Monitoring environmental effects of shale gas exploitation at Wysin in Poland

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Introduction 1

Environmental effects of shale gas exploration and exploitation are extensively studied in the framework of **"Shale Gas Exploration and Exploitation Induced Risks"** project (**SHEER**, H2020-LCE 16-2014-1). One of the main components of this study is on-site monitoring of the effects at Wysin shale-gas play of the Polish Oil and Gas Company in Pomerania, Poland. This includes monitoring of seismicity and water and air quality.

At the beginning of the **SHEER** project in May 2015, there was one vertical well at the site, reaching gas-bearing shale formations at nearly 4km depth. Later on, two horizontal wells, each of about 1.7km length, were drilled (late Autumn 2015) and fracked (June – August, 2016). This time table has provided the opportunity to record background seismicity and baseline data on water and air quality, and then to record the immediate and delayed effects of hydrofracturing operations. The monitoring will continue for least 1.5 years after the completion of technological activity at the site.
https://www.sheerproject.eu

The **SHEER** database is located on
"IS-EPOS Platform for the Research into Anthropogenic Seismicity and other Anthropogenic Hazards"
https://tcs.ah-epos.eu
The data will be fully accessible after 30/04/2018

Seismic monitoring 2

According to the seismic monitoring plan, the equipment installed at the site consists of:

- 6 surface broadband (BB) seismometers
- 25 surface short-period (SP) seismometers
- 3 borehole broadband (BBB) seismometers.

Surface Stations

The stations form three small aperture arrays:

- GLOD (BB) and GLO1-9 (SP),
- PLAC (BB) and PLA1-8 (SP),
- CHRW (BB) and CHR1-8 (SP).

The surface setup is complemented by three other BB stations, namely SKRZ, SZCZ, STEF. The distribution of surface seismic monitoring stations is presented in Fig. 1.

The final compromise for array location, also taking into account possible anthropogenic noise sources and land use, was to place the three arrays with a triangle geometry at a distance of about 2-4km from the injection well.

The geometry of the broadband stations was chosen using the following concept. Three broadband stations were located at the site of the small-scale arrays, in order to compare signals for neighbouring stations equipped with short period sensors. The geometry of the three remaining broadband stations was chosen to reduce the azimuthal gap around the injection site, and to slightly increase the epicentral distance (up to about 5km from the injection well, Fig. 2).

Shallow Borehole Stations

Three boreholes for the seismic monitoring, GW1S, GW2S and GW4S and the other four hydrological boreholes, GW1, GW2, GW3, GW4 were drilled in November 2015. The location of the boreholes for the seismic monitoring, GWxS, is the same as the location of hydrogeological boreholes, GWx (Fig. 1). Two of the locations do not have electric power supply, therefore solar panels were installed to power the equipment. However, these solar panels did not provide enough power during winter time. After building two wooden shelters at GW1S and GW4S (Fig. 3) the stations at these locations have been powered by fuel cells.

Fig. 3. The wooden shelter for the surface equipment of the shallow borehole seismic station; view from outside.

Detection of Background and Hydrofracturing Induced Seismicity

A microseismic synthetic catalogue is generated to assess the monitoring performance during the pre-operational phase, where seismic information only concerns the noise conditions (Fig. 4) and the potential background seismicity [2].

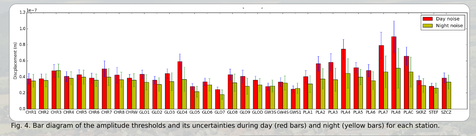


Fig. 4. Bar diagram of the amplitude thresholds and its uncertainties during day (red bars) and night (yellow bars) for each station.

The network detection performance is assessed in terms of the Magnitude of Completeness (Mc) through two different techniques using:

1. An amplitude threshold approach: we compare the maximal amplitude of noise free synthetic waveforms with different noise levels. A regular grid at an averaged depth for the horizontal fracking drillings of 3.91 km is fixed to map spatially the Mc, based on empirical relations and imposing the simultaneous detection by at least 4 stations (Fig. 5).

2.Coherence: we apply a recentle developed automated full waveform detection algorithm based on the stacking of smooth characteristic function and the indentification of high coherence in the signals recorded at different stations. [1] (Fig. 6)

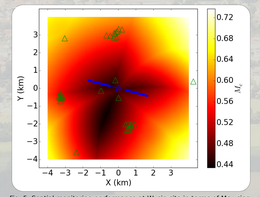


Fig. 5. Spatial monitoring performance at Wysin site in terms of Mc using an amplitude threshold estimated from real osie during night hours using array techniques with SNR=2.

