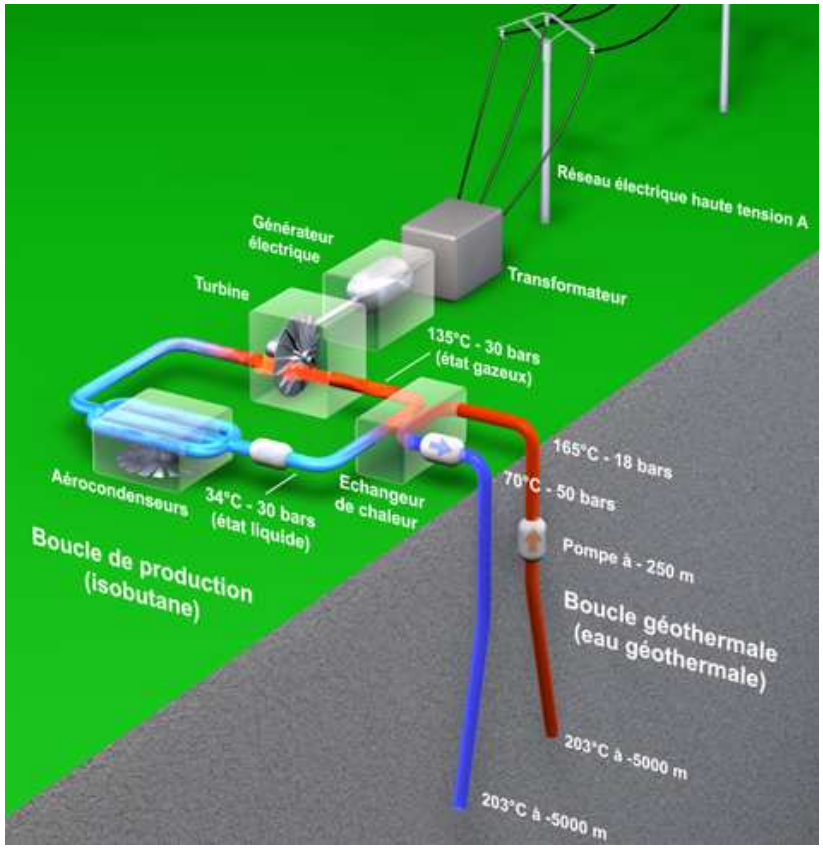
- **Installation of surface equipment (turbine and generator, heat exchangers, cooling systems …)**
- **Installation of the LSP in GPK2 at - 350 m**
- **Inauguration of the power plant 13.06.2008**
- **Installation of the ESP in GPK4 at - 500m**



Power plant construction

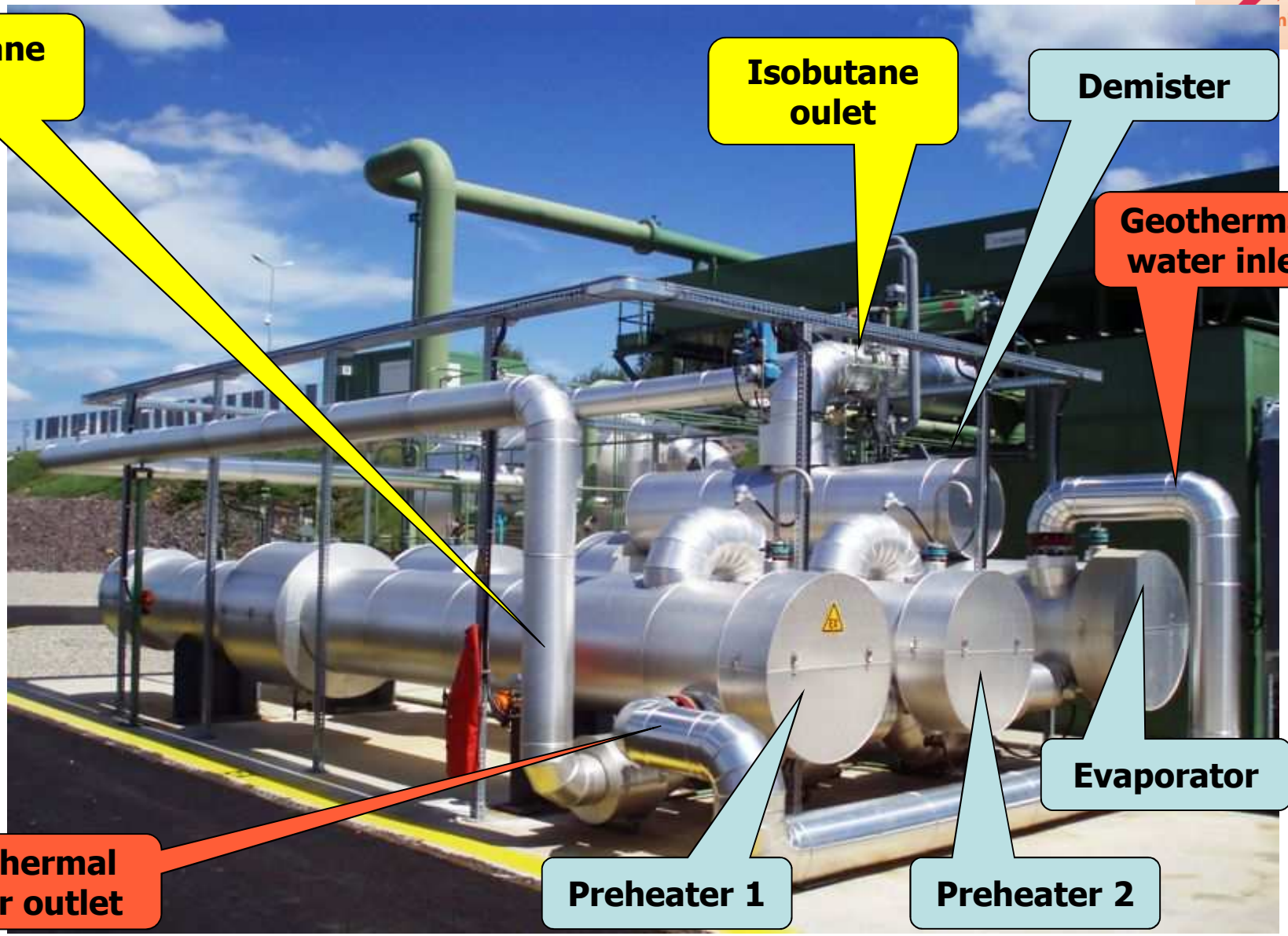
Down hole pump technologies

MOVIE



www.geothermie-soltz.fr

HEAT EXCHANGERS



LSP (LINE SHAFT PUMP) IN GPK2

- 250 m
- Max power ~ 300 kW

LSP PUMP DISMANTLING – SCALING (CARBONATES)

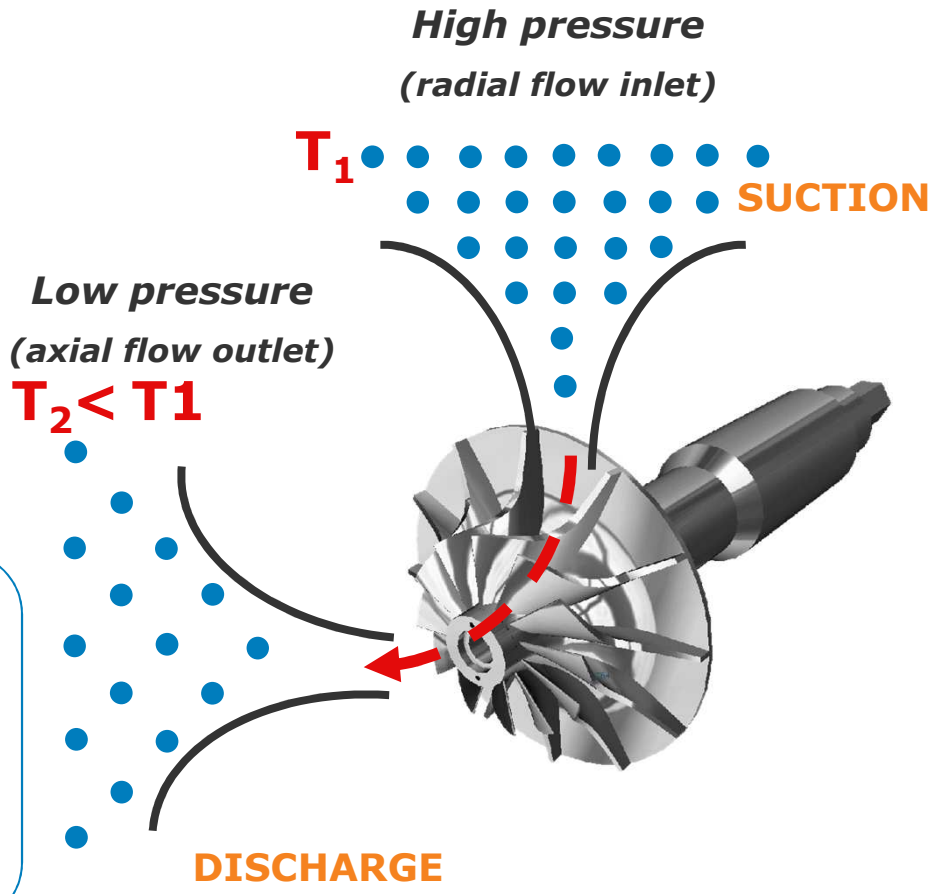
TURBINE RADIALE (CRYOSTAR)

A turbine is a rotating machine that converts energy from a process stream into mechanical energy.

