WP 4.3: GPK-4 chemical stimulation during exploitation, monitoring and efficiency

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DESTRESS Final Conference, 24-25 November 2020

Key words: Geothermal Energy, Chemical stimulation, DESTRESS European project, Soultz-sous-Forêts, Monitoring

Soultz-sous-Forêts, geothermal site

Fig. 1: Soultz geothermal power plant

The Soultz-sous-Forêts geothermal project started in 1987 and 3 deep wells reach the granitic basement at 5 km depth (Fig. 2). From European pilot to full industrial site, the plant owned by EEIG Heat Mining is operated by ESG, producing electricity >90%year since June 2016 (Fig. 1).

The installed gross capacity of the plant is 1.7 MWe. GPK2 is used as a production well and GPK3/GPK4 as injection wells. GPK4, which shows poor hydraulic properties and a bad connection to the reservoir, has been selected for a chemical stimulation in the framework of the H2020 DESTRESS project, aiming to develop soft stimulation treatment for geothermal reservoirs (GEIE EMC, 2017).

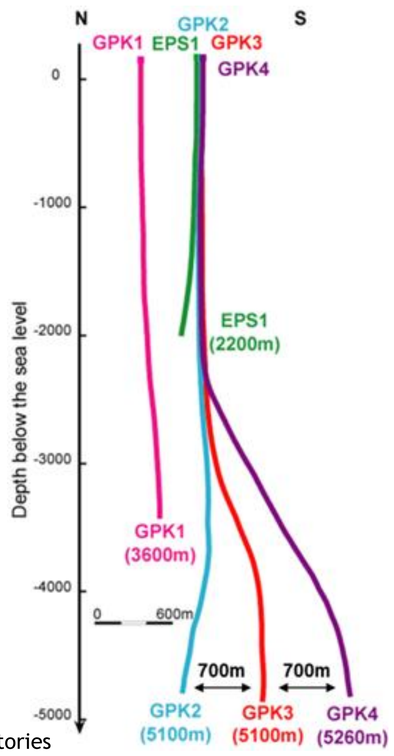


Fig. 2: N-S vertical cross-section of the well trajectories

Baseline establishment

A baseline of GPK4 well and hydraulic properties is required. Logging data set in the open-hole section and into the casing section have been acquired and analyzed during DESTRESS project, Injectivity index is assessed based on continuous injection and exploitation of the well.
The geothermal brine is also monitored in order to demonstrate the sustainability of the production. Electrical conductivity and pH are analyzed periodically on-site with the experimental device (Fig.3) and brine chemistry is monitored with external lab as well as dissolved gas content.

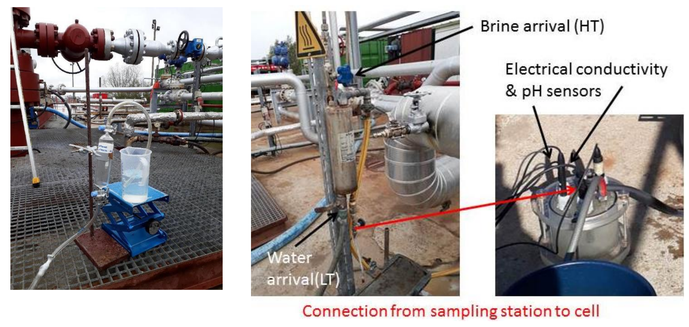


Fig. 3: Brine sampling station, under controlled temperature and flowrate and gas sampler

GPK4, Well properties & Stimulation zone

The GPK4 well is a complex well drilled down to 5260 MD from August 2003 to April 2004. It is a vertical well up to 2135 m, and then deviated with variable inclinations (35° max.), until reaching a total depth of 5260 MD with an inner casing of 9 5/8". The casing shoe is located at 4756 MD (corresponding to 4489 TVD). Casing is floating, only cemented on the last 756 meters above the casing shoe. The open-hole section is about 504 m long and was drilled in a crystalline basement with a diameter of 8 ½". A 2005 masterlog is given in Fig 4. Few chemical stimulations have been performed improving in 75% cases the injectivity indexes, results are given Fig 5.

Chemical stimulation	Injectivity index L/s/bar		
	Date	before	after
HCl (0,20%)	Feb 2005	0,2	0,3
RMA : HCl (12%) HF (3%)	May 2006	0,3	0,4
NTA: Na3NTA (19%), NaOH	Oct 2006	0,4	0,3
OCA : C6H8O7 (5-10%), HF (0,1-1%), HBF4 (0,5-1,5%), NH4Cl (1-5%)	Mar 2007	0,4	0,5

Fig. 5: Chemical stimulation phases from 2005 to 2007, after Nami et al. (2008).

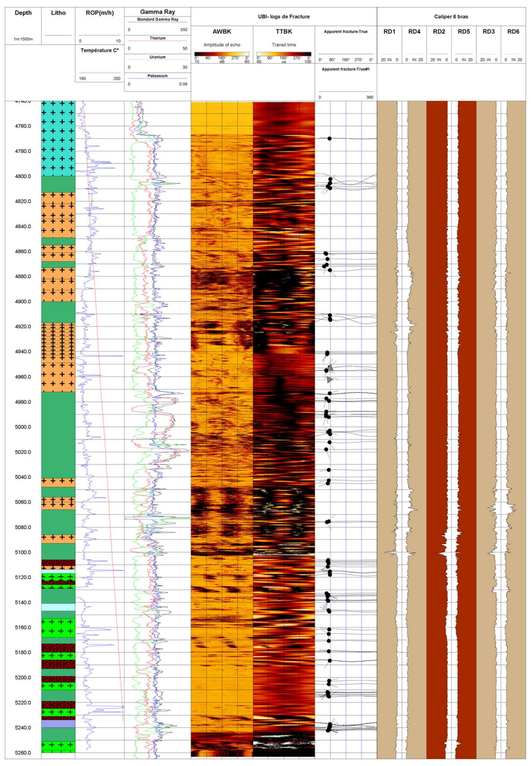
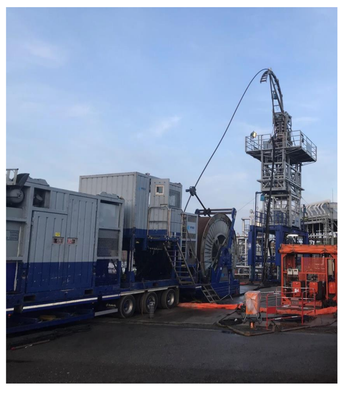


