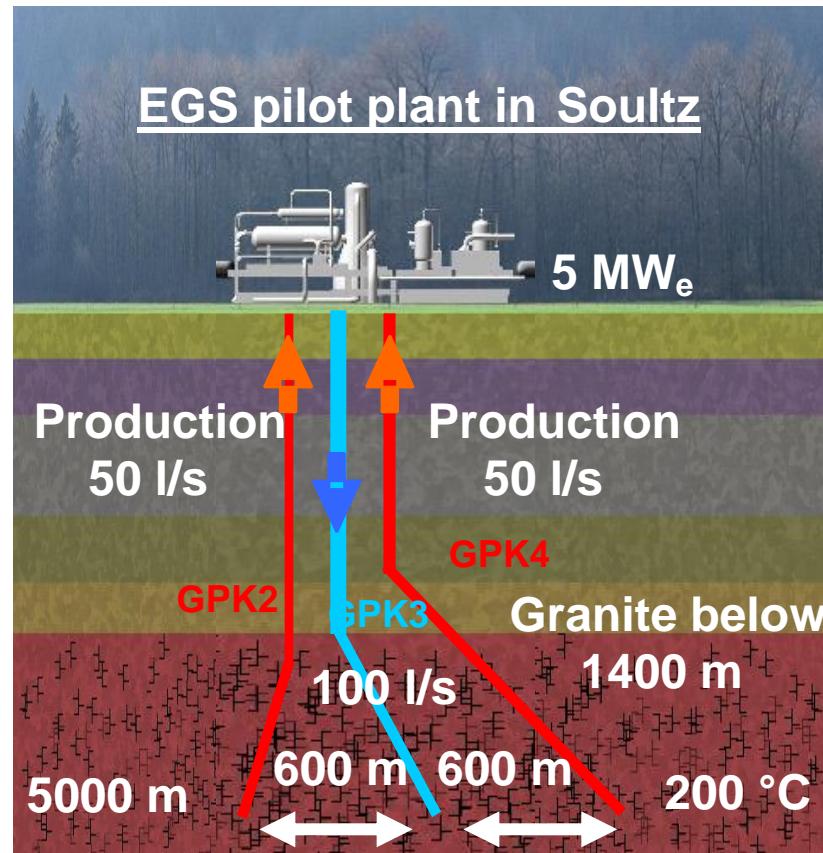


Chemical stimulation of the Soultz wells

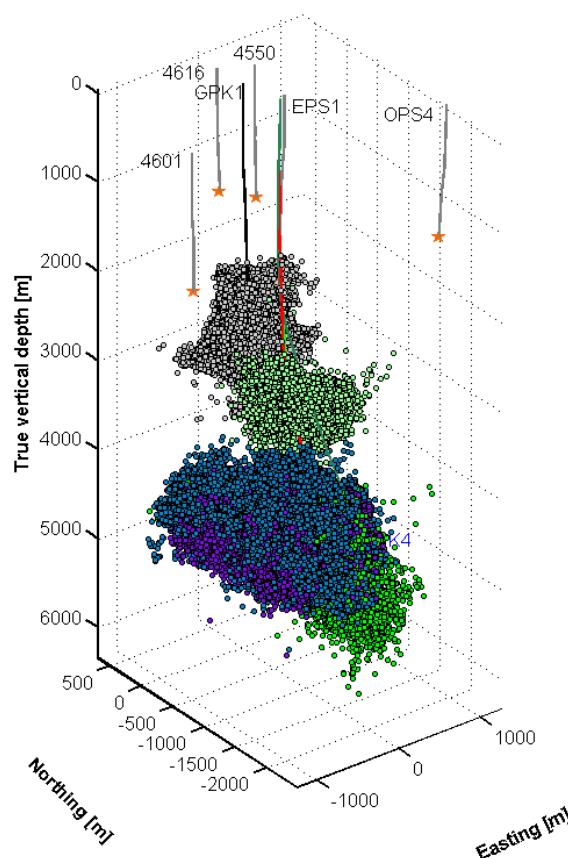
- Introduction
- Soultz wells after hydraulic stimulations
- Chemical stimulation GPK2
- Chemical stimulation GPK3
- Chemical stimulation GPK4
- Conclusions

Introduction: The Soultz project



Reservoir development by hydraulic stimulations 2000 - 2005

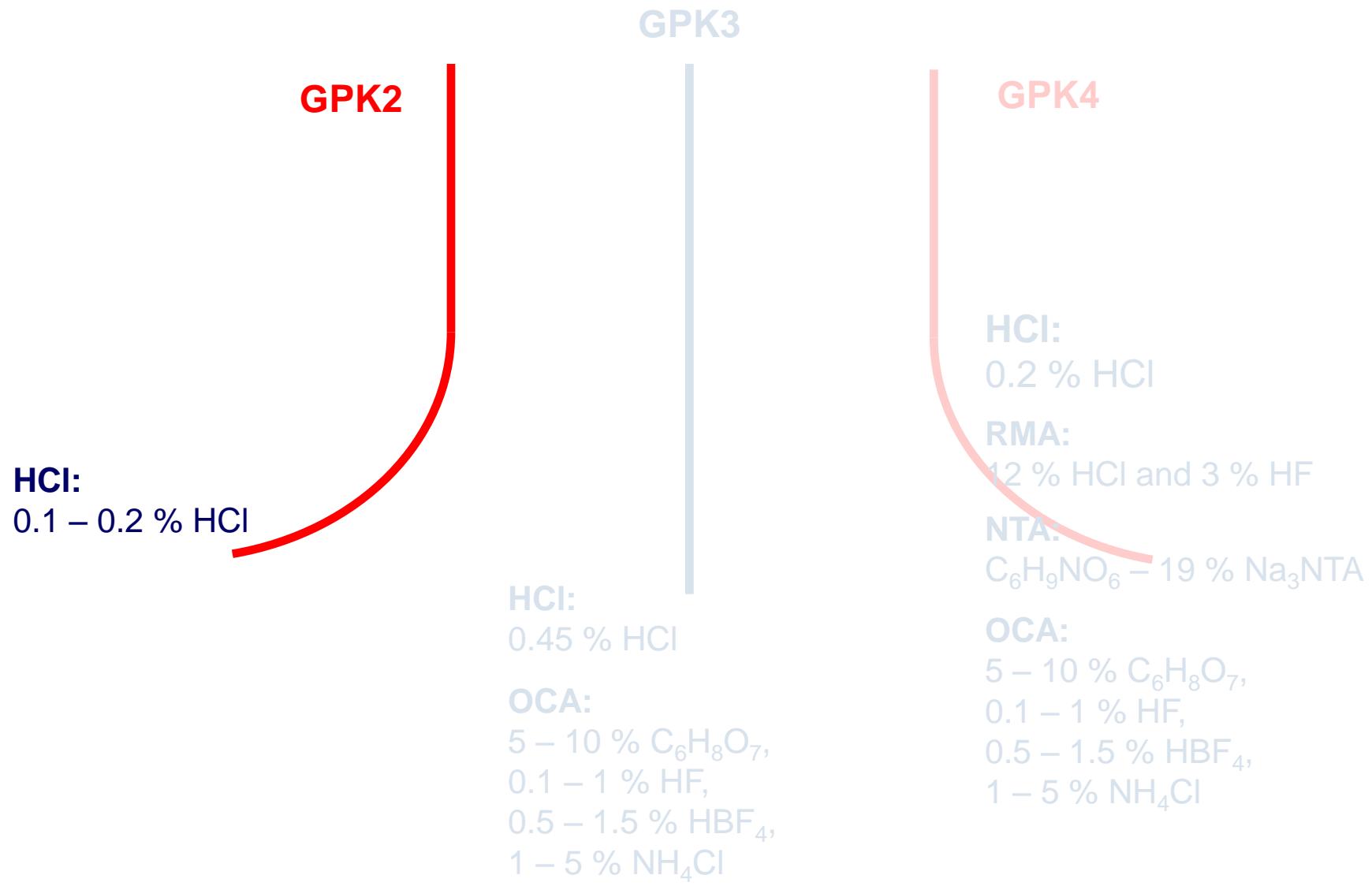
	Initial prod. [l/s/bar]	Achieved prod. (2 d) [l/s/bar]
GPK2	0.02	0.4
GPK3	0.2	0.3
GPK4	0.01	0.2



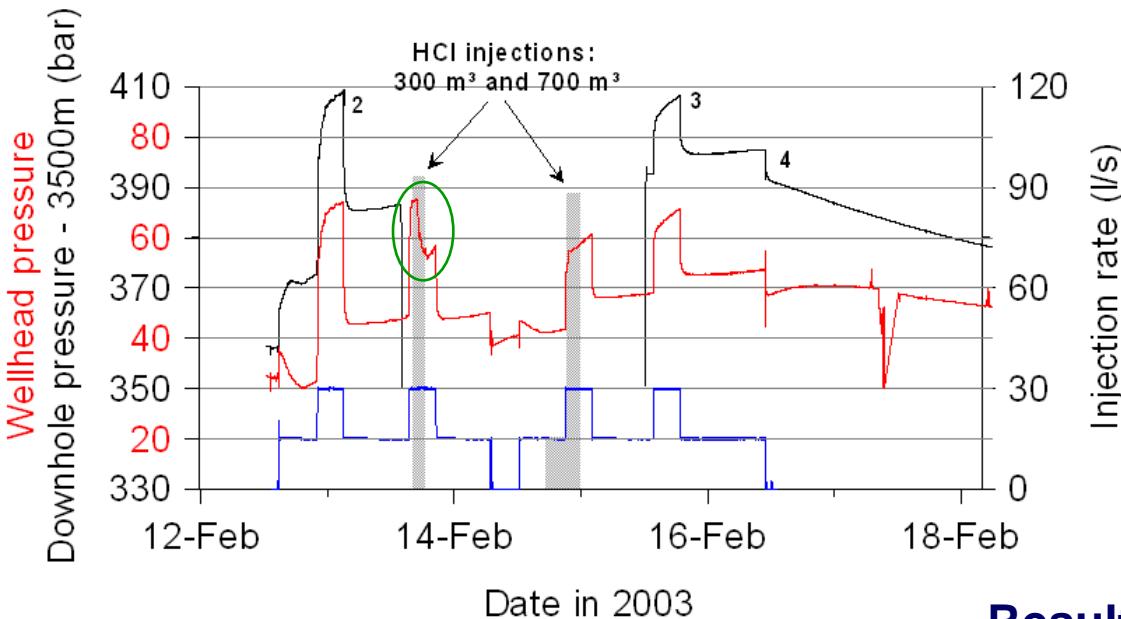
Injection of acids and chelatants in GPK2, 3, and 4 to

- Improve the near wellbore performance without additional seismicity
- remove scaling minerals like calcite and illite from the natural fractures

Chemical treatment in GPK2

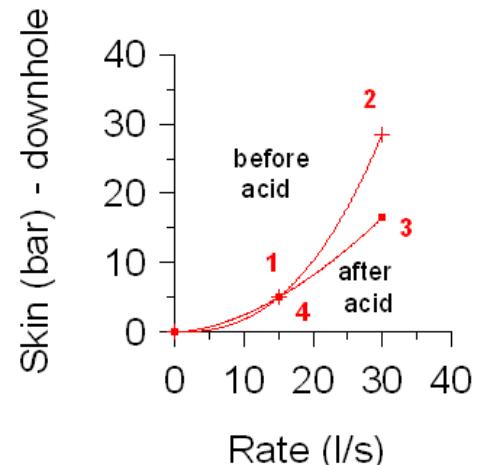


GPK2 acidizing with HCl



HCl injection
to dissolve calcite.

