



# Tracer testing at Soultz-sous-Forêts (France) using naphthalene disulfonate compounds (2000-2003)

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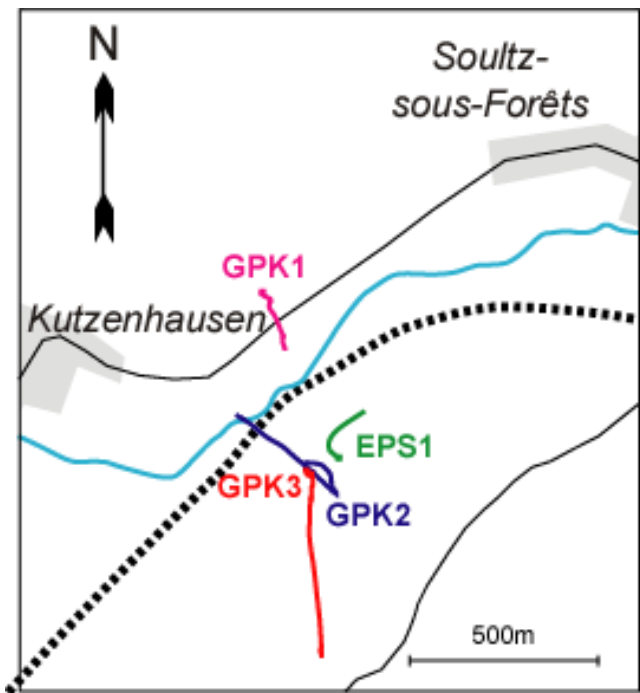
<sup>1</sup> BRGM, <sup>2</sup> EGI (University of Utah), <sup>3</sup> EEIG



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EHDRA Scientific Meeting, April 7-8, 2004

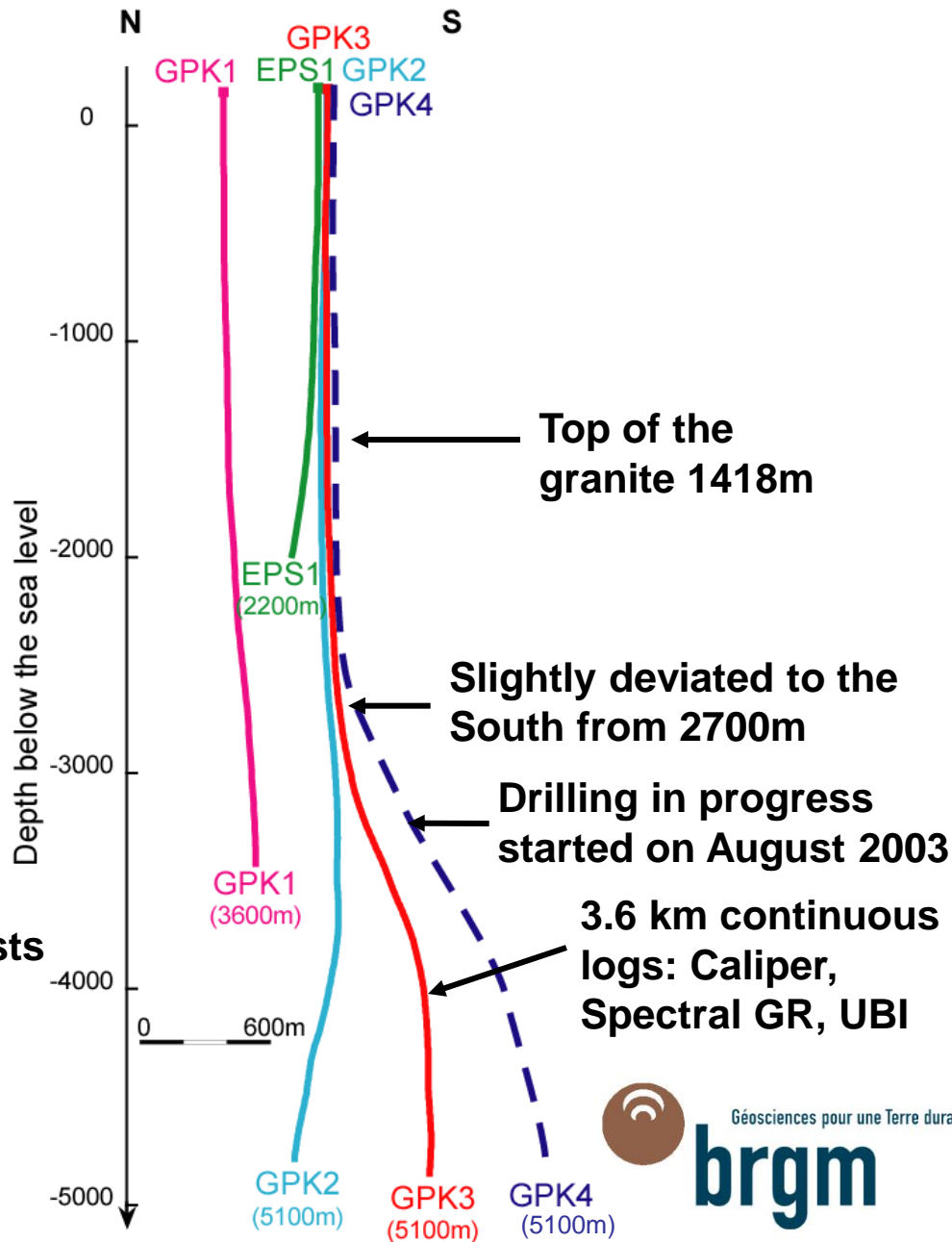
# Soultz site location



Since 1987:

- EPS1 fully cored → exploration
- GPK-1 → preliminary injection tests
- GPK-3 → injection well
- GPK-2 and future GPK-4 → production wells

