DESTRESS

Demonstration of soft stimulation treatments of geothermal reservoirs

Rittershoffen soft stimulations
Dr Clement Baujard

DESTRESS Mid Term Conference, Glasgow, 05th April 2018

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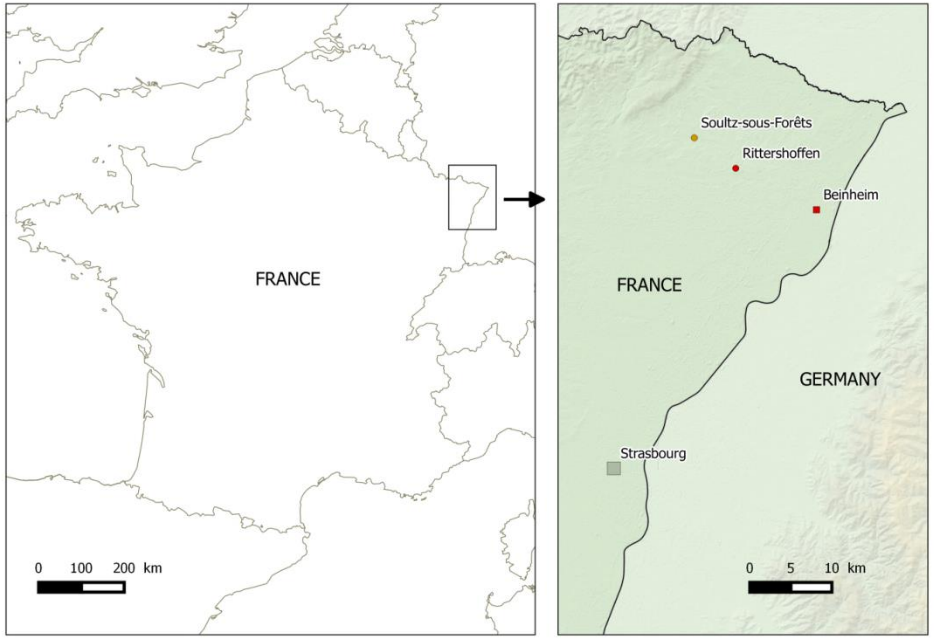
Outline

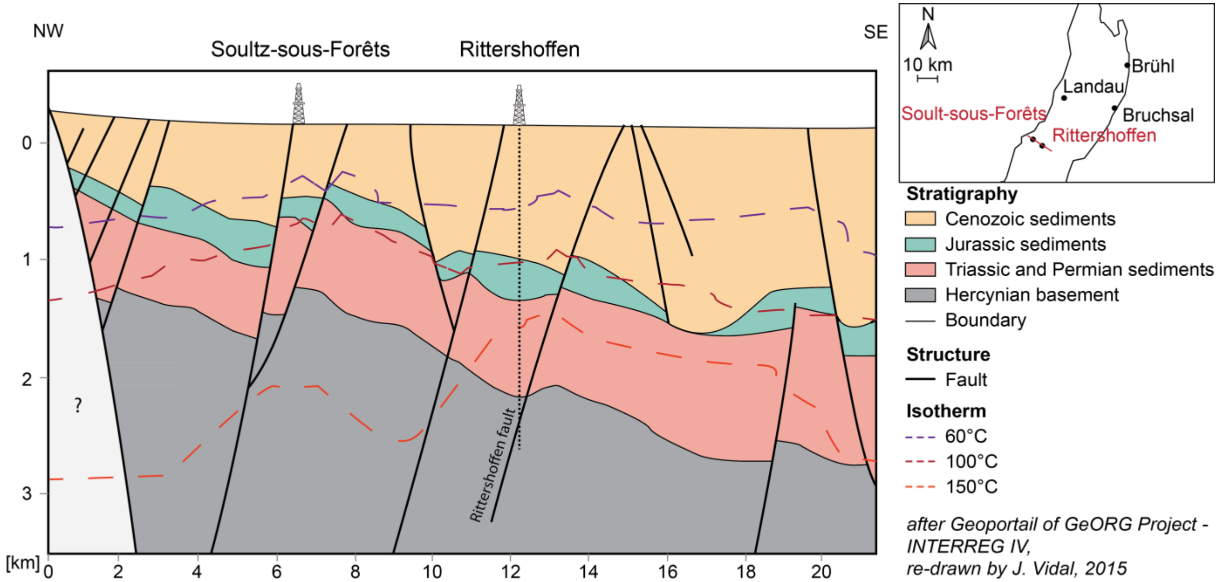
- Rittershoffen site overview
- Rittershoffen operation feedback after 2 years heat production
- Rittershoffen in Destress
  - Hydrothermal properties of the reservoir
  - Detailed GRT-1 stimulation analysis
  - Stress drops analysis

Rittershoffen site overview

Rittershoffen site location

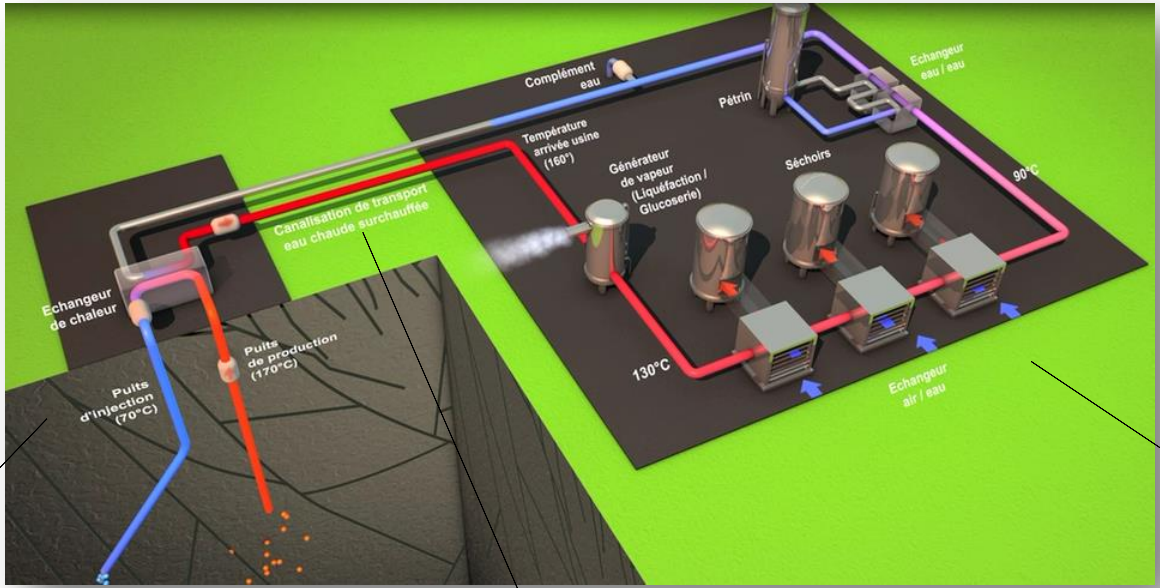
- Industrial geothermal site located in the Upper Rhine Graben, 8km east of Soultz-sous-Forêts
- Target: regional fault zone in granite basement





