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Induced vibrations during a geothermal project and acceptability, how to avoid divorce?

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ABSTRACT

Deep geothermal projects using the EGS method ("Enhanced Geothermal System") can induce during their life cycle small disturbance for local residents, as can be generated by any project of this type.

To ensure the acceptability of geothermal projects, it is strongly required to measure and to control these different types of vibrations. Ideally, they must remain not felt by the local population.

With experience gathered thanks to the three main geothermal projects in Alsace (Soultz-sous-Forêts, Rittershoffen-ECOGI and more recently Illkirch-Graffenstaden) "Électricité de Strasbourg" acquired a strong expertise in order to minimize the impact of geothermal project on the neighbourhood quality of life. In this paper we will discuss specific vibrational impact that may occur during different phases of a geothermal project by using datasets collected in the geothermal projects from Northern Alsace.

1. EXPLORATION PROGRAM

The exploration program carried out in the early stages of this kind of project is often constituted by a seismic reflection survey. The sources used (vibro seismic trucks) generate such vibrational issues among population.

For the Illkirch-Graffenstaden project, located a few kilometers south of Strasbourg, seismic acquisition devices have been deployed in the city (Figure 1). If the geophones deployment represents a very localized disturbance (Figure 4), the transit of the vibrator trucks was a real challenge both in terms of logistical and acceptability.

Rural and urban acceptability studies regarding deep geothermal projects are quite recent in France (Lagache et al., 2013). "Électricité de Strasbourg" decided to organize an early informative and sharing approach by presenting to the population a vibroseismic truck on a market square few days before the seismic acquisition campaign (Figure 1).

Figure 1: Booth with all seismic equipment presented during the local market (Illkirch)

The seismic acquisition parameters have been tuned and validated by independent experts in vibration to set thresholds for power and safety distances.

So prior to the acquisition, specialist in acoustic and vibration undertook measures to quantify and qualify vibrations emitted by vibroseismic trucks (Figure 2). Safe distances and maximum vibration powers to respect were enacted.

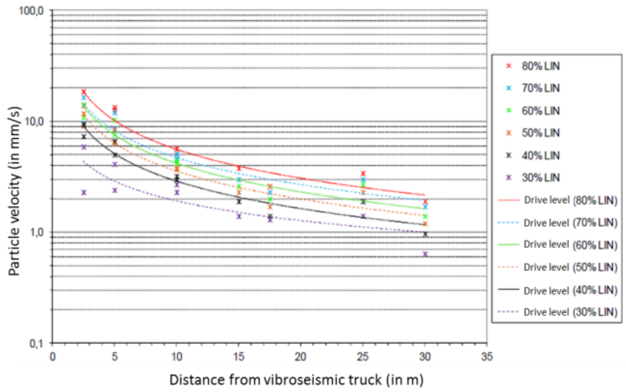

Figure 2: Particle velocity expressed in mm/s function of the distance to the vibroseismic source. Each line represents a different "Drive Level" (source power).

Then the first day of the acquisition was devoted to parameters tuning by acquiring one test line with different geophones and sources layout. One major conclusion was that in urban context, one single vibroseismic truck should be enough to sufficiently image the subsoil while drastically reduce disturbance for citizens (Thacker et al., 2014 and Figure 3).

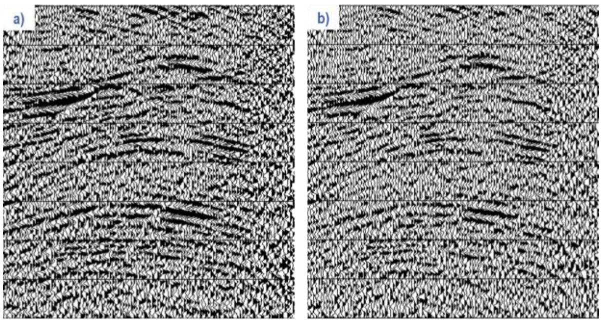

Figure 3: Raw stack section of 40 vibrated points acquired by a) a single vibro truck at high drive and b) by 3 vibro trucks at low drive.