At Cryostar, this equipment is a radial inflow expansion turbine.

Gas, at a high pressure level, is expanded through a turbine wheel to a lower pressure level.

Thus, the power generated, can drive a compressor or a generator.



TURBINE =

EXPANSION

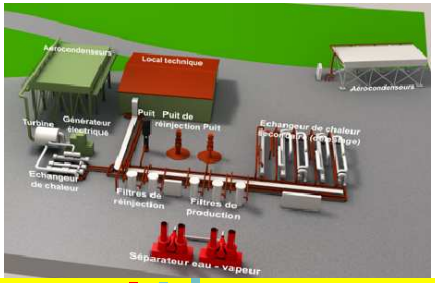
+

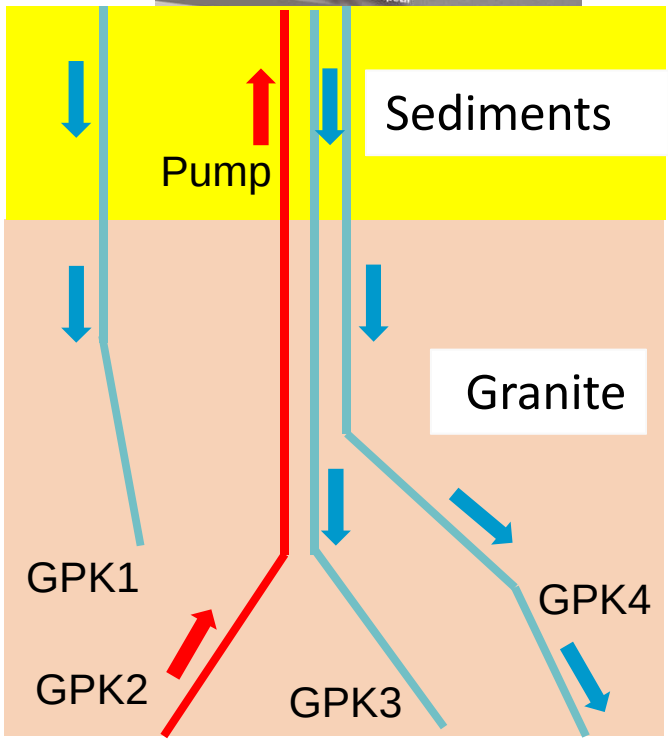
POWER RECOVERY

THE SOULTZ POWER PLANT

On-going activities

GEOTHERMAL SOULTZ SITE





Power plant

Max 1,5MWe

Organic Rankine Cycle

Geothermal system

Production Well GPK2

26L/s @157°C 19bar

PHASE III: CHALLENGES DURING EXPLOITATION

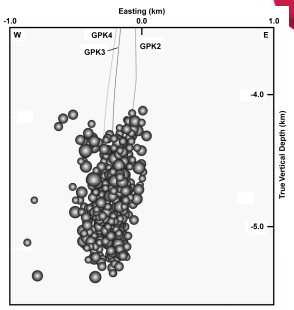
Environment

Noise
Vibration
Natural radioactivity
Visual impact

Power plant technology

Corrosion/scaling
Down-hole pumps

Reservoir Performance



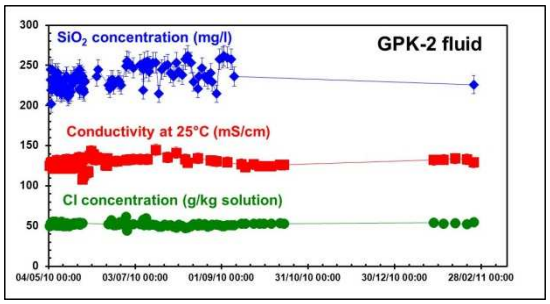
Micro-seismicity activity
Low pressure re-injection
Well production enhancement

CHALLENGES DURING EXPLOITATION: RESERVOIR

- Power Plant Monitoring
- Well measurements

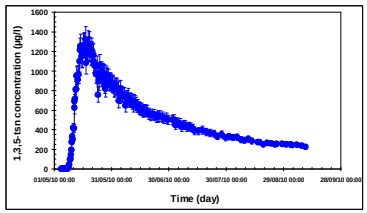
- Induced Seismicity
- Seismology

- Reservoir modelling
- 3D modelling/Exploration

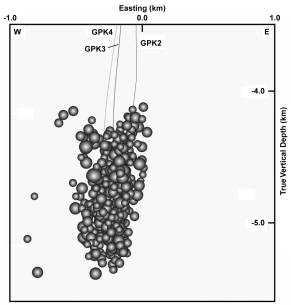


Physico-chemical monitoring

Geothermal fluid



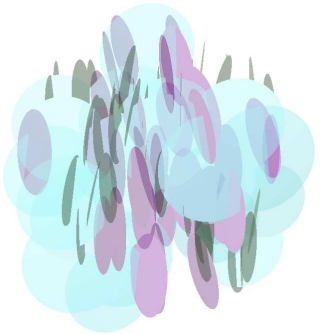
Inter-well tracer



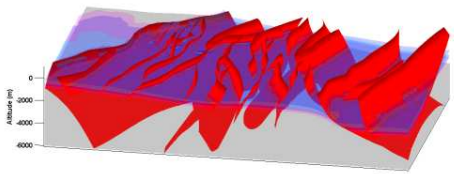
Micro-seismicity monitoring

Reservoir Performance

Micro-seismicity activity
Low pressure re-injection
Well production enhancement



Tracer modelling
In fractured media



3D fault modelling

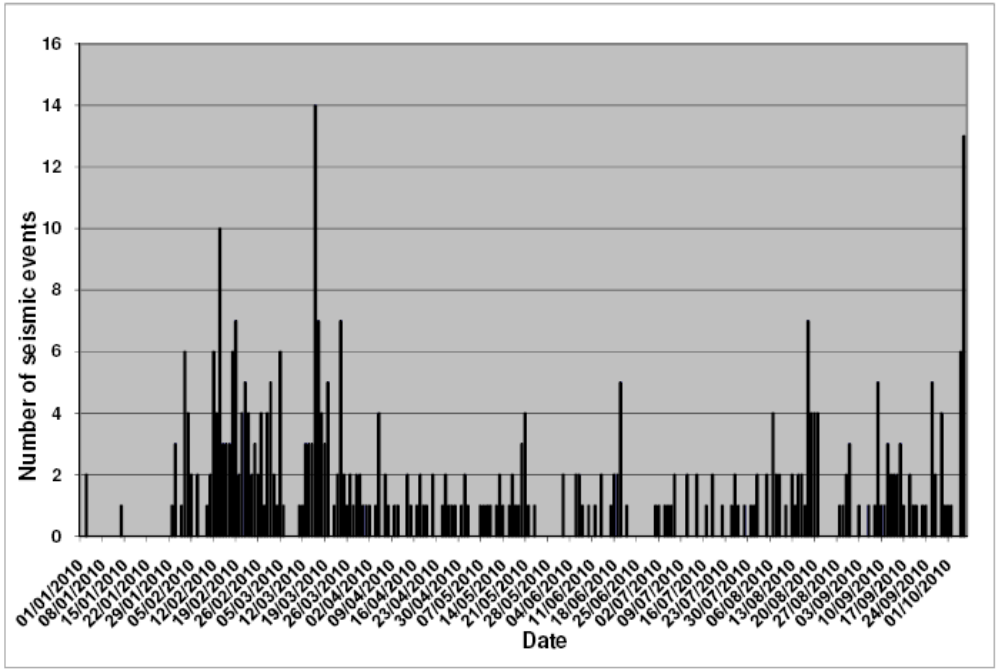
RESERVOIR: MICRO-SEISMICITY ACTIVITY

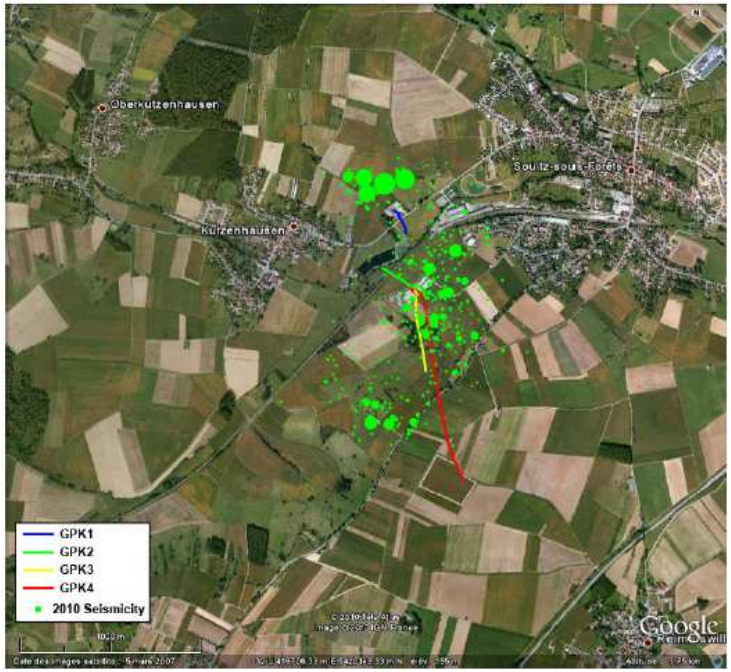
Longest hydraulic circulation test never done at Soultz: >10 months