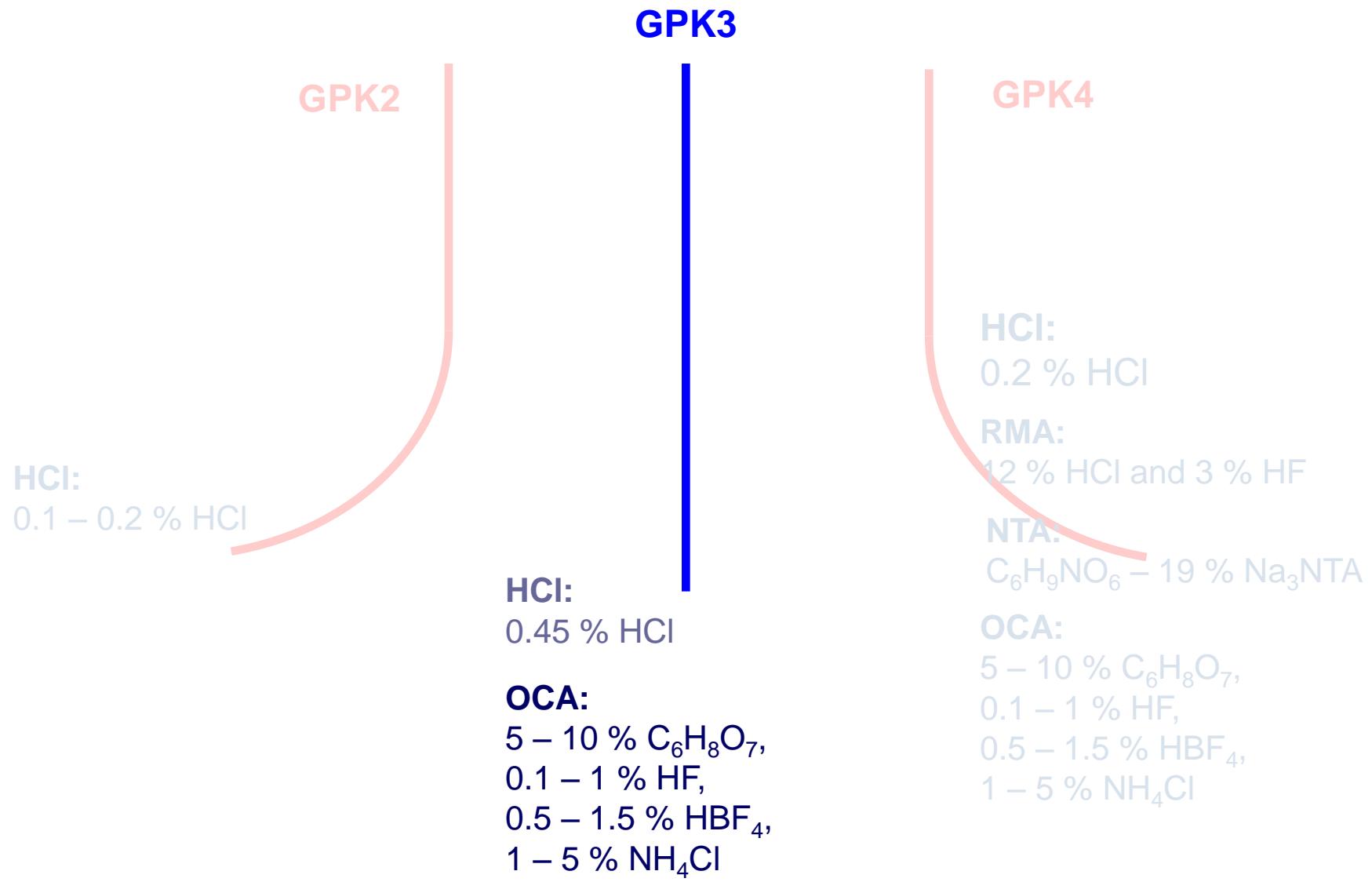
Observation: first pulse had immediate impact in or very close to the well, second one only minor



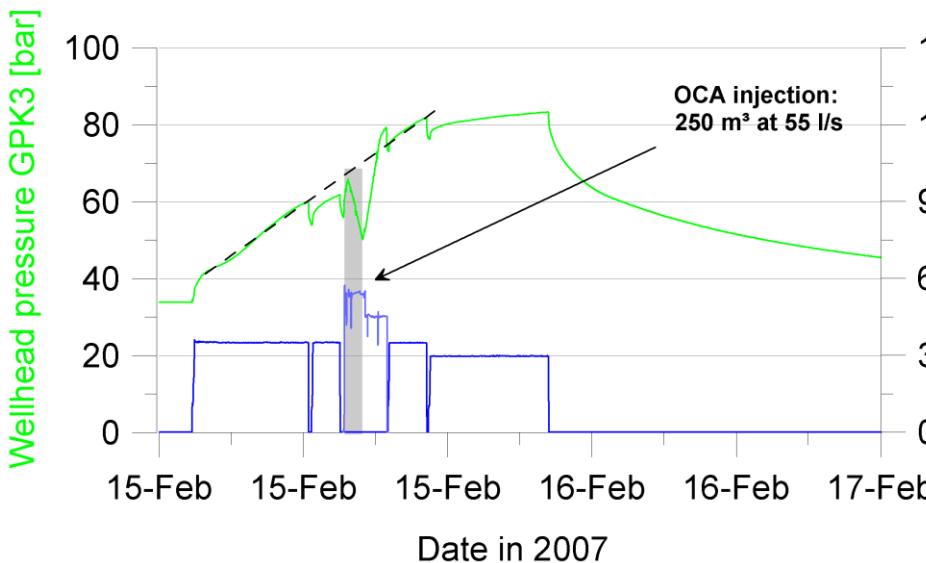
Result:

- Reduction of turbulence only at higher flow rates
- Correlation with casing restriction at 3900 m TVD
- improvement in formation is not significant

Chemical treatments in GPK3



GPK3 acidizing with OCA



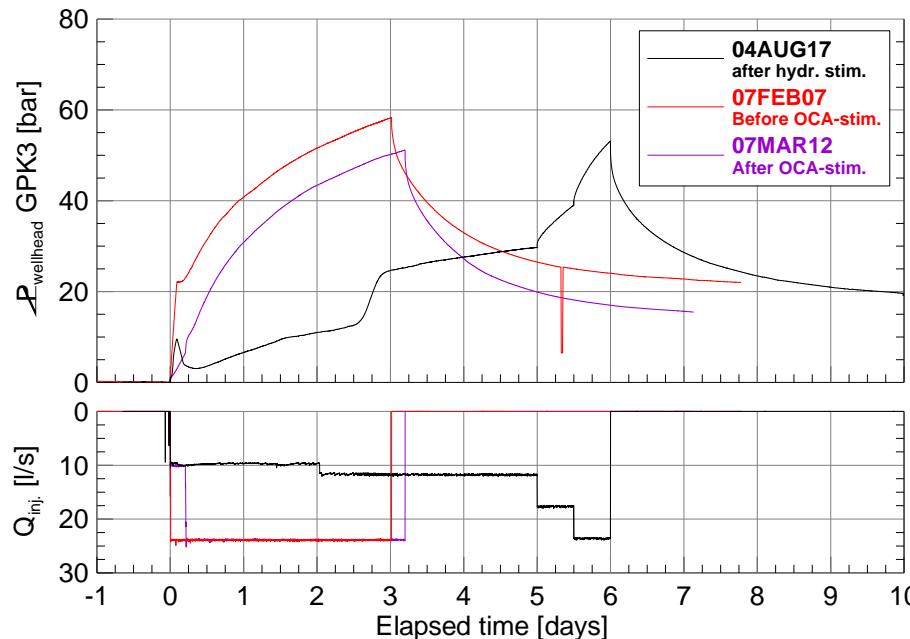
OCA (Organic Clay Acid) injection
for high temperature formations or
chlorite: retarded acid

Observations: pressure increase
during pre- and postflush is similar –
only minor improvement

