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On-going seismic monitoring of the Rittershoffen and the Soultz EGS projects (Alsace, France)

V. Maurer[(1)], N. Cuenot[(1)], A. Richard[(1)], M. Grunberg[(2)]
vincent.maurer@es.fr

[(1)] ES-Géothermie
26, Boulevard du président Wilson
F-67000 Strasbourg
FRANCE

[(2)] Université de Strasbourg
EOST
UMS 830
F-67000 Strasbourg

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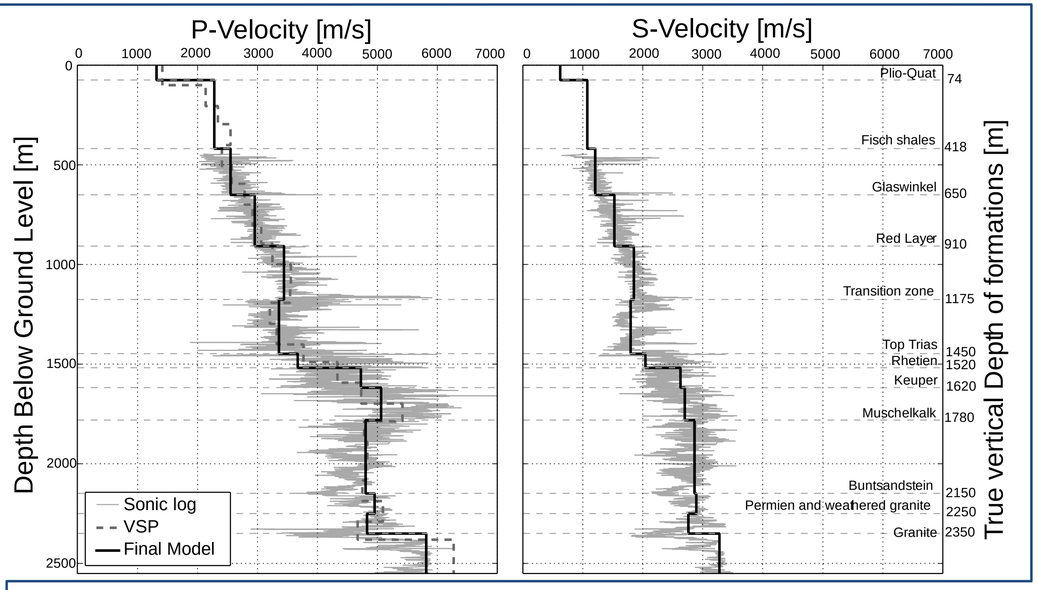
Introduction