Low induced micro-seismicity activity

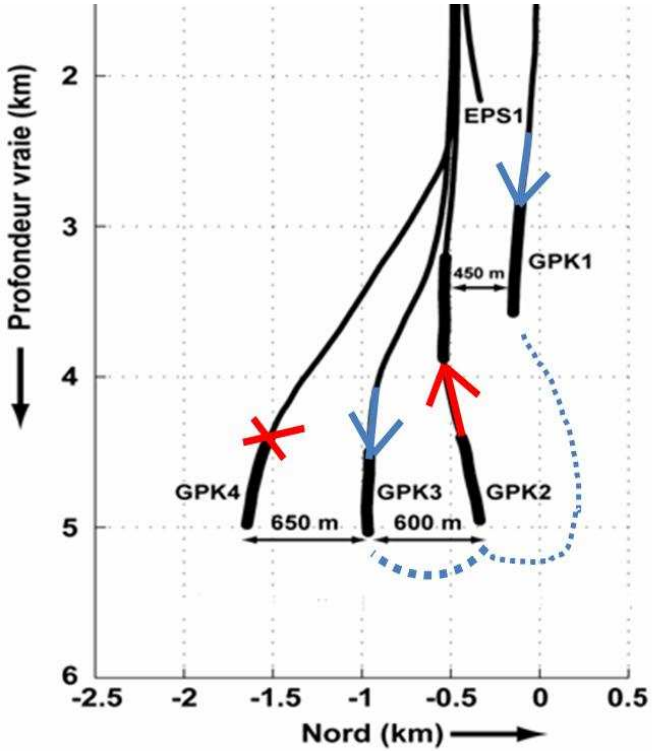
Average rate is less than 2 µevents/day from January 2010

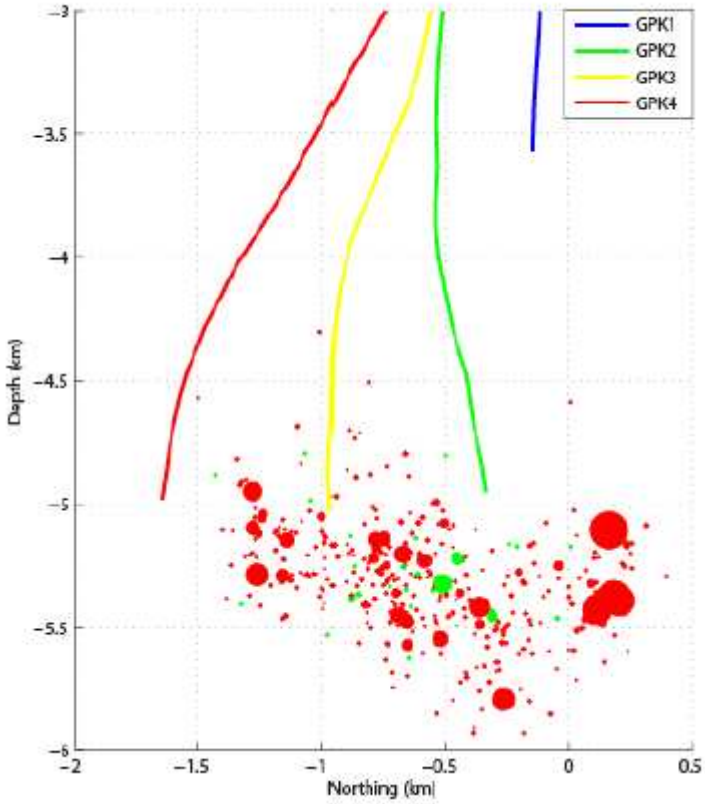
Maximum magnitude was 2.3, none felt





RESERVOIR: INDUCED MICRO-SEISMICITY ACTIVITY AT DEPTH



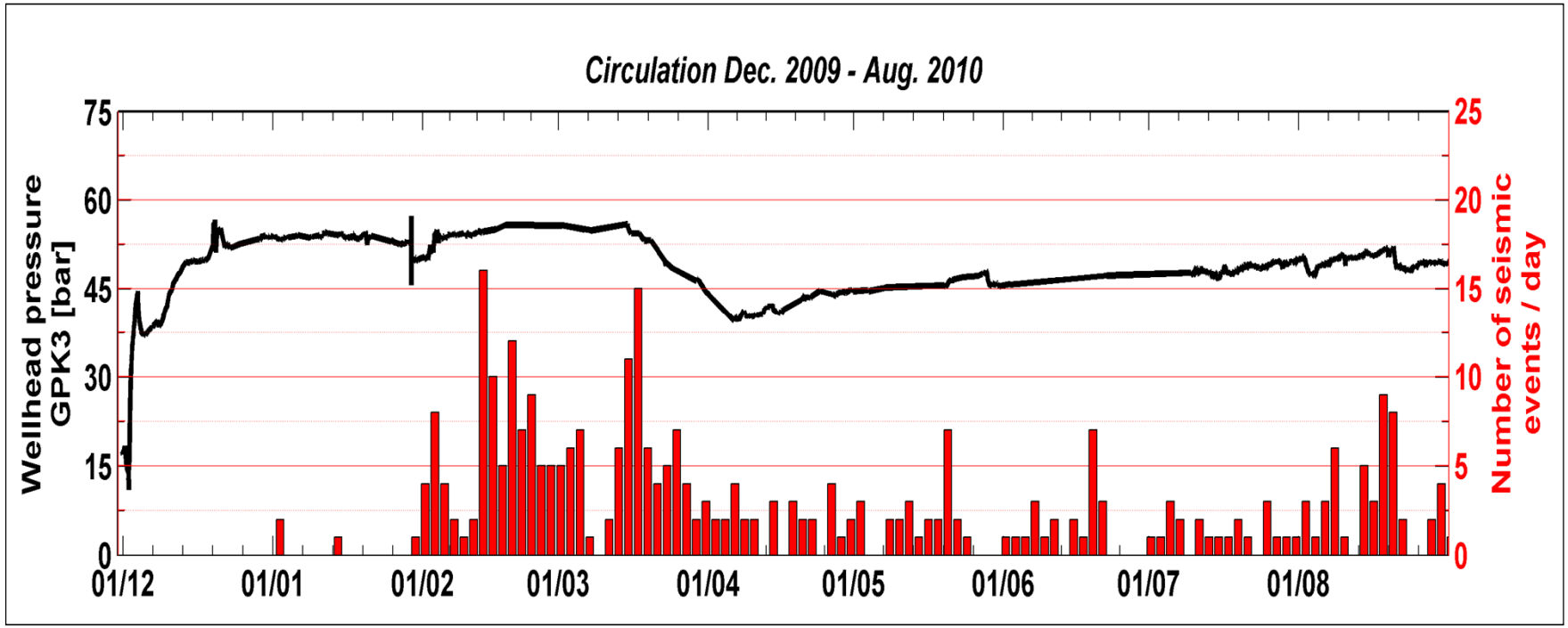


In green, October events

During recent circulation tests, micro-seismicity developed always in the same areas

RESERVOIR: HYDRAULIC MONITORING

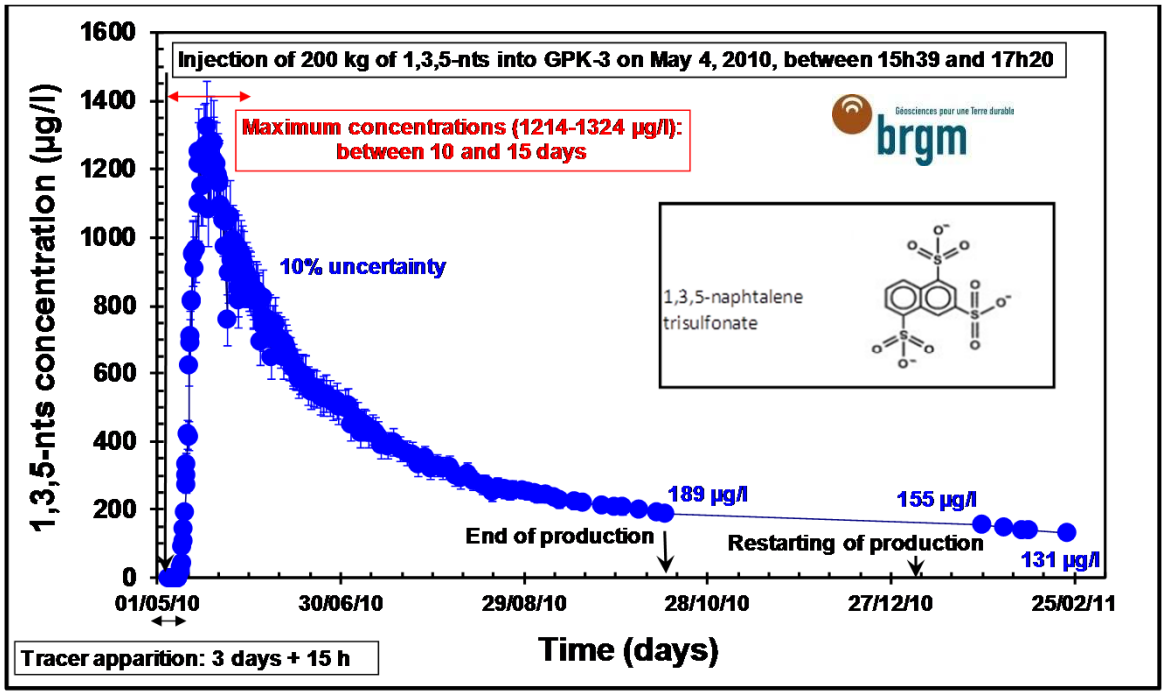
Induced micro-seismicity activity at depth,
December 2009 – August 2010:

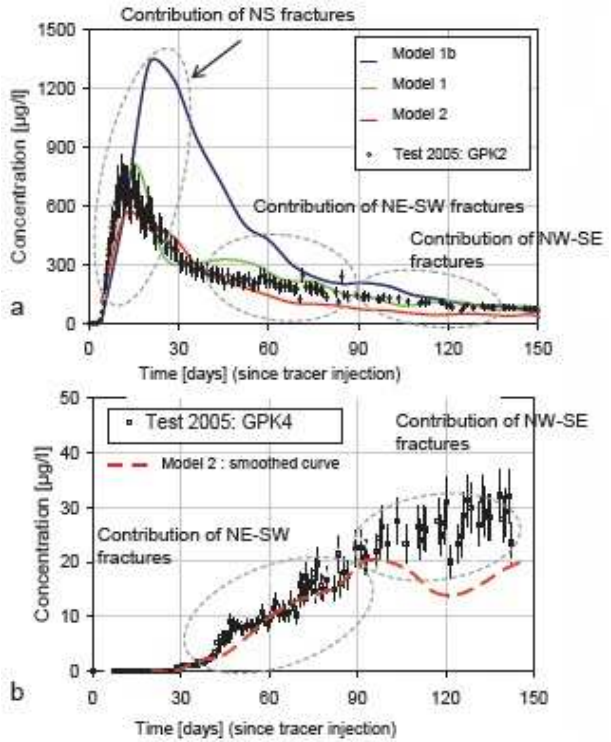


RESERVOIR: TRACER TEST BETWEEN 2 WELLS

- Tracer test between GPK3 and GPK2 in stable hydraulic conditions at 18l/s

- Organic non-reactive tracer (1,3,5 nts) injected on May 4th 2010



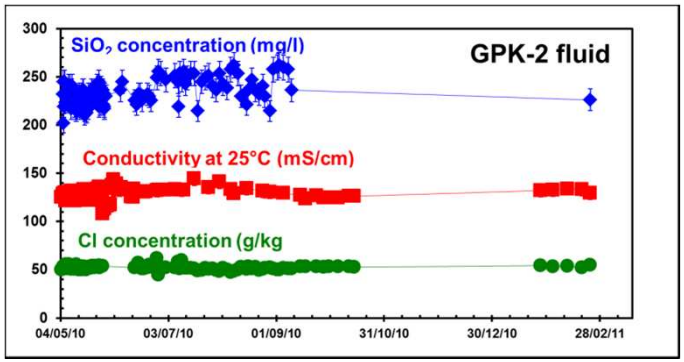


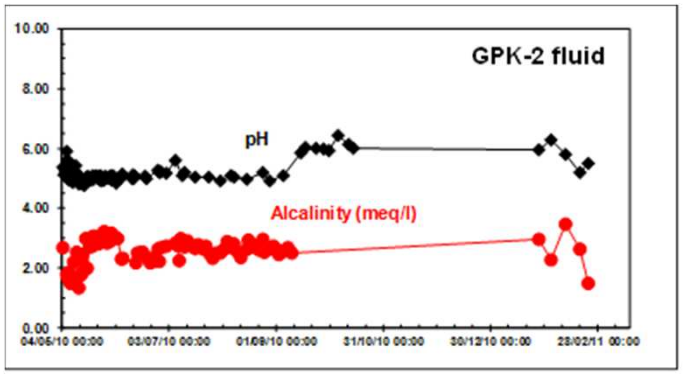
Field data, Sanjuan, 2011

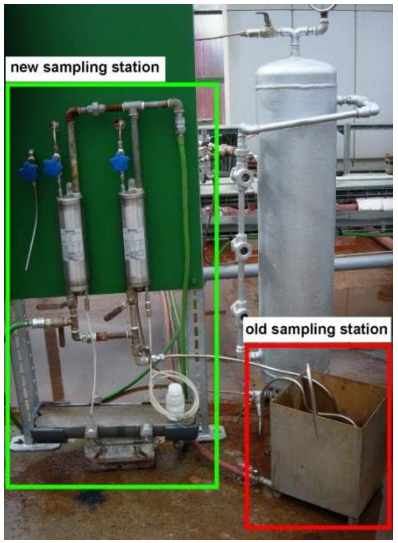
Tracer modelling
Gentier et al., 2011

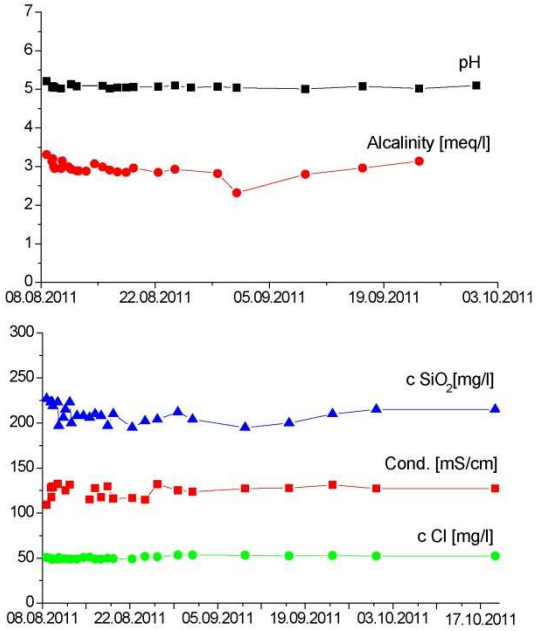
Fluid monitoring at production (165°C)

- Physico-chemical fluid monitoring: Cl, HCO_3, SiO_2, pH, conductivity, Redox



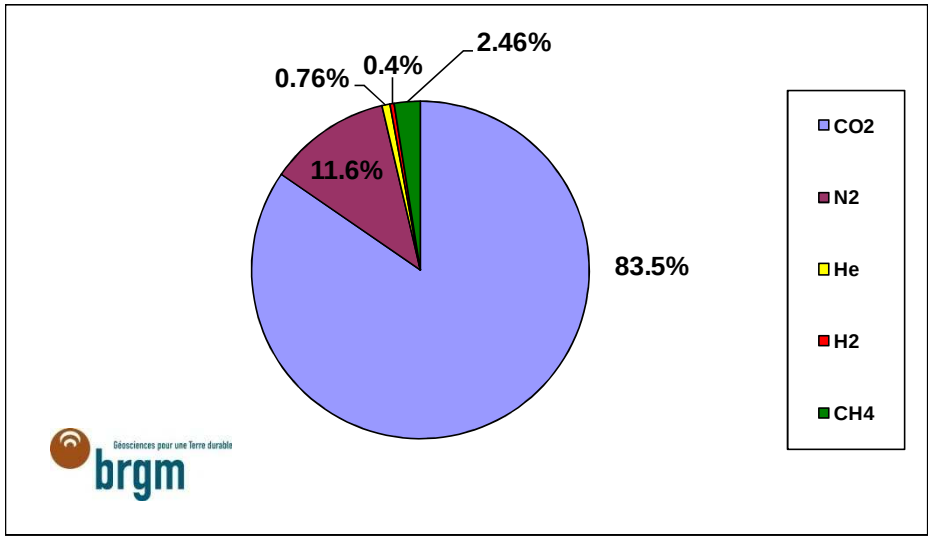






Fluid data: Native brine

- Gas and geothermal water analyses



Gas sample collected on February 22, 2011
GLR (Gas Liquid Ratio) = 104% vol. = 0.18% mass