And finally, during the acquisition, a real-time monitoring of each vibrated point was done at the nearest house to ensure that the vibrations emitted do not exceed the safety standards (Figure 4).

Figure 4: The picture on the left side shows the single vibroseismic truck used inside the city, the geophones layout along the road and the vibration monitoring made at each vibrated point. The seismogram on the right side was the output of the vibration monitoring (PGV in mm/s)

2. DURING DRILLING OPERATIONS

The next step of a geothermal project after the exploratory phase is to achieve drillings. These operations can of course induce vibrations. But could they be felt by the population?

To answer this question two seismological stations (Sercel 4Hz, L43-C sensor) installed for the Rittershoffen – ECOGI project, located 50 km North of Strasbourg, were analysed. The first one was directly located on the drilling rig and the second one was 2.5km away from the rig and was installed in a citizen’s garden (Figure 5).

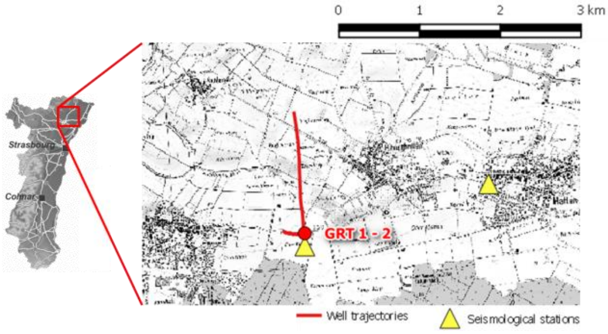

Figure 5: Location map with ECOGI wellhead and the two seismological stations used for the ambient noise vibration analysis.

For both, the vertical ground speed records were averaged hourly throughout the recording time after being filtered between 5 and 50 Hz (higher frequencies were dramatically affected by noise). These hourly averages were done over two distinct periods. During the period of drilling, from the 25th of March 2014 to the 1st of June 2014, and after the drilling from the 1st of June 2014 to the 13rd of November 2014. Figure 6 shows the results.

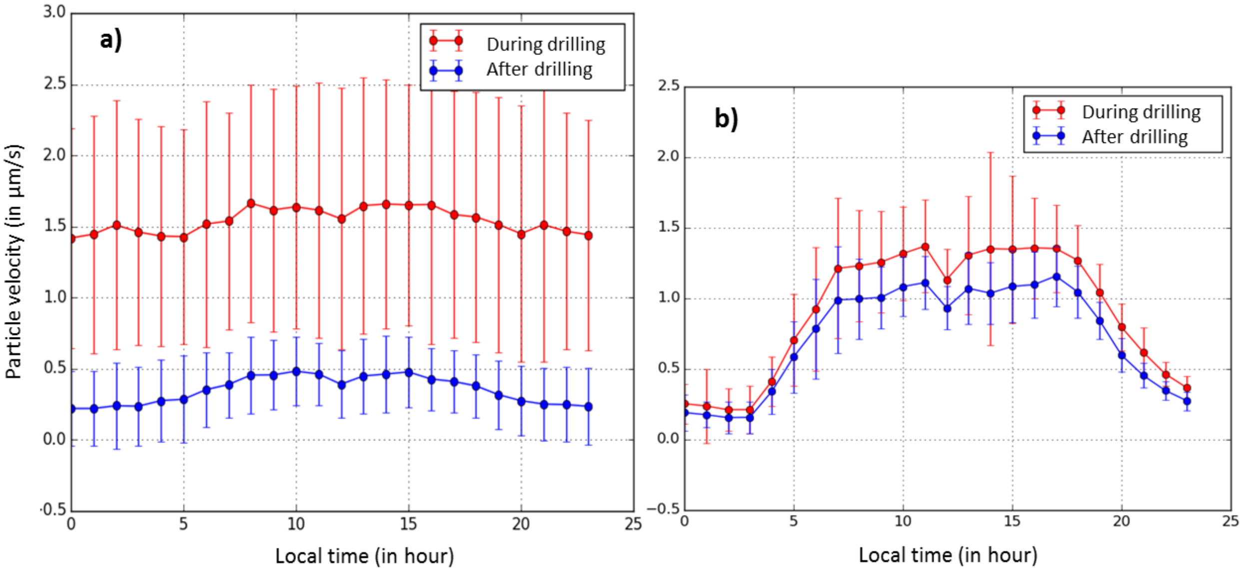

Figure 6: Particle velocity expressed in µm/s in function of time for a station a) on the drilling rig and b) at 2.5km. Red and blue lines represent respectively the ambient noise during and after the drilling.

