ELEMENTS GOVERNING THE RATIO HYDRAULIC PERFORMANCES/INDUCED MICROSEISMIC NUISANCES DURING THE STIMULATION OF 3EGS SOULTZ TYPE » RESERVOIRS

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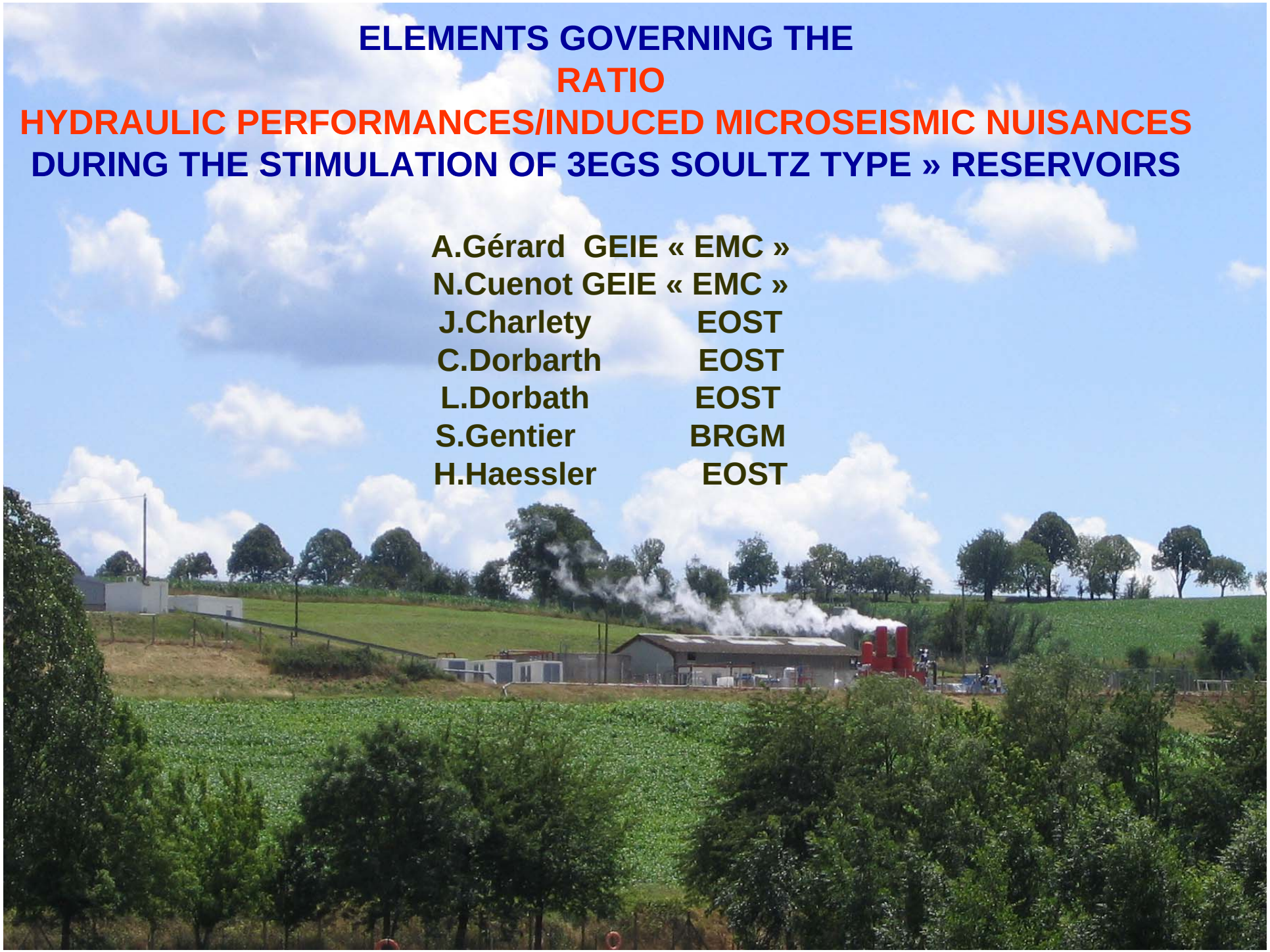

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- Basic available informations today:
  - What we know about the structure of the natural medium (geothermal reservoir) around the wells
  - The main results of previous stimulation tests already performed at -4000m/-5000m at Soultz
- Basic questions to day:
  - What seems to limitate the efficiency of hydraulic stimulations at -4000m/-5000m already performed at Soultz?
  - What could be the key parameters favourizing or limiting the pressure waves propagation (i.e. microsismicity propagation in a natural geothermal system of Soultz type?