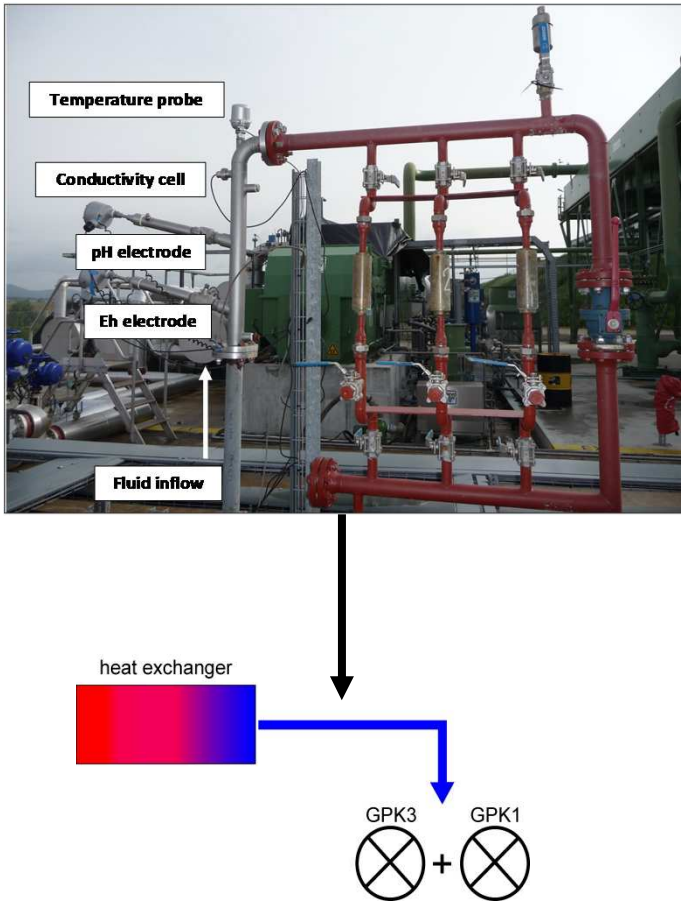
Isotopic δD value: - 41.3‰

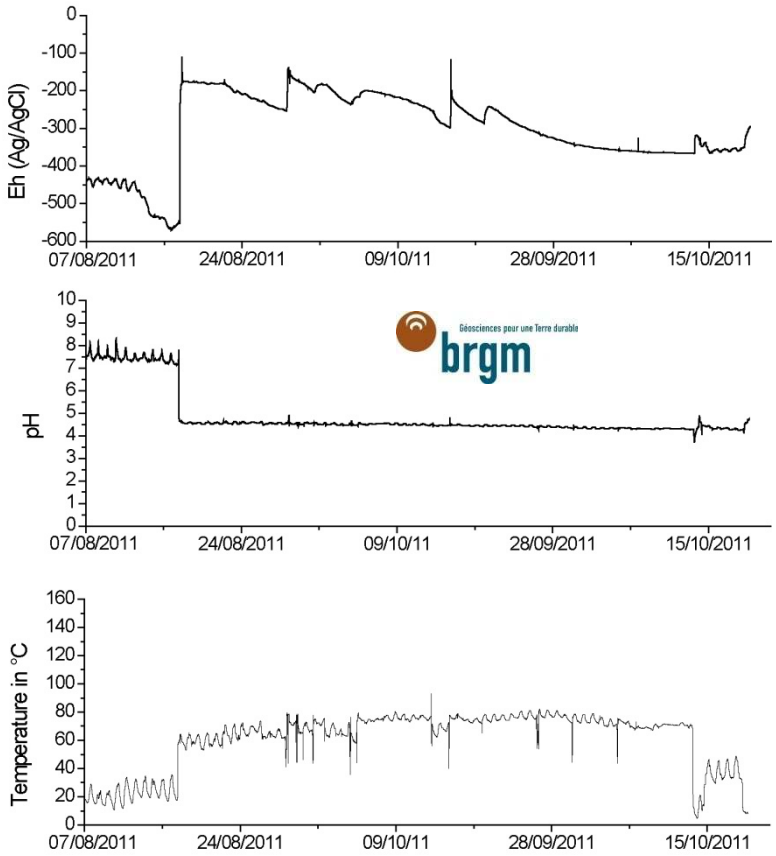
Isotopic $\delta^{18}O$ value: -2.5‰

$\delta^{13}C$ value (-3.9‰) suggests a mixed sedimentary-magmatic CO2 signature

Closer from the Native Geothermal Brine
it remains less than 1% of injected freshwater in February 2011

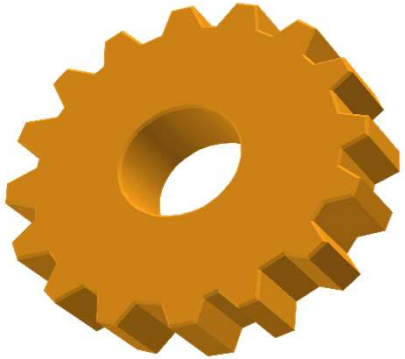
Fluid monitoring at reinjection (70°C)





CHALLENGES DURING EXPLOITATION: TECHNOLOGY

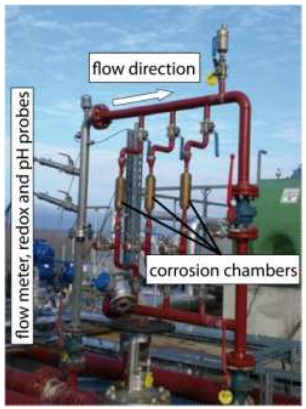
Power plant technology



- Corrosion
- Scaling

- Down-hole pumps

- Heat exchangers, filters
- ORC, air cooling



Corrosion by-pass

Scaling: mineral deposits

Heat exchanger

Down-hole Pump

SURFACE TECHNOLOGIES: CORROSION STUDY (LTS)

Low Temperature Skid : LTS

On-going corrosion study at on-site reinjection conditions (70°C) and in laboratory (EIfER)

Different steels are currently tested

Casing: P110 & N80

Surface pipe: P265GH, P235GH, …

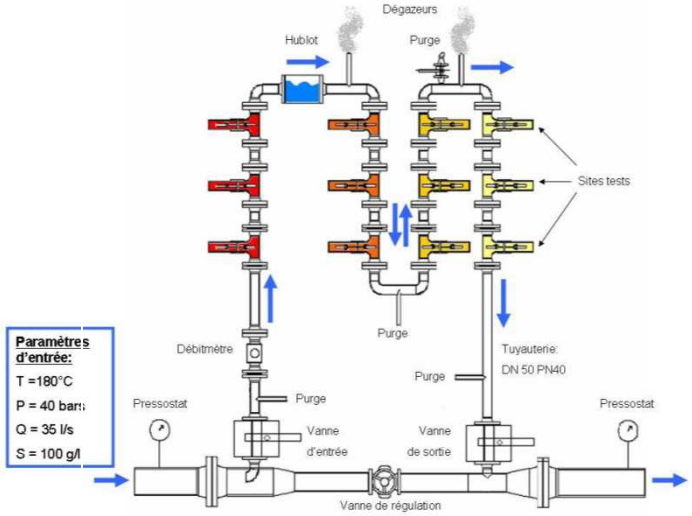
Designed, constructed & tested in 2008 by GEIE
Operational conditions of the LTS:
T = 50 - 70°C
P = 20 bar
Flow = 0.9 m/s

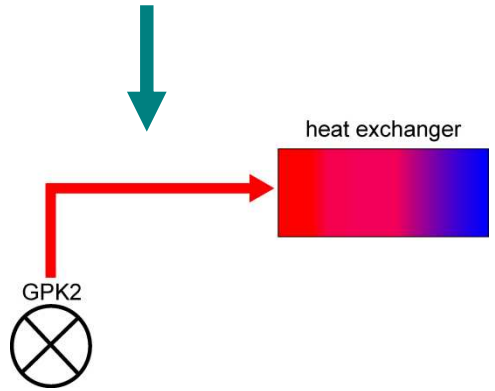
Longest on-site corrosion test in reinjection conditions (70°C) between May and October 2010

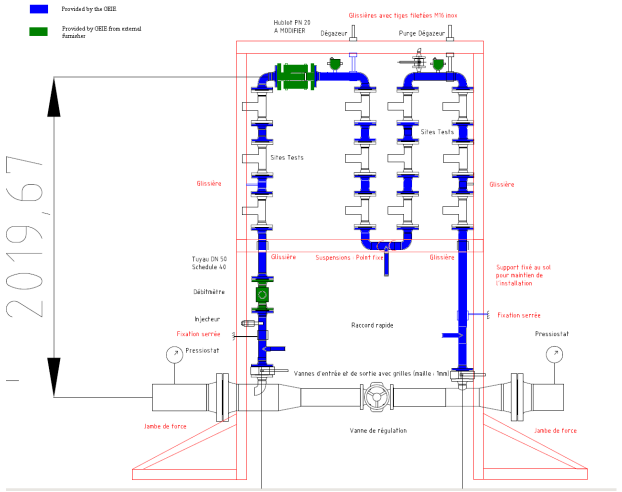
Corrosion rate ~0.2 mm/year

SURFACE TECHNOLOGIES: CORROSION STUDY (HTS)

High Temperature Skid (HTS)
Designed in 2010 by GEIE
In construction since July 2011
First experiments expected in 2012
Operational conditions of the HTS
- Height: 2.2m, width: 1.5m
- T = 155 - 165˚C
- P = 20 bar
- flow = 2 m/s