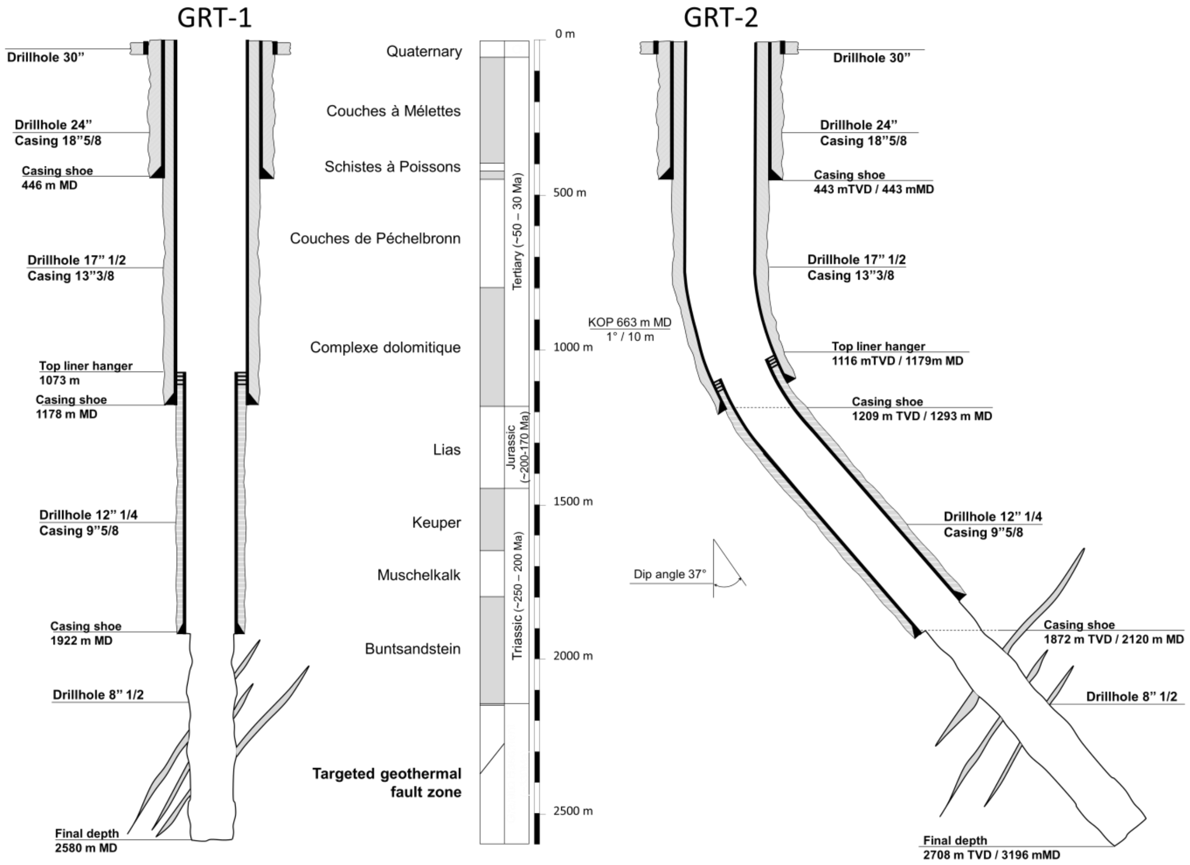
after Geoportail of GeORG Project - INTERREG IV, re-drawn by J. Vidal, 2015

Rittershoffen site overview: 100% heat direct use



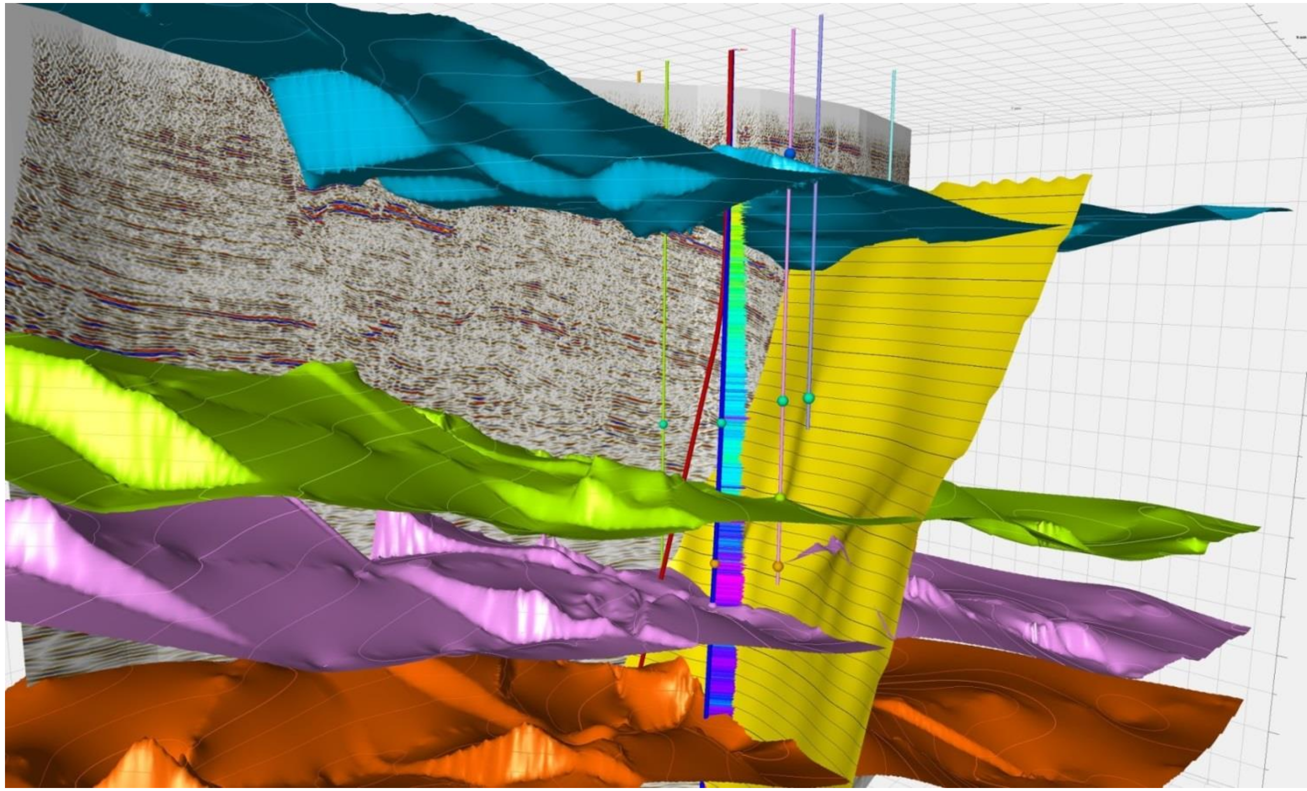
26 MWth
Production Temp.: 168°C
Operation flowrate: 270m3/h