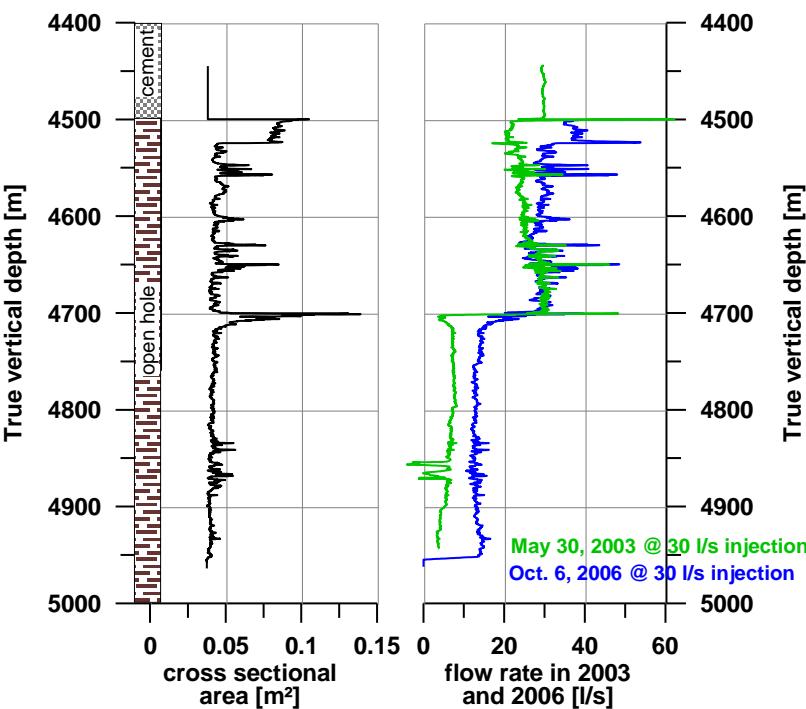
Injection flow rate [l/s]

Result:

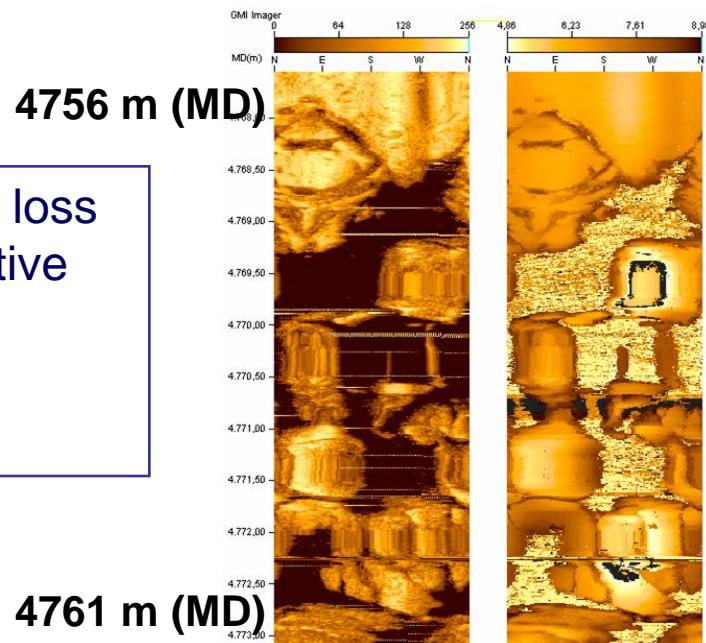
Only marginal improvement was
achieved.



GPK3 flowlog, UBI and hydraulics



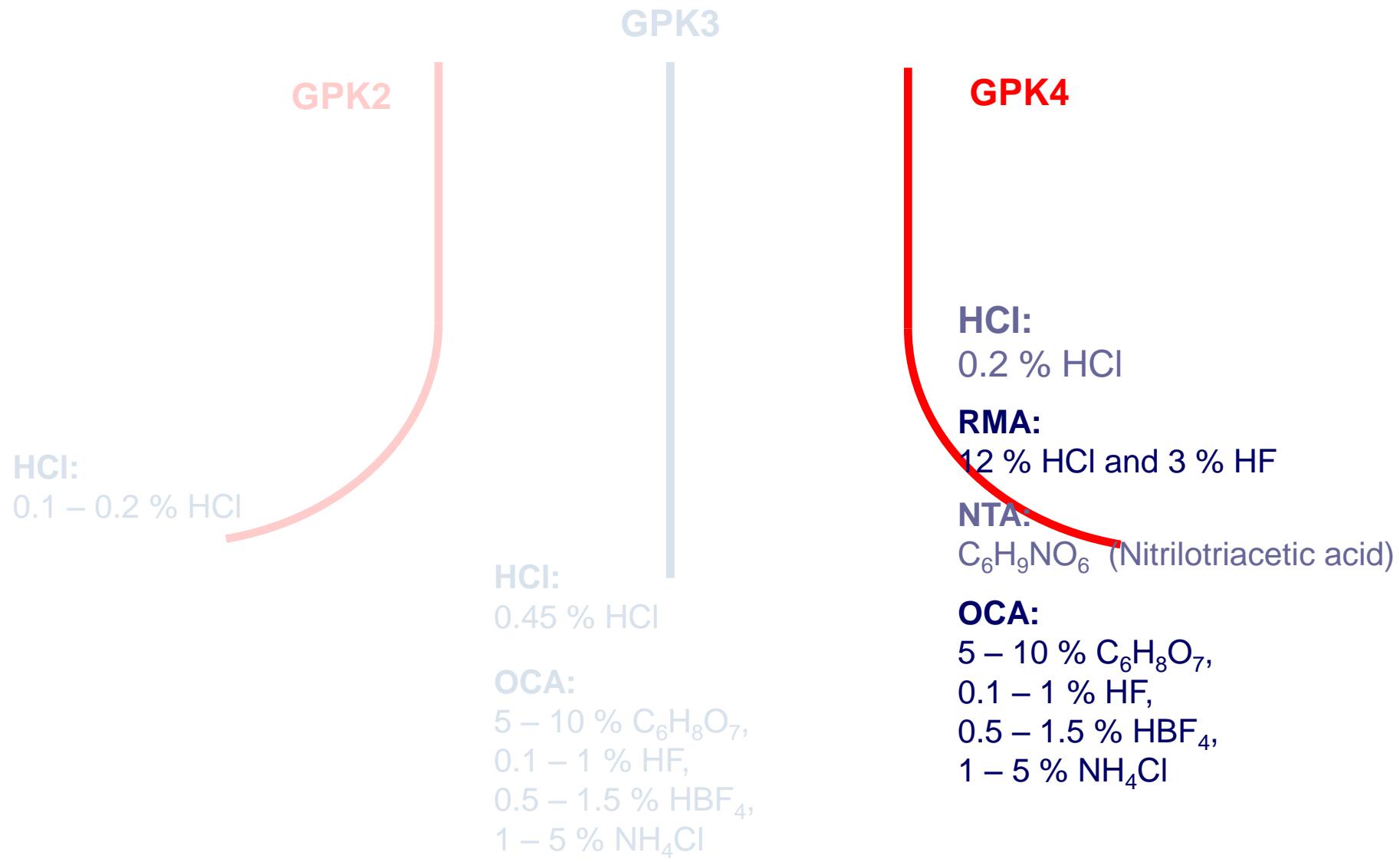
60 – 70 % flow loss
in high conductive
fracture zone:
4700 m TVD
(4756 m MD)



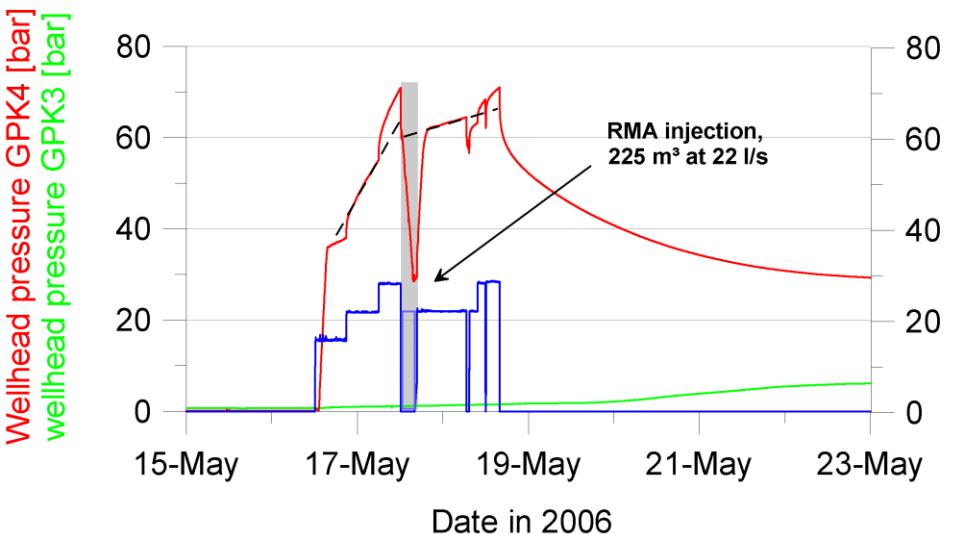
The removal of minerals on already high conductive fracture areas has only small potential to improve the wells productivity. A similar result was observed for the injection of HCl into GPK3.

→ HCl and OCA did not significantly improve the reservoir.

Chemical treatments in GPK4



GPK4 acidizing by RMA

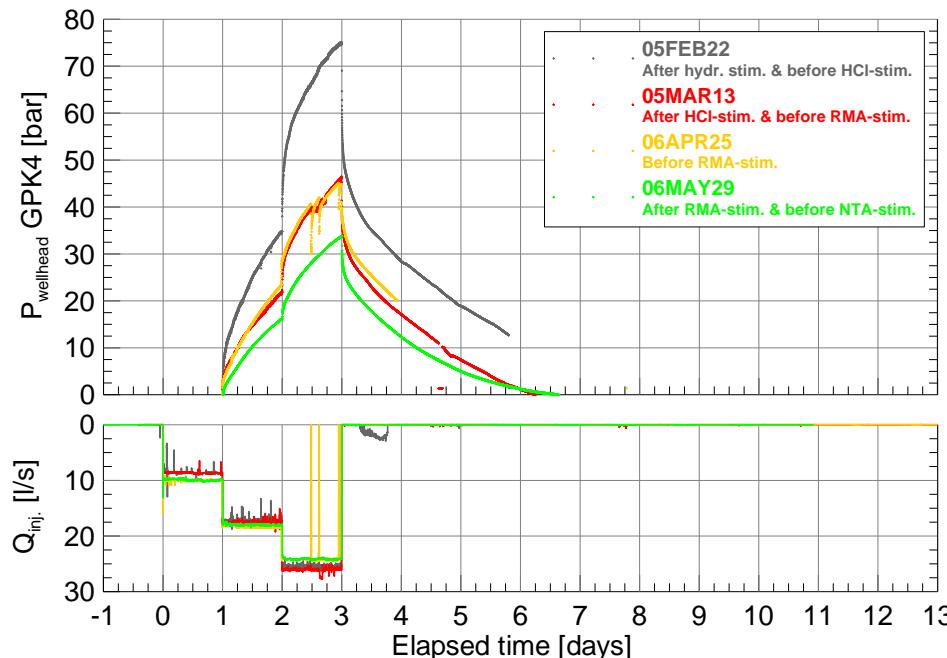


RMA (Regular Mud Acid) injection
to target hydrothermal deposits as
carbonates and clays.

