A new generation of seismic nodes enabling high trace density seismic surveys for all industries.

Amine Ourabah, STRYDE

Abstract

The demand for improved seismic images at a lower cost , lower environmental impact and lower HSSE exposure is driving the need for more compact and efficient seismic acquisition systems. Emerging renewable industries such as geothermal and CCUS have been particularly affected by the high cost of seismic surveys historically which limited its use, even though seismic is essential to de-risk subsurface activities. High trace density seismic acquisitions have become the new norm in most hydrocarbon exploration projects because of the unprecedented high quality of seismic images and attributes they provide, but they do require significantly more source-receiver recordings on the surface, putting more constraints on the process. The old, bulky cabled seismic equipment, which were limiting the efficiency of surveys, especially in challenging terrains and urban environments, are gradually being replaced by nodal systems, which are more compact and flexible, and within this new family of autonomous nodes, a new sub-group of nimble nodes is creating a paradigm shift in the way seismic is acquired, making high-density seismic an affordable option not only for hydrocarbon exploration but also renewables. These new autonomous nodes have been used to acquire the two densest land seismic surveys on the planet for hydrocarbon and CCUS, in a very efficient way. In this article, we will revisit many aspects of these iconic surveys to highlight the key factors enabling this efficiency as well as the impact of such trace density on data quality.

Introduction

More compact and efficient seismic acquisition systems are required to respond to the continuous need of better seismic images at lower cost, lower environmental impact and lower HSSE exposure. In addition, some emerging renewable industries like geothermal, and Carbon Capture Utilization and Storage (CCUS) are expressing the need to acquire better seismic at a much lower cost to allow de-risking their subsurface activities. High trace density seismic acquisition has become the new norm in survey design thanks to the fantastic benefits it provides for imaging and seismic attributes (Ourabah et al, 2015), however, by definition, it does require significantly more pair of source-receiver recording on the surface, putting evermore constraints on the above. Old cabled seismic equipment is too bulky and heavy to respond to this new wave or seismic requirements especially in difficult terrains and urban environments and are gradually being replaced by nodal systems which are much more compact and offer more flexibility in the field. A new generation of seismic nodes in particular is creating a paradigm shift in the way seismic is acquired, making high-density seismic finally an affordable option for hydrocarbon and renewables. To demonstrate this fact, we will show how these nodes have been used to acquire the two densest land seismic surveys on the planet both for hydrocarbon and CCUS in a very efficient way.

Figure 1 *- Selection of land nodal systems on the market. Image courtesy of Tim Dean*

Nimble nodes and the land Seismic Recording System Market

The seismic recording market landscape, as described by Wilcox et al (2019) (Figure 1), has not changed significantly today. Systems can be broadly fit into 4 categories, which we classify as follows: “Nimble Nodes”: ultra-light weight (under 200g), with no remote QC capabilities. “Medium Nodes”: with a weight between 650g and 1000g. These have some level of remote QC capability, whilst some also allow real time data transmission. “Large Nodes” with a weight over 1Kg. These are usually older generation nodes with external batteries and/or sensors, and multiple connecting options. "Cabled systems" which have a significantly higher weight per channel but offer real-time data transmission.

Some equipment providers have elected to prioritise technical features and specifications, in turn sacrificing unit cost and weight. Conversely, other providers will have instead focussed their efforts on one or more of reliability, price, scalability and ultimately, operational efficiency. The Nimble nodes fall in this latter category and are enabling very high efficiency surveys, not only for the hydrocarbon exploration, but also for renewables who traditionally suffer from much more budgetary constraints than the former. These nodes, although proven to show huge benefits on seismic acquisition by themselves, show their full potential when combined with very efficient fast moving source operation like simultaneous source acquisition or compact source equipment which can keep up with the fast-moving receiver crews. To demonstrate this fact, we will show case the two densest land seismic surveys in the world, for Hydrocarbon and CCUS applications, which have been acquired using this very power combination.

A 184 million traces/km2 seismic survey for hydrocarbon exploration

in 2019, as part of the last development phase of the nimble node system, ADNOC acquired a seismic survey which achieved 184 million traces per km2 (Nehaid et al, 2019) combining an inventory of 50,855 nimble nodes (known as the STRYDE nodes today), and 16 Vibroseis operated in a simultaneous shooting technique.