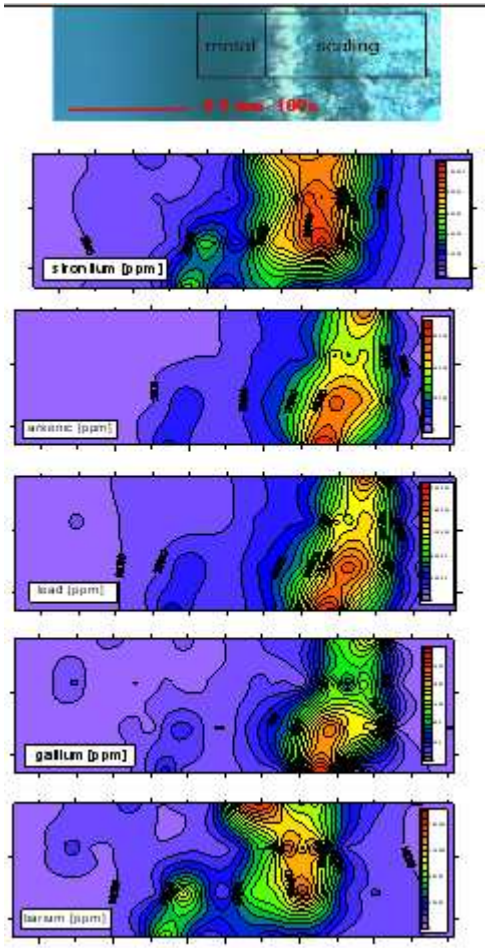






Coating experiments

CORROSION STUDY: CHEMICAL RESULTS



Sr

As

Pb

Ga

Ba

N80 coupon Chemical maps

sample	Corrosion rate (mm/y) **On-site corrosion loop**	Corrosion rate (mm/y) **Electrochemical measurement***
P110	0.15	0.177
N80	0.148	0.08
P265GH	0.22	0.252

with geothermal water from Soultz-sous-Forêts + CO_2, 80 °C, pH 4.8, laboratory

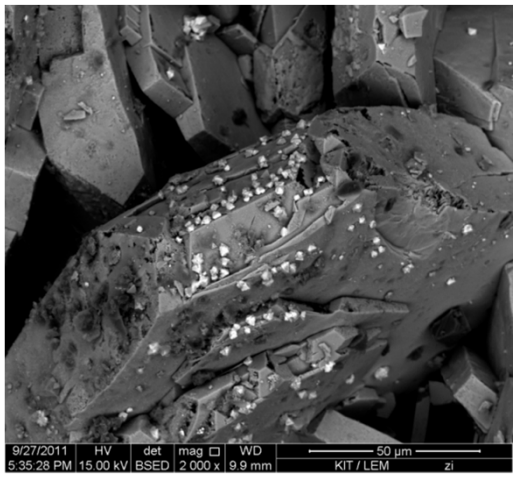
Barito-Celestine deposit $(Ba,Sr)SO_4$: Ba, Sr

Galena deposit PbS: Pb, As, Ga

SCALING STUDY: MINERALOGICAL RESULTS

- Scaling characterization
  - Mineralogical and geochemical studies with KIT/EnBW
- Main minerals: Barite-Celestine (Ba, Sr) SO_4 & Galena (PbS) and trace minerals (other sulfides)

Scaling sample from GPK4 pipe



SEM - Microscopy
Barite-Celestine dominated.
Only traces of sulfides

Geochemical characterization: Trace elements (metals)
What are the mineral formation conditions (sulfides) ?

ANTI-SCALING STUDY

- Investigations about anti-scalants with a German company

- Comparison of the effectiveness of several polyphosphonates
- Laboratory experiments with closed bottle tests
- Artificial solutions and original fluid (GPK2)

without inhibitor

orange 3ml

orange 5ml

red 5ml

blue 5ml

Two products selected
An injection system has been designed for doing a test in real operational conditions

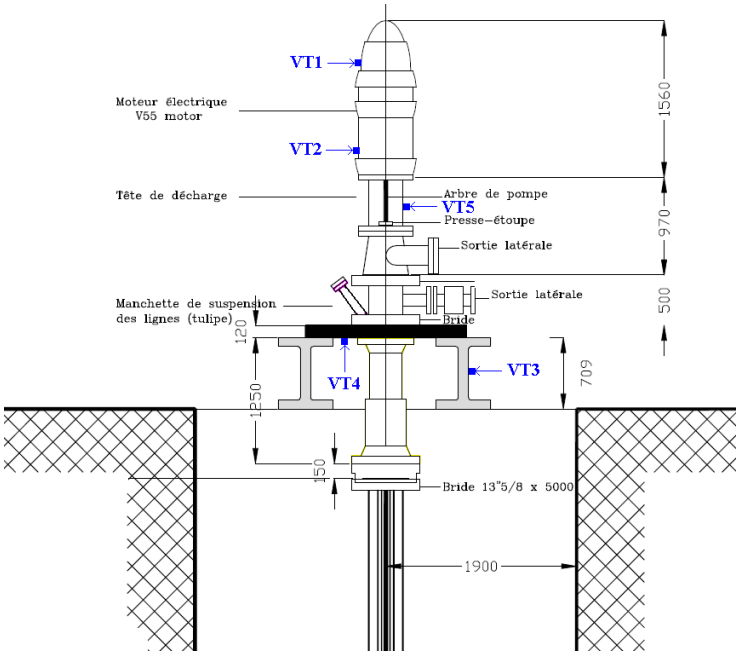
DOWN-HOLE PUMP: LSP FAILURE APRIL 2011

Hydraulic part of the LSP

Damaged impellers

cutting samples

DOWN-HOLE PUMP IMPROVEMENTS



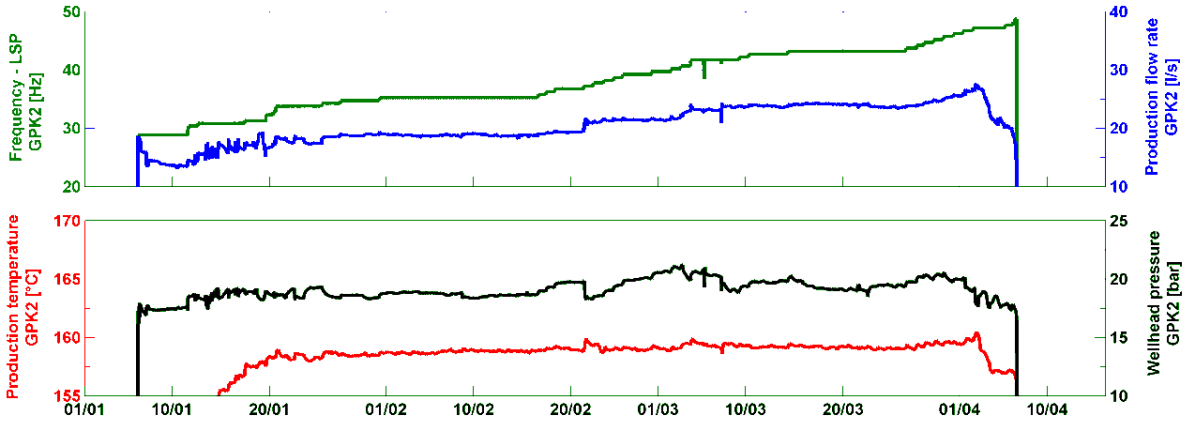
Production well GPK-2

Technical sketch of the well-head showing the location of the vibration sensors

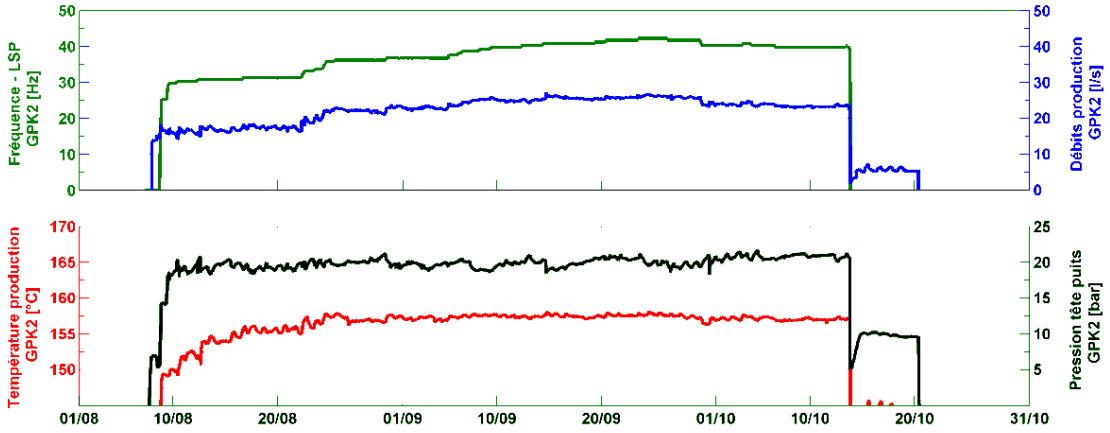
New screwing tool used for dismantling the production pump

Hydraulic part of the LSP showing a boronized diffusor

DOWN-HOLE PUMP FREQUENCY IN GPK-2 IN 2011



January to April 2011 @ Production well
Frequency, Flow rate, Temperature and Pressure



August to October 2011 @ Production well
Frequency, Flow rate, Temperature and Pressure