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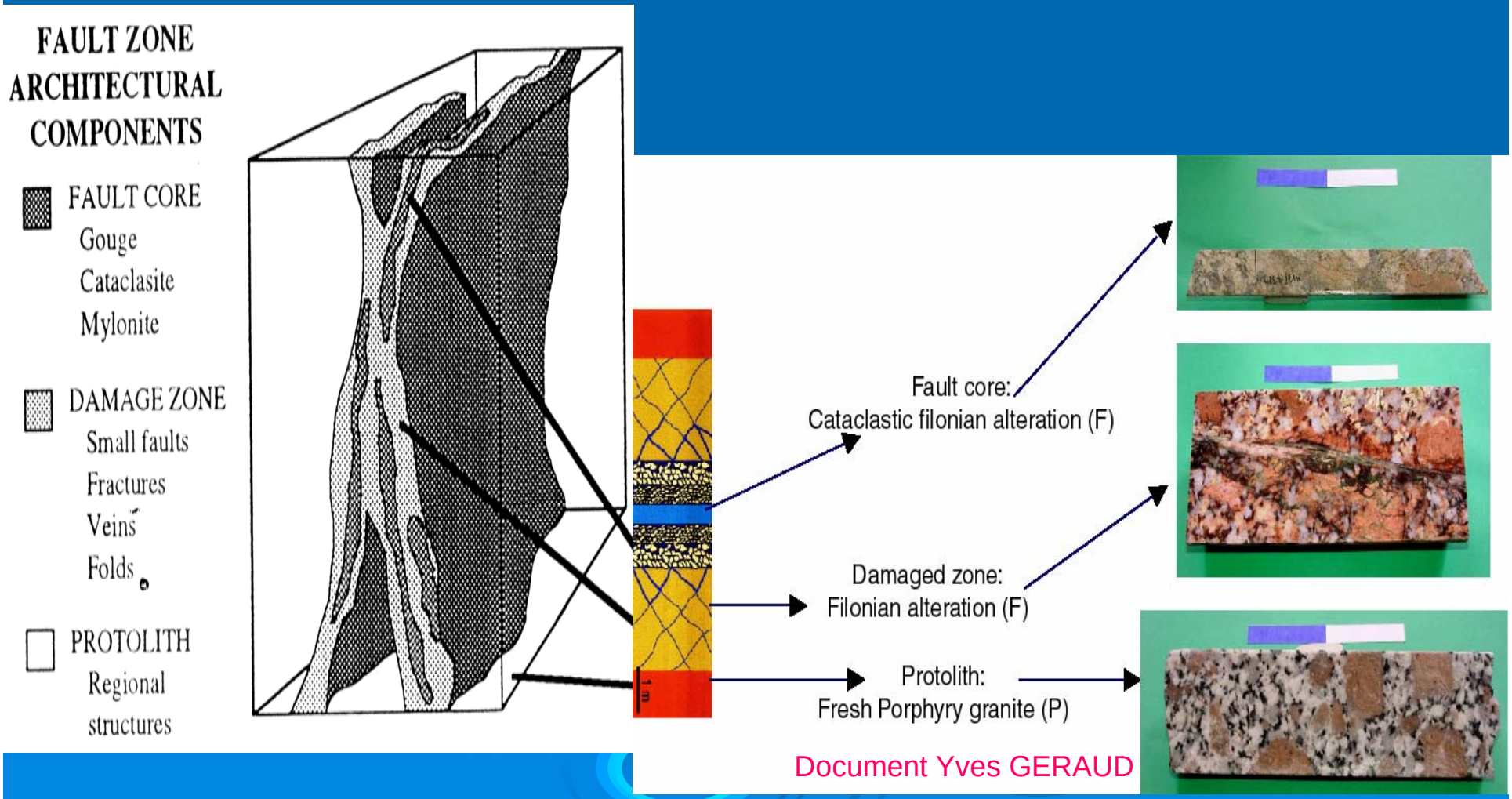
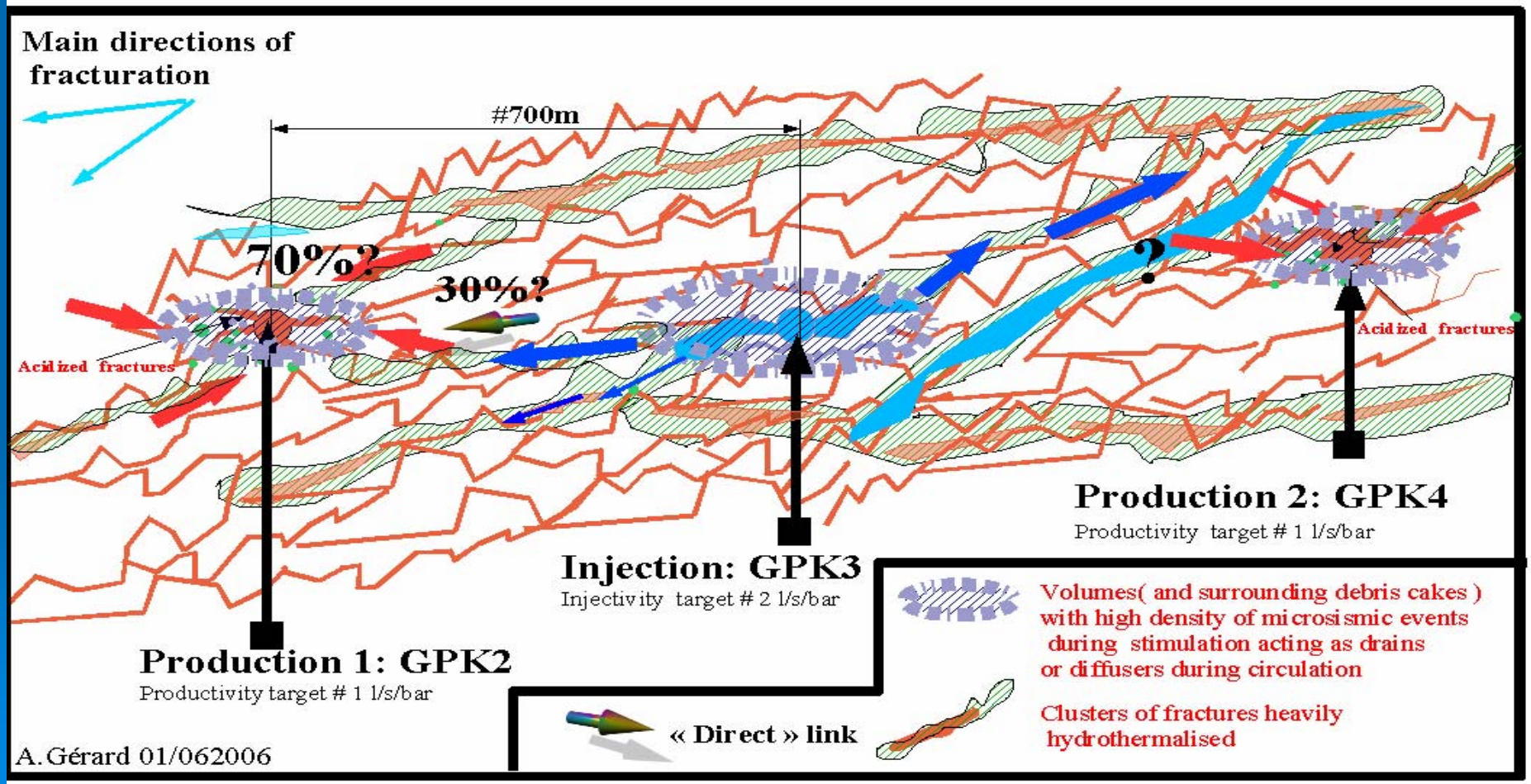
- The previous questions rise other questions:
- Is it likely that there is any systematic exploitable link between the **pressure waves propagation** and the **main water flows** between the wells and towards the **far field** in the natural geothermal reservoir at Soultz?
  - **Some today available experimental results are suggesting that the answer to that question is far to be obviously always yes.**
- **What could be the guide lines towards an experimental approach aiming at the improvement of stimulations efficiency (ie better hydraulic results for lower costs and nuisances) at Soultz?**