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# Hydraulic stimulation experiment carried out in GPK-2 (July 2000)

## > **Water injection**

- 26,800 m<sup>3</sup> of fresh water and 1,000 m<sup>3</sup> of heavy brine

## > **Tracer injection**

- Na-benzoate and 1,5-nds were continuously injected into GPK-2 during the hydraulic stimulation operation at a controlled concentration close to 2 mg/l

# Four production tests carried out in GPK-2 after stimulation (Dec. 2000 - April 2002)

## > **First test (December 11 - 21, 2000)**

- Total discharged volume  $\approx 1,170 \text{ m}^3$

## > **Second test (Jan. 30 - Feb. 23, 2001)**

- Total discharged volume  $\approx 2,720 \text{ m}^3$

## > **Third test (June 21 - 28, 2001)**

- Total discharged volume  $\approx 450 \text{ m}^3$

## > **Fourth test (April 23 - 24, 2002)**

- Total discharged volume  $\approx 253 \text{ m}^3$

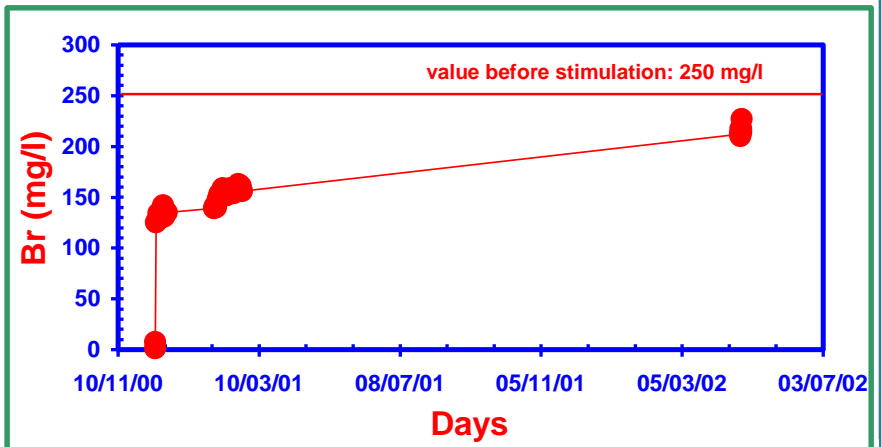
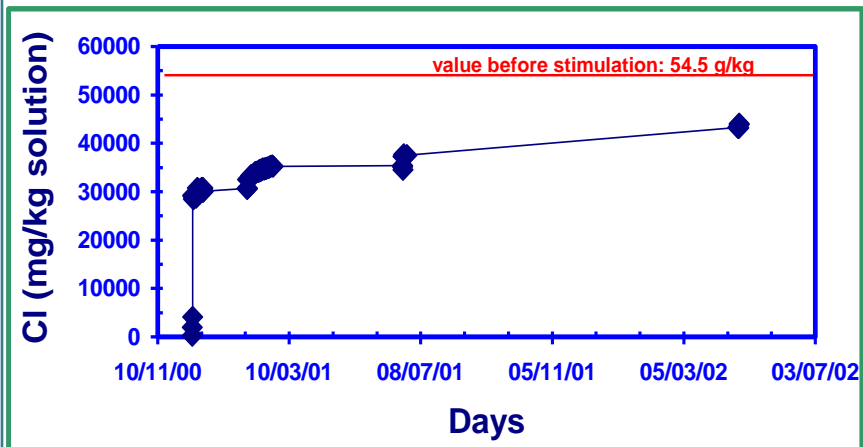
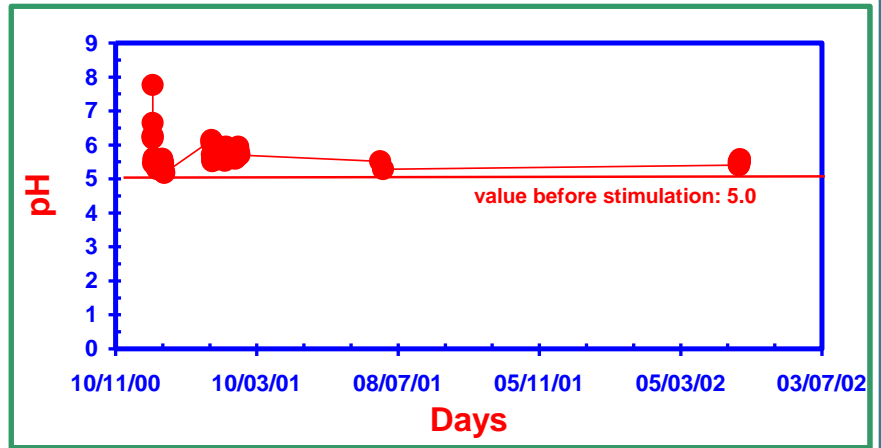
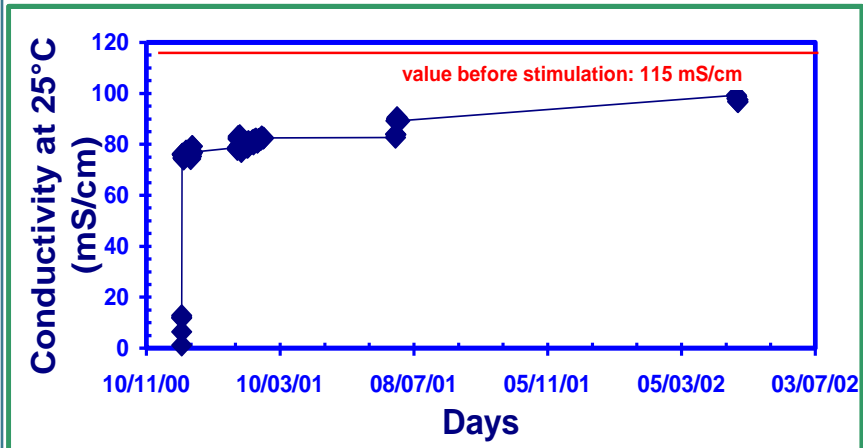
## > **Total discharged volume $\approx 4,600 \text{ m}^3$**