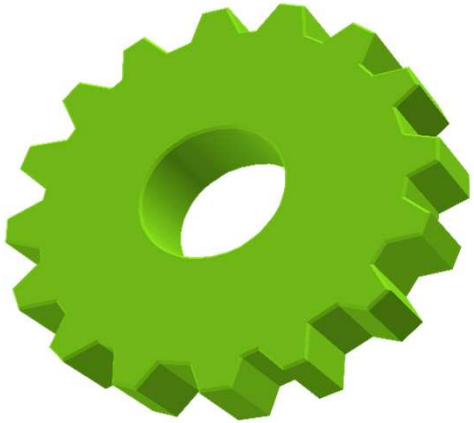
CHALLENGES DURING EXPLOITATION: ENVIRONMENT

- Noise
- Vibrations
- Natural radioactivity

High speed turbine

Air cooling system

Environment



Noise
Vibration
Natural radioactivity
Visual impact

Geothermal equipment

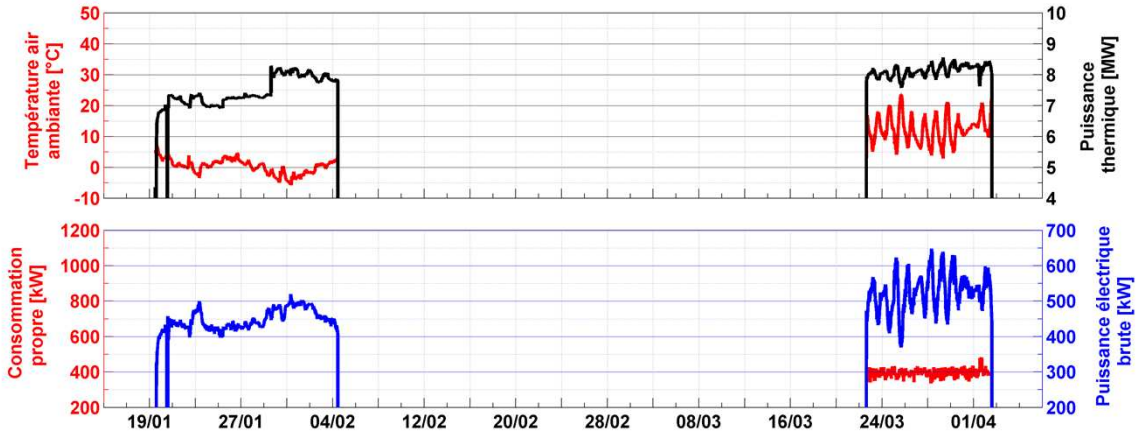
On-site radioprotection measurements

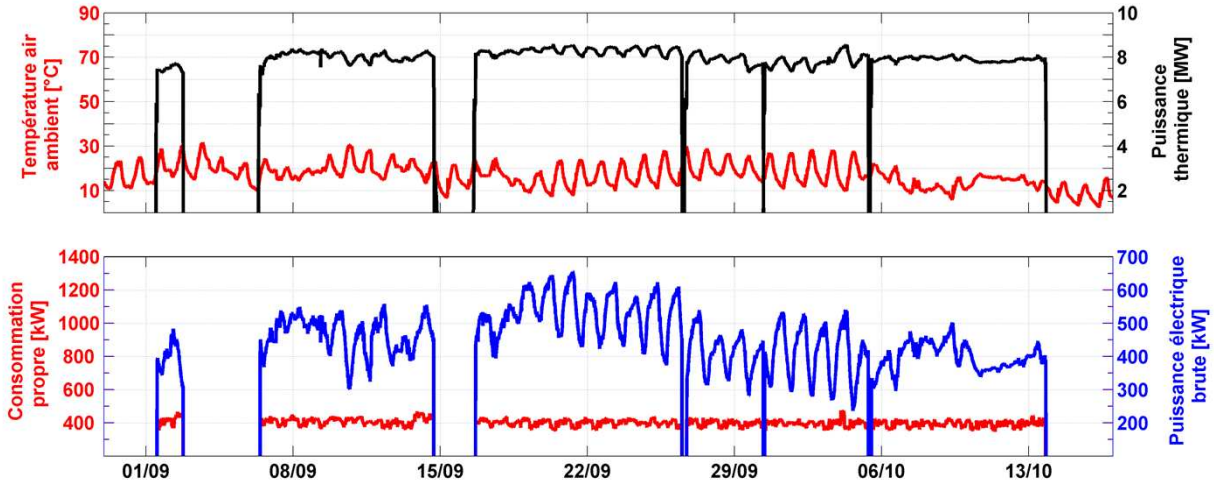
ENVIRONMENT: NATURAL RADIOACTIVITY

- Radioprotection for workers (blue line, dosimeter)
- Maximum legal annual authorized level: 1 mSv permanently
- Regular monitoring on GPK1/GPK2 plate-forms: 350 measurements
- ASN (Autorité de Sûreté Nucléaire) de Strasbourg
- Max value is 10µSv/h, Average value 2µSv/h
- Reinjection part (low Temp, 70°C) of the geothermal power point shows higher radiation dose values than the production part (high Temp, 160°C)

Research study on anti-scalant products
Test in real conditions

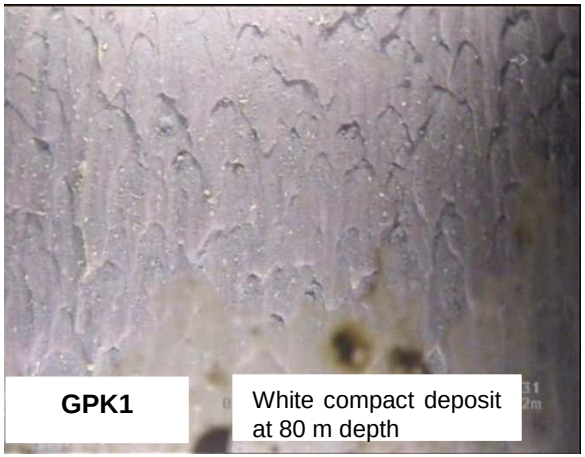
Power production in 2011

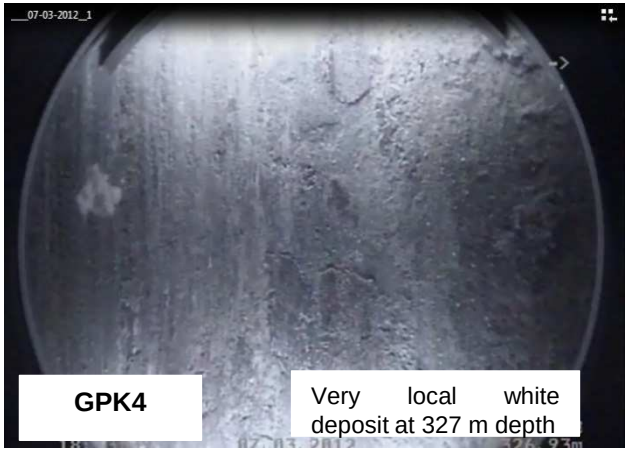




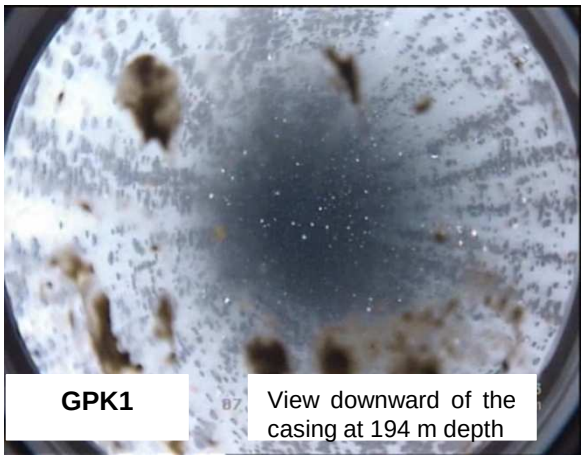
Video camera: Scaling visible on the internal surface of the casing