The medium: Main hydrothermally active structures making the natural geothermal reservoir at Soultz

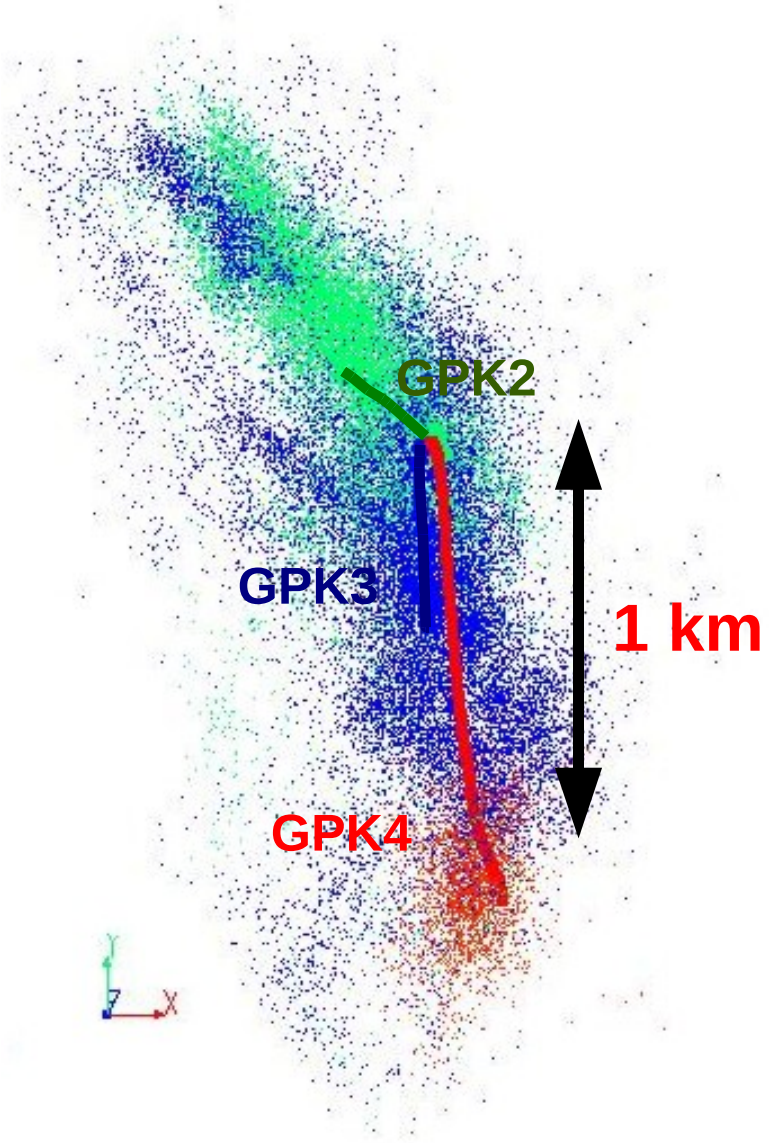


Document Yves GERAUD

The medium: A general conceptual model of the geothermal reservoir at Soultz

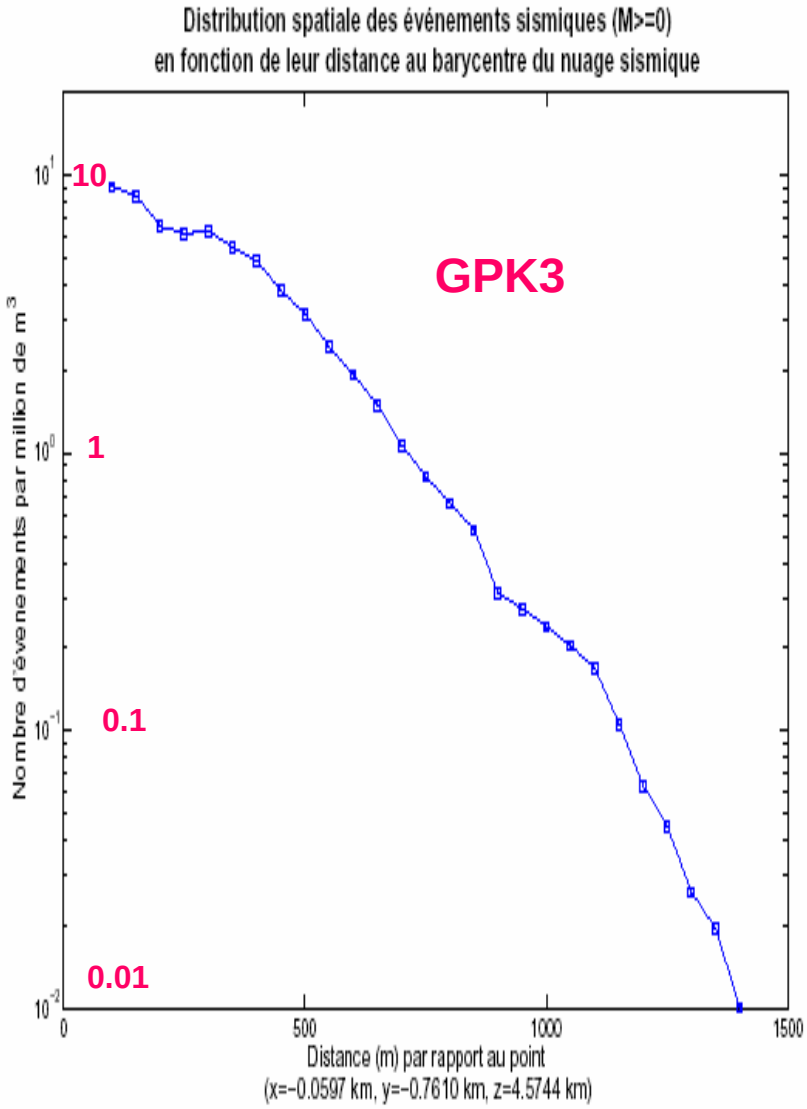


Hydraulic stimulations of GPK2, GPK3, GPK4: Induced microseismicity

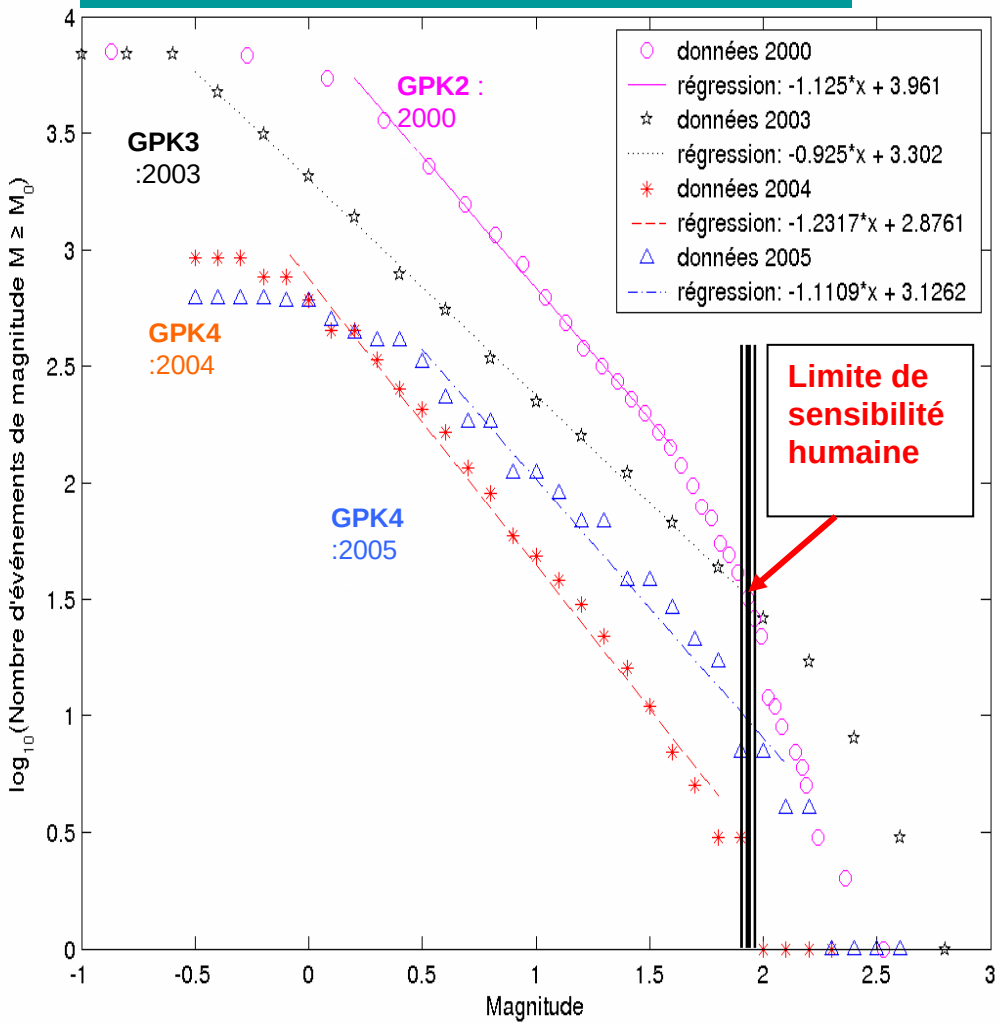


- Blue: Microseismicity during GPK3 stimulation:
  - Maximum injected volume and flows; Largest cloud, largest nuisance
    - Injectivity before: 3l/s/MPa
    - Injectivity after: 3l/s/MPa
- Green: Microseismicity during GPK2 stimulation:
  - Medium injected volume and flows; Medium cloud, medium nuisance
    - Injectivity before: 0.2l/s/MPa
    - Injectivity after: 4l/s/MPa
- Red: Microseismicity during GPK4 stimulation:
  - Minimum injected volume and flows; minimum cloud, minimum nuisance
    - Injectivity before: 0.2l/s/MPa
    - Injectivity after: 2l/s/MPa