# Geochemical monitoring of the fluid discharged from GPK-2 after stimulation (Dec. 00 - April 02)

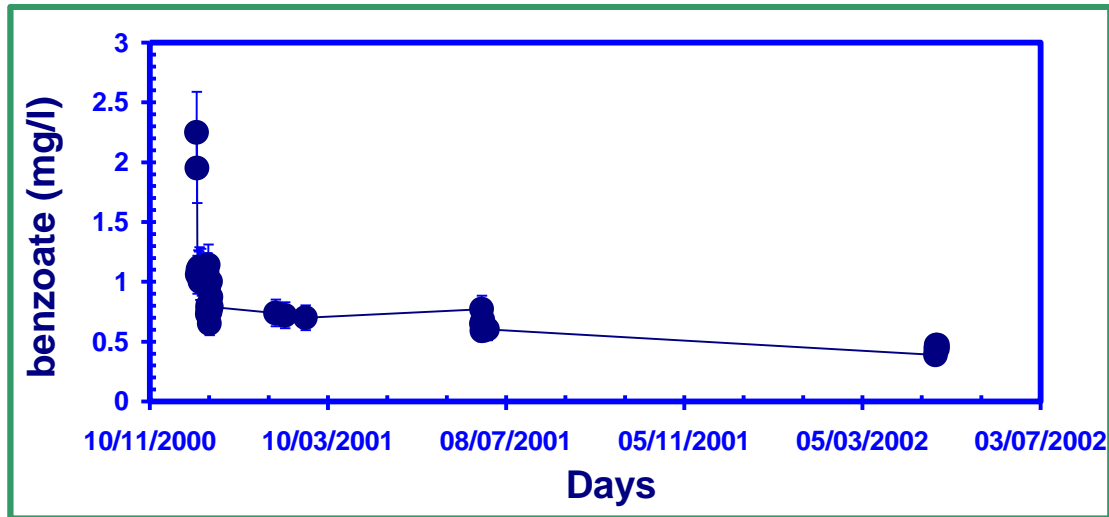
## > **Surface fluid sampling for on site measurements and chemical analyses**

- T, conductivity, pH, Eh, alkalinity, SiO<sub>2</sub> analyses
- Cl, Na, Ca, SO<sub>4</sub>, Br and Li analyses
- Organic tracer determinations by HPLC (1,5-nds also analysed by EGI of the University of Utah - P. Rose)

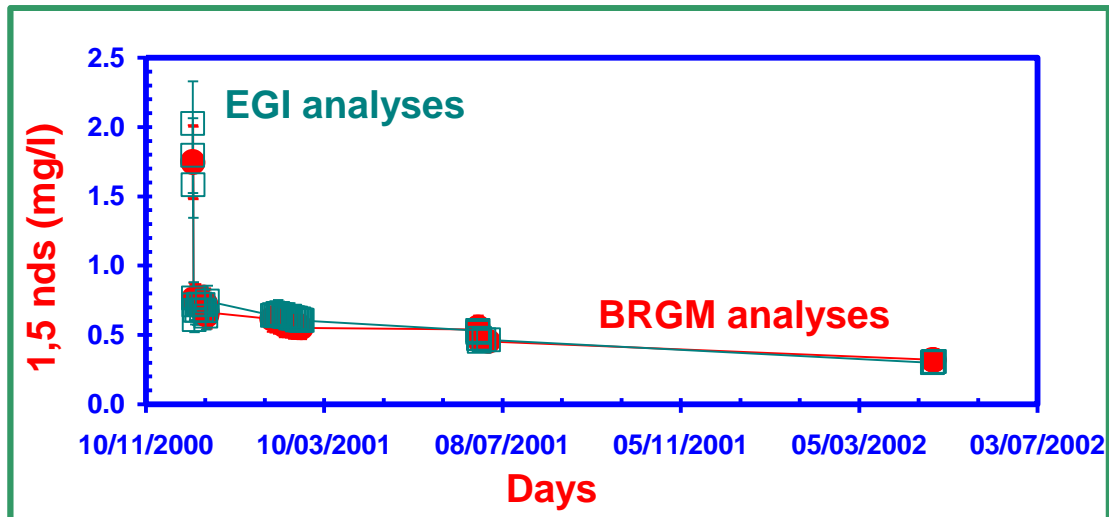
# Evolution of the fluid composition as a function of time (Dec. 2000 - April 2002)



