geoconvention
Calgary · Canada · June 20-22 2022

# Ultra-High Density Seismic Survey at Carbon Management Canada's Field Research Station

*Amine Ourabah[1], Allan Châtenay[2], Greg Maidment[3], Marie Macquet[3]*

*[1] STRYDE*

*[2] Explor*

*[3] Carbon Management Canada (CMC)*

## Summary

In 2021, STRYDE, Carbon Management Canada (CMC), and Explor collaborated to acquire an ultra-high density (UHD) seismic survey at the Containment and Monitoring Institute (CaMI) site in Alberta, Canada, (Ourabah & Chatenay, 2022). The CaMI Field Research Station is a 200-hectare active, small-scale $CO_2$ injection site that provides facilities and equipment to test and develop measurement and monitoring technologies to track $CO_2$ stored underground and to determine the detection threshold of $CO_2$ at shallow to intermediate depths (Lawton et al, 2019; Macquet et al., 2019). Since 2019, it has brought over 400 people through for training, research, and partnership development. This included the International Energy Agency (IEA), ministers from the Federal Department of Innovation, Science and Economic Development Canada (ISED), and researchers from numerous international locations. The 2021 survey at the CaMI site was conducted using efficient and affordable source/receiver equipment and produced a raw trace density of 257 million traces/km$^2$. The UHD survey was acquired using 19,872 STRYDE nodes deployed at 7.5m x 7.5m grid spacing and two types of sources: Explor PinPoint impulsive sources achieving 9,041 source points and a Vibroseis source deployed on a 30 m x 7.5 m grid achieving 3,910 source points. By obtaining all source points into the all-live receiver spread, a total of 257.4 million raw traces were acquired into the 1 km$^2$ survey (both source types combined), setting a new global record for seismic trace density. In this abstract, we discuss the operational efficiency of this survey as well as the seismic products generated. We also explore the current trends in seismic equipment and how it impacts low budget industries such as CCUS and Geothermal Energy.

## Survey set-up and data

The core field team of ten (10) people deployed 19,872 nodes in five (5) days. Retrieval of the nodes took five (5) days, although with a reduced crew size of just eight (8) people. The PinPoint acquisition averaged 565 source points per day and the Vibroseis acquisition averaged 651 source points per partial night shift (Figure 1).

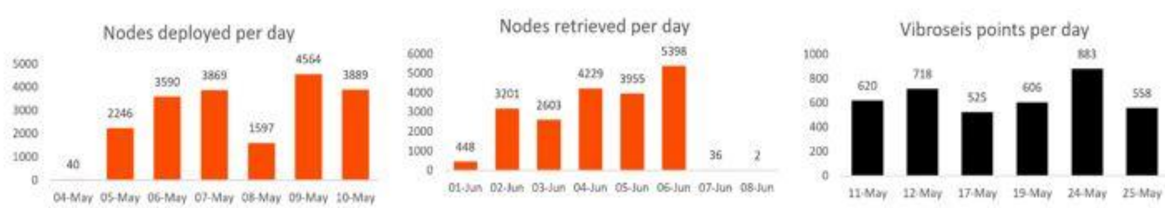


***Figure 1**: Operational statistics for receivers and sources.*

The $CO_2$ injection was stopped during the active seismic survey, and active source operations ceased prior of resuming the planned $CO_2$ injection. The full spread of 19,872 nodes continued passive recording for an additional 5 days, during the resume of injection. The passive data is aimed at exploring the potential use of seismic interferometry in monitoring $CO_2$ injection. The data volume for the 1 $km^2$ survey, which included receiver gathers, shot gathers and continuous 24-hour recordings from deployment to retrieval, was just over 78 terabytes (TB). Data was harvested on the STRYDE Nimble server system and was output directly to an Amazon Web Services (AWS) Snowball Edge, a 100 TB edge appliance that facilitates the upload to the AWS cloud and subsequently to STRYDE's Centre of High-Performance Computing (CHPC) in less than 4 days. The raw seismic data recorded by this nodal system is navigation-merged and contains the source and receiver headers for the data processing to start. Further, it contains a multitude of seismic and engineering headers that are useful to integrate to the conventional QAQC (Crosby et al, 2020). A high resolution (< 2 cm ground sample distance) photogrammetry with drones was used to generate a digital elevation model (DEM) which was further compared to the RTK values of the PinPoint source deployment showing a 0.11m mean error, and from the self-positioning values from the nodes showing a 2.43 m mean error.