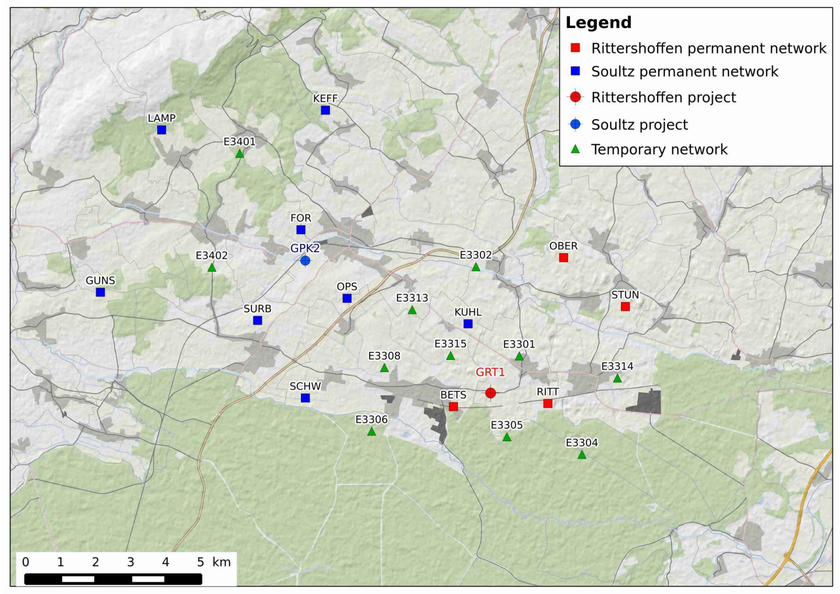
- **The Soultz project:** The scientific pilot power plant at Soultz-sous-Forêts established in a deep fractured granitic massif, has resulted in the development of the EGS (Enhanced Geothermal System) concept and has provided the international scientific community with a unique high quality data set with no equivalence anywhere in the world. After a complete renovation of the facilities, the plant has been exploiting a geothermal brine at 150-160°C with a flowrate of about 30 l/s to produce a gross power of 1,7 MWe since the beginning of July 2016. Currently the brine is pumped out of GPK-2 and reinjected into GPK-3. The renewed plant is operating now as an industrial project.
- **The Rittershoffen project:** Located at Rittershoffen, 6 km east of Soultz-sous-Forêts, in Northern Alsace, it exploits a geothermal brine trapped in the fractured hard rocks. This geothermal project is designed to produce 24 MWth (170°C, 70 l/s) which is delivered to a bio-refinery located 15 km away. The exploitation of the geothermal plant started end of May 2016. Two deep wells have been drilled between 2012 and 2014 to 2500 m TVD for targeting local normal-faults located close to the interface between the clastic Triassic sediments and the top crystalline basement. Due to a poor initial injectivity index, the first well was developed by using various thermo-mechanical and chemical treatments. The results were positive, since the initial well injectivity index was multiplied by a factor of four. The second hydrothermal well was good enough hydraulically after drilling operation and thus, it was not necessary to enhance its natural permeability.

Velocity Model

- **Rittershoffen :** A 1D velocity model was built based on both 3C sonic logs, VSP, and litho-stratigraphic logs performed in the two deep wells. Both VSP and sonic logs provide regular measurements of velocity, but without taking into account the change of geology all along the well. To build the 1D P-velocity model, the main geological formations identified in GRT-1 were considered. Since no V_S information was provided by the VSP, an averaged V_P/V_S ratio of the sonic log was used for each formation to determine the 1D S-velocity model (see Figure on the right).
- **Soultz :** A 1D velocity model based on the work of Cuenot et al . , 2008 is currently used to relocate induced microseismicty .

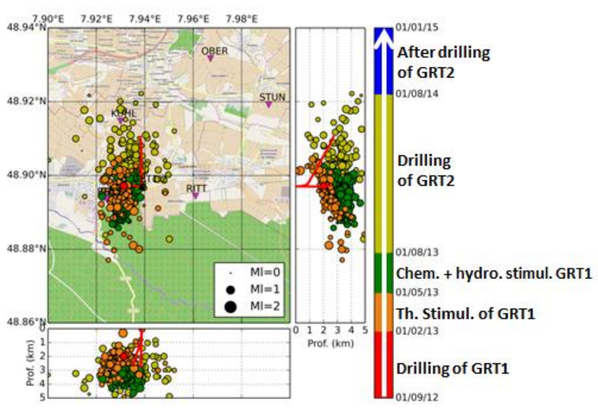


Seismic networks



- **The Soultz permanent seismic network**, composed of 8 short-period (1Hz) stations, one or three components sampled at 150 Hz (blue squares on the map).
- **The Rittershoffen permanent seismic network**, composed of 4 three components short-period stations (1Hz) sampled at 200 Hz (red squares on the map).
- **Real-time temporary seismic network** installed specifically for the starting of the exploitation operations, composed of three components broad band stations (120s) sampled at 250 Hz (green triangles on the map).