Wells GRT-1 and GRT-2: completion and well trajectories



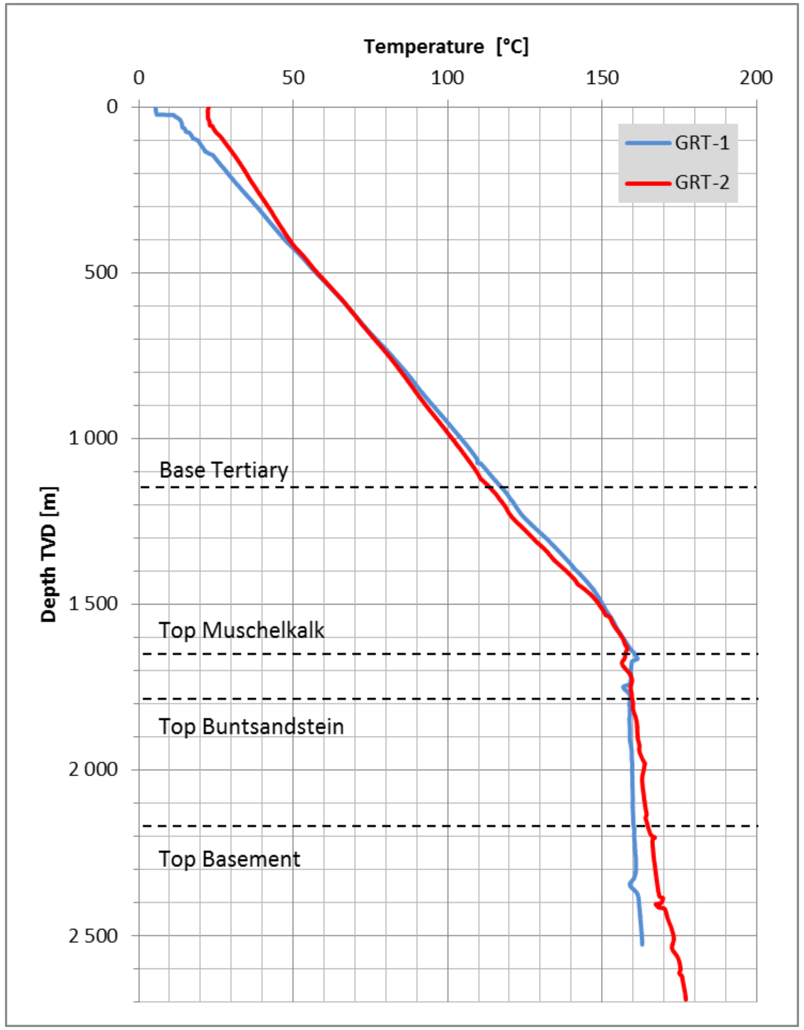
2013

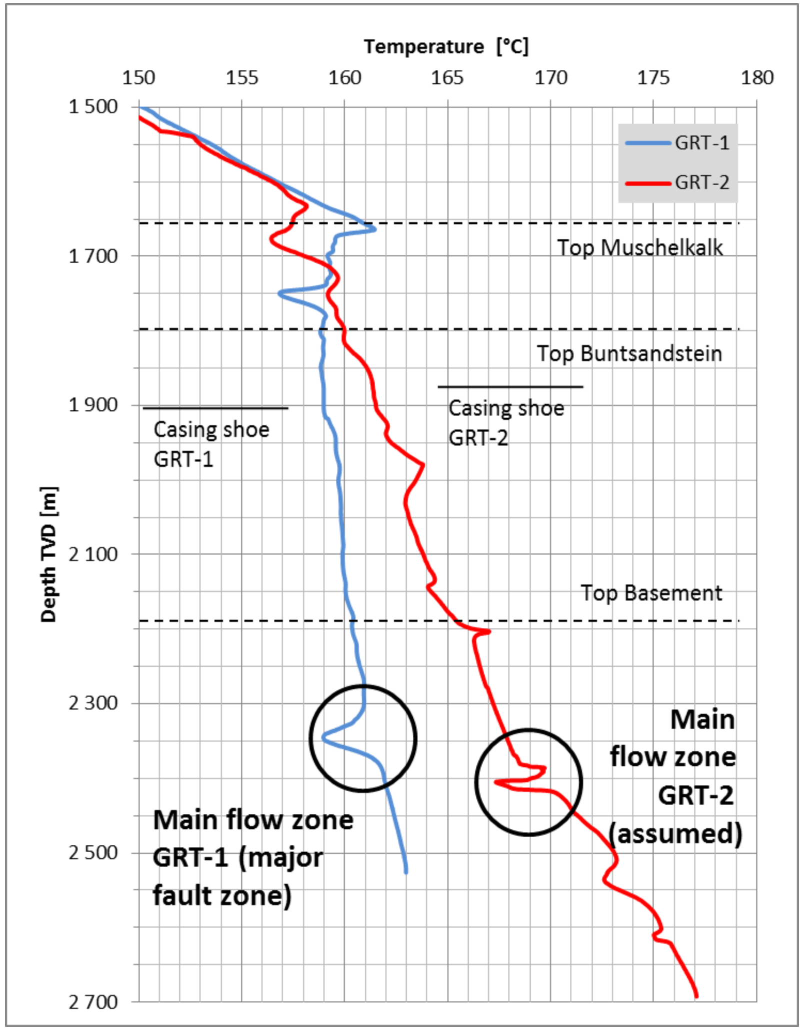
2015



Wells GRT-1 and GRT-2: temperatures

Temperature profiles at equilibrium



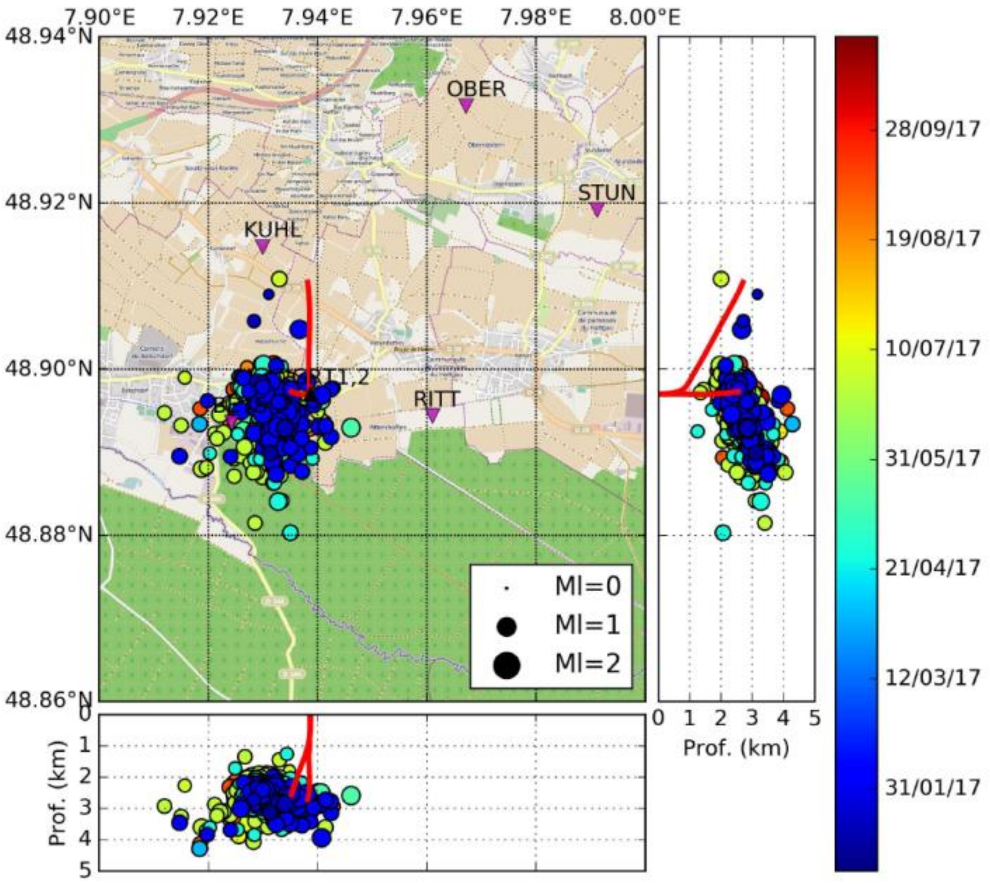


Operation feedback after ~2 years use

Rittershoffen operation feedback last 21 months

- In operation since April 2016
- No felt seismicity

Parameters	Values
Number of induced events in 2017	734
Max Magnitude (Mlv)	1,3
Max PGV (mm/s)	0,24 mm/s



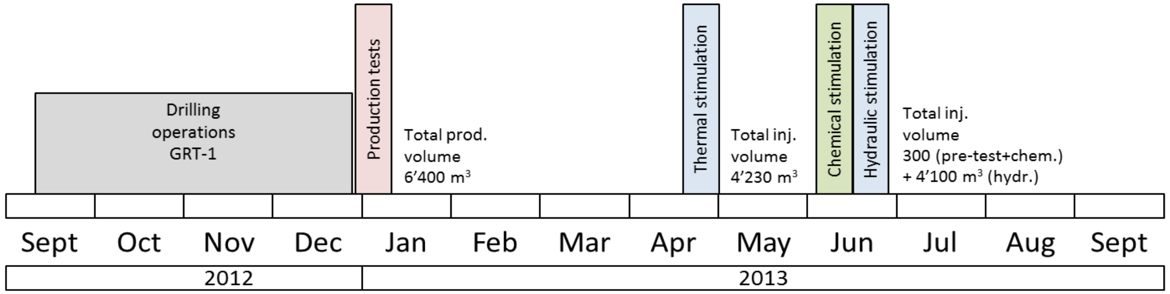
Rittershoffen operation feedback last 21 months

- In operation since April 2016
- Availibility > 90%
- Estimated avoided CO2 emissions in 2017: 35 kTo

	Mois	Nbr arrêt	Durée totale d'arrêt	Heures de marche	Disponibilité centrale	Énergie th centrale	Énergie th fournie	Efficacité réseau	Puissance th moyenne	Émission CO2 évitées
2016	Septembre	1	3 h	717 h	99.6 %	9 330 MWh_{th}	7 960 MWh_{th}	85.3 %	11.5 MW_{th}	1 976 tCO_2
	Octobre	2	8 h	736 h	98.9 %	10 652 MWh_{th}	9 080 MWh_{th}	85.2 %	12.7 MW_{th}	2 254 tCO_2
	Novembre	5	393 h	327 h	45.4 %	4 440 MWh_{th}	3 864 MWh_{th}	87.0 %	11.7 MW_{th}	959 tCO_2
	Décembre	2	132.5 h	611.5 h	82.2 %	9 271 MWh_{th}	8 181 MWh_{th}	88.2 %	13.6 MW_{th}	2 031 tCO_2
