WILL THE NEW SEISMIC TECHNOLOGY SHAKE THE GEOTHERMAL INDUSTRY?

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Summary

Geothermal energy is expected to play an important role in the new zero-carbon emission era where renewable, sustainable and environmentally friendly energy sources should grow in the energy mix. The reduction of the subsurface risk for the geothermal energy development requires exploration technologies that can be borrowed, and adapted, from the O&G industry: the seismic method has a major role in the geothermal exploration. The challenges of "geothermal seismic" often come from the urban environment, with its obstructions and restrictions limiting the geometry options, the high incoherent noise level.

The Oil&Gas industry has been pushing the limit of the seismic acquisition technology allowing denser surveys to be acquired. However, the price of these acquisition systems and their associated operation cost has been prohibitive, especially for non-Oil&Gas industries, limiting survey designs to 2D or sparse 3D.

The emergence of new acquisition technologies, such as a new generation of much more nimble seismic nodes, allows agile and light operations, and opens new possibilities for urban exploration. Combined with the modern processing and imaging approaches, including model based coherent noise attenuation to precondition data not adequately sampled, allow deploying frugal and agile methods to deliver 3D seismic images at reduced cost.

Will the new seismic technology shake the geothermal industry?

Introduction

Geothermal energy is expected to play an important role in the new zero-carbon emission era where renewable, sustainable, and environmentally friendly energy sources should take the lead over conventional fossil fuel. The reduction of the subsurface risk for the geothermal energy development requires exploration technologies that can be borrowed, and adapted, from the O&G industry. The seismic method has a major role ion the geothermal exploration.

A particular constraint for a successful geothermal exploration is that the energy source has to be in the vicinity of the end-user. Most seismic surveys for geothermal application are likely to be in urban or suburban areas which sets the context for the usage of seismic equipment in such environment. The context brings some logistics advantages compared to remote locations, but it comes with its own challenges: complex permitting, very limited room for any disturbance, disruption or damages, expensive compensations, very rigid and limited time window for shooting, vibration control, etc. In urban seismic the obstructions are simply everywhere: often a very small percentage of the area is accessible to operations, and the acquisition geometries are constrained by the urban structure itself.

Cable systems have been used for a long time in this context, with increasing complexity as denser surveys were required. Bulky to transport, they are highly visible and attract unwanted attention; crossing roads, tramway lines, canals require extra effort and hazards. They are also subject to frequent line cutting which stops the whole survey as data is not recorded when communication is broken.

The move to nodal systems was necessary and happened gradually in the last decade or so. Early nodes were not particularly small nor light, and some even kept the inconvenience of cables, especially when arrays were used. Nodes kept getting smaller, lighter and very reliable which had widely contributed to the acceptance of what is commonly called *blind shooting*, i.e: continuous recording without live QC of the data. With these systems, seismic data is recorded by each node independently, with no need of system troubleshooting, no system down-time due to “cuts”. The increase of productivity, besides the reduction of the operation duration or to the increased density over the same period, also reduce the unit cost of the acquired data.

Small nodes also present several advantages in terms of safety and impact on the environment, for example by eliminating the need of line cutting for receivers (Brooks et al, 2018). These systems significantly reduce operational time, risk exposure: the very small footprint when deployed allows operating in dense areas without disruptions and disturbance. Even when terrains are not particularly difficult, reducing the number of the vehicles required for transportation has a significant impact on safety: road related accidents are often the highest risk of seismic operations, especially in urban environments. It is well accepted that the use of lighter autonomous nodes allows today operating in very challenging areas: on one hand, mountainous, difficult access, remote, high security areas. On the other hand, the urban areas in western Europe. And the reduction of the crew size and of the required contacts significantly reduces the COVID risk in the current pandemic.

HITA planned a series of geothermal surveys in different areas of Belgium, with targets at different depth and in multiple geological contexts. The development of a dedicated seismic exploration strategy and technology allowed a fast acquisition of 3D surveys in complex urban areas.