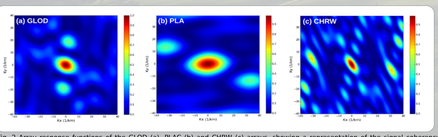
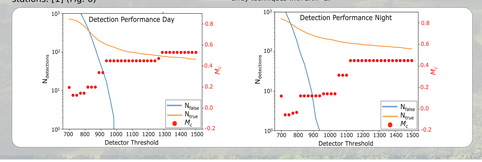


Fig. 2 Array response functions of the GLOD (a), PLAC (b) and CHRW (c) arrays, showing a representation of the signal coherency among array stations as function of slowness and back azimuth; the colour scale plot is normalized and ranges between 0 (blue) and



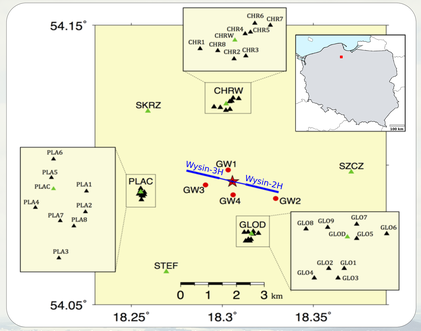


Fig. 1. Seismic monitoring. Green triangles-BB stations; black triangles– SP stations, red circles– BBB stations. Thin and thick blue lines show the projection of the vertical and horizontal production wells).

We apply an automatic detection algorithm to real data for the time period June-August 2016, coverig pre-operational, fracking and post-operational stages, generating an unsupervised detection catalogue [3]. A manual revision of the detected signals revealed that most detections are associated to local and regional seismic signals, generated far from the injection well. Only two events could be assigned to the volume potentially affected by the fracking operations (Fig. 7). More details are presented in the closely related poster [3].

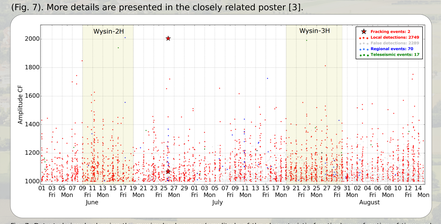


Fig. 7. Detected signals showing the maximal coherence (amplitude of the characteristic function) as a function of time and manual revision of the catalog, according to the chosen event classification (legend).

Fig. 6. Detection performance using coherence techniques [1]. for the synthetic catalogue with different detector thresholds. The number of real detections corresponding with the synthetic catalogue (orange line) and the number of false detections (blue line) are shown. Black dots represent the values of magnitude of completeness for different detector threshold.

References 5

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Note: interested users to preview Lassie can write to: sebastian.heimann@gfz-potsdam.de

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Groundwater monitoring 3

The groundwater monitoring network consists of four wells (GW1 to GW4) drilled at the beginning of the project (Nov. 2015). They reach a main underground water reservoir, the intermoraine reservoir Golebiewo. The location of the wells with respect to the Wysin play is shown in Fig. 1.

The monitoring programme includes collection of three complementary datasets: continuous monitoring of borehole data, laboratory analyses of water samples and field monitoring of water quality parameters (Fig.8). The downhole probes (continuous monitoring) record absolute pressure, temperature and electrical conductivity.

Whilst the borehole is being purged, physico-chemical parameters are monitored using a multi-parameter probe. This probe measures and records temperature, specific conductivity, pH, dissolved oxygen and redox potential within the water (Fig.9).

Hydrocarbon gas content within the water is below detection limits for methane, ethane, ethene and propane gases.

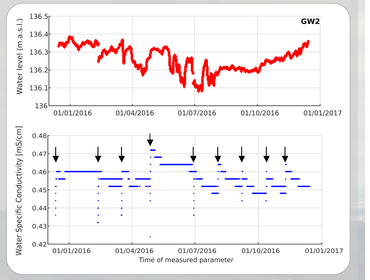

Fig. 9. Example of water measurements results from GW2 well at Wysin site, IS-EPOS Platform (tcs-ah.epos.eu); purging and sampling marked with black arrows.

Fig. 8. Monitoring physico-chemical parameters during purging of GW4 borehole.

Air pollution monitoring 4

Air pollution monitoring is performed by means of an automatic station. The station is situated east from the Wysin rig at a distance of some 1200m (Fig. 10, 11). There is one additional barometric logger located at GW1. Westerly winds dominate in the region, so the potential air pollution from the rig area will pass through the station area. Additionally, the distance is appropriate in order not to measure direct emission of pollutants. The nearest residential buildings are at a distance of approximately 150m. The station monitors the content of NO, NO_2, NO_x, CO, PM_{10}, O_3, CO_2, CH_4, NMHC and Radon (Fig.12).

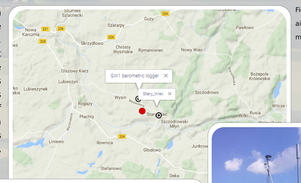

Fig. 10. Location of air station. Wysin site marked with red dot.

Fig. 11. Air quality monitoring station

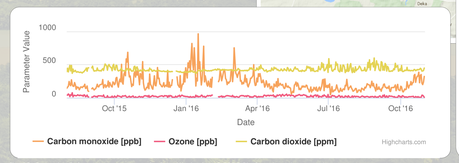

Fig. 12. Example of air measurements results from Wysin site, IS-EPOS Platform (tcs-ah.epos.eu).

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