	Total 2016	**10**	**536.5 h**	**2931.5 h**	**81.5 %**	**33 693 MWh_{th}**	**29 085 MWh_{th}**	**86.3 %**	**12.4 MW_{th}**	**7 220 tCO_2**
2017	Janvier	1	10 h	728 h	97.8 %	13 654 MWh_{th}	12 583 MWh_{th}	92.2 %	17.3 MW_{th}	3 124 tCO_2
	Février	3	16.5 h	655.5 h	97.5 %	12 813 MWh_{th}	11 822 MWh_{th}	92.3 %	18.0 MW_{th}	2 935 tCO_2
	Mars	4	293.5 h	449.5 h	60.6 %	8 317 MWh_{th}	7 561 MWh_{th}	90.9 %	17.5 MW_{th}	1 877 tCO_2
	Avril	5	16 h	704 h	97.8 %	13 232 MWh_{th}	12 322 MWh_{th}	93.1 %	17.7 MW_{th}	3 059 tCO_2
	Mai	4	13.5 h	730.5 h	98.2 %	14 050 MWh_{th}	12 941 MWh_{th}	92.1 %	17.6 MW_{th}	3 213 tCO_2
	Juin	1	1.5 h	718.5 h	99.8 %	13 013 MWh_{th}	12 050 MWh_{th}	92.6 %	16.8 MW_{th}	2 992 tCO_2
	Juillet	2	223.5 h	520.5 h	70 %	9 161 MWh_{th}	8 233 MWh_{th}	89.9 %	16.4 MW_{th}	2 044 tCO_2
	Août	2	16 h	728 h	97.8 %	13 824 MWh_{th}	12 812 MWh_{th}	92.7 %	17.6 MW_{th}	3 181 tCO_2
	Septembre	2	4 h	716 h	99.4 %	15 345 MWh_{th}	14 030 MWh_{th}	91.4 %	19.6 MW_{th}	3 484 tCO_2
	Octobre	0	0 h	745 h	100 %	15 970 MWh_{th}	14 744 MWh_{th}	92.3 %	19.8 MW_{th}	3 661 tCO_2
	Novembre	4	19 h	701 h	97.4 %	12 455 MWh_{th}	11 230 MWh_{th}	90.2 %	16.6 MW_{th}	2 788 tCO_2
	Décembre	1	4 h	740 h	99.5 %	13 808 MWh_{th}	12 492 MWh_{th}	90.5 %	18.1 MW_{th}	3 102 tCO_2
	Total 2017	**29**	**623.5 h**	**8136.5 h**	**92.9 %**	**155 642 MWh_{th}**	**142 820 MWh_{th}**	**91.7 %**	**17.8 MW_{th}**	**35 461 tCO_2**