Material and methods

For the purpose of this study, we decided first to evaluate the lightest and smallest node on the market, the STRYDE node. Also known in the industry as the nimble node (Manning et al, 2018), it is a very compact autonomous node, weighting only 150g in a completely sealed cylindrical casing 13x4cm. Its sensor is a piezoelectric accelerometer with a flat response between 1 and 125Hz. The node can record continuously for 28 days, which allows flexible operations and make it suitable for both active and passive seismic.

The STRYDE peripherals provide an agile and light deployment and retrieval node system in the field and the charging and harvesting of the data in the base camp.

To assess the performance of the system, and its suitability for the planned geothermal exploration program, an initial 2D comparative test has been acquired and processed. A short 2D line has been deployed, recording simultaneously with two independent sets of nodes: the STRYDE and, as a benchmark, a popular, well accepted and state-of-the arts system.

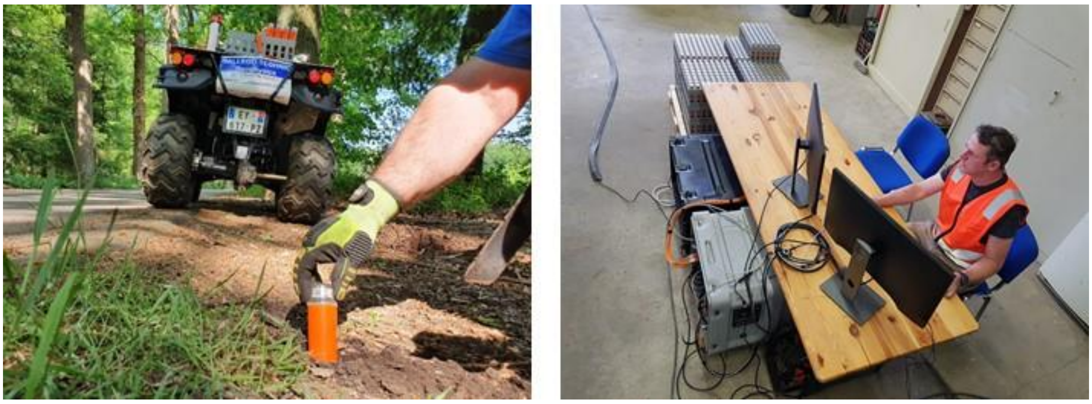

Figure 1 *Exemple of deployment of STRYDE nodes for the 2D test. Light field system for the deployment and harvesting of the nodes*

The benchmark test has been analysed thoroughly, evaluating the frequency response, the signal to noise ratio, the coupling variability, and ultimately confirming the choice of deploying the STRYDE system for the coming set of surveys, for its high data quality and its logistics and operational advantages