# Evolution of the organic tracer concentrations as a function of time (Dec. 2000 - April 2002)



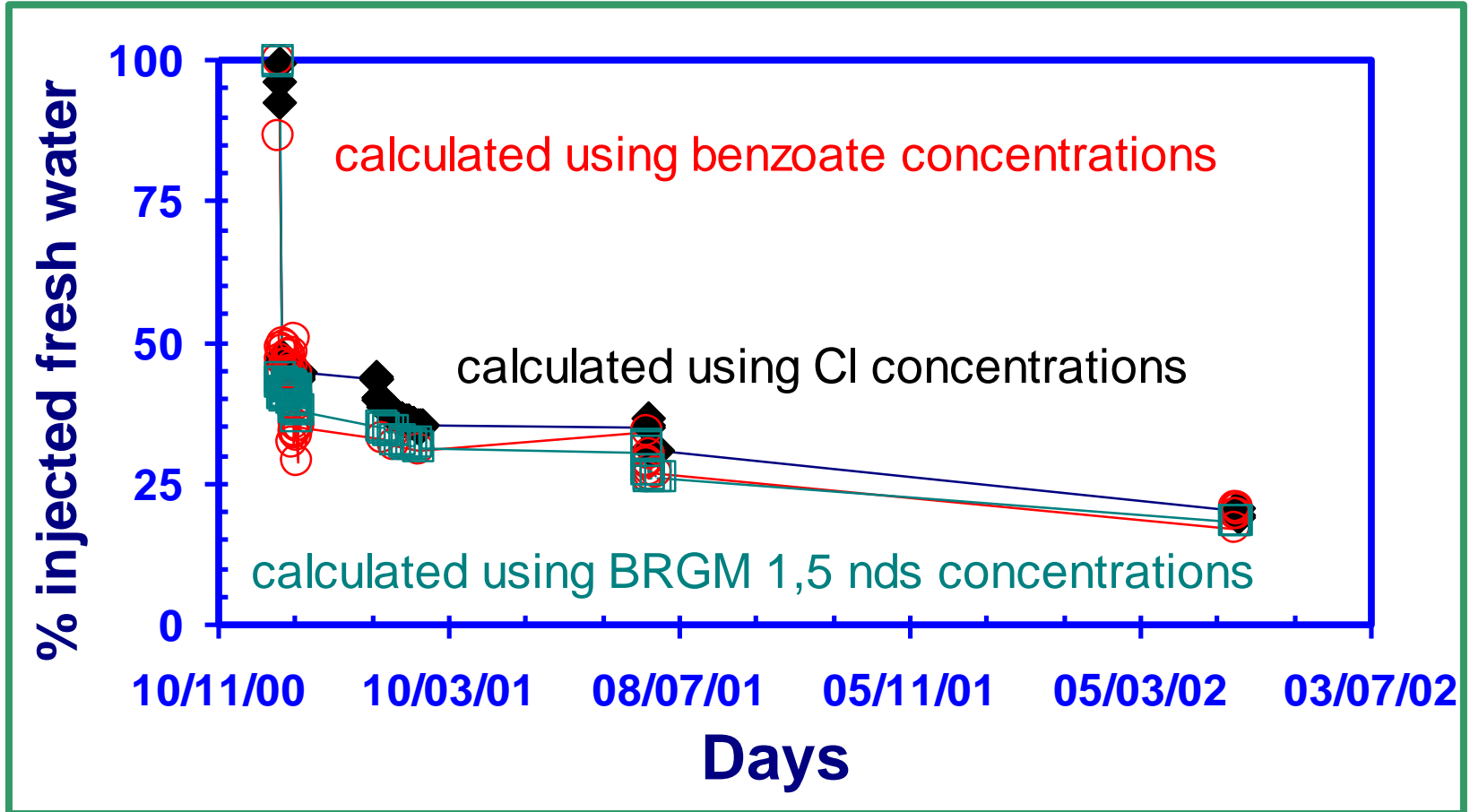
> Relative analytical uncertainty : 15 to 20%



> Very good agreement between BRGM and EGI analyses

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# Proportion of injected fresh water in the fluid discharged from GPK-2



At the end of the 4<sup>th</sup> test, concordant values close to 19% are obtained (less than 7% of fresh water injected into GPK-2 was recovered)



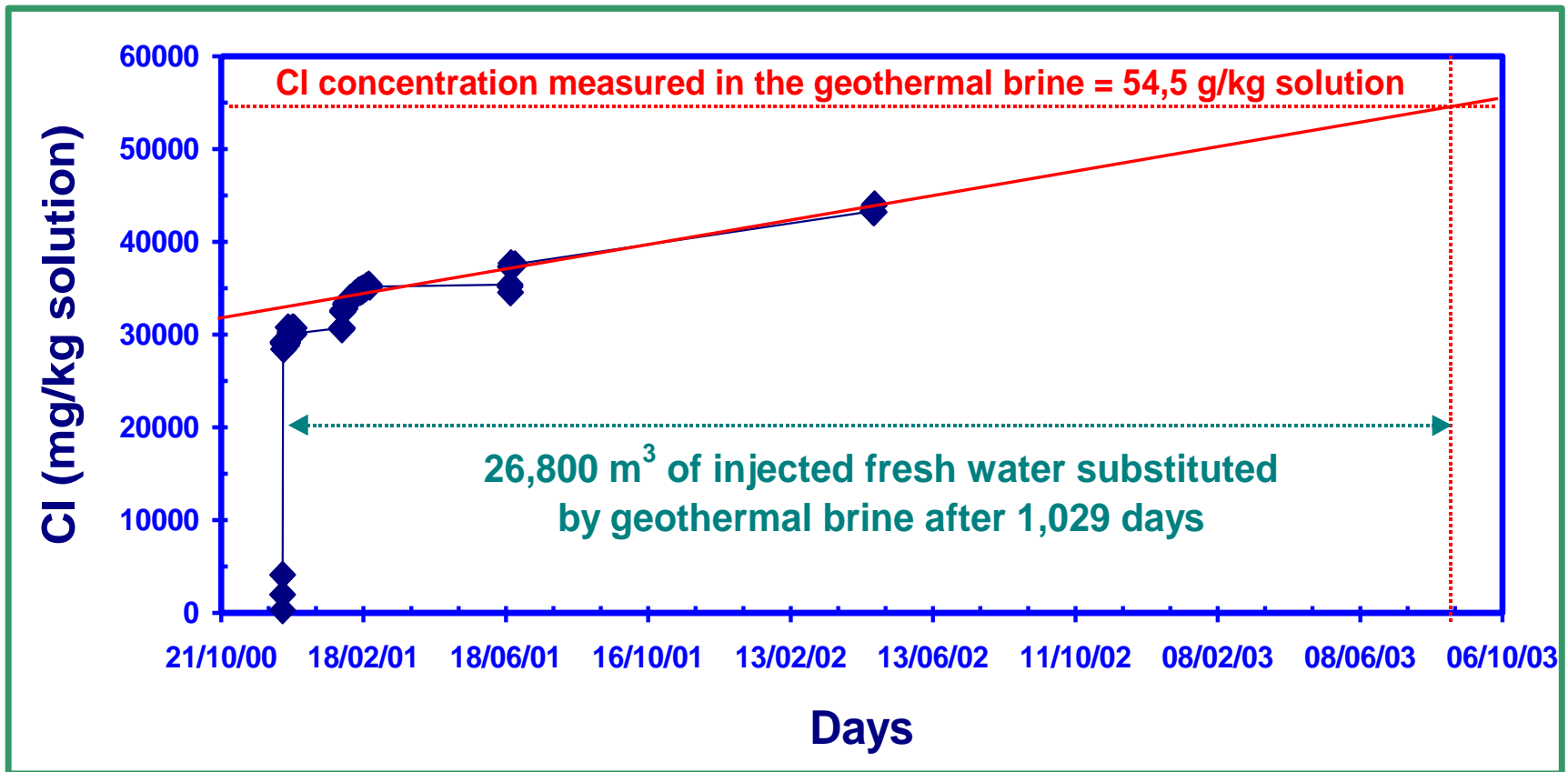
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# Main results obtained during the GPK-2 tracer test