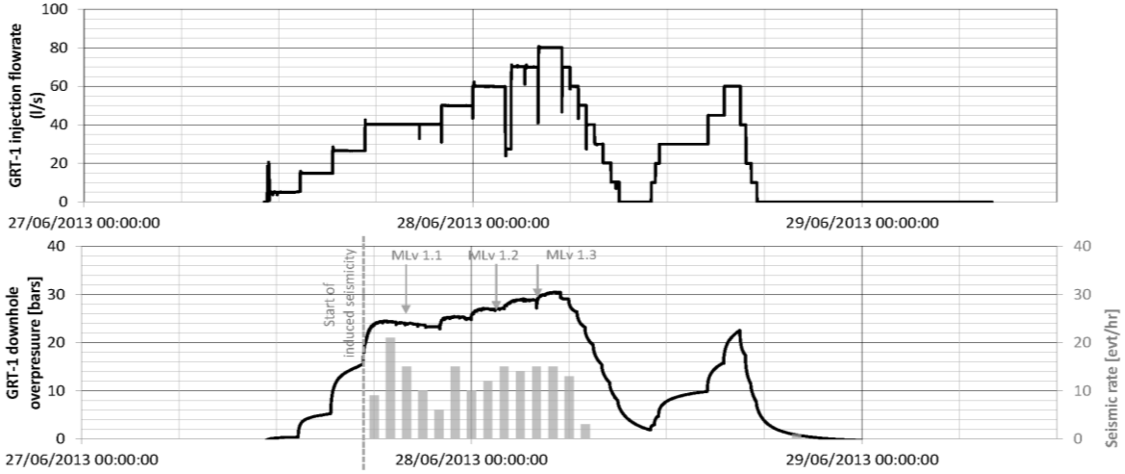
Rittershoffen in Destress:
reservoir caracterization and detailed analysis of GRT-1 stimulation

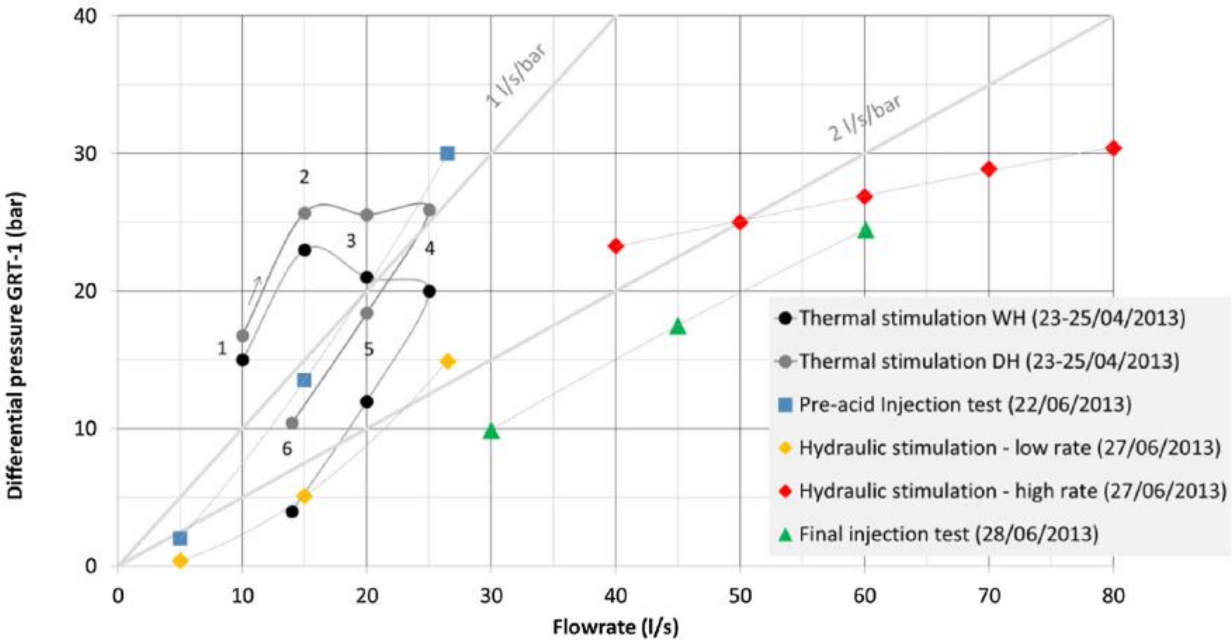
GRT-1 stimulation sequence and injectivity index



