RECOMMENDATIONS ON THE OCCURRENCE OF SEISMICITY DURING SHALE GAS RESERVOIR STIMULATIONS

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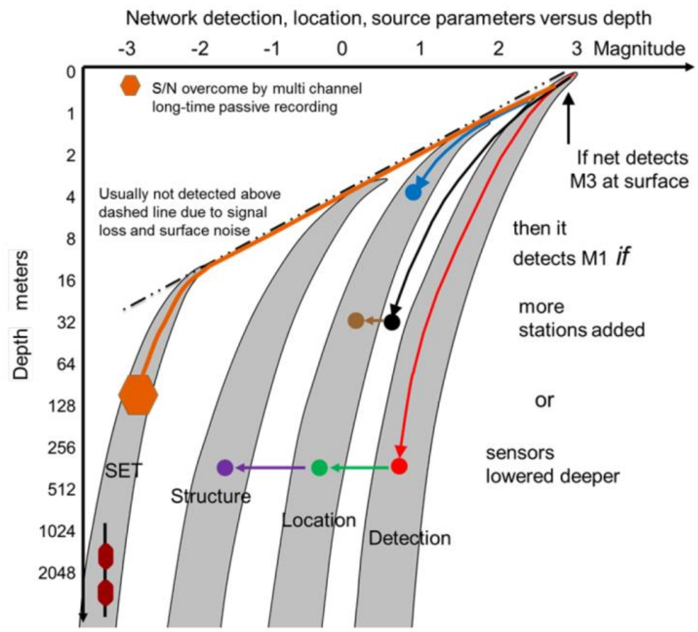

The diagram exemplifies a toolbox to design an relevant seismic monitoring network design for respective objectives to monitor seismicity at low detection thresholds and subsequent tasks.

Background

Different to waste-water disposal, the occurrence of induced seismicity related to stimulation of shale gas reservoirs has not been a major concern in the past. Recently this has changed due to induced seismic events directly related to fluid injection with magnitudes M exceeding M=4 in individual cases. This has resulted in calls for independent monitoring before, during and after reservoir production.

To date no uniform practice for it exists despite the fact that in few cases individual induced earthquakes recently resulted in considerable anthropogenic seismic hazard to local population and infrastructure and few reservoirs are monitored using dedicated local networks of seismic sensors.

Study

A thorough review on known occurrences of induced seismicity related to shale gas reservoir stimulations was performed. Results are then related to the cases of induced seismicity in other geo-reservoirs in the frame of stimulations or waste-water disposal.

A best practice for adequate microseismic monitoring is proposed combining recent developments in instrumentation, data processing and network geometry. It includes various field kits, installations and workflows to ensure cost-effective passive reservoir monitoring considering the needs of case-by-case boundary conditions.

The study includes a review of new, emerging, technology such as Optical Fiber seismic instrumentation for behind casing.

Results

The best practices passive microseismic monitoring program presented here aims at three project phases, each with step-wise options for development of the monitoring system.

These options encompass different phases of a reservoir development plan. It begins with detecting background seismicity before stimulation as a pre-requisite for estimating the local potential for induced seismicity. It includes options for high-resolution monitoring during reservoir treatment and long-term options for post-injection times.

Using well established current methods, individual behind-casing seismometers can be installed as part of standard well completions. These can acquire important data for both long-term management of induced seismicity as well as leakage and long-term leak detection. More advanced methods, based on Optical Fiber technology is just emerging.

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Science-based Recommendations

- The recommended best practices seismic monitoring program for shale gas reservoirs aims at three phases. Each includes step-wise options for development of the monitoring system. These options cover not only regulatory compliance, but also advanced characterization and management of the particular reservoir.
- Phase 1 aims at determining the background level and rough locations of local seismicity. It provides means for estimating the seismic potential of the area using the well-known Gutenberg-Richter relation. This phase can be realized with one or several local seismic stations to be deployed at the surface or in existing wells.
- Phase 2 involves short-term monitoring of reservoir stimulation operations and requires a multi-station - preferably borehole based - local seismic network. This allows for low detection threshold and precise hypocenter determination. If data are processed fully automatic it will ensure a feedback option for short-term reduction of flow rates in case of increasingly strong induced seismic events.
- Phase 3 aims at long-term passive seismic monitoring for potentially hazardous earthquakes and along-well gas leakage, and for optimizing resource recovery. This phase can be accomplished with a limited number of permanent –preferably behind-casing downhole seismic stations.

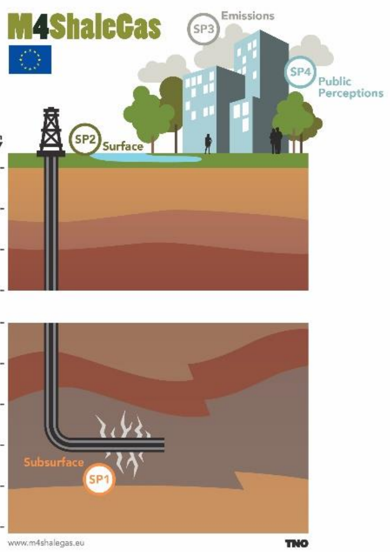
TABLE - common instruments, deployments, and relative costs for 5 x 5 km target area

Type	Usable bandwidth	Instrument OD	Sensor cost	Relative sensor + deployment cost: surface	posthole	deep well	Step 1	Step 2	Step 3
							suggested deployment		
BB	40s-20Hz	~250 mm	high	moderate	moderate		~ 4 @ 1 m		
1 Hz	4s-100Hz	~200 mm	moderate	low	low	high	~ 2 @ 30 m	~ 6 @ 30 m	
4.5 Hz	1-500Hz	70 mm	Low	low	low	moderate	~ 1 @ 300 m	~ 4 @ 300 m	~ 12 @ 300 m
15 Hz VSP	4-2000Hz	50 mm	lowest			high	≤ 3000 m VSP array		
4.5 Hz SET	1-500Hz	70 mm	Low		moderate	high	~ 36 @ 100 m buried SET array		

Overview on the optional sensor types with relevant sensor characteristics such as (from left to right) natural frequency, frequency bandwidth, outer diameter, cost level and suggested number and spacing for the three proposed monitoring phases.

The Project

M4ShaleGas examines the potential environmental impacts and risks related to **shale gas** exploration and exploitation in Europe with the goal to build a technical and social knowledge base on best practices and innovative approaches for **m**easuring, **m**onitoring, **m**itigating, and **m**anaging these impacts.



4 sub-programs:

- SP1-subsurface
- SP2-surface
- SP3-air emissions
- SP4-public perceptions

Funding:
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Horizon 2020 Topic LCE-16-2014:
Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation.

Project duration:
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Coordination:

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