Fig. 4: GPK4 masterlog from 2005

Prior to the new chemical stimulation, GPK4 has been logged in January 2019, identifying stimulation zones and strategy, three targets have been stimulated (Fig 7a) in two acid jobs (SSB 007, SFB 007) thanks to a coiled tubing (Fig 7 b).

Depth Casing/OH	Estimated Fracture zone size in m	Alteration thickness in m	Flow contribution in %	Mineral 1 to dissolve: Carbonate (calcite mainly)	Mineral 2 to dissolve: Clays	Mineral 3 to dissolve (possible): Quartz
Zone 1: 4707 m MD casing	About 400 m of lateral extension Large fracture zone	20 m	40%	Low carbonate content (3.5%)	Illite and Illite / Smectite interstratified	Secondary quartz
Zone 2: 4823 m MD OH	Minimum 150-200m of lateral extension Medium size	6 m	5%	Low carbonate content (4.6%)	Illite and Illite / Smectite interstratified	Secondary quartz
Zone 3: 4924 m MD OH	Minimum 100-150m of lateral extension Medium size	2 m	5%	High carbonate content (17.8%)	Illite and Illite / Smectite interstratified	Secondary quartz

Fig. 7: a) Stimulation targets and b) picture of coiled tubing for acid job (Dec. 2019).



GPK4, Hydraulic properties

The injection into GPK4 is performed without the help of injection pumps: it means that the injection pressure is regulated by the surface pressure in the geothermal installations.

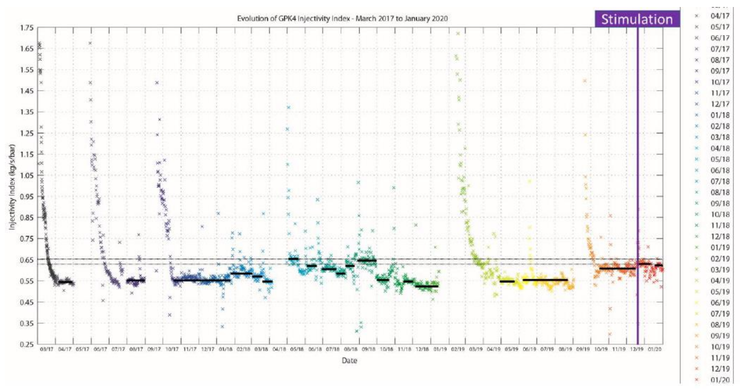


Fig. 8: Injectivity index monitoring from March 2017 to February 2020.

GPK-4 hydraulic characteristics during the monitoring period (early 2017 to February 2020), highlight that the injectivity index varied between 0.54 kg/s/bar and 0.65 kg/s/bar (Fig 8).

Geothermal brine monitoring

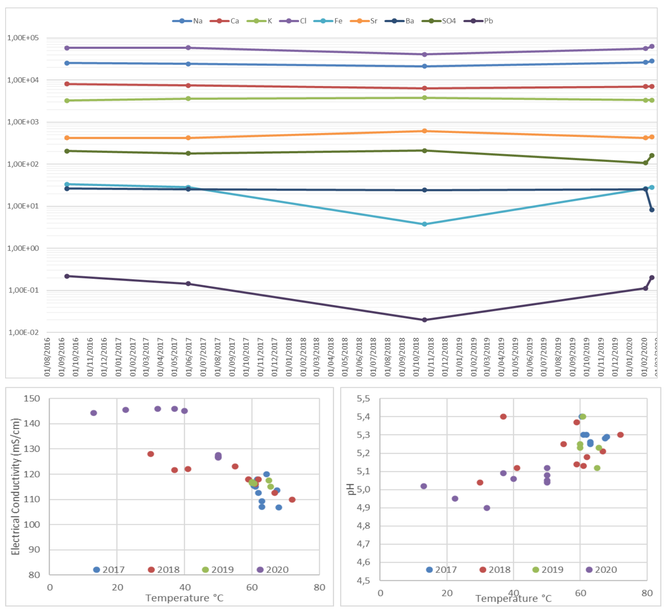


Fig. 9: Geochemical monitoring from 2016-2020, ions, pH and Electrical conductivity

Geothermal brine salt content is stable within operation time and in accordance with post-stimulation first values. Slight differences are due to lab experimental accuracy and not physical variation. Iron content is stable suggesting no corrosion sign. No clear impact occurs on pH and electrical conductivty measurements.
Changes are related to temperatures and devices variation.

Acknowledgements

This work was performed in the framework of the H2020 DESTRESS project which has received funding from the EU Framework Programme for Research and Innovation under grant agreement No 691728.

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Demonstration of soft stimulation treatments of geothermal reservoirs

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Conclusions

GPK-4 chemical stimulation has been performed on December 2019

- During exploitation and managing all HSE risks
- Getting good lessons learned on monitoring methodology
- Getting any impact on the production brine, and any corrosion damage due to acid injection
- Getting a slight improvement of the Injectivity index right after the acid job, stabilized at 0,54 kg/s/bar.