The first remark to be done concerns the level of ambient noise with low amplitudes in the frequency range studied here Figure 6a.
Indeed, particle velocity recorded at both stations are less than 2 µm/s, so 500 times lower than the minimum velocity felt by population (1 000 µm/s) (Murphy et al. 1977, Wald et al. 1999 and Kaka et al. 2004).
The second remark concerns the ambient noise shape clearly visible on the Figure 6b. Indeed, the increasing noise from 6h to 11h and from 13h to 18h is directly correlated with human activities (cars, trains, industry…). In the same way, the low ambient noise from 0h to 6h, from 11h to 13h and the decreasing noise starting at 18h are also directly correlated with low anthropic noise.
In conclusion, the ambient vibration is clearly affected by the drilling operation but remains at very low amplitudes that could not be felt by the local population.
Then, we analysed maximum of particle velocity without applying any average processing. Indeed, population could be disturb by very punctual disturbance occurred on the rig.
The Figure 7 presents these velocities for respectively the stations installed directly in the citizen's garden and the one deployed on the rig. First of all, maximal recorded velocities are also lower than the felt threshold for both stations.
Only one peak is visible on both stations and occurred the 2sd of April 2014. This event was due to a weight drop from the drilling machine. The main peak visible on Figure 7a happened on the 14th of July and is actually correlated with the French national day and its fireworks.
All the maximal amplitudes that could have been emitted from the rig are lower than the felt threshold.

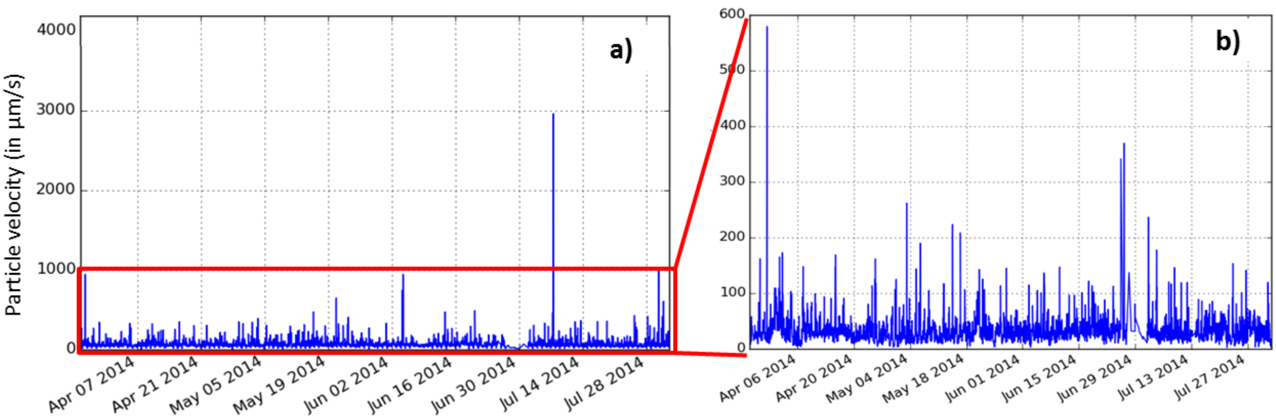

Figure 7: Maximum of the amplitude per day for the station a) in the citizen's garden and b) on the rig.

3. DURING WELL DEVELOPMENT

When productivity index is to low, well development could be considered as an option.

The main vibrational impact during these kinds of operations is directly linked with the occurrence of induced microseismic events.

To monitor this specific period, seismological stations are deployed all around the geothermal project. Data are transmitted in real-time to a processing server which processes them in order to detect the smallest event possible in order to control reservoir behavior and to adapt in real-time injection rate.

