DAS-3DVSP Data Acquisition at 2018 Hydrate-01 Stratigraphic Test Well

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ABSTRACT

The use of fiber optic cable as a seismic sensor, Distributed Acoustic Sensing (DAS) to record borehole seismic or Vertical Seismic profile (VSP), has become a common alternative practice largely due to the advancement in the technology and the cost saving. As the entire borehole length is covered by the cable, it only requires a minimal number of source shots to record high density data over the well length. We present here the acquisition of the largest known onshore DAS-3DVSP survey recorded using a single mode fiber optic cable installed permanently in our first methane hydrate research test well in North Slope Alaska. The DAS fiber-optic cable was installed in December 2018 and the 3DVSP survey was conducted early in 2019. Here we present the highlights and some field data examples from the survey.

An intensive survey design and modelling was carried out for this first DAS VSP to be recorded for the hydrate research program. Despite some logistic and weather challenges, a total of 1701 shot points were successfully recorded over 12 days using a commercial DAS interrogator with the seismic source coming from two artic vibroseis trucks, sweeping simultaneously in-phase. The VSP program included sweep parameters testing, prior to the production shooting to ensure optimum seismic energy can be recorded within the limited time window. This has also allowed acquisition decision to be made before the main survey starts. On time data quality control and assurance were carried out at the site. The recorded DAS data were of high quality and high energy content up to 180Hz.

It is our hope that the 3D VSP data will help to evaluate the methane hydrate reservoir quality and confirm local structural heterogeneity around the potential production well location.

Keywords: gas hydrate, distributed acoustic sensing, DAS, 3DVSP

1. INTRODUCTION

Distributed acoustic sensing (DAS) is a technology that uses Rayleigh scattering in a fiber-optic cable to detect acoustic signals along the path of the sensing fiber (Hornman et al., 2013). Any type of fiber cable can be used in conjunction with an interrogator unit to record VSP, although single mode fiber is preferred due to less attenuation losses. The interrogator unit acts as a source laser pulse and detects the Rayleigh backscattered light to measure the strain along the fiber.

One of the key advantages of DAS is the ability to record acoustic signal over the entire fiber length or well length with a single shot. This reduces the time required to move the sensors in the conventional point-sensor measurements, such as the wireline deployed geophone array tool. However, DAS is a single component measurement; therefore its sensitivity is reduced with offset or arrival angle.

2. PRE-SURVEY DESIGN AND DATA ACQUISITION

The DAS VSP survey objectives were to obtain i) time-depth velocity and seismic tie; ii) High resolution imaging around target reservoirs and iii) Structural characterization of the test site for geo data well and production well placement.

The first task once the basic shooting configuration has been established, which is a spiral centered around the midpoint of the effective DAS length, is to perform a simulation using a velocity model constructed from the Logging-while-drilling (LWD) logs obtained at the well (Haines et al., 2020). An approximation of a flat snow thickness and no travelling restriction on tundra were made for this modelling exercise, as these conditions can be known only a few days ahead of the operation.

The VSP logging program consists of vibroseis parameters testing to confirm best sweep parameters, prior to the vertical incidence VSP (VIVSP) along the well path and 3DVSP. A spiral shooting pattern was adapted for this 3DVSP survey. To avoid vibroseis trucks crossing the pipeline multiple times, the northern section was surveyed first then followed by the southern section, as indicated by the void area in Figure 2. The shooting started from near borehole, and moved radially away from the well pad.

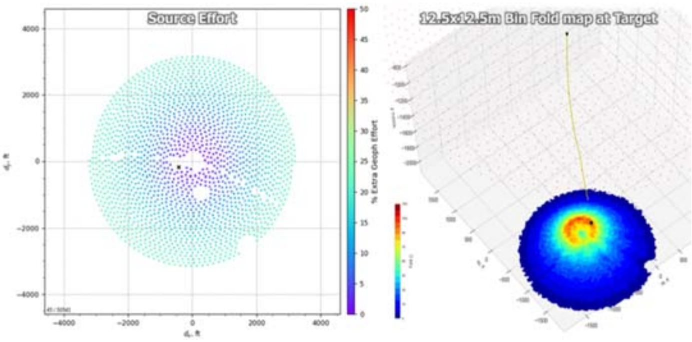

Figure 1. The modeling result shows the source effort as distance function from well centre (left) and bin fold map for primary target reservoir.

A total of 1701 shot points were successfully recorded from the planned 1740 shot points. The acquisition parameters are summary in Table 1.