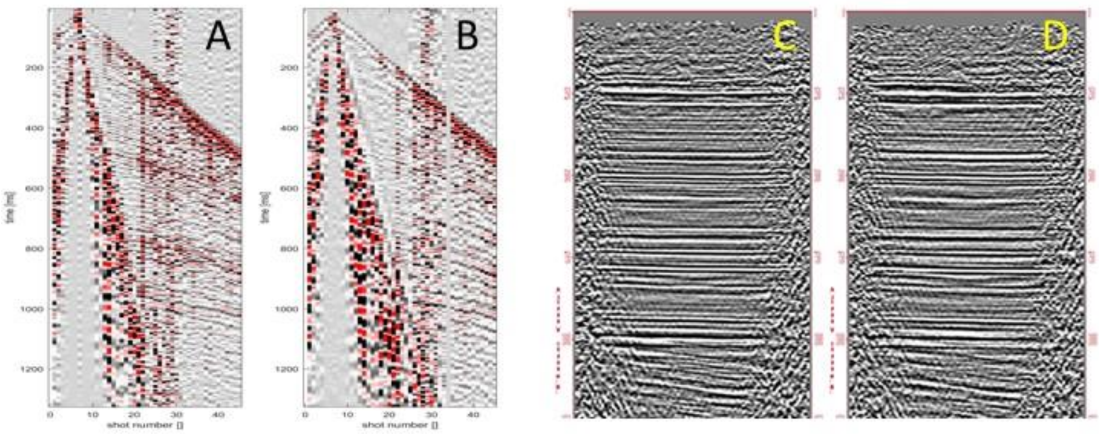

Figure 2 *Comparison of raw shot gathers (A STRYDE,, B other node) and of brute stack produced in the field to compare the image quality (C:STRYDE,D: other node).*

Frugal 3D geometries enabled by acquisition and processing technologies

The survey design is a critical step of every seismic project, and ultimately can be seen as an optimization exercise. Doubling the density of any survey, even the densest, is still likely to improve its imaging and seismic attributes (Ourabah et al, 2015). On the opposite end, designing a frugal survey in a highly obstructed area requires assessing and mitigating the associated quality risk, the risk of a survey that might not meet its objectives

Three main items will be discussed with a special care for the critical sub-items, in the implemented workflow

- define the surface acquisition scheme, assess scenarios, and evaluate the estimate performances
  - analyze the illumination potential and its link with processing and imaging
  - detect potential weakness of the scheme (what could make the project at risk)
- process the data to build the final 3D cube
  - the near surface model and primary statics computation
  - coherent and incoherent noise attenuation
  - The multidimensional interpolation/regularization
  - The imaging

Although these items are performed in a sequential manner, before, during and after the field operations, it is important to keep in mind that the full process has to be considered as a whole. Continuous feedback loops should help to keep the project on track, to avoid unnecessary efforts, to better adapt to final objective and to improve overall quality.

The designed geometries are assessed based on standard metrics, but also considering quantitatively the performance of the key elements of the processing and imaging chain.
Extra redundancy is built in the geometry, adding extra data points with redundant reciprocity between source lines and receiver lines, and designing an adaptive density as a function of the objectives and of the subsurface geometries. The data density is also adapted to the need of appropriate fold build-up and migration margins, producing a completely scattered and chaotic distribution of the mid points, with albeit a designed minimal data density in space, in the different domains such as offset and azimuth, to guarantee the required performance of the multidimensional regularization.
The design exercise is particularly challenging because of the very tight access constraints: only very irregular geometries are often allowed; a full-azimuth, live spread approach is selected.

Results

The integrated approach has been tested in two 3D surveys in Belgium, with multiple objectives, including implementing a cost-efficient, low-impact and fast survey, able to image the geological objectives in 3D. The need of a short turnaround, and of a small-size crew, operating in a COVID bubble added further complexity to the field operations. The efficiency of the operations, as already proven in O&G applications (Ourabah et al, 2020), has been confirmed in the urban context of geothermal exploration.

The light Stryde system was a key element in the field operational efficiency, the reduction of the crew size and of the duration of the operations, to limit the COVID risk.

As an example, a small 3D survey in the city of Herentals, acquired at the end of 2020, was acquired and processed in a month: this includes the field operations, the data harvesting and reconstruction, and a complete processing in time and depth, including model-based noise attenuation, beyond aliasing, a complete surface consistent signal processing, multidimensional (5D) regularization and interpolation.

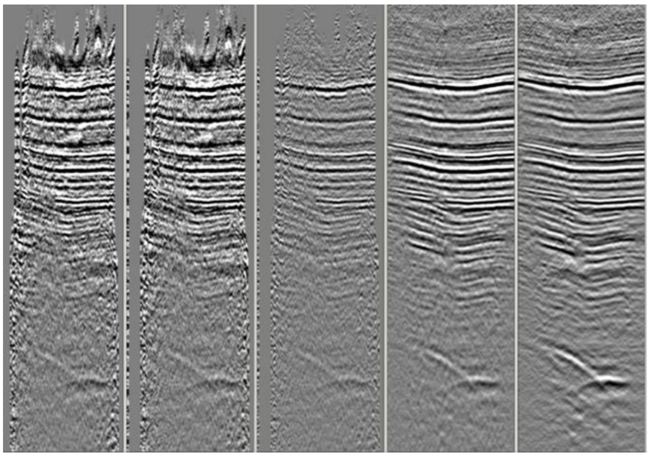

Figure 3 *Exemple of evolution of the one inline across the processing sequence, before migration*