Induced seismicity previously detected

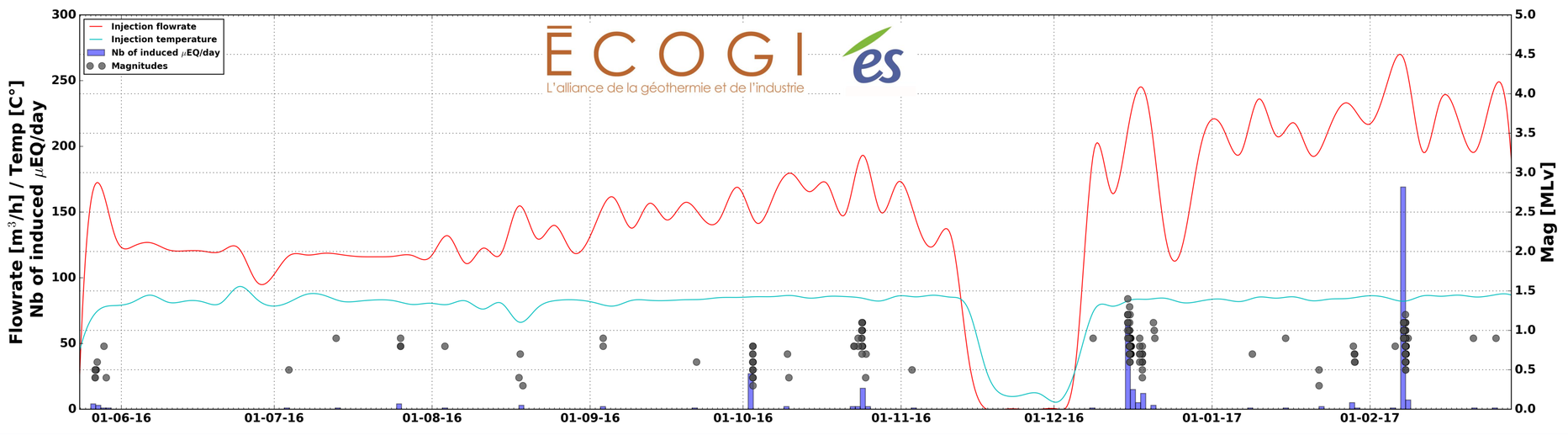


- **Thermal stimulation of GRT-1:**
113 µEQ (M_{max} = 1.2)
- **Hydraulic stimulation of GRT-1:**
> 1 000 µEQ (M_{max} = 1.6)
- **During the GRT-2 drilling operations:**
186 µEQ (M_{max} = 1.2)

Induced seismicity detected during exploitation at Rittershoffen and Soultz

- **Rittershoffen:** No induced seismicity was detected since the drilling of GRT-2. In December 2015, the down-hole pump was installed at depth in the production well. Since May 2016 and the beginning of the exploitation, the micro-seismic activity is carefully monitored in real–time. Until March 2017, 365 induced µEQ were detected (M_{Lv} max = 1.4) all located at the level of the injection well GRT-1 despite a low reinjection pressure. The microseismicity is distributed into successive crisis, generally when the injection flowrate is higher than 180 m^3/h. In particular, during the last crisis of February 2017, 176 µEQ were detected while the injection flowrate reached 275 m^3/h (see figure below), close to the maximum flowrate injection of the hydraulic stimulation. The focal mechanisms in strike-slip suggested that this crisis achieved the GRT-1 stimulation at that flowrate.
- **Soultz**: After the dismantling of the previous facilities in 2015, a new geothermal loop and a new ORC unit have been built since the beginning of 2016. The new power plant was commissioned in July 2016 and has been running successfully since then. After 8 months of almost continuous operation, only 1 µEQ (M_{Lv} = 0.7) was detected, probably because of the low reinjection pressure in the GPK-3 well. Recently, the injection was divided between GPK-3 and GPK-4, without detecting any rise of microseismicity in the vicinity of both downhole wells.

The induced seismicity occurred recently in Rittershoffen and the observations made in the past in Soultz-sous-Forêts highlight the need to continue the seismic monitoring, even during the exploitation phase of power plants, which is now explicitly required by the French mining authorities for getting the exploitation license.



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