Cable type	Single mode
Gauge Length	10m
Operation days	11.75
Cable Total Depth	3450 ft
Channel spacing	1m
Number of levels	972
No. of Vibro Source	2 x AHV-IV
Sweep Frequency / length	2 – 200Hz / 20 s
Sweeps # per station	10 – 20
SP Interval	Variable offset spiral
Sampling Rate	1ms
Total SP recorded	1701 [1740]

Table-1. VSP acquisition parameters:

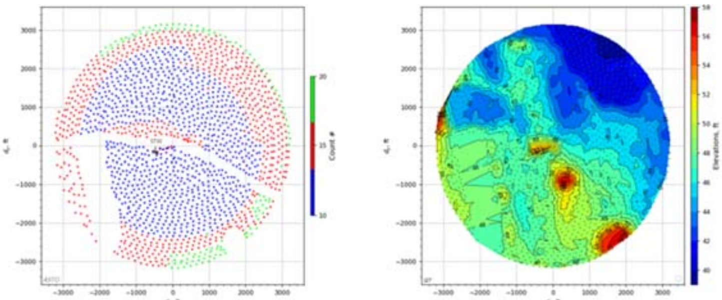

Figure 2. Acquisition layout with sweep count per location (left) and ground elevation map (right).

3. QC AND FIELD DATA EXAMPLES

Data QC and quick processing were carried out at site to validate the data and acquisition parameters. We presented here some of the field processed results.

The reflected energy from the target Unit-B and Unit-D are clearly visible on the raw stack gather (Figure 3). Mode converted shear energy is also visible on this near offset gather. It also has content wide energy bandwidth, up to 180 Hz.

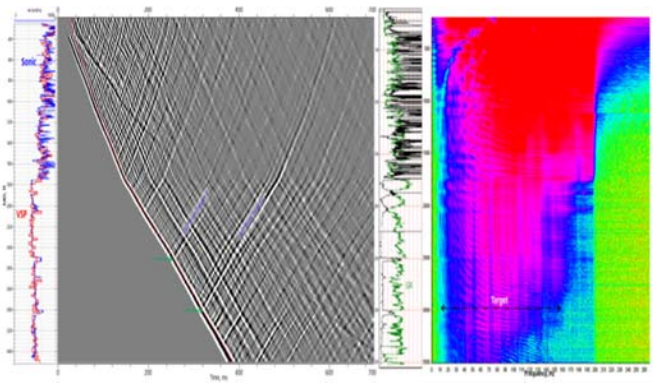

Figure 3. DAS Vertical Incidence VSP (VIVSP) raw stack waveforms with LWD sonic and gamma ray logs. Amplitude spectrum is shown on the right panel.

The data QC includes randomly monitor the signal to noise ratios (SNR) of the stacked waveform at each station (Figure 4). 3DVSP QC examples are presented in Figures 5, 6 and 7.

