Passive electrical monitoring of a geothermal doublet: Rittershoffen EGS project, northern Alsace

Girard[1], J-F., Matthey[1] P-D., Abdelfettah[1,2], Y., Sailhac[1], P., Dalmais[3], E.,, Maurer[3], V.

[1] Institut de Physique du Globe de Strasbourg, EOST/CNRS UMR7516, University of Strasbourg, Strasbourg, France

[2] Institut für Nukleare Entsorgung INE, Karlsruher Institut für Technologie (KIT), Karlsruher, Germany

[3] ES-Géothermie, 3A chemin du gaz, 67500, Haguenau, France

jf.girard@unistra.fr

Keywords: electrokinetic, geothermal exploitation, modelling, field experiment, Upper Rhine Graben

ABSTRACT

Fluid movement in fractured and permeable rocks generates electrical signals via electrokinetic and conduction effects which are link to flow regimes, permeability, aperture of fractures, etc...

Previous work in northern Alsace, at the EGS field of Soultz-sous-Forêts, have proved the detectability of electric signal recorded in surface linked with water circulation in the reservoir at 5 km deep. They demonstrated it was due to the metallic casing of the boreholes which create a short-circuit between surface and the deep fractured crystalline reservoir.

The current project consists in continuous recording of the electrical field in surface, with one potential measurement directly connected to the boreholes casing of the Rittershoffen geothermal doublet designed to produce 24 MWth (170 °C, 70 l/s) and located at less than 10 km from Soultz-sous-Forêts. Data processing consists to lower the electric noise level, especially using the synchronous recording of the electrical field at a remote site to try to identify electrical signals link with water circulation in the reservoir. If this first step is achieved, the interpretation of these signals will consist to cluster the electric events, correlate them with production chronicles and micro-seismic activity. The final objective is to obtain a classification of the electrograms that could lead to characterize the evolution of the reservoir during production.

1. INTRODUCTION

Fluid movement in fractured and permeable rocks generates electrical signals (via electrocinetic effect) which are associated with flow regimes, aperture of fractures, etc... Previous work in Soultz-sous-Forêts (Marquis et al., 2002, Darnet et al., 2006) have proved the detectability of electric signal recorded in surface linked with water circulation in the reservoir 5 km deep. They demonstrated it was due to the metallic casing of the boreholes which create a short-circuit between surface and the reservoir (Darnet et al., 2004).

The monitoring of passive EM signals induced by geothermal production is an old idea. It was studied at field scale (Ushijima et al., 1999 for instance) and recently at small scale experiments (Borner et al., 2015).

In addition, surface self-potential (SP) has been considered to detect and locate leakage along boreholes (Revil et al. 2015), considering the metallic casing (Maineult 2016) as an antenna to generate electrical potential variations measurable at the surface.

By a continuous monitoring of electric potential directly on the metallic casing, we expect to increase the signal to noise ratio. But, if successful, the electrical signals will provide only temporal information. Indeed, the spatial information will be lost because the electric current is driven to surface through the borehole casing (i.e. if no direct detection of the electric sources). The spatial localisation of the electrical events could be obtained through the localisation of synchronous micro-seismic cracks (recorded by the microseismic network), and this task will need close collaboration. Even more, a simultaneous inversion of the electrograms and seismograms would lead to a rich description of the fluid movement induced (Mahardika 2012).

2. PREVIOUS EXPERIMENTS

The SP signals recorded in the northern Alsace during a stimulation of geothermal boreholes at Soultz-sous-Forêts (few km from the current experiment at the new Rittershoffen geothermal plant) were observed correlated with the hydraulic data and micro-seismicity (see Fig. 1, from Darnet et al., 2006).

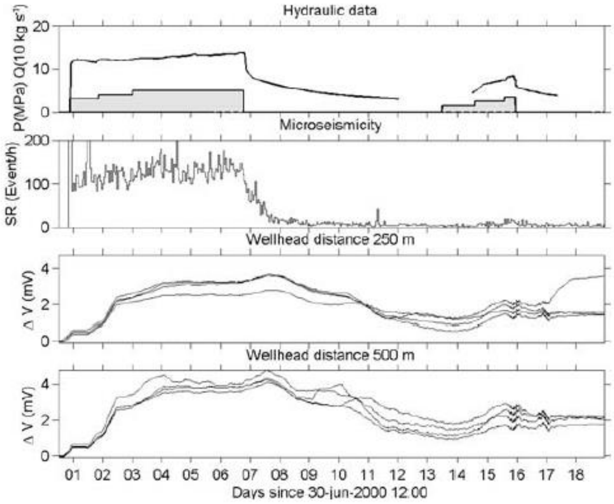

Figure 1: Soultz-sous-Forêts 2002 experiment, from top to bottom, hydraulic data, microseismicity, surface SP at 250 and 500m from wellhead (from Darnet et al., 2006).

An ambitious 4D monitoring, using active and passive electrical methods was performed at Hatchobaru geothermal field (close to Kyushu, Japan) recorded significant SP variations (Fig. 2, from Ushijima et al., 1999).