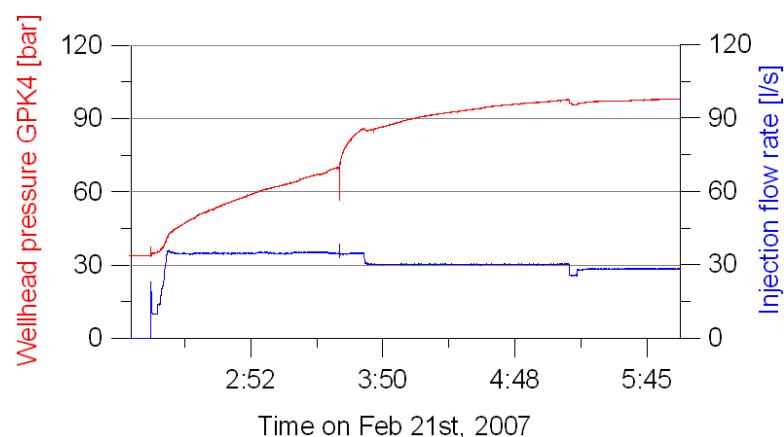
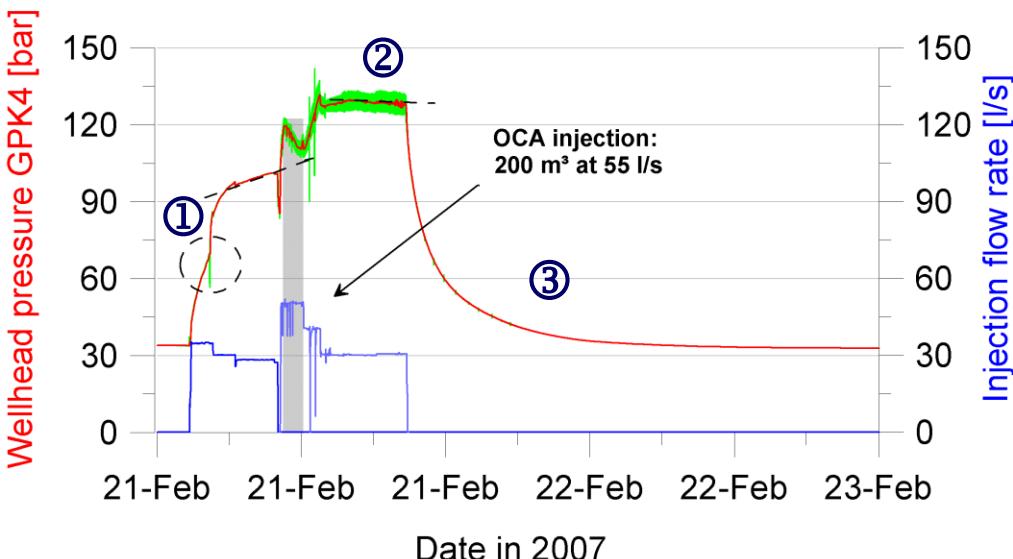
Observations: slope of pressure
increase gets smaller from pre- to
postflush

Result:
from pre- and post-
stimulation step-rate tests:

Before RMA: 0.3 l/(s*bar)]
After RMA: 0.4 l/(s*bar)]



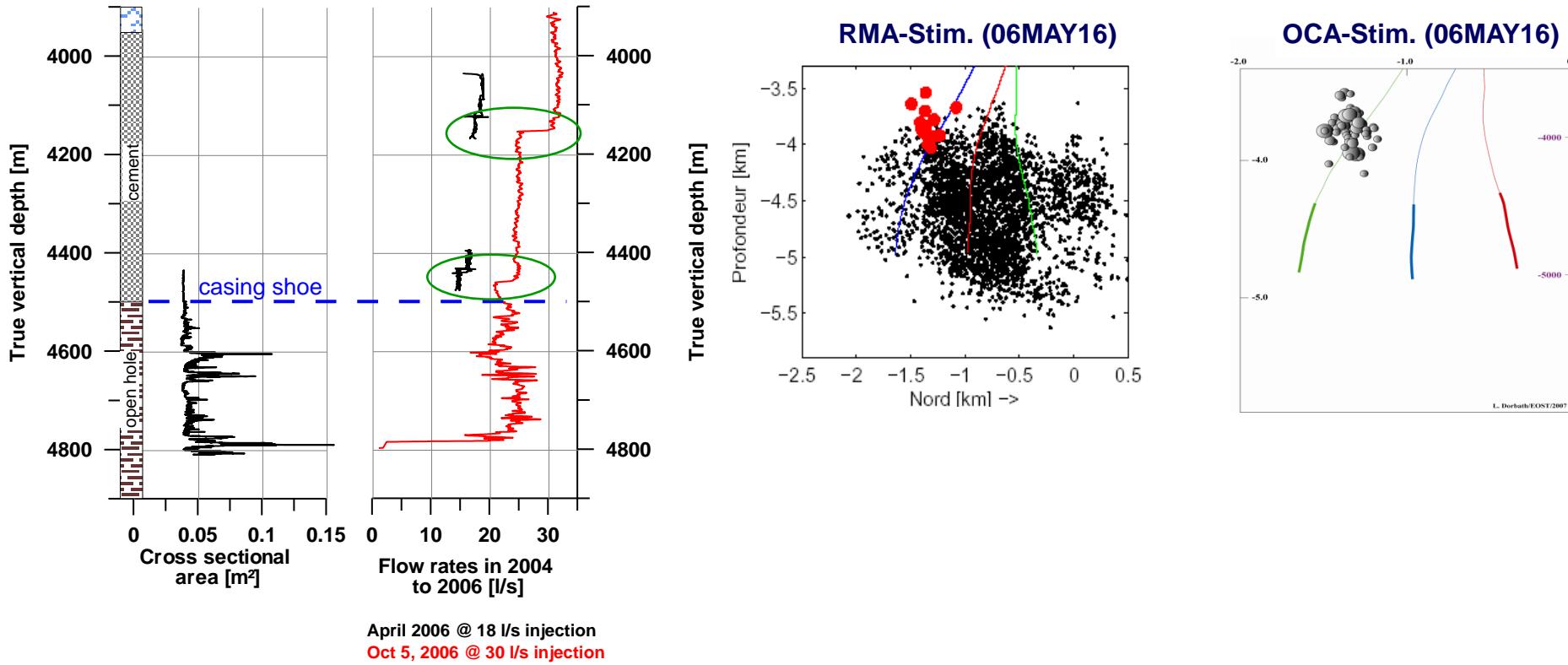
GPK4 acidizing with OCA



Observations during OCA injection:

1. Black circle indicates pressure increase during fresh water injection
→ plugging?
2. Flat pressure curve at abnormal high level
→ appears like a fracturing process: due to the plug, we increased pressure up to fracturing pressure?
3. Fast pressure decrease during shut- in
→ connection to an additional structure?

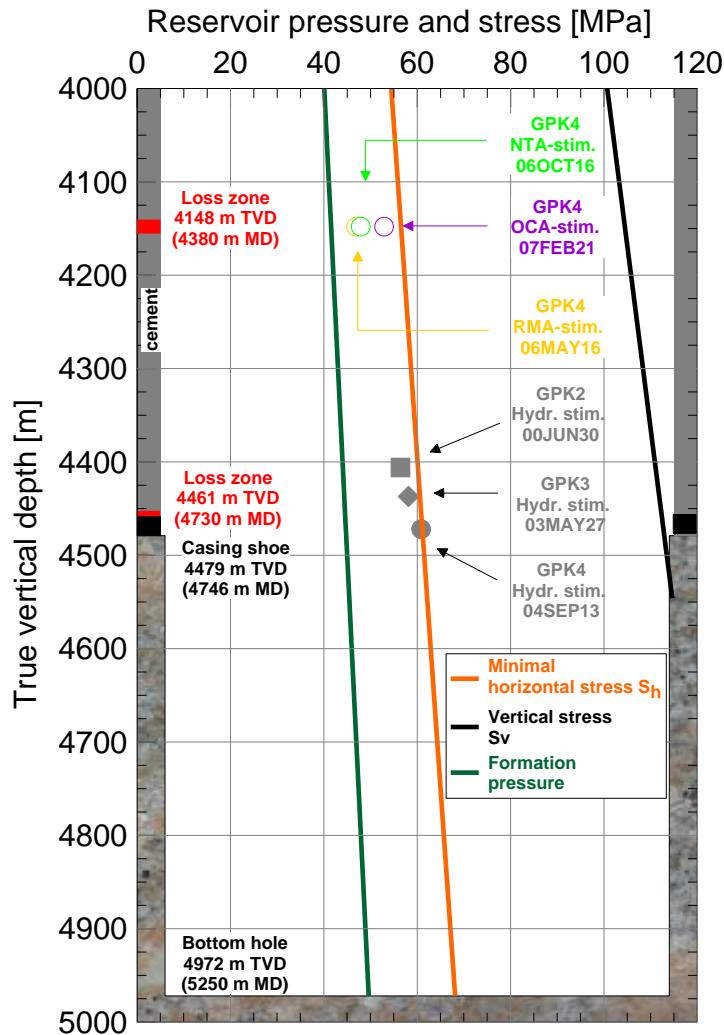
GPK4 flowlog and seismicity



Indications of WHERE the possible fracturing and additional productivity comes from:

- the flowlog: Leakages in the cased section at ~ 4110 and ~ 4440 m TVD
- and seismicity during the two injections