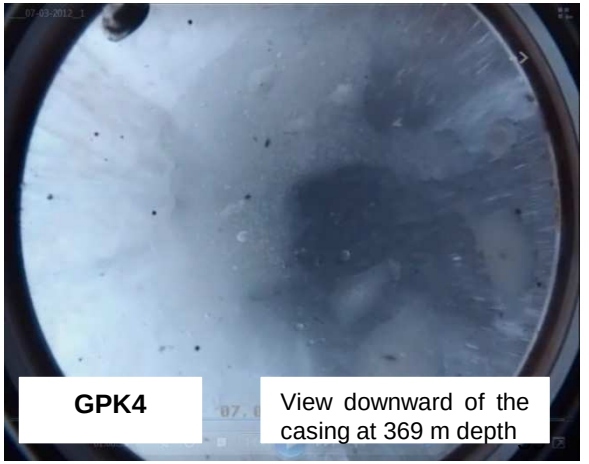
Video tool





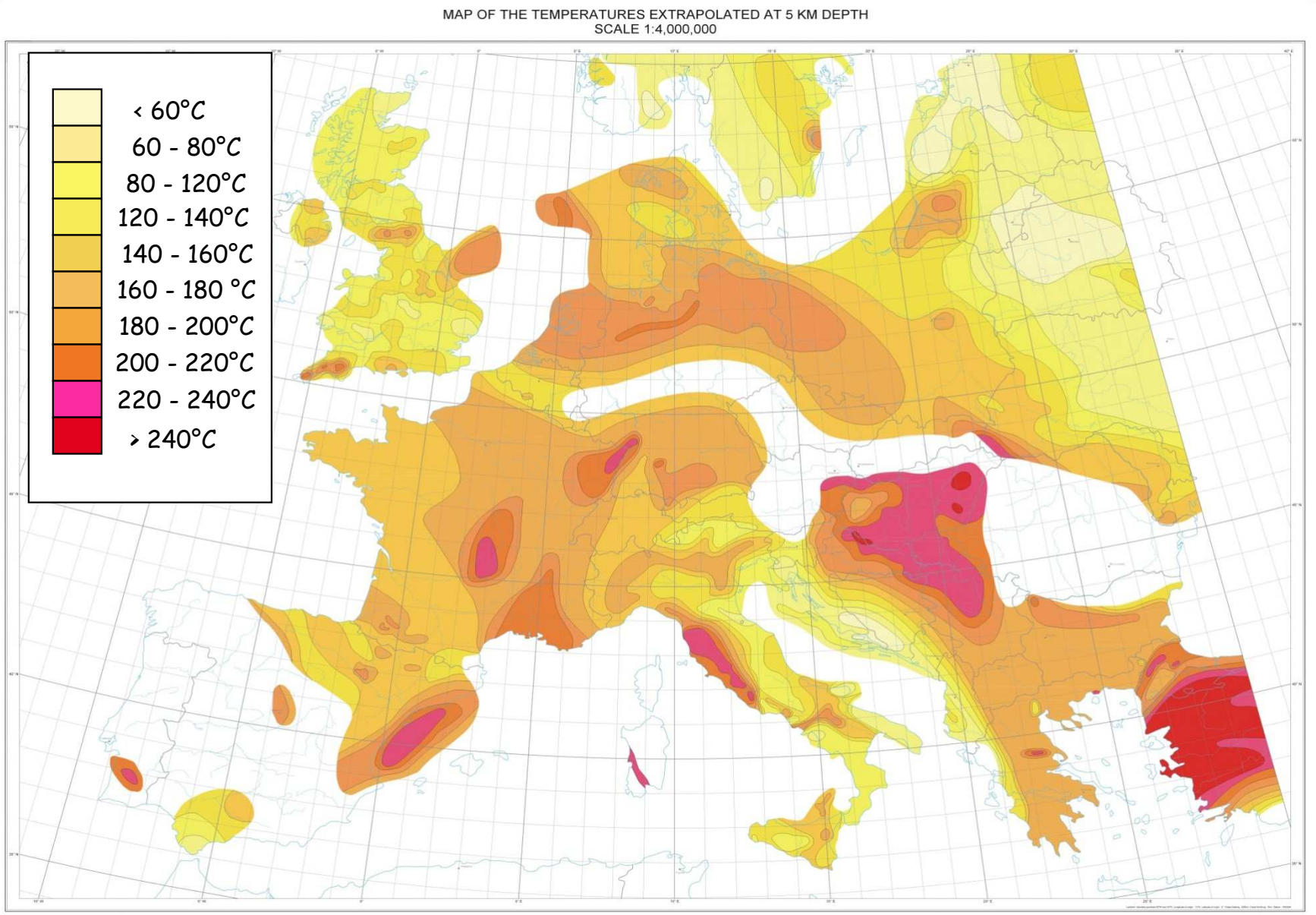
Data acquisition system





Perspectives
New projects
Dissemination

DEEP TEMPERATURES IN EUROPE



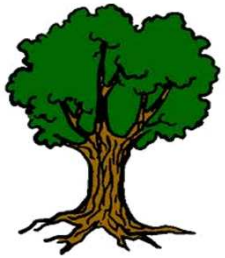
ACCEPTABILITY OF DEEP GEOTHERMAL ENERGY: OPINION SURVEY

Kutzenhausen and Soltz villages
Agreement from the 2 mayors
Questionnaire with 80 questions
203 interviews

Radioactivity

Pollution

Noise



Visual Impact

Sismicity

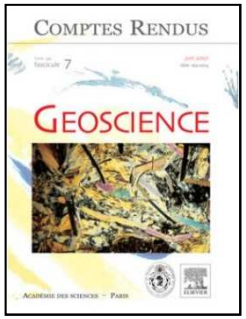
Positive feed-back from local population

EGS PROJECTS WITHIN THE UPPER RHINE VALLEY

- In Germany,
  - Landau, Insheim
  - Bruchsal

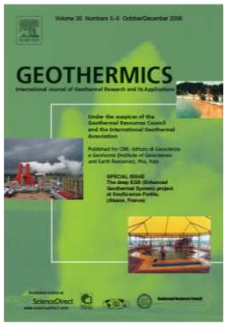
- In Northern Alsace, a new company ECOGI started in 2011, a new geothermal project close to Soltz (Rittershoffen-Hatten)
- Objective is to produce heat for drying cereals by drilling a well at 2,5 km. Expected temperature is about 150-170°C. First geothermal drilling, started in September 2012
- Other oil/geothermal companies are looking for geothermal exploration
- Labex G-EAU THERMIE PROFONDE (EOST Strasbourg)

DISSEMINATION IN THE GEOTHERMAL COMMUNITY

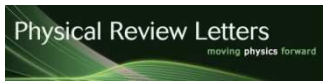


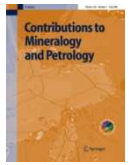
June 2010

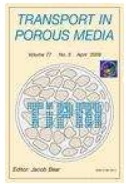
238 peer review papers
725 presentations in conferences
136 diploma students (51 PhD)

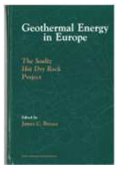


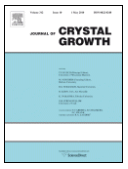
Dec. 2006

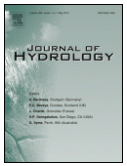


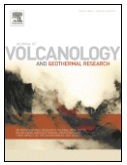


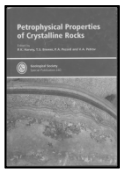












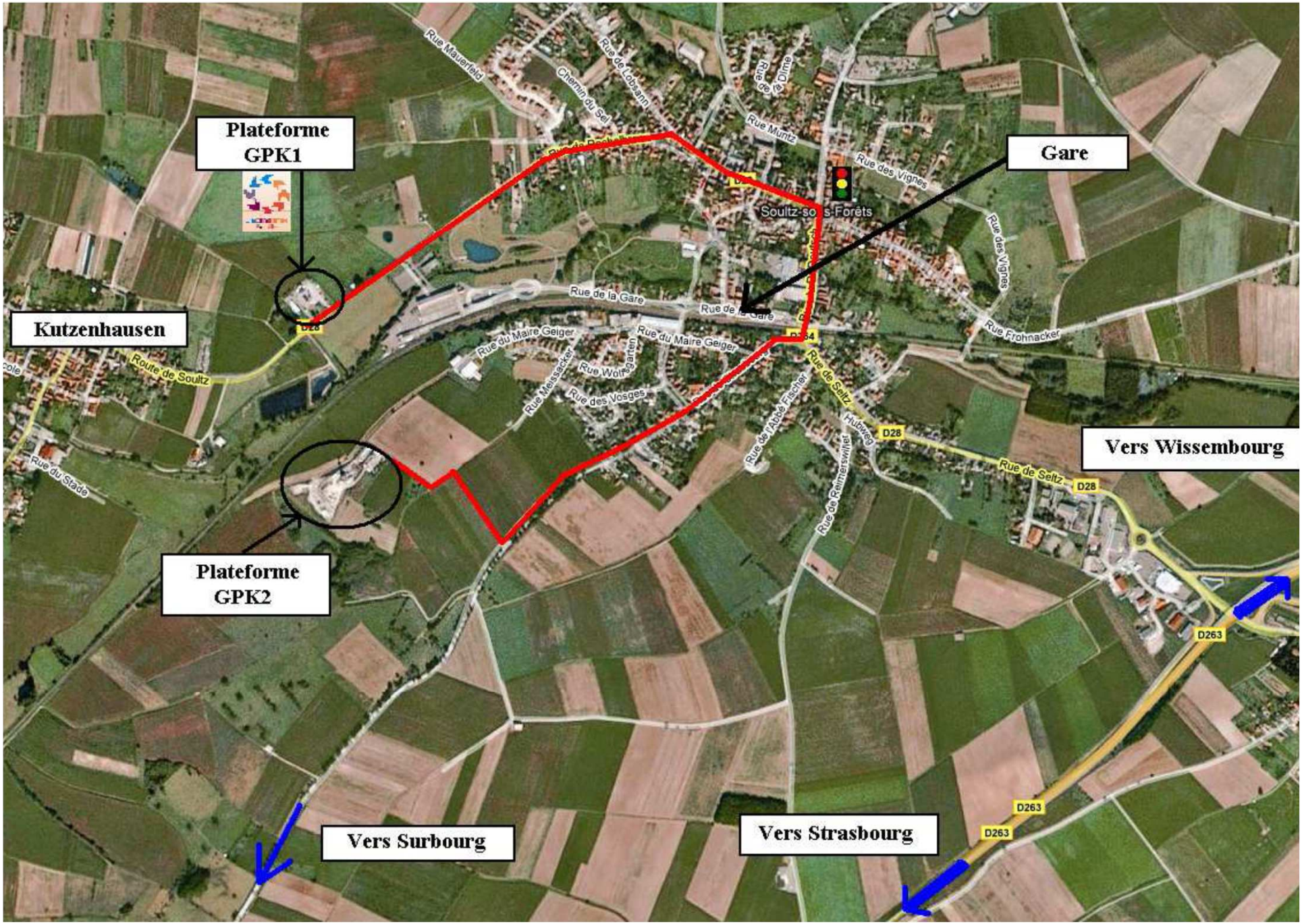
DISSEMINATION TO A LARGE AUDIENCE

Website: English, French German versions on-line

http://www.geothermie-soultz.fr/

Soultz Geothermal Conference
150 participants

Soultz geothermal power plant visits
2000 visits per year


Plateforme GPK1
Gare
Kutzenhausen
Plateforme GPK2
Vers Wissembourg
Vers Surbourg
Vers Strasbourg
Soultz-sous-Forêts
Rue de la Gare
Rue du Maire Geiger
Route de Soultz
Rue du Stade
Rue des Vignes
Rue Frohnacker
Rue de Seltz
Rue des Vosges
Rue Muntz
D28
D263

Géothermie Soltz

Merci pour votre attention

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

ptj Projektträger Jülich Forschungszentrum Jülich

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

EDF

groupe ÉS

EnBW

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

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