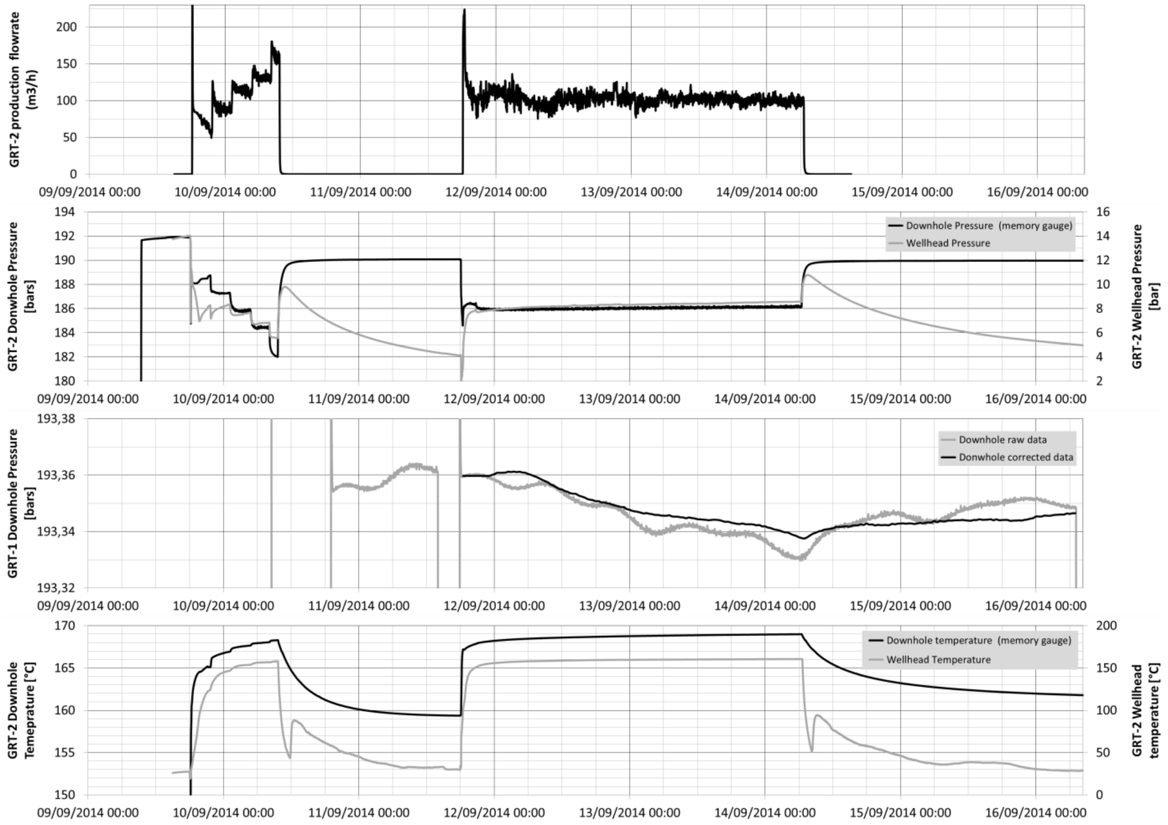
Initial injectivity x5

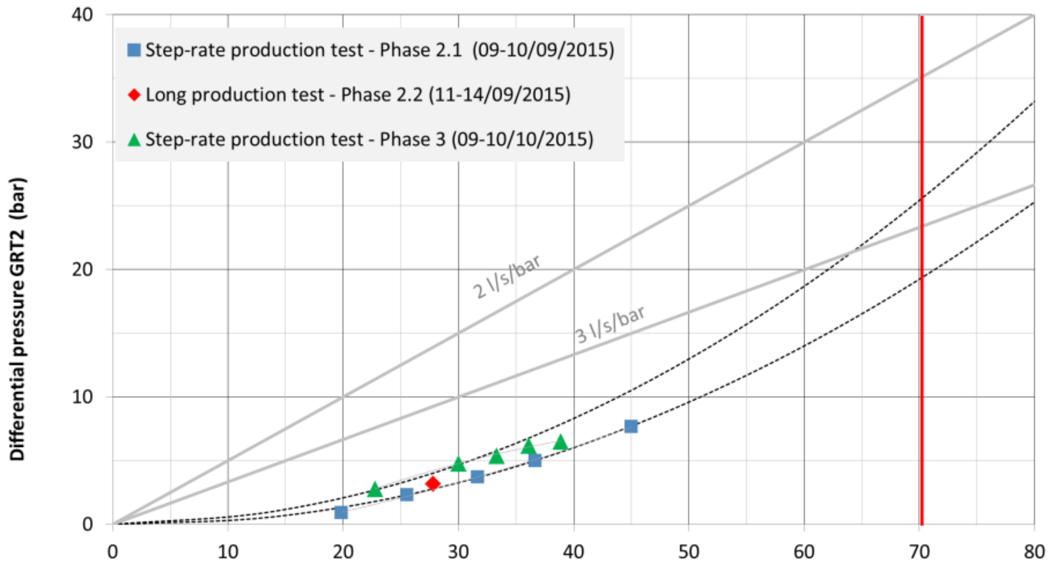
- No felt events
- Economic threshold reached





GRT-2 well testing sequence and injectivity index





GRT-1 and GRT-2 hydraulic analysis
-> See details in *Baujard et al. (2017), Geothermics*

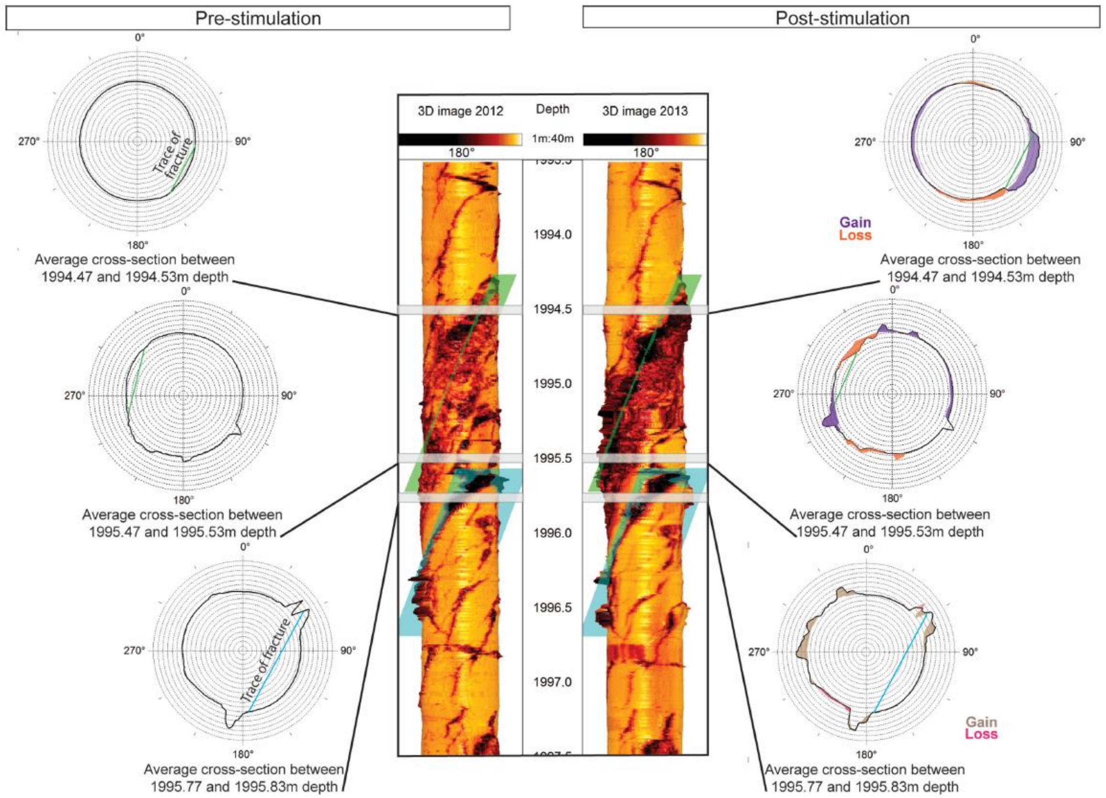
- No clear boundary effect to be seen on the hydraulic tests
- Circulation test performed:
  - Tracer breakthrough in 14 days
  - Pressure connection in 30 minutes
  - Downhole distance between open sections : 1200m

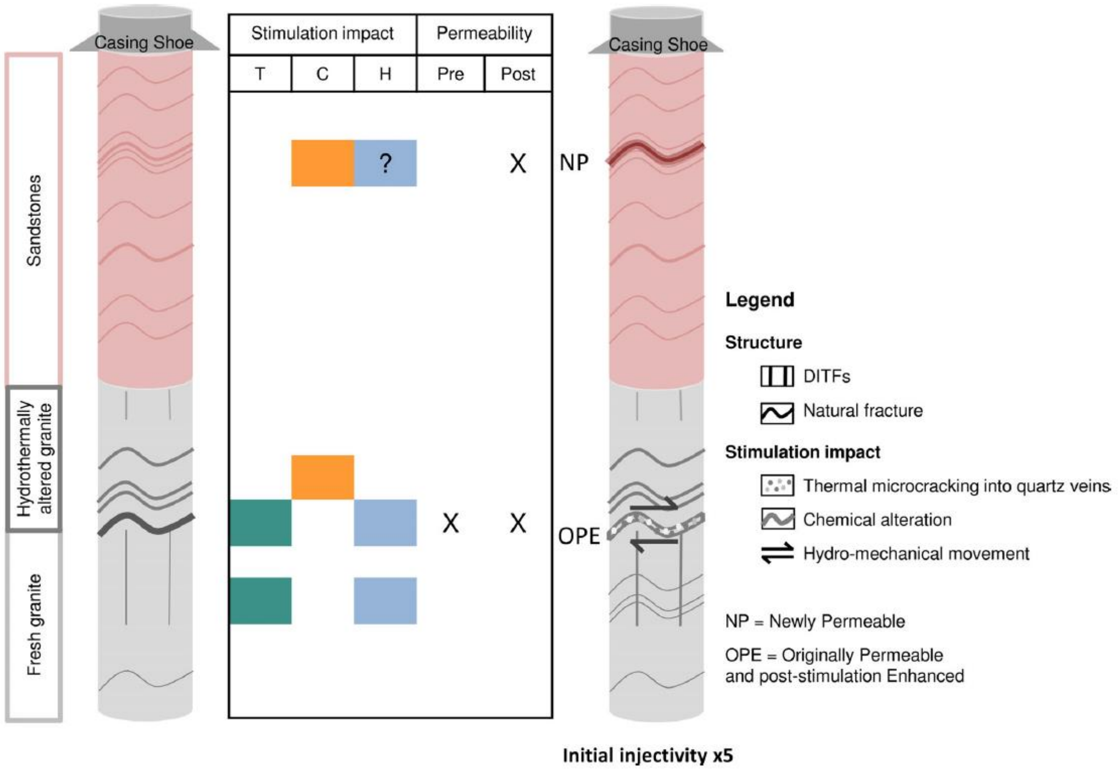
		GRT-1	GRT-2
Well	Dimensionless skin factor [-]	21.3	1.8
Fault	Hydraulic cond. [$m \cdot s^{-1}$]	-	$2.9 \cdot 10^{-06}$ (40m)
	Specific storage [m^{-1}]	-	$7.2 \cdot 10^{-07}$ (40m)
Matrix	Hydraulic cond. [$m \cdot s^{-1}$]	$6.1 \cdot 10^{-08}$ (500m)	$5.3 \cdot 10^{-07}$ (500m)
	Specific storage [m^{-1}]	$7.2 \cdot 10^{-07}$ (500m)	$5.2 \cdot 10^{-07}$ (500m)