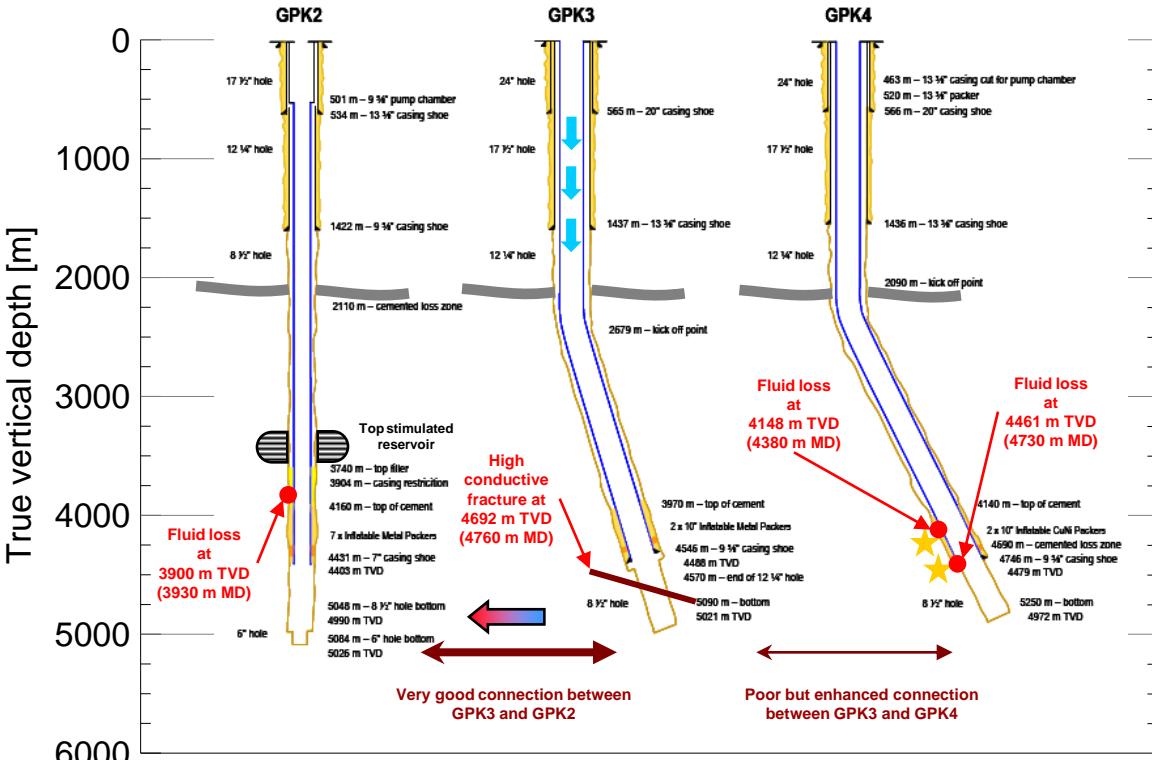
GPK4 fracture gradient at leakage depth



- improvements achieved partly through leakages and partly in the open hole?
- if main improvement comes from leakages, production temperature might be affected!

Conclusion

~0.5 l/(s*bar) **~0.4 l/(s*bar)** **~0.5 l/(s*bar)**



→ Acidizing has moderately improved the near well performance in all wells, but especially in GPK4 the impact in the reservoir via the openhole is questionable.

GPK2

- Productivity ~ 0.5 l/(s*bar)
- HCl acidizing reduces turbulence in or near well bore
- Probably at the casing restriction

GPK3

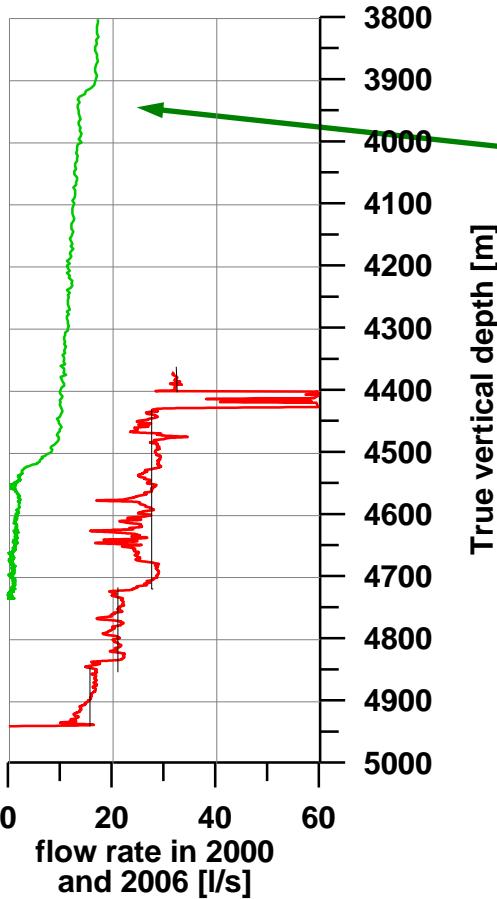
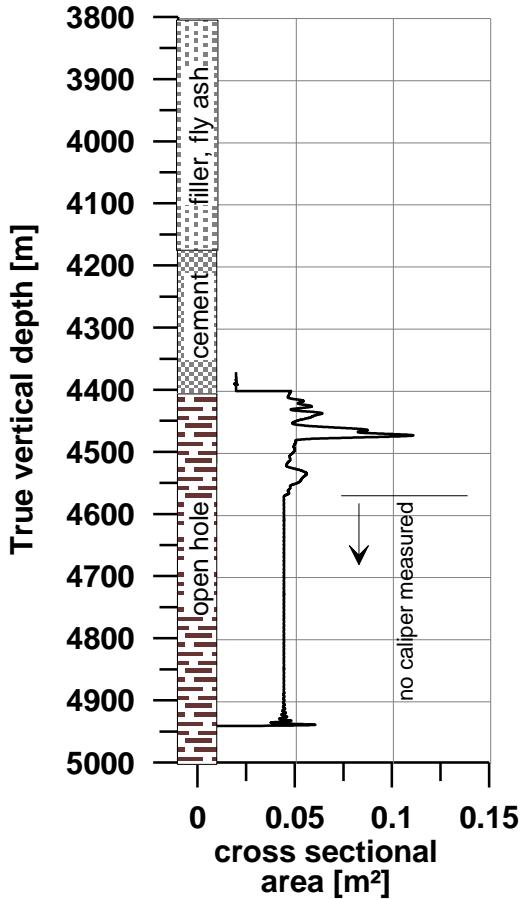
- Productivity ~ 0.4 l/(s*bar)
- Chemical stimulation success only small because of high conductive fracture at 4700 m TVD

GPK4

- P ~ 0.5 l/(s*bar)
- Leaks at 4150 and 4460 m TVD contribute to ~20 % and 10 % fluid loss respectively
- The productivity improvement after RMA- and OCA-injection is for a part attributed to a hydraulic stimulation in the leakage zones

Thank you for your attention!

GPK2 situation from flowlogs



~ 30 % flow loss at
casing restriction with
stuck tool :
3910 m TVD
(3930 m MD)

July 2000 @ 30 l/s injection
April 2006 @ 1.7 l/s injection (scaled!)

HCl injections in the other wells

Well	Date	Dura-tion [hours]	Total injected HCl [t]	Concentra-tion [%]	Diluted HCl injected [m ³]	Injection flow rate [l/s]	result	
GPK2	13.02.2003	6	1.4	0.18	650	30		
	14.02.2003	10		0.18	810	15		
				0.09		30		
GPK3	27.06.2003	12	3	0.45	865	20		
GPK4	02.02.2005	48	11	0.2	4700	27.2		

More about chemical stimulations....

OCA stimulation for GPK3 – for high temperature sandstone formations or formations with more than 5 % zeolite or chlorite. Was tested on GPK3 cutting samples.

Preflush ~ 1200 m³ of fresh water at 35 l/s (GPK4 30 l/s)

Main flush of 250 m³ OCA: 5 – 10 % citric acid C₆H₈O₇, 0.1 – 1 % HF, 0.5 – 1.5 % HBF₄, 1 – 5 % NH₄Cl at 55 l/s (in weight: 10 – 20 t citric acid, 0.2 – 2 t HF, 1-3 t HBF₄, 2 – 10 t NH₄Cl)

Postflush ~ 1300 m³ of fresh water with flow rates of 45 and 30 l/s (GPK4 40 and 35 l/s)

RMA stimulation for GPK4 – hydrothermal deposits like carbonates and clay

Preflush of 2000 m³ fresh water at steps of 18, 22 and 28 l/s

Preflush of HCl, 25 m³ at concentration of 15 % (deox.) at 22 l/s (3 t)

Main flush of 200 m³ RMA, 12 % HCl and 3 % HF plus inhibitor at 22 l/s (24 t HCl & 6 t HF)

Postflush of 2000 m³ fresh water at 22 and 28 l/s

NTA stimulation for GPK4 – strong chelating capacity with respect elements like Ca, Mg, Fe and other metals

Chelatants form complexes with cations like Fe, Ca, Mg, and Al and dissolve calcite etc...