## Results

The active source dataset was processed by STRYDE and went through several fast-track processing sequences to answer requests from the various stakeholders involved in the survey. In the end, a full pre-stack time migration sequence was facilitated to assess the full potential of the outstanding trace density.

Figure 2 shows 2D sections of raw and processed data, using PinPoint source and VibroSeis source, compared to the legacy 3D-3C survey from May 2014 (Lawton et al., 2014). The near surface showed exceptional resolution linked mainly to the trace density achieved by both source and receivers. Some of the very shallow detail disappeared quickly when the source density was decimated to run source comparisons. Additionally, we observed that low energy sources such as PinPoint were sufficient to reveal details of the first 300m of the subsurface which can be used for near-surface modelling as well as an end-product in some specific scenarios. The imaging at depth was performed with a better signal to noise (S/N) ratio by the Vibroseis which also performed well on the easy access terrain of the CaMI.FRS. In terms of seismic product deliverables, multiple post-stack and pre-stack migrated volumes were generated at different stages of the processing sequence to assess the added value of each stage. The powerful cleaning effect of the migration process on a UHD dataset is impressive and can fast track quality products throughout the duration of the processing (Figure 2). This approach transforms the migration process into a QAQC tool instead of an end-product and has been made practical by both the optimization of different types of migration algorithms as well as the increase in hardware and software power available on high-performance computing environments. Early steps in processing delivered products with a stacked image quality close to the final processed volumes. However, other deliverables such as pre-stack gathers, AVO and Azimuthal AVO products and other more subtle imaged features require a more thorough processing flow to achieve their technical limits.