**➔ Natural flow rate estimated to 1.0-1.2 m<sup>3</sup>/h  
(existence of an internal convection  
in the reservoir)**

# Hydraulic stimulation experiment carried out in GPK-2 (January - March 2003)

## > Water injection into GPK-2 (3 tests)

- 23,978 m<sup>3</sup> of fresh water (January 23-30: 9,214 m<sup>3</sup>; February 12-16: 5,814 m<sup>3</sup> and March 11-16: 8,950 m<sup>3</sup>; flow rate: from 15 to 30 l/s)

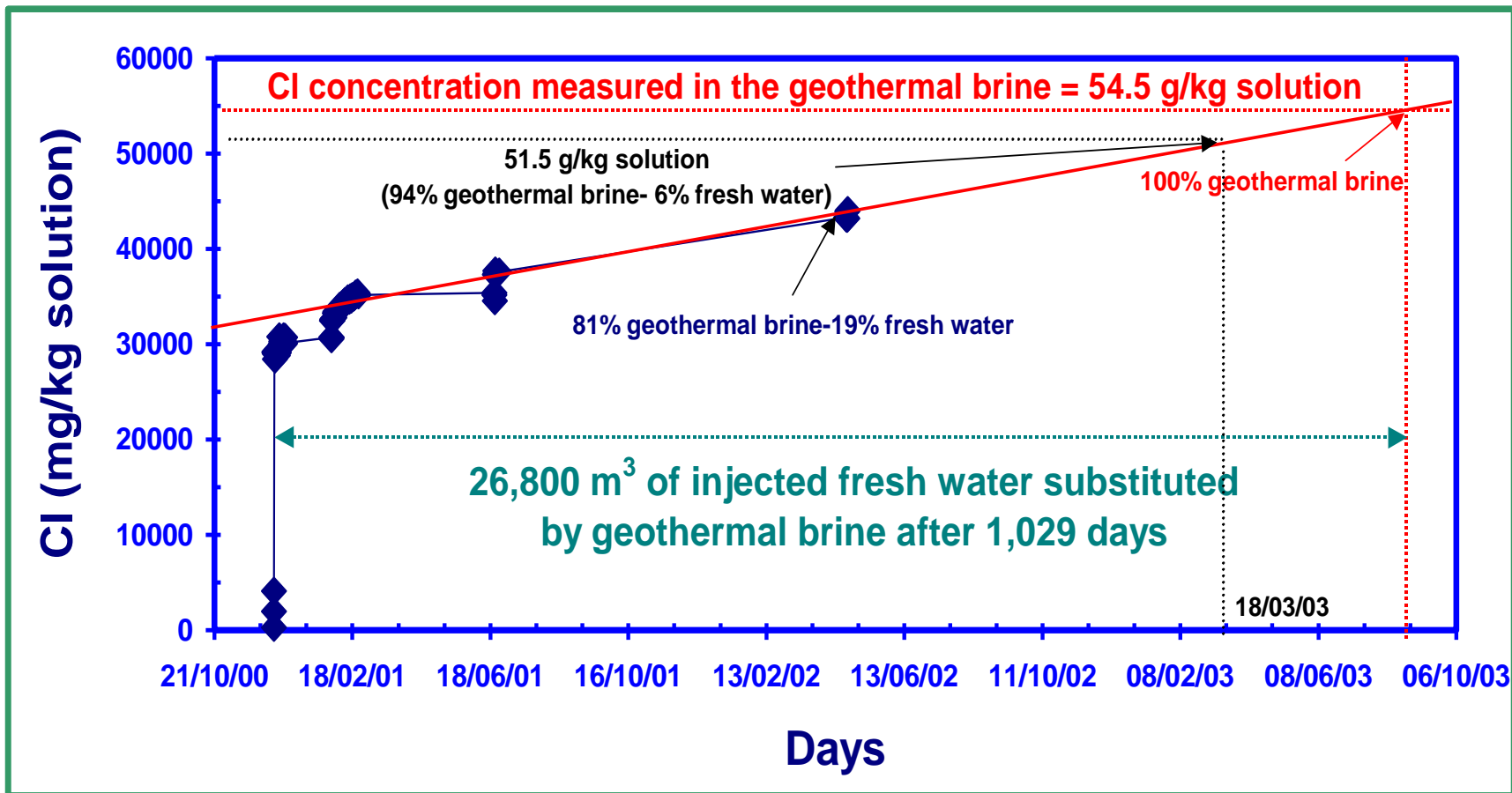
## > Tracer injection into GPK-2

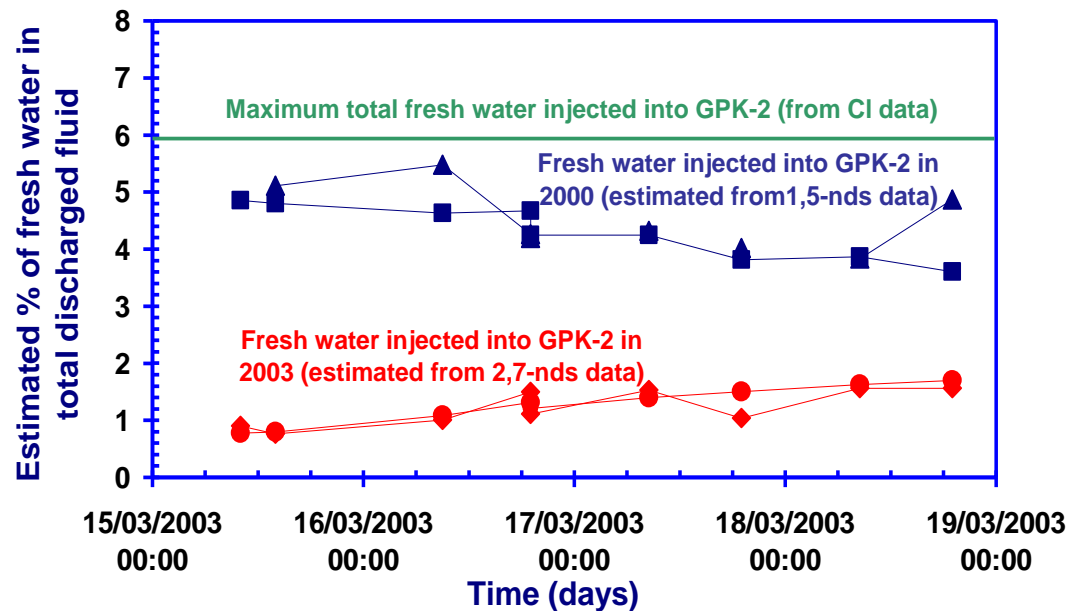
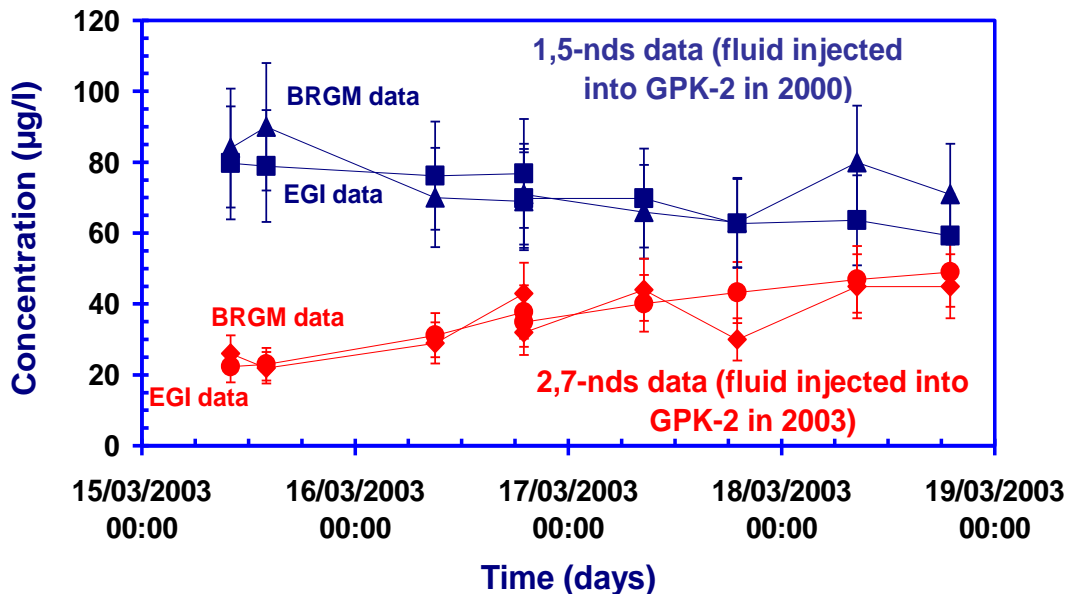
- 2,7-nds was continuously injected into GPK-2 during the hydraulic stimulation operation at a controlled concentration close to 3 mg/l

## > Production test on GPK-3

- 1,890 m<sup>3</sup> were discharged from GPK-3 in March 2003 (4 l/s)
- Geochemical monitoring: T, conductivity, pH, Eh, alkalinity, SiO<sub>2</sub>, Cl, Na, K, Ca, SO<sub>4</sub>, Br and Li analyses, organic tracer determinations by HPLC (2,7 and 1,5-nds also analysed by EGI of the University of Utah - P. Rose)

# Geochemical monitoring of the fluid discharged from GPK-3 in March 2003





## Geochemical monitoring of the fluid discharged from GPK-3 in March 2003

- > Relative analytical uncertainty : 15 to 20%
- > Very good agreement between BRGM and EGI analyses
- > 4% of freshwater injected in 2000 and 2% in 2003
- > Only 0.13% of the fresh water injected into GPK-2 in 2003 was recovered from GPK-3