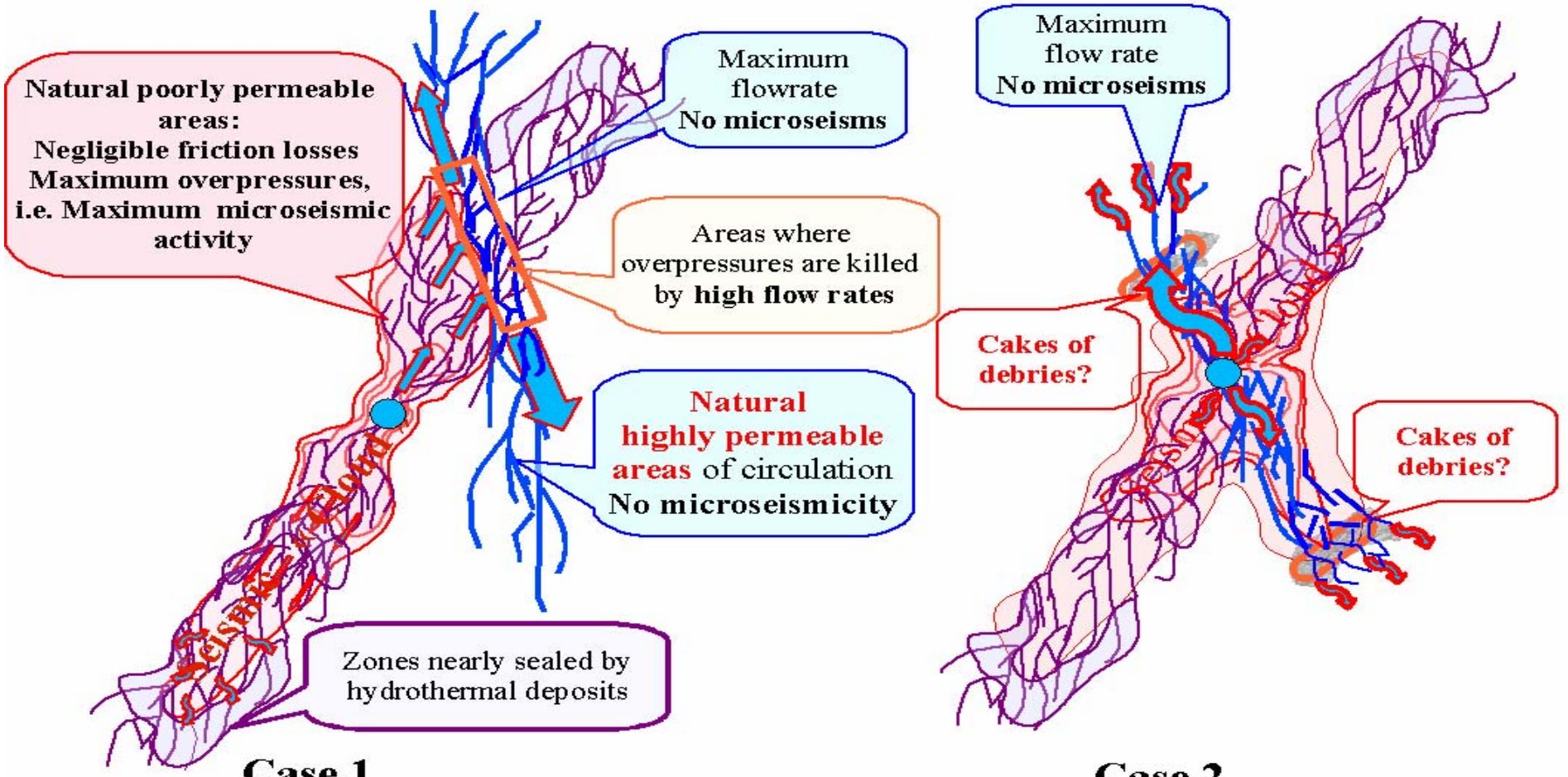
Spatial and magnitude distributions of the microseismic events at Soultz