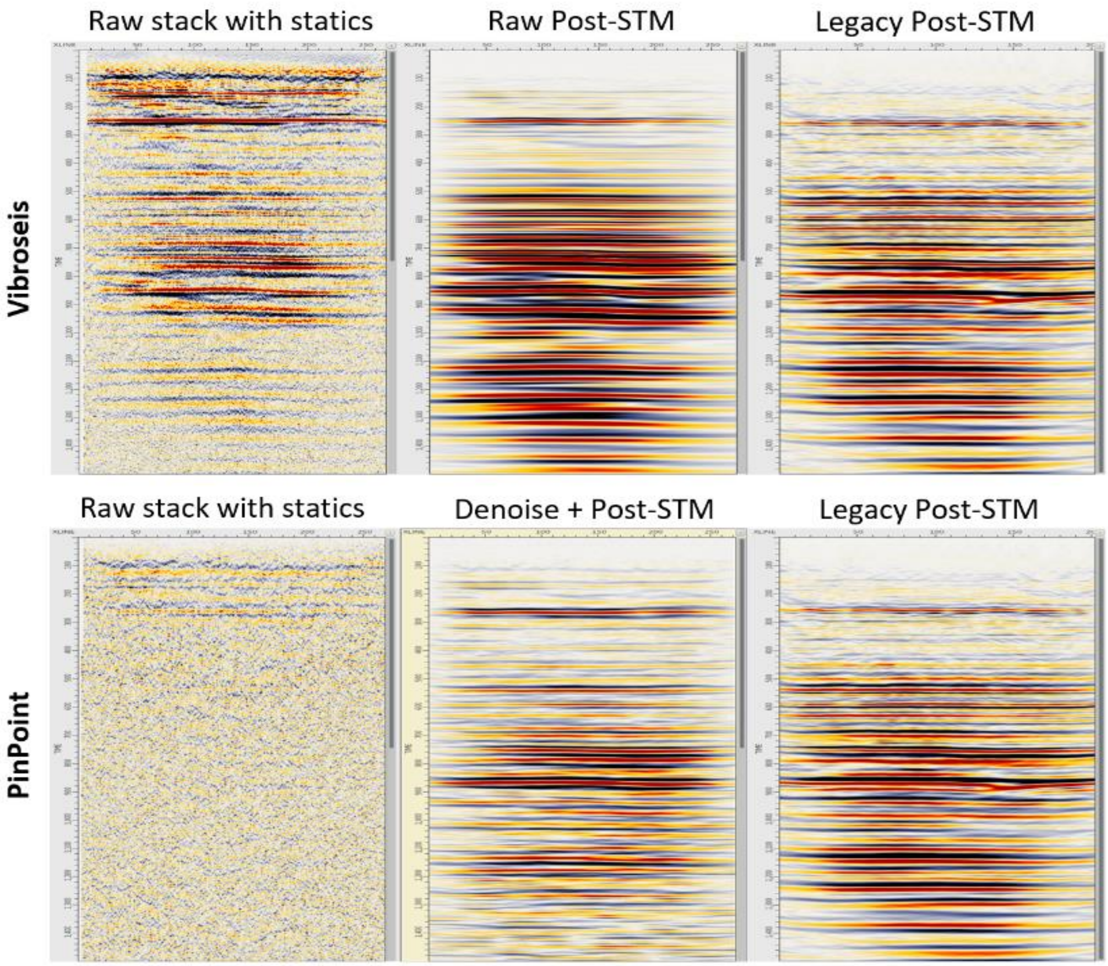


***Figure 2:*** *Progression of S/N on Vibroseis data (top) and PinPoint data (bottom) through a fast-track processing sequence, compared to the legacy Post-STM (2014).*

## Conclusions

This unique survey and the processing developed using the dataset may change in the future if shorter links are found between raw data and the deliverables. Nevertheless, the value of seismic products is often judged looking through an oil & gas lens, which took decades to mature and reach a level of complexity that comes at a cost. It is therefore important to review what is currently available and how we can redefine the developmental road map of seismic products to support such industries which might seem familiar from a technical perspective but would require adjustment from the oil & gas perspective.

In the CaMI UHD example, using the latest receiver technologies may have launched a new era of source innovation. This era aims to achieve the portability and efficiency of the nimble receivers seen in previous years. Simultaneous source technology with Vibroseis has been at the origin of a leap in trace density in the oil & gas industry in the early 2000's; however, although it achieved adequate efficiency, it lacked accessibility. This is expected to be a serious constraint for CCUS or geothermal projects if their fate is to follow the consumer location. The answer might be a hybrid solution as has been observed in this UHD survey where PinPoint performed well at shallower depths, whereas Vibroseis performed better at greater depths. Other environments might require several types of sources to achieve the optimal solution in terms of cost, time, environmental footprint, and data quality. Geothermal and CCUS are few of several promising technologies that can potentially allow the world to reach a net-zero carbon future. We are interested in these technologies because they require a thorough understanding of the subsurface to progress and reach the success rate the hydrocarbon industry has managed to achieve with seismic data. The nimble nodes have opened a new era of innovation for the source technology and set the bar of efficiency very high which should lead to affordable seismic with no environmental footprint for any industry that needs it. By solving the receiver side, UHD seismic is no longer a product exclusive to the oil & gas industry and has now become accessible to more funding constrained industries that can benefit immensely from it.

## Acknowledgements

We thank STRYDE, Explor and CMC for authorization to publish this work. We especially thank Celina Giersz, Zhongmin Song, Evgeny Kokoshin, for the fast and high-quality processing; Ken Doherty, Cosmin Vasile. Richard Gray, Philip Sokol, Ysabel Garcia and Lin Lu, for acquisition support and innovative QAQC; Don Lawton for the opportunity to complete this survey on the CaMI site and his valuable inputs; Greg Maidment, Malcolm Bertram (Vibroseis) and Marie Macquet. And finally, we thank Jack Bouska for his incredible work on source control systems and Paul Thacker for his vision and mentorship.

#### References

Crosby, A., Manning, T., Ourabah, A., Brooks, C., Dieulangard, D., Quigley, J., Vasile, C., and Ablyazina, D., 2020, In-field quality control of very high channel count autonomous nodal systems. SEG Technical Program Expanded Abstracts: 46–50. https://doi.org/10.1190/segam2020-3425467.1

Lawton, D. C., Bertram, M. B., Bertram, K. L., Hall, K. W., and Isaac, J. H., 2014, A 3C-3D seismic survey at a new field research station near Brooks, Alberta: *CREWES Research Report*, **26**, 48, 18

Lawton, D. C., Dongas, J., Osadetz, K., Saeedfar, A., & Macquet, M., 2019, Development and analysis of a geostatic model for shallow CO2 injection at the Field Research Station, Southern Alberta, Canada. *Geophysics and Geosequestration. Cambridge University Press, Cambridge*, *280*, 296.

Macquet, M., Lawton, D. C., Saeedfar, A., & Osadetz, K. G., 2019, A feasibility study for detection thresholds of CO2 at shallow depths at the CaMI Field Research Station, Newell County, Alberta, Canada. *Petroleum Geoscience*, *25*(4), 509-518.

Ourabah A. and Chatenay A., 2022, Unlocking ultra-high-density seismic for CCUS applications by combining nimble nodes and agile source technologies. The Leading Edge 41: 27–33. https://doi.org/10.1190/tle41010027.1