The 3D processing and imaging allowed delivering high resolution images, with a 10m vertical resolution at the lower cretaceous unconformity, and stable attributes, showing structural and stratigraphic features in the entire section.

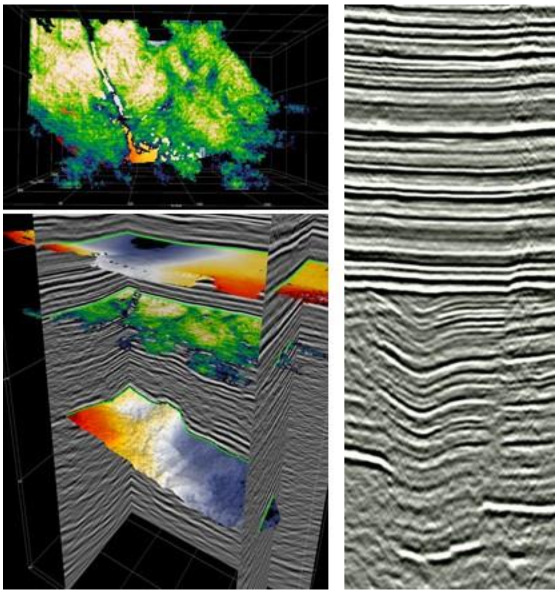

Figure 4 *Exemple of an inline of the 3D PSDM cube, showing the resolution below one of the main unconformities, and of a similarity slice*

Conclusions

Geothermal Energy is a sustainable, renewable and environmentally-friendly energy source that is still largely untapped; it has the potential to be a part of the energy mix and meet some of the heating, cooling and electricity demands for future cities. The success of any geothermal project is closely related to how well the subsurface in and around the reservoir is understood.

The subsurface imaging is key to a successful exploration, to reduce the subsurface risk of the geothermal development.

The seismic surveys also provide the needed elements for better microseismic monitoring and alerting systems, providing the structural framework and the velocity and attenuation models.

The transfer of the technologies that have been developed in the Oil&Gas industry in the past decades, and the adaptation to the specific challenges and financial models of the geothermal industry, can allow a safer and broader development of this energy. The recent seismic technologies, including the light autonomous nodes and the advanced processing and imaging approaches are an important contribution.

References

Ourabah, A., Bradley, J., Hance, T., Kowalczyk-Kedzierska, M., Grimshaw, M. and Murray, E., 2015, Impact of acquisition geometry on AVO/AVOA attributes quality – A decimation study onshore Jordan: 77th Conference and Exhibition, EAGE, Extended Abstracts.

Ourabah, A., Crosby, A., 2020, A 184 million traces per km2 seismic survey with nodes – Acquisition and processing: SEG International Exposition and 90th Annual Meeting, Extended Abstracts

Brooks, C., A. Ourabah, A. Crosby, T. Manning, J. Naranjo, D. Ablyazina, V. Zhuzhel, E. Holst, and V. Husom, 2018, 3D field trial using a newnimble node — West Siberia, Russia: 88th Annual International Meeting, SEG, Expanded Abstracts, 6–10, doi: https://doi.org/10.1190/segam2018-2995441.1

Manning, T., Brooks, C., Ourabah, A., Crosby, A., Popham, M., Ablyazina, D., Zhuzhel, V., Holst, E., and Goujon, N. [2018]. The case for a nimble node, towards a new land seismic receiver system with unlimited channels. SEG Technical Program, Expanded Abstracts, 21-25.