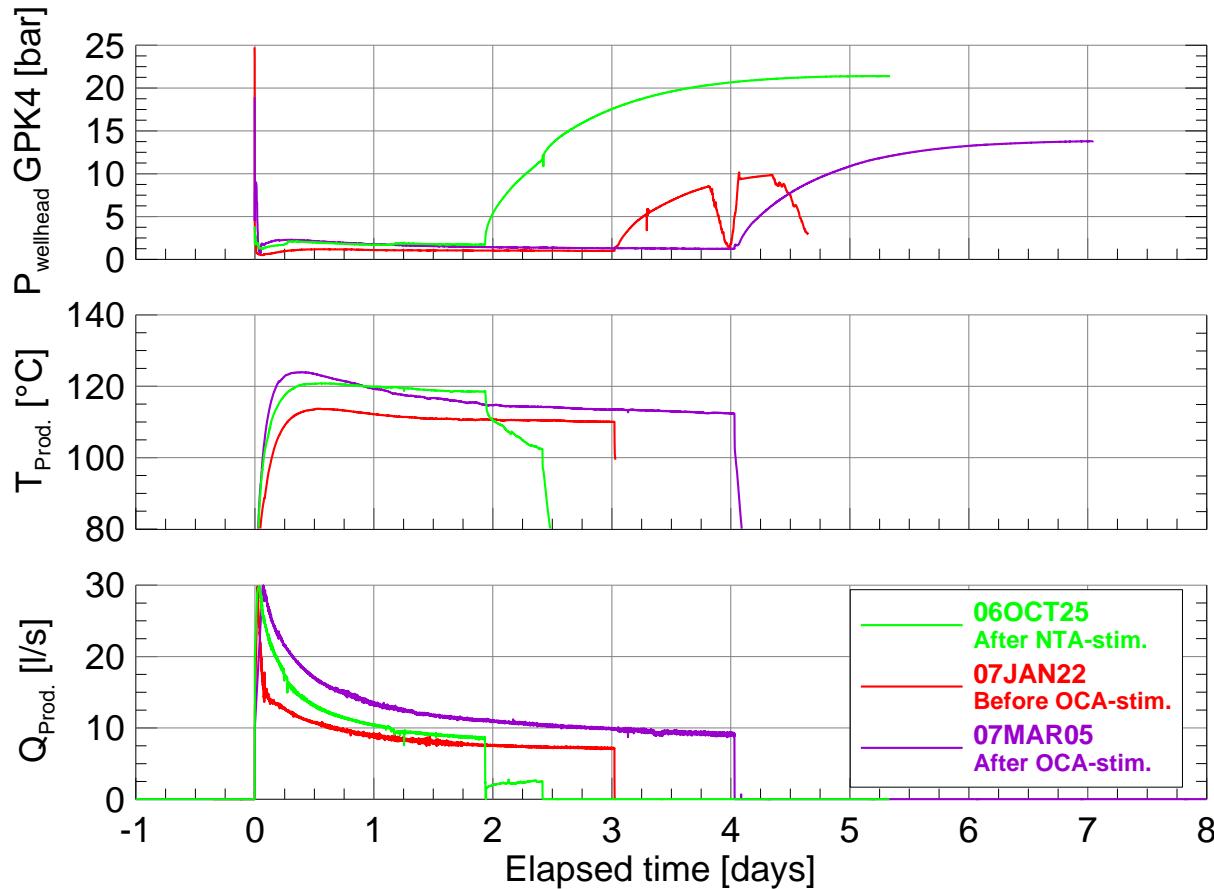
C₆H₉NO₆ -- Nitrilotriacetic acid.

Preflush (to pressurize reservoir??) of 4500 m³ at 24 l/s

Main flush of 200 m³ of caustic soda and 19 % diluted Na₃NTA at 35 l/s (38 t)

Postflush of 400 m³ fresh water at 40 l/s

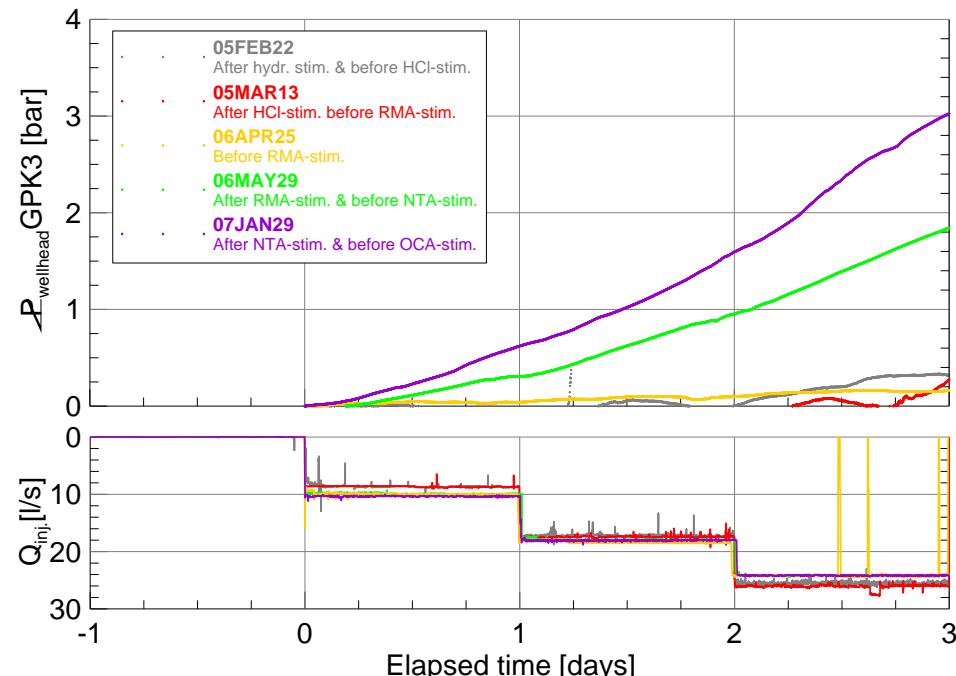
Productivity of GPK4 after OCA-stimulation



Before OCA: 0.4 l/(s*bar)]

After OCA: ~0.5 l/(s*bar)]

Hydraulic connection between GPK3 and GPK4

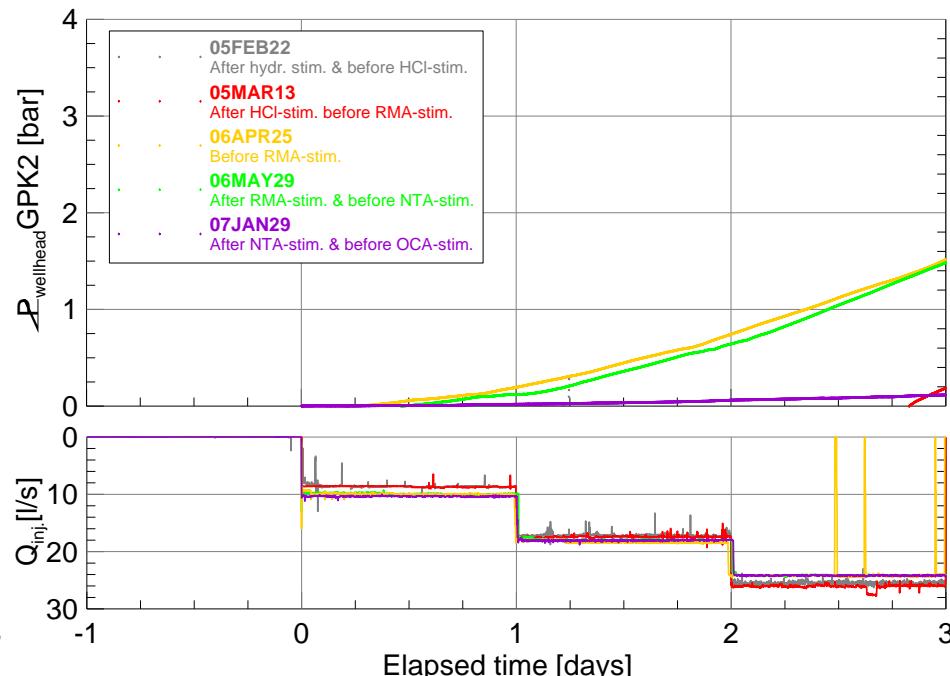


Pressure difference in GPK3.

GPK3 during test 06APR25 not activated

~2 bar after RMA (although GPK3 not activated at the beginning of the step-rate test)

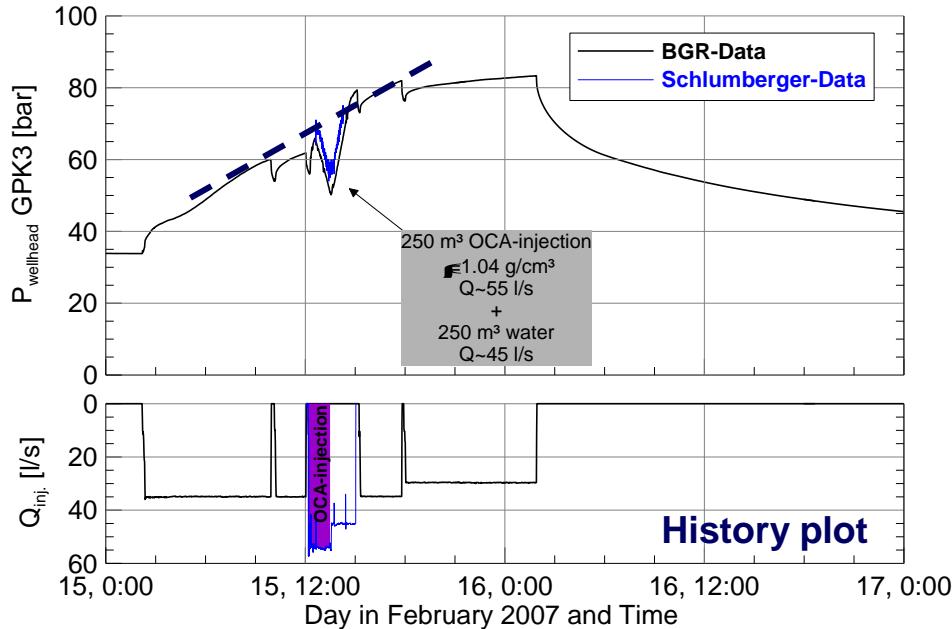
~3 bar after NTA



Pressure difference in GPK2.