# Fluid injection into GPK-3 and geochemical monitoring of the fluid discharged from GPK-2 (May-July 2003)

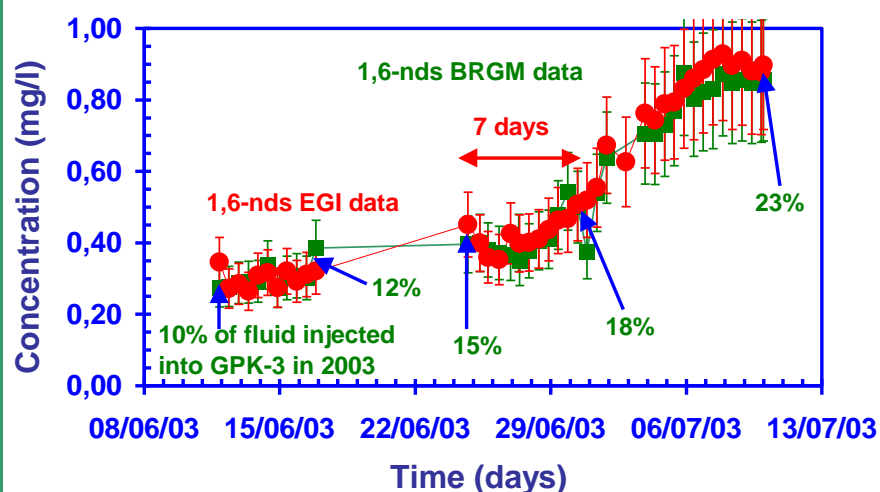
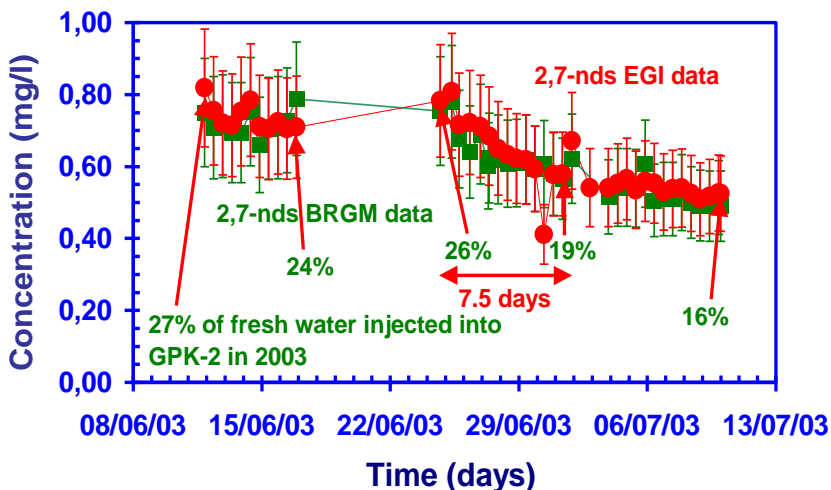
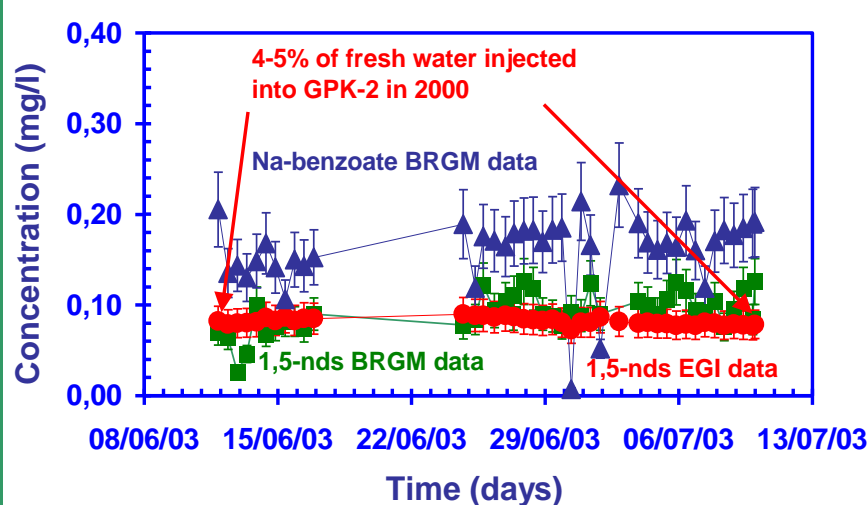
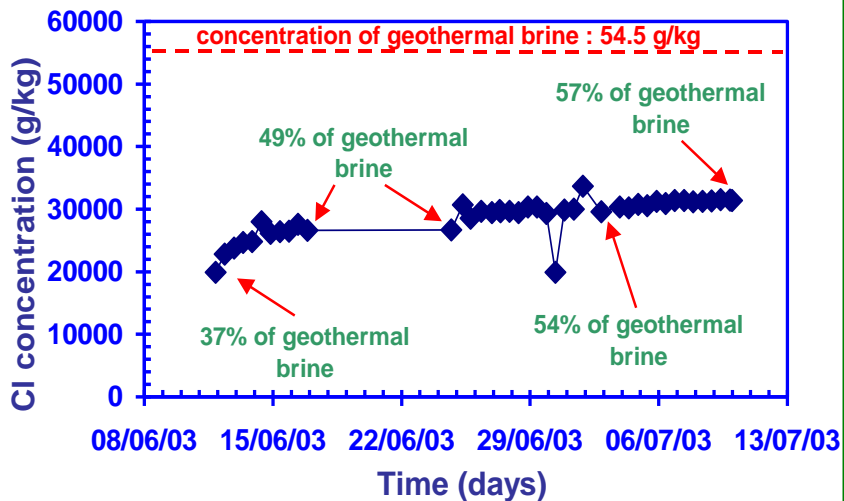
## > **Hydraulic stimulation carried out in GPK-3**