Acoustic Image Logs comparison before and after stimulations in well GRT-1

-> See details in *Vidal et al. (2016), Geophysical Journal International*

- Quantification of the impact of different stimulations (thermal, chemical and hydraulic) on the different sections of well GRT-1



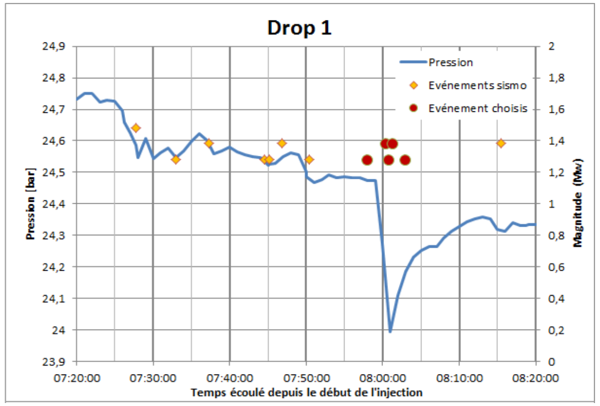


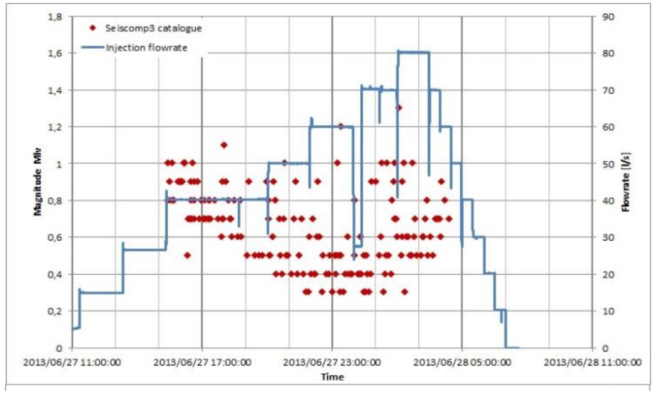
Pressure drop analysis

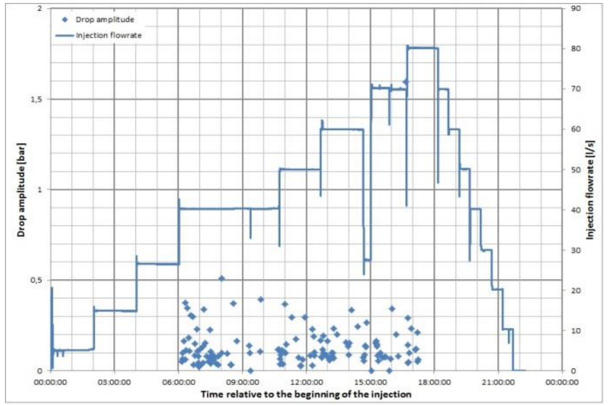
-> See details in *Meyer et al. (2017) Stanford Geothermal Workshop*

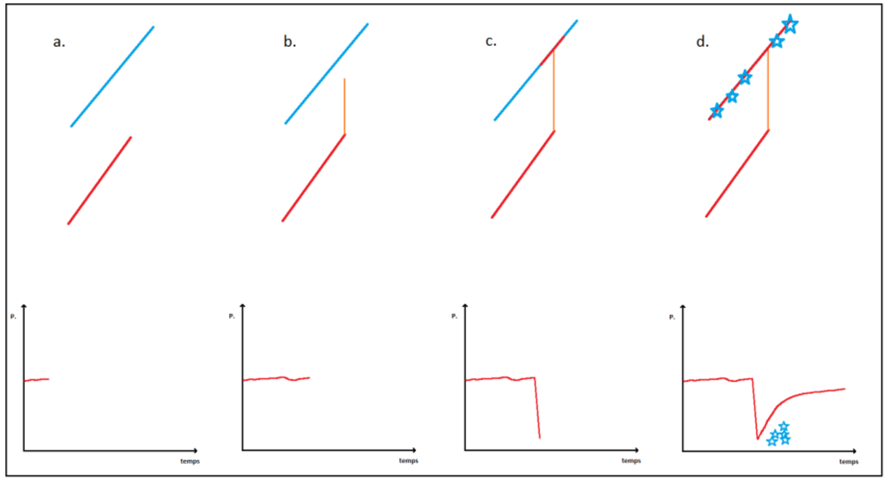
- Detailed analysis of hydraulic stimulation performances applied to fractured hard rocks in GRT-1 and pressure drops mechanism investigations

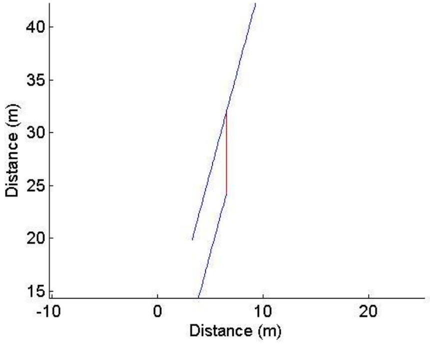
- Correlation of pressure drops and induced seismicity
- Proposition of a pressure drop mechanism and modelling of the process using CFRAC (McClure)