Nonetheless it has to be reminded that well development operation are not always necessary and represent only few days in comparison with the full life cycle of a geothermal project which is calculated in decade.

The Soultz-sous-Forêts project could be a good example to see how the seismic risk mitigation during reservoir exploitation was improved (Cuenot et Genter, 2015). Different production/injection strategies, involving 2, 3 or 4 boreholes were tested with different production/injection flowrates. Induced seismicity was continuously monitored with a surface seismological network of 8 permanent stations (Cuenot et Genter, 2015).

By reducing the reinjection well-head pressure from 50 to 20 bars, the number of events detected and the maximum magnitude of induced events were reduced (Figure 8). In 2010, more than 400 microseismic events were detected with a maximum magnitude of 2.3. Then in 2011, 5 events were detected with an associated magnitude of 1.7. Finally, in 2013 only 2 events were induced and the maximum magnitude was only 0.3.

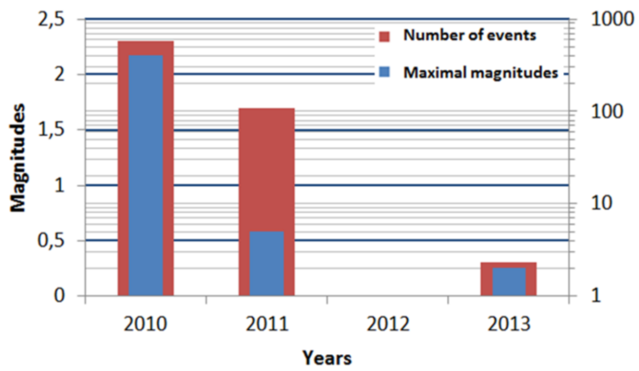

Figure 8: Variation of the number of induced events and their magnitudes over the time for the Soultz-sous-Forêts geothermal project.

The last felt event at Soultz occurred the 10th of June 2003 and was related to a hydraulic stimulation of a deep borehole.

4. DURING PRODUCTION

Based on the same analysis presented in section 2 (During drilling operations), the variation of particle velocity with time at Rittershoffen (Figure 9) shows the daily ambient noise with and without geothermal production average over a period of 20 days.

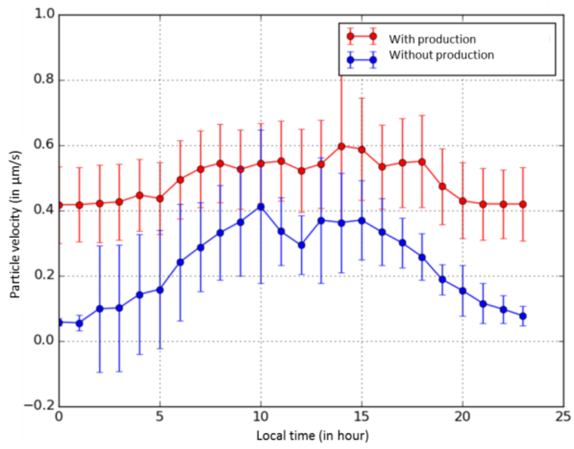

Figure 9: Particle velocity in function of time for a station on the platform. Red and blue lines represent respectively the ambient noise with and without geothermal production.

When the geothermal plant is in activity the ambient noise is sensitively increased by approximately a factor 2. However, vibrations all around the vicinity of the platform remain less than during drilling operations and furthermore definitively less than the felt threshold.

During the closed circulation of the geothermal fluid, rare microseismic events are detected but ever associated with low magnitude. Therefore, production period of a geothermal project is not generating any vibration noise that could be felt by the population.

3. CONCLUSIONS

To ensure the acceptability of an EGS geothermal project, disturbance caused by vibrations have to be managed at the early stage of the project. Indeed, exploration phase include very often a seismic reflexion acquisition. Moreover in case of project in an urban context, communication policy is a critical aspect to obtain consent of the population.

Then during all the other steps developed in a given geothermal project (drilling, well development, production), the monitoring of all potential induced vibrations is a key point to maintain the acceptability of the geothermal site. We presented for various development phase of Soultz-sous-Forêts and Rittershoffen geothermal projects that vibration amplitudes remain lower than the felt threshold.

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