- about 34,000 m<sup>3</sup> of fresh water were injected into GPK-3 with a constant concentration of 1,6-nds at about 3 mg/l (May 27-June 6)
- 4,030 m<sup>3</sup> of fluid were discharged from GPK-2 using flow rates of 10-15 l/s (June 11-16)

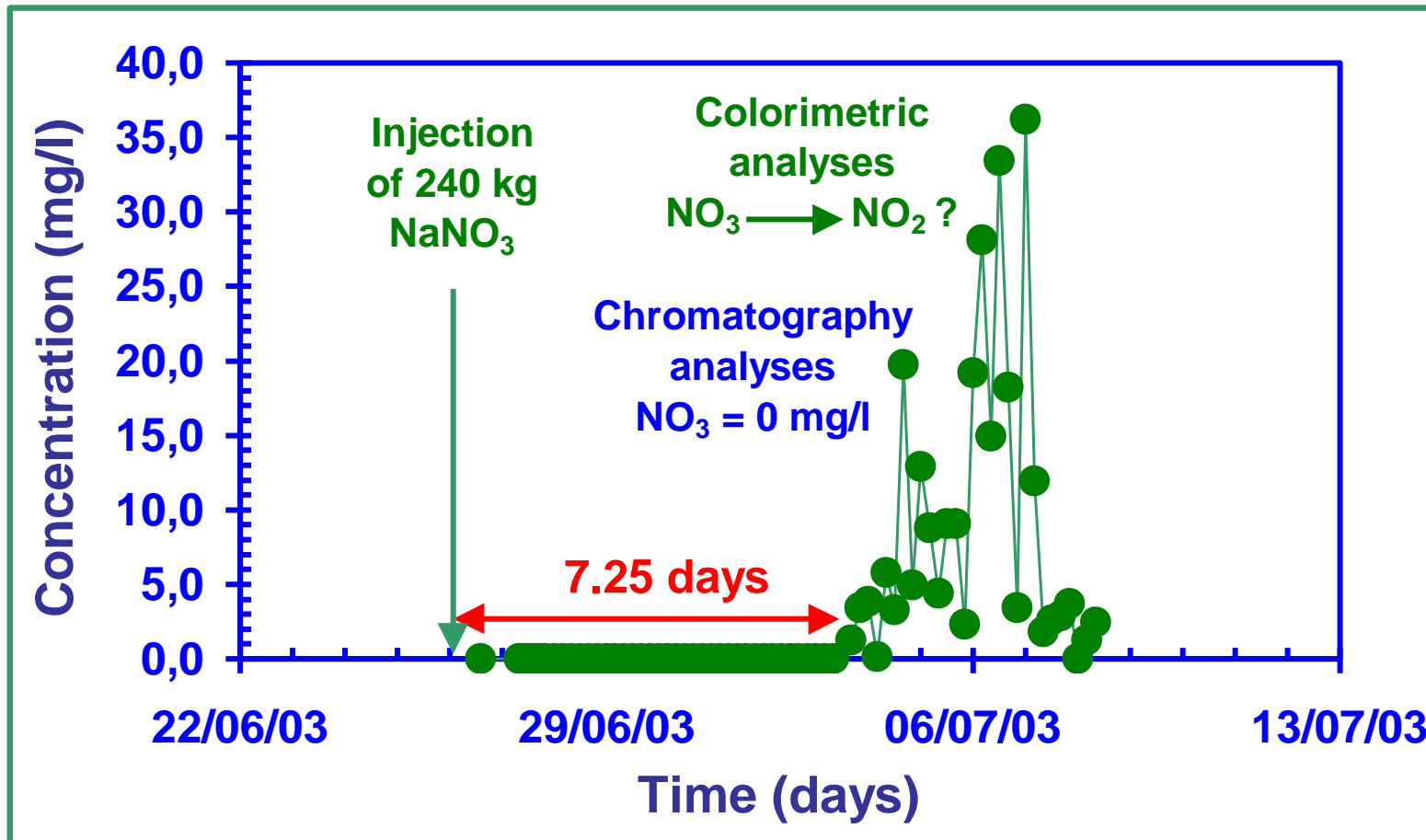
## > **Circulation test between GPK-3 and GPK-2 (June 24-July 11)**

- 25,305 m<sup>3</sup> of a mixture of geothermal brine produced from GPK-2 and fresh water were injected into GPK-3 with a concentration of 1,6-nds at about 4-5 mg/l (flow rates of 15-23 l/s). 240 kg NaNO<sub>3</sub> were also injected into GPK-3 on June 26
- 22,456 m<sup>3</sup> of fluid were discharged from GPK-2 using flow rates of 12-20 l/s

# Geochemical monitoring of the fluid discharged from GPK-2 (June - July 2004)



# Geochemical monitoring of the fluid discharged from GPK-2 (June - July 2004)



- > Similar results to those obtained for the circulation tests carried out in 1997 between GPK-1 and GPK-2 (rate ~ 3.73 m/h)

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# Conclusions

- > Conservative behavior of the 1,5-nds organic tracer during 3 years at high T (200°C)
- > Less than 7% of fresh water injected into GPK-2 in 2000 was recovered from GPK-2 between 2000 and 2002. Existence of an internal convection in the reservoir with a relatively significant flow rate (1.0-1.2 m<sup>3</sup>/h)
- > Before GPK-3 hydraulic stimulation, the percentage of fluid injected into GPK-2 in 2003 was lower than 2% in the fluid discharged from GPK-3. After stimulation, the percentage of fluid injected into GPK-3 in 2003 ranged from 10 to 23 % in the fluid discharged from GPK-2. Less than 10% of fluid injected into GPK-3 was recovered from GPK-2 in 2003
- > Only 7.25 days were necessary for NaNO<sub>3</sub> and 1,6-nds to be advected from GPK-3 to GPK-2 (rate ~ 3.7 m/h)