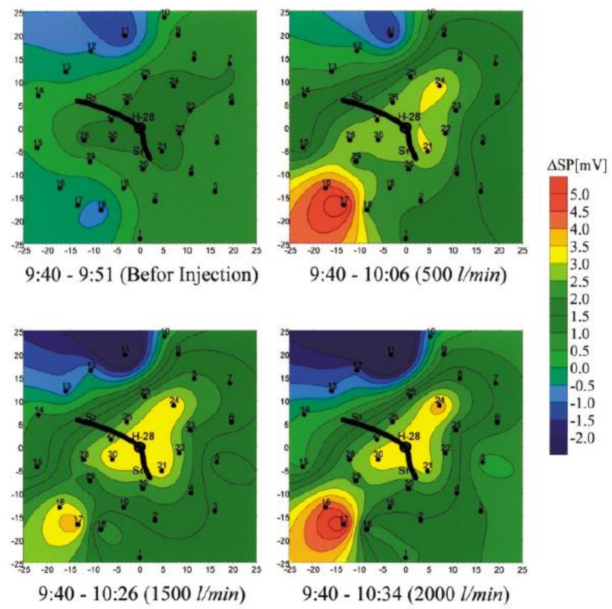

Figure 2: Hatchobaru observed SP distributions during water injection (from Ushijima et al., 1999).

These surface SP signals were inverted in 3D to locate electrical current source at depth. These current sources locations appeared coherent with the cloud of micro-seismic events. This data-set was revisited by Mahardika et al. 2012 to model electric field and seismograms in surface. For a typical seismic event at 800m depth, they estimated an amplitude of 10^{-7} V/m, so of the order of 1 microV for a 10m long dipole in surface.

2. DATA ACQUISITION

Since the start of the production of the new geothermal plant in Rittershoffen, we have started a continuous passive monitoring of electric dipoles, gps synchronized. The starting phase of the plant being the most probable to generate variable electrokinetic signals. One receiver, with a 100 Hz sampling frequency has been installed connected to the exploited geothermal doublet (GRT-1 and GRT-2).

A second receiver has been installed connected to an observation borehole of the Soultz-sous-Forêts plant. This borehole depth stops in the sediments and does not reach the reservoir depth (which is ~5km deep in the granite). Because the Soultz-sous-Forêts plant is stopped during the start of the Rittershoffen plant, we expect this 2nd recorder to provide a reference recording.

In addition, 2 local magneto-telluric stations have been installed, running permanently with a 512 Hz sampling frequency, gps synchronized. For the processing of these measuring stations, a remote MT station 70 km away, is also recorded continuously (Abdelfettah et al., 2016).

3. OBJECTIVES

The 1st recorder is connected to the production borehole, equipped with an electric pump. At the time of the writing of this abstract, the level of the electrical noise induced is not known.

Data processing will consists to lower the EM noise level to try to identify electrical signals link with MT signal and water circulation in the reservoir. If this first step is achieved, the interpretation of this signals will consist to cluster the electric events, correlate them with production chronicles and micro-seismic activity.

3. CONCLUSIONS

The interest of combining electrical signals and microseismic induced by geothermal production is widely established. The main issue is to measure such signals, in industrial condition, exploiting a 2.5 km deep reservoir below a thick sedimentary column (quite conductive, so attenuating the electrical field). We attempt to measure SP by continuous monitoring of surface SP and MT, and electrical potential of metallic production borehole.

The preliminary results will be presented.

Acknowledgements

This study is financially supported by a project of LABEX "G- EAU-THERMIE PROFONDE", University of Strasbourg. Guillaume Ravier, Fernand Kieffer, Julien Kirba and Jean Marc Ehrhardt are thanked for their help during data acquisition at

ECOGI site. We acknowledge the GEIE Soultz-sous-Forêts and Nicolas Cuenot for facilitating the access to the piezometer head for the 2nd continuous recorder.

REFERENCES

Abdelfettah Y., Sailhac P., Schill E., Larnier H., Matthey P-D., Continous and time-lapse geothermal monitoring at Rittershoffen EGS project, northern Alsace, using magnetotelluric, European Geothermal Congress, Strasbourg, 19-24 Sept 2016..

Borner JH, Bar M, Spitzer K, Electromagnetic methods for exploration and monitoring of enhanced geothermal systems - a virtual experiment, 2015, Geothermics, 55,pp78-87.

Darnet M, Marquis G, Sailhac P, Hydraulic stimulation of geothermal reservoirs: fluid flow, electric potential and microseismicity relationships, Geophys. J. Int, 2006, 166,438-444.

Darnet M, Maineult A., Marquis G, On the origins of self-potential (SP) anomalies induced by water injections into geothermal reservoirs, Geophysical Research Letters, 2004, 31(19), L19609.

Mahardika H, Revil A, Jardani A, Waveform joint inversion of seismograms and electrograms for moment tensor characterization of fracking events, Geophysics, 2012, 5,ID23-39.

Marquis, G., M. Darnet, P. Sailhac et al., Surface electric variations induced by deep hydraulic stimulation: An example from the Soultz HDR site, Geophys. Res. Lett., 2002, 29(14), 1662, doi:10.1029/2002GL015046.

Revil A, Mao D, Haas AK, Karaoulis M, Frash L, Passive electrical monitoring and localisation of fluid leakages from wells, 2015, Journal of Hydrology, 512, pp 286-301.

Ushijima K, Mizunaga H, Tanaka T, 1999, Reservoir monitoring by a 4D electrical technique: The Leading Edge, 1999, 12, p1422-1424.

Maineult A., Estimation of the electrical potential distribution along metallic casing from surface self-potential profile, 2016, Journal of Applied Geophysics, 129, 66-78.