~1.5 bar after RMA and NTA

Chemical stimulation of GPK3 with OCA



Preliminary analysis

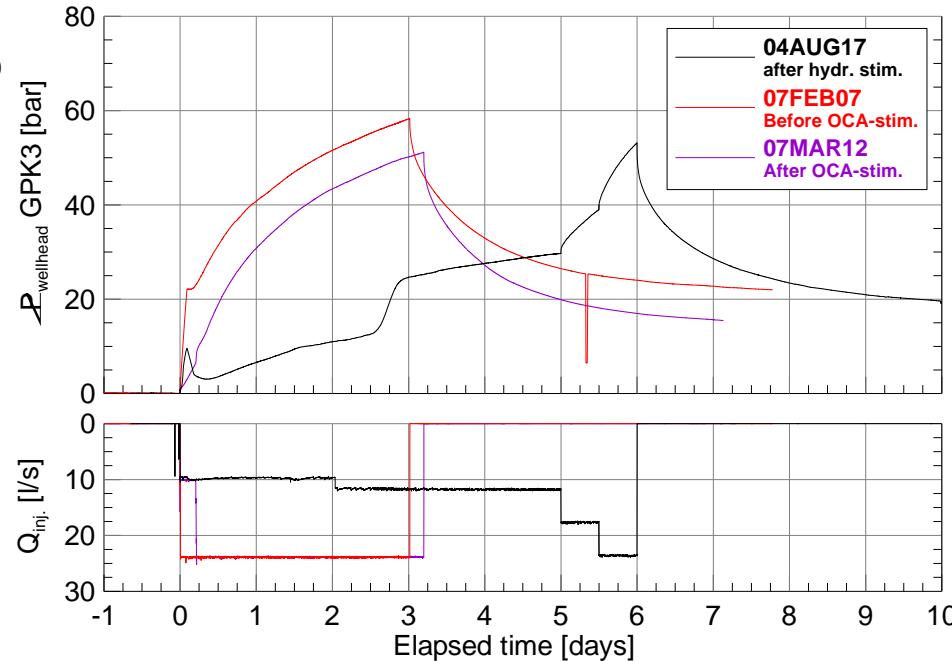
Almost similar pressure slope before and after the stimulation

⇒ very moderate results

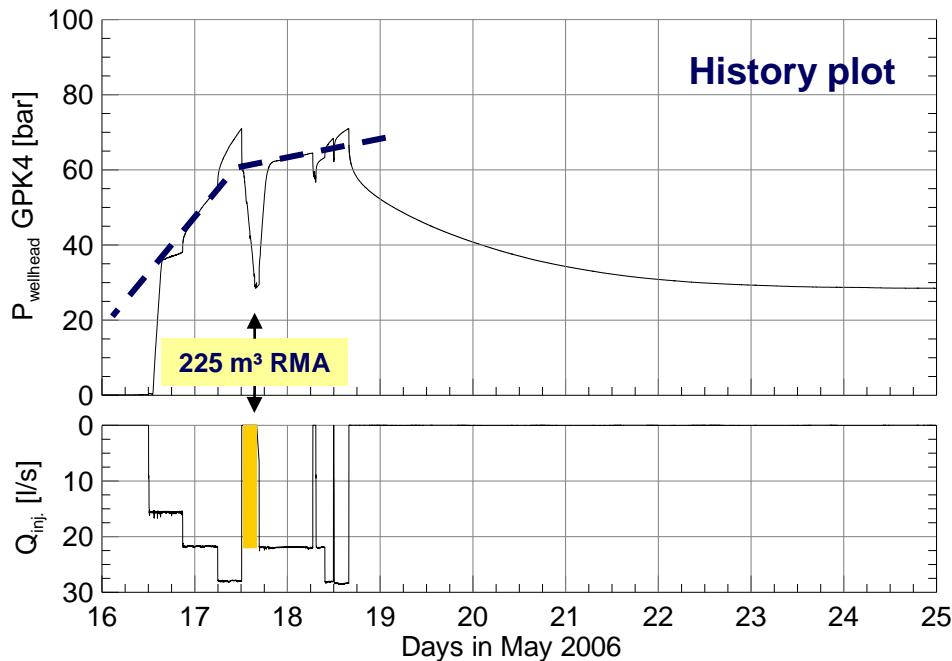
Pre- and post-stimulation injection tests

Before OCA: 0.35 l/(s*bar)

After OCA: ~0.39 l/(s*bar)



Chemical stimulation of GPK4 with RMA



Preliminary analysis

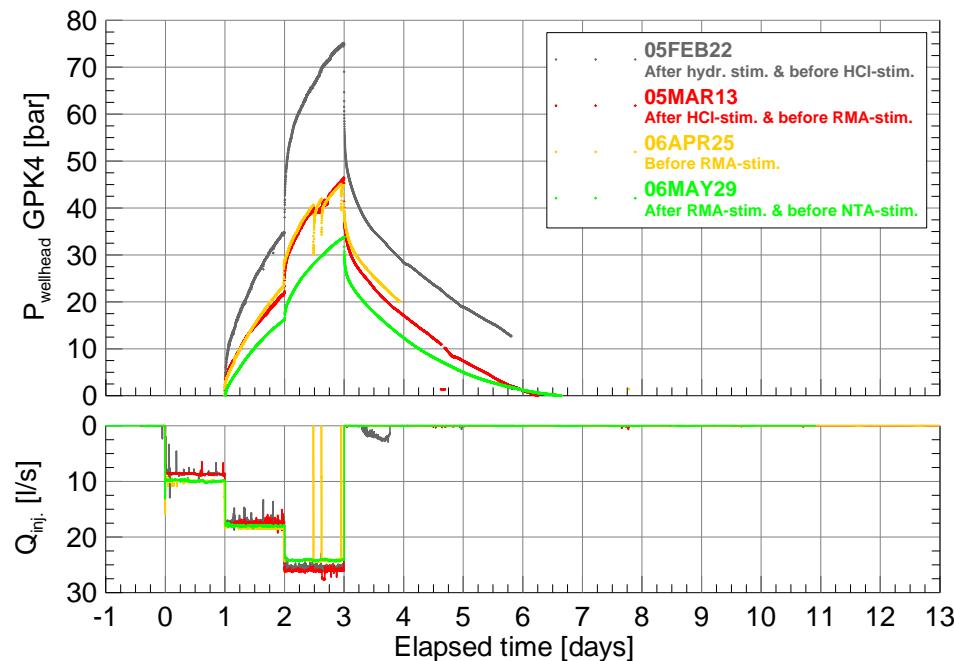
Less pronounced pressure increase after chemical treatment than before

⇒ Gain in productivity

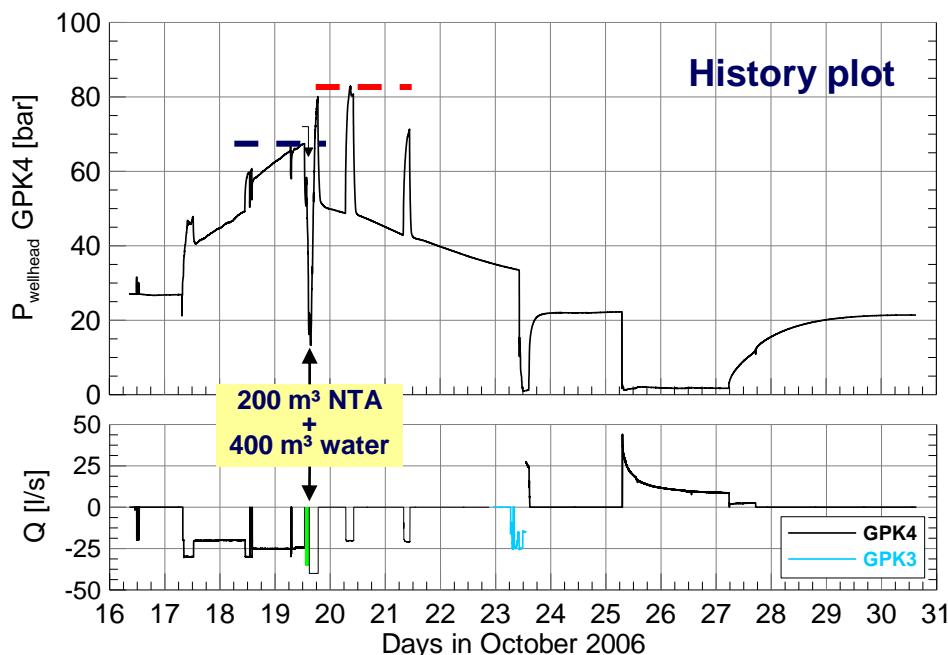
Pre- and post-stimulation step-rate tests

Before RMA: 0.3 l/(s*bar)]

After RMA: 0.4 l/(s*bar)]



Chemical stimulation of GPK4 with NTA



Preliminary analysis

Wellhead pressure after chemical treatment higher than before

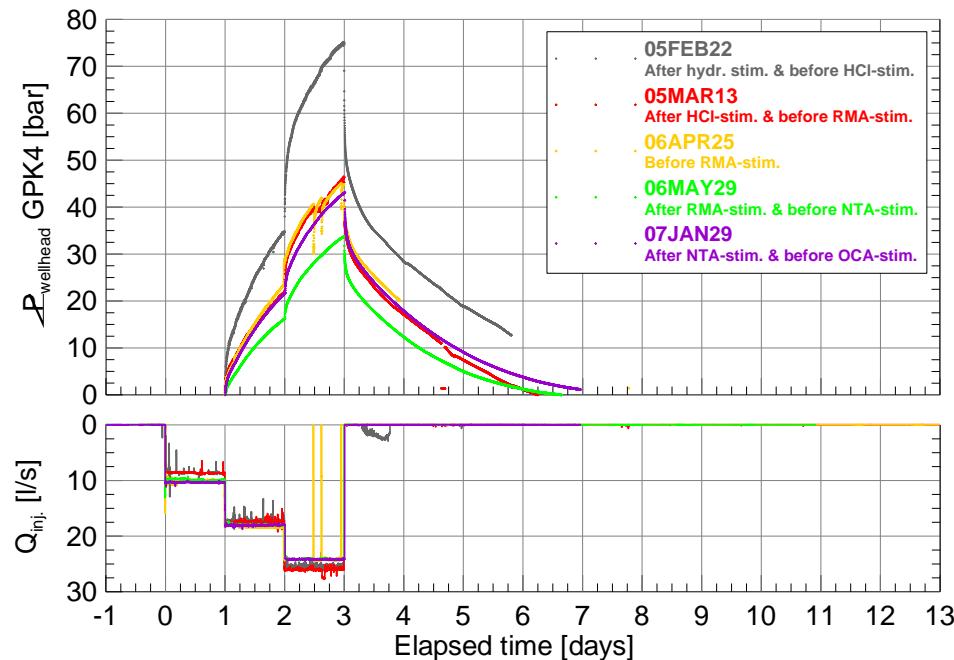
⚠ Suspicion of plugging the productive zones