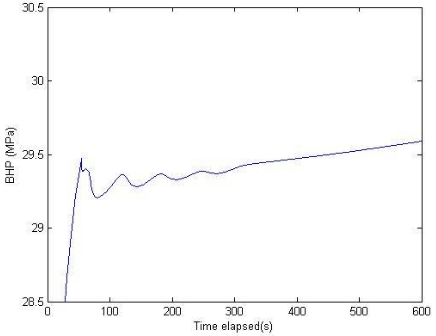












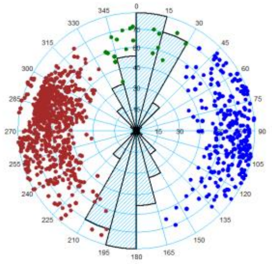
Lesson's learned

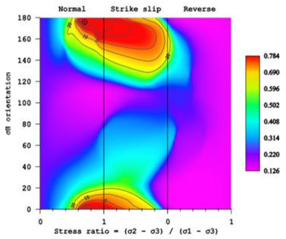
- At a reservoir scale
  - Regional faults are flow zone in the Rhine Graben
  - Convection between to Muschelkalk and weathered granite
  - In-fault convection ?
- Succesfull stimulation of GRT-1
  - Chemical stimulation impacted Triassic sandstones and basement permeability
  - Hydraulic stimulation impacted mostly basement permeability
  - Great injectivity increase of GRT-1
  - There is a link between pressure drops and seicmicty (seismic clusters)
  - No relation between pressure drop amplitude and seismic magnitude could be highlighted
  - The CFRAC model seems to confirm the inferred mecanism
  - In any case, pressure drops are related with near-well phenomenons (50-100m max)
- Operation
  - Continuous injectivity increase of injection well
  - LSP (Line shaft pumps) show good results for high temperature and high salinity fluids
  - Induced seismicity can be handled
  - High temperature corrosion and scaling inhibitors available

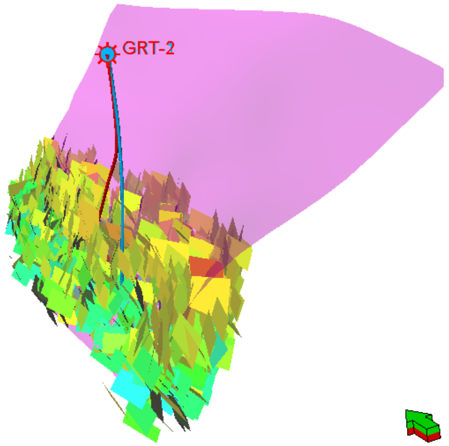
On-going work

- Contribution to GRC 2018 submitted : *“Experience learnt from a successful soft stimulation and operational feedback after 2 years geothermal power and heat production plants in Rittershoffen and Soultz-sous-Forêts (France)”,* by Baujard et al.

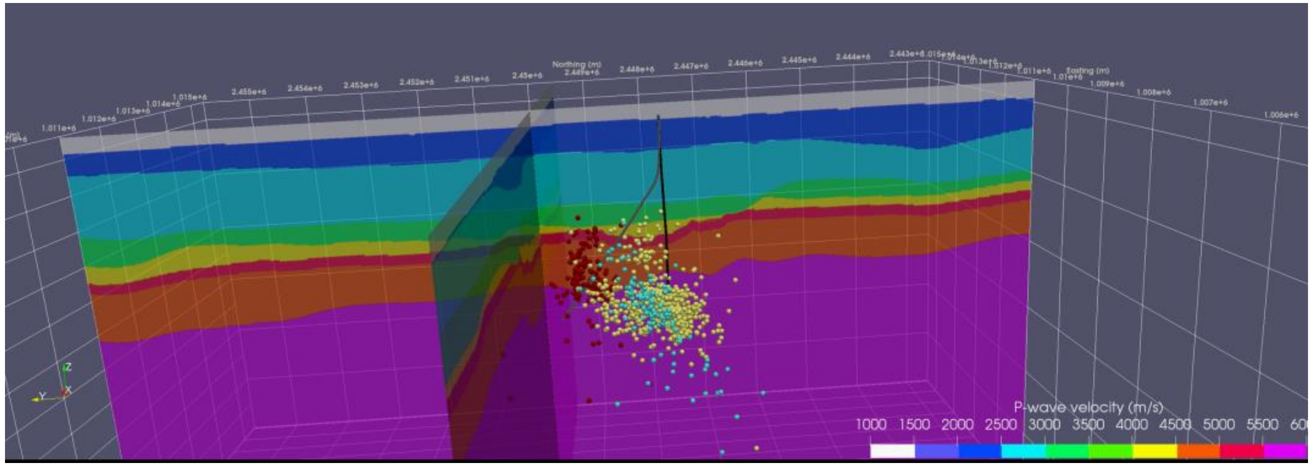
- Contribution to EAGE 2018 submitted by Sosio et al. (SCHLUMBERGER)

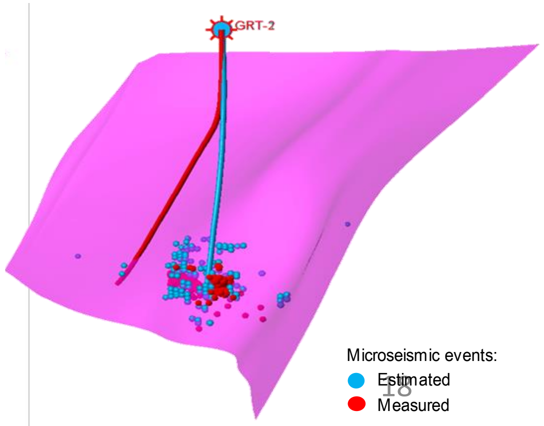






- Paper preparation on GRT-1 induced seismicity catalogues, by Maurer et al.





Related publications

- Peer reviewed journals
  - BAUJARD C., GENTER A.,DALMAIS E., MAURER V., HEHN R., ROSILLETTE R., VIDAL J., SCHMITTBUHL J., (2016). Hydrothermal Characterization of wells GRT-1 and GRT-2 in Rittershoffen, France: Implications on the Understanding of Natural Flow Systems in the Rhine Graben, submitted to Geothermics, July 2016.
  - VIDAL J., GENTER A., SCHMITTBUHL J., (2016). Pre- and post-stimulations of the geothermal well GRT-1 (Rittershoffen, France): insights from acoustic image logs on hard fractured rock investigations, Geophysical Journal International. 206, 845-860.

- Reports
  - MEYER, G. (2016) Advanced analysis of the stimulation of GRT-1 geothermal well (Rittershoffen, France), ESG Report 16-0186, 78pp - Confidential

- EGC Conference
  - BAUJARD C., GENTER A., DALMAIS E., MAURER V., HEHN R., ROSILLETTE R., (2016). Temperature and hydraulic properties of the Rittershoffen EGS reservoir, France. European Geothermal Congress 2016, EGC2016, 19-22 September 2016, Strasbourg, France.
  - HEHN R., GENTER A., VIDAL J., BAUJARD C., (2016). Stress field rotation in the EGS well GRT-1 (Rittershoffen, France). European Geothermal Congress 2016, EGC2016, 19-22 September 2016, Strasbourg, France.
  - VIDAL J., CHOPIN F., GENTER A., DALMAIS E., (2016). Natural fractures and permeability at the geothermal site Rittershoffen, France. European Geothermal Congress 2016, EGC2016, 19-22 September 2016, Strasbourg, France.

- Other Conference
  - VIDAL J., GENTER A., SCHMITTBUHL J., BAUJARD C., (2016). Hydraulic stimulation or low water injection in fractured reservoir of the geothermal well GRT-1 at Rittershoffen (France)?AGU Fall meeting, 12-16 December 2016, San Francisco, California, USA.
  - MEYER et al. (2017) , “Analysis and numerical modelling of pressure drops observed during hydraulic stimulation of GRT-1 geothermal well (Rittershoffen, France)”, Stanford geothermal workshop, California

Thank you very much for your attention

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Acknowledgements

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