Figure 2 *- Top right: the nodal central system in camp with its three core units inside 20ft standard containers. In the foreground we see 35,000 nodes (out of the 50,855 nodes used) prepared for deployment. Bottom right: 1500 nodes on a back of a pick-up truck including recovery strings. Left: downloading and charging racks capable of turning around 20,000 nodes per day.*

The area was divided into five zippers with a 12.5x12.5m carpet of receivers and a 100x12.5m source grid acquired with a 3km crossline offset in a double parallel sided geometry. The 16 vibroseis trucks swept simultaneously (single vib per source point) over both sides of a ~43,000 nodes live spread. Beside the size and weight of the nodes (13x4cm, 150gr), the receiver system comprises three core peripheral units, with remarkable turnaround rate capacity, installed in standard shipping containers (download and charging unit (20,000 nodes /day, cleaning unit 40,000nodes/day and recording unit) using a standard 200kW generator for power supply (figure 2). Following initial mobilization and setup of the system in the basecamp - which took two technicians 1 day to complete - 36 operators were trained over two days to use the handheld devices and backpacks for deployment and retrieval. A "no surprises test" was completed before the start of the production survey to tweak final parameters for source and receivers. Production started one week after initial offloading of the material in the base camp.

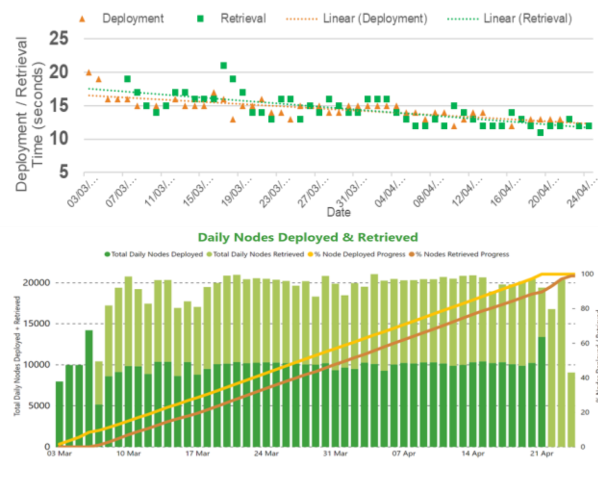

Figure 3 *– Left: Daily deployment and retrieval rate. The crews achieved their target of 10,000 nodes deployed and 10,000 retrieved per day within 7 days of the start of the LSFT. Right: Median deployment and retrieval time of the nodes. The crews achieved 15 seconds per node on average (12.5m spacing).*

More than 500,000 individual node deployments were completed in 53 days and more than 340,000 vibrator point were shot during the survey with peak production approaching 10,000 source points per day. Within the first 7 days of deployment crews were consistently deployed 10,000 nodes per day and retrieved another 10,000 nodes the same day, averaging 15 seconds per station which were 12.5m apart (Figure 3). These figures were achieved with a line crew of 12 deployment teams of 3 people and 13 retrieval teams of 2 people.

To support this rapid deployment and retrieval rate, about 10,000 nodes were rotated through the download & charging unit every day in less than 12 hours, with each node containing around 5 days' worth of data. The seismic data was processed by several contractors and delivered similar results to the one shown on Figure 4 showing outstanding uplift of the overall image quality especially around the target area (clinoforms visible in the center of the section)

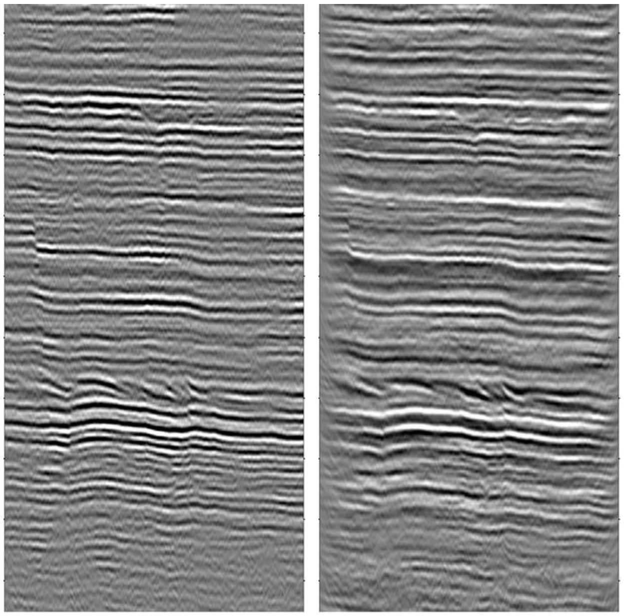

***Figure 4 –** Left, legacy data acquired with array sources (4 Vibroseis repeating sweeps up to 6 times) and 48-geophone arrays per station. Right, new UHD survey acquired with 16 single point Vibroseis shooting in a blended mode and single sensor (Stryde Nodes) on 12.5x12.5m carpet grid.*