⇒ Production to remove NTA-residuals

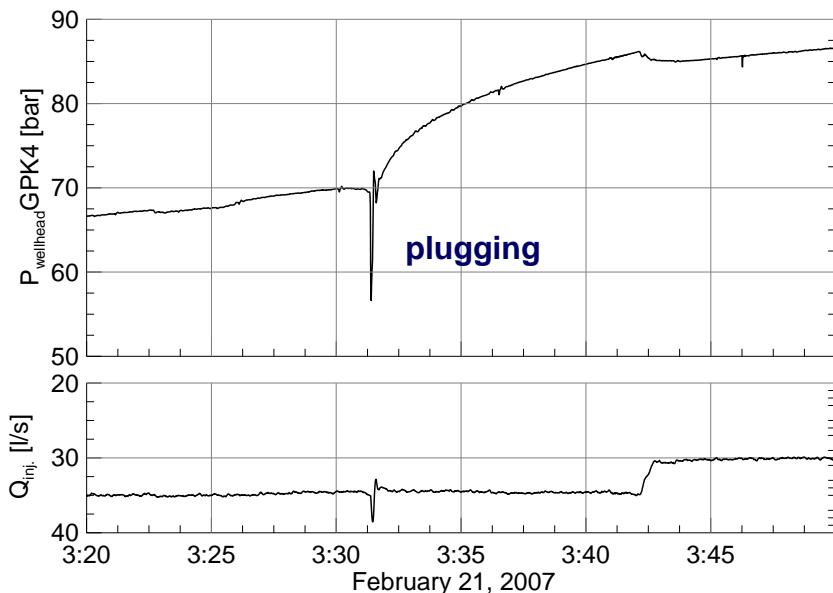
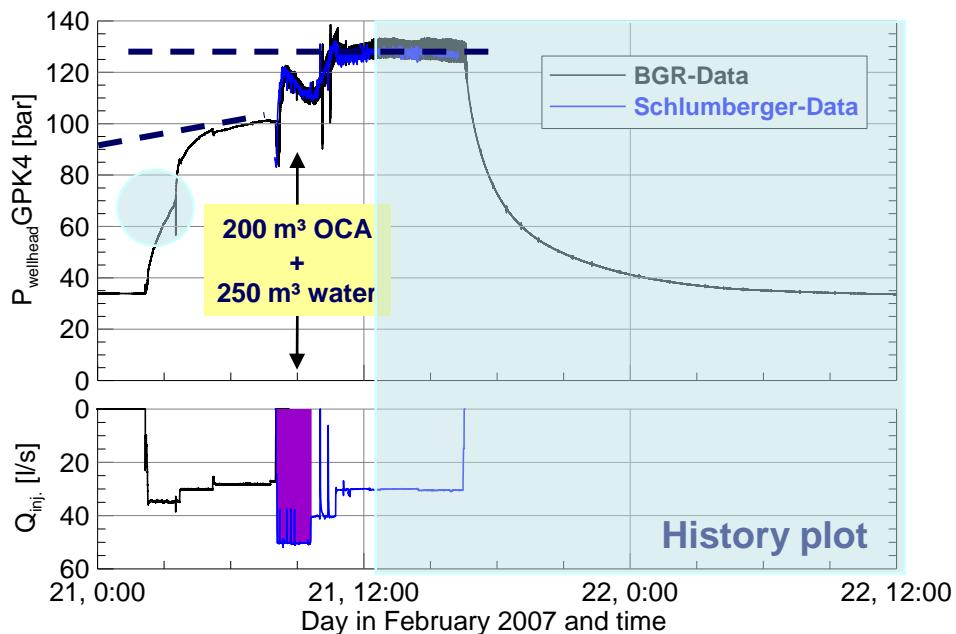
Pre- and post-stimulation step-rate tests

Before NTA: 0.4 l/(s*bar)]

After NTA: ~0.3 l/(s*bar)]



Chemical stimulation of GPK4 with OCA



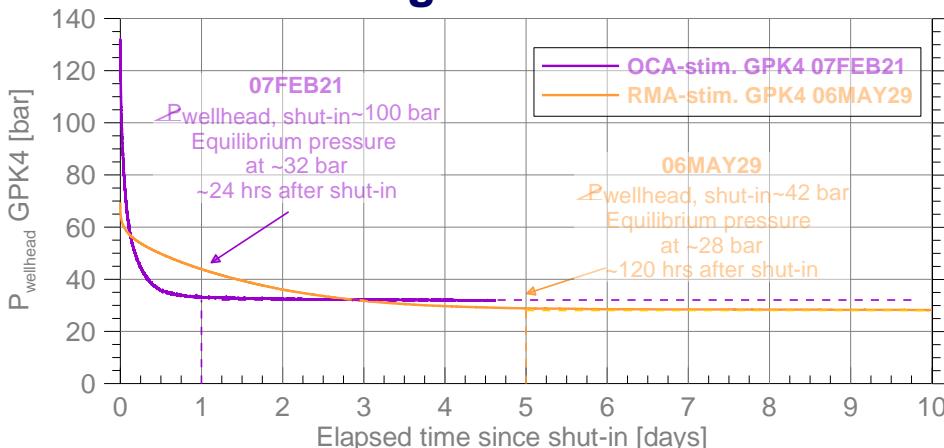
Preliminary analysis

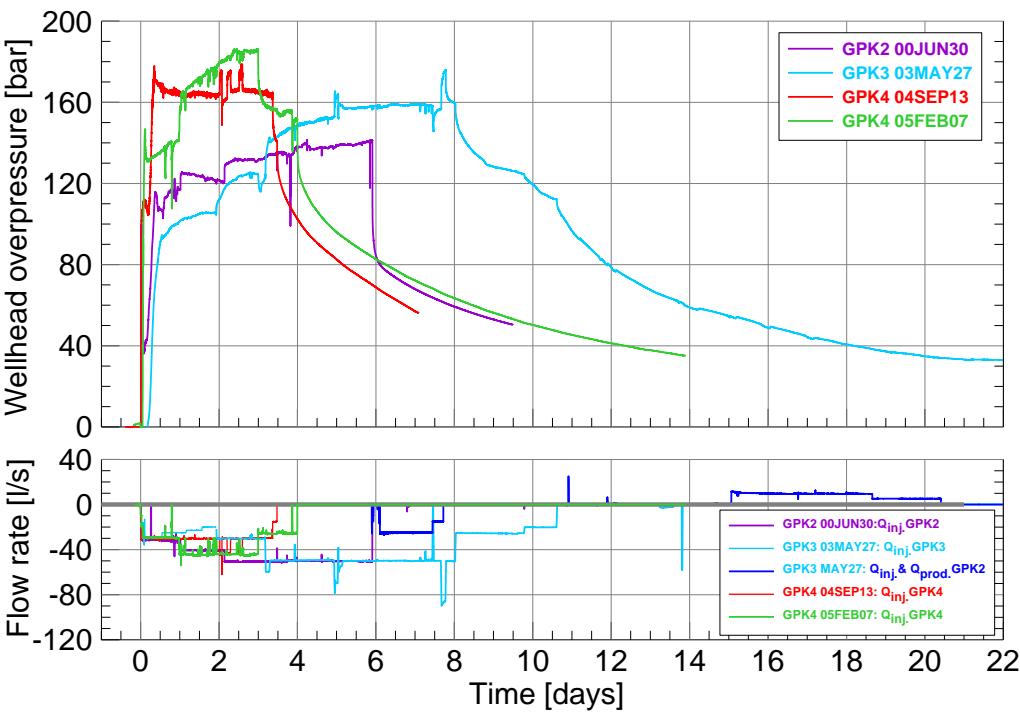
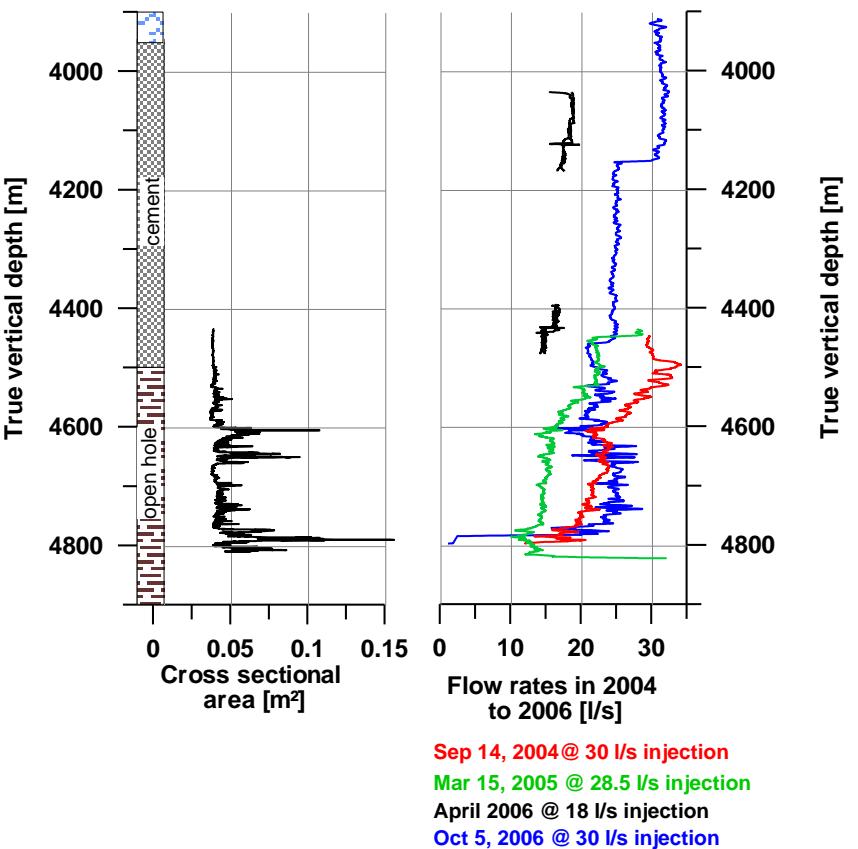
Steady-state during postflush,

$p_{\text{wellhead}} \sim 130 \text{ bar}$

⇒ „fracturing“ shape

Shut-in during RMA – and OCA-stim.





Chronology of chemical treatments

Injection of acids and chelatants in GPK2, 3, and 4 to

- Improve the near wellbore performance without additional seismicity
- remove scaling minerals like calcite and illite from the hydrothermalized and altered fractures