Gutenberg-Richter distributions

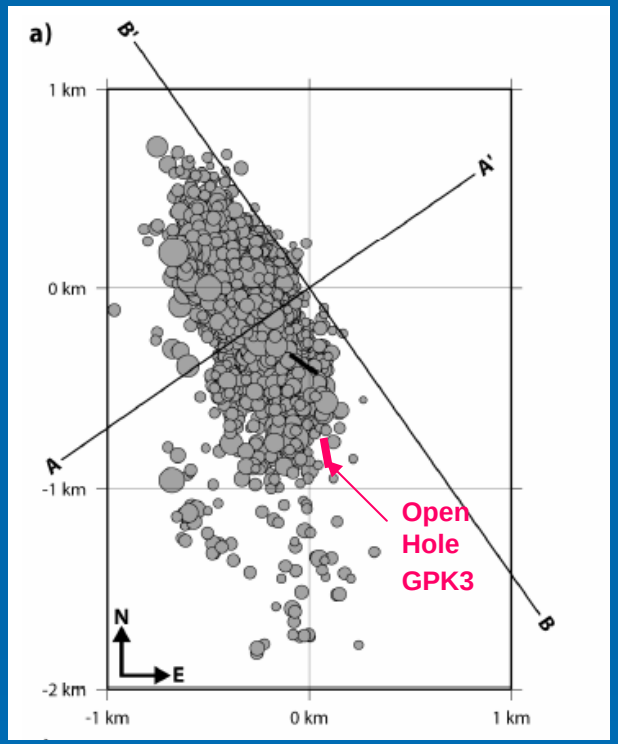


Basic features governing microseismic events distribution at Soultz



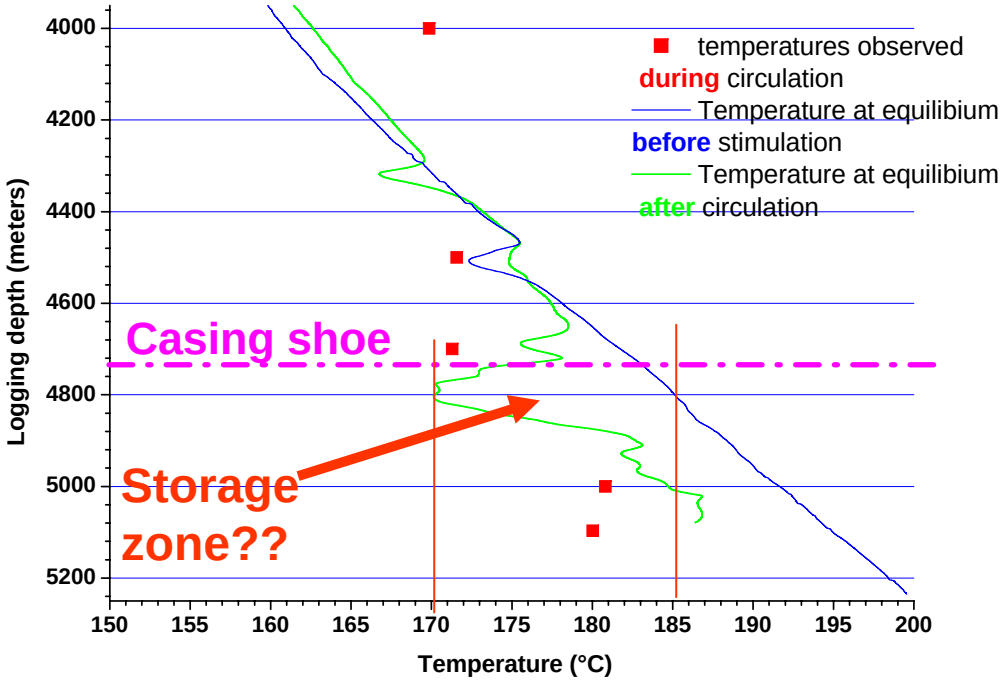
What can the microseismicity generated by injections tell us at Soultz?

Some observations



- During the massive hydraulic stimulation of GPK2 the « microseismic cloud » extended mostly northward and was not covering the location of GPK3 open hole:
  - Nevertheless the hydraulic conection GPK2-GPK3 was observed while drilling GPK3 (Tracer return) and confirmed as being major before any stimulation of GPK3
- Thermic traces of near wellbore storages can be observed
- Overpressurized volumes can be observed close from drained zones

Storage zone in GPK4



At equilibium before stimulation temperatures were:~183°C at casing shoe and 191°C at 5000m (Logging depth)

Temperatures observed **during** production:

~172° at casing shoe

~180°C at ~5000m

After 5.5 months of production and total of 35000 m3 produced:

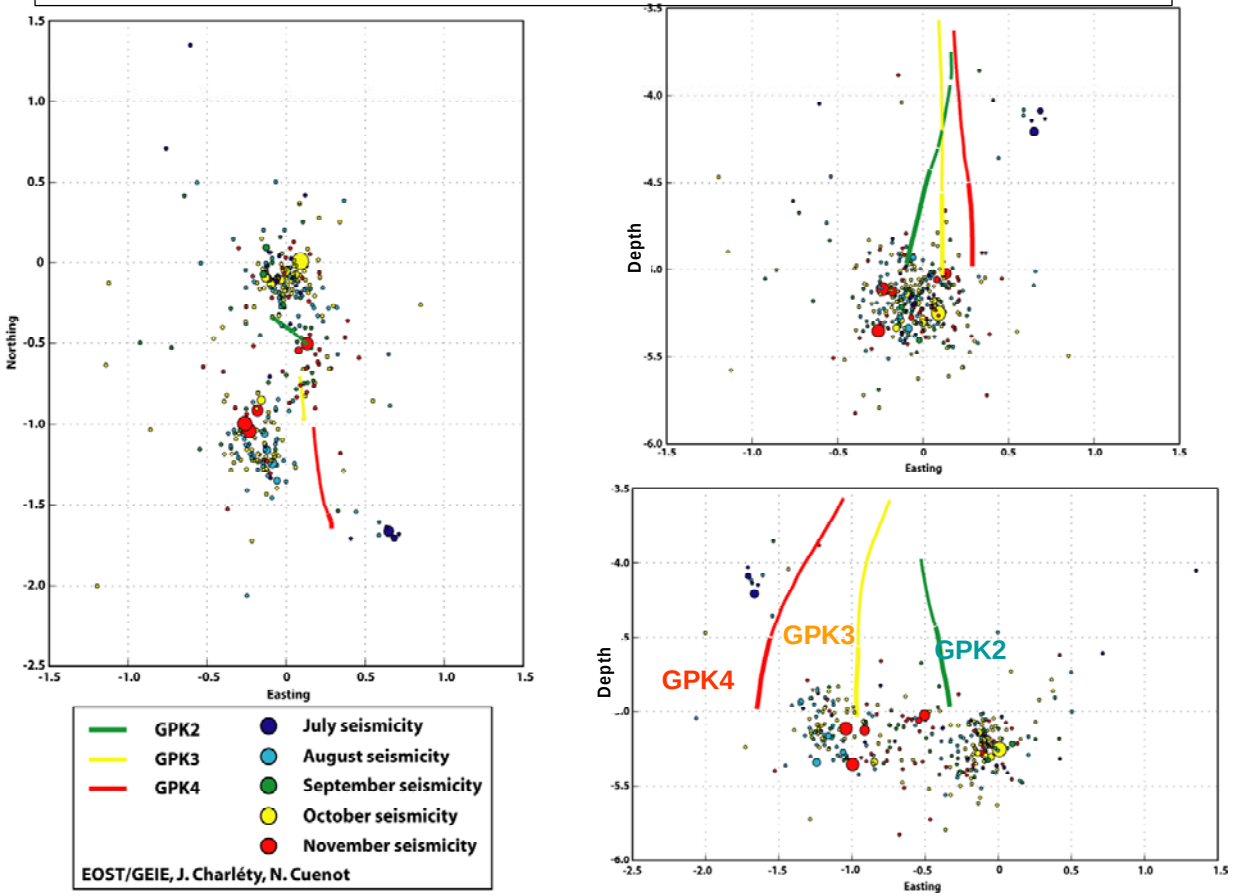
Only 7000m3 of fresh injected water recovered

The produced flow contained ~85% of natural geothermal brine

In the storage zone the temperature was still ~15°C lower than at equilibrium

Microseismicity generated under GPK2 by over pressures in GPK3

Main results December 2005:
Closed loop circulation test:
Microseismicity: July to November 2005



GPK2 :

Downhole **under pressure**:

~ - 1.3MPa

GPK3:

Downhole **over pressure**:

~ + 4.5 to 6 MPa

GPK4 :

Downhole **under pressure**:

~ - 1MPa

Main conclusions

In a complex natural geothermal reservoir of Soultz type:

- **Massive hydraulic stimulation techniques** will generate a **large microseismic activity in the far field** which can be considered as a problematic nuisance.
- **There is no demonstrated link** between the improvement of the wells hydraulic performances and this far field microseismic activity .
- **Nevertheless hydraulic stimulation at Soultz-5000m- seemed sometimes to show a limited efficiency** (Mostly at rather short distance from the wells for the improvement of their connexions to large natural drains which could exist in the vicinity?) .
- **What could be the investigations and/or tests** which will be useful (or necessary) for getting rapidly similar (**or better**) results with much less nuisances in Soultz type EGS projects.

What could be the future techniques being both more efficient than up to now and limiting the microseismic nuisances during EGS operations ?

- Injections of little volumes at high flow rates? (followed by production?)
- Chemical stimulations?
- Combination of both? (Acid frac ?)
- Others?