A 257.4 million traces/km2 seismic survey for CCUS

To support CCUS and other alternative energies where seismic data plays a key role in their success, STRYDE, Carbon Management Canada (CMC), and Explor have collaborated to acquire an ultra-high density (UHD) seismic survey at the Containment and Monitoring Institute (CaMI) site in Alberta, Canada, using a very efficient and affordable receiver and source equipment available in the market and achieved an outstanding raw trace density of 257 million traces/km2 (Ourabah and Chatenay, 2022). This new UHD survey was achieved using 19,872 STRYDE nodes deployed at 7.5m x7.5m grid spacing and two types of sources: Explor PinPoint impulsive sources with three different configurations were deployed at 7.5x7.5m grid interleaved with the receiver grid (source points were offset 3.75m x 3.75m from each receiver point) achieving 9,041 source points. An Envirovibe source deployed on a 30 m x 7.5 m grid achieving 3,910 source points with a single linear sweep of 10-120 Hz over 10 seconds at each location. By acquiring all source points into the all-live receiver spread, a total of 257.4 million raw traces were acquired into this 1 km2 survey (both source types combined), setting a new global record for seismic trace density, albeit on a small scale.

The field crew included mostly graduate geoscientists, a GIS analyst, a biologist, a reservoir engineer, and a seasoned Canadian field supervisor. Not all team members in the field were allocated to layout and pickup as there were other activities being performed. 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.

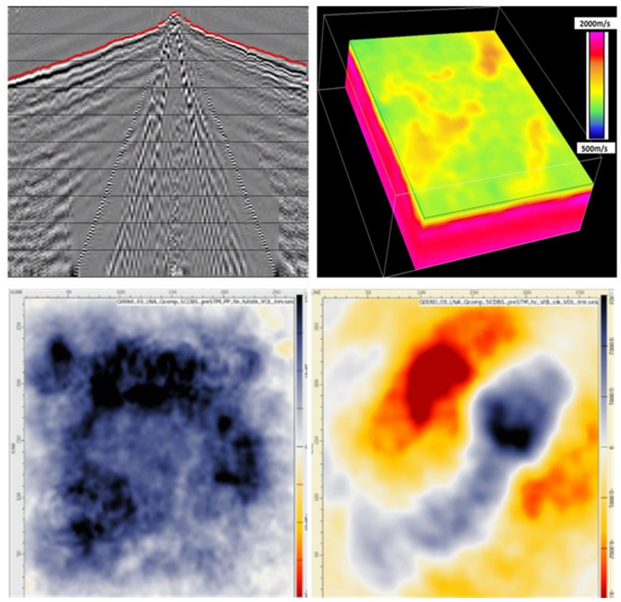

***Figure 5 –** (top) Raw shot records and refraction tomography model, (bottom) shallow time slice at target level from PinPoint sources data (left) and at a deeper level from the Vibroseis data (right).*

PinPoint acquisition averaged 565 SPs per day and the vibroseis, which operated in the evenings, averaged 651 source points per partial night shift. Active source operations ceased prior to commencement of the planned CO2 injection, and the full spread of 19,872 nodes continued recording with no active source for an additional 5 days. This passive data is aimed at exploring the potential use of seismic interferometry in monitoring CO2 injection. The data volume for this 1 km2 survey (including receiver gathers, shot gathers and continuous 24-hour recordings from deployment to retrieval) was just over 78 terrabytes (TB). Data were harvested on the STRYDE Nimble server system and 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 all the source and receive headers for the data processing to start. It also contains a multitude of seismic and engineering headers that are useful to integrate to the conventional QAQC (Crosby et al, 2020).

The active source dataset was processed by STRYDE and went through several fast-track processing sequences to answer requests from the different stakeholders involved in this survey (Ourabah & Chatenay, 2022) at the end of which a full Pre-stack time migration sequence was facilitated to assess the full potential of this outstanding trace density. The results are summarized as follows:

Conclusions

High trace density seismic surveys are the new sought-after designs in seismic acquisitions. Despite their crucial importance in delivering high quality subsurface images and attributes, they have been out of reach for a long time because of the constraints imposed by bulky and heavy cable equipment making HSE and cost unbearable, especially in difficult terrains. The arrival of a new generation of nimble autonomous nodes is creating a paradigm shift in the way these surveys are being acquired, significantly reducing the impact on the environment as well as lowering the cost and the safety exposure. The two examples presented above also show how this new generation of nodes can deliver record breaking trace density and operational efficiency numbers when combined with highly efficient sources. This demonstrate that the end users of the seismic data, whether it is an O&G operator or one of the emerging renewable industries, can acquire the seismic surveys they need rather than the one they can afford.

References

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