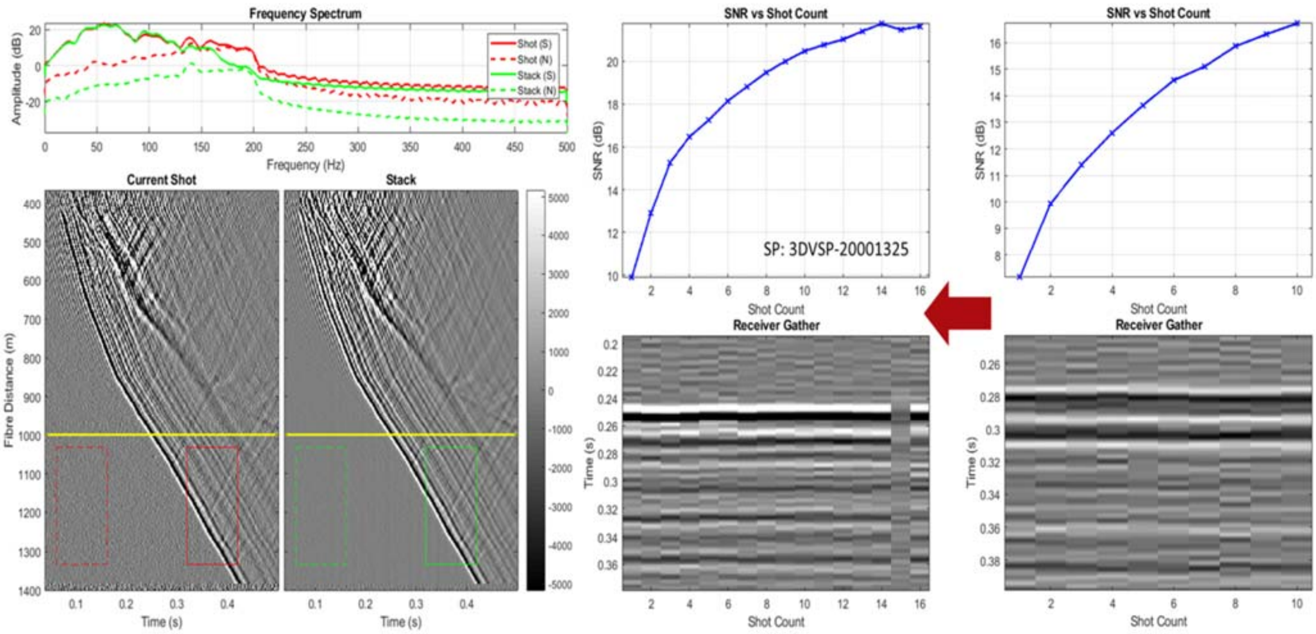

Figure 4. Data QC with SNR analysis to ensure sufficient shots and stacked are collected for each distance.

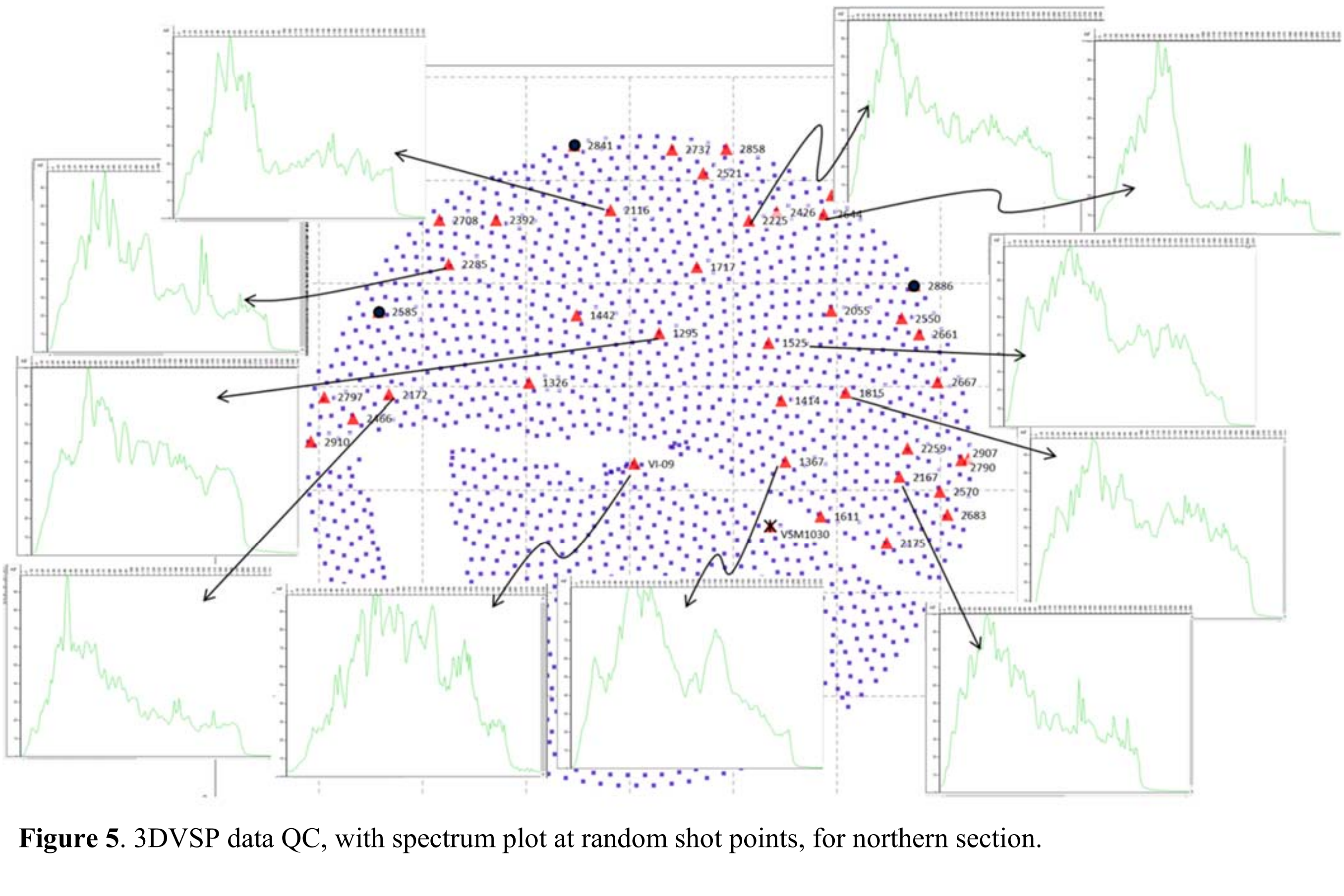

Figure 5. 3DVSP data QC, with spectrum plot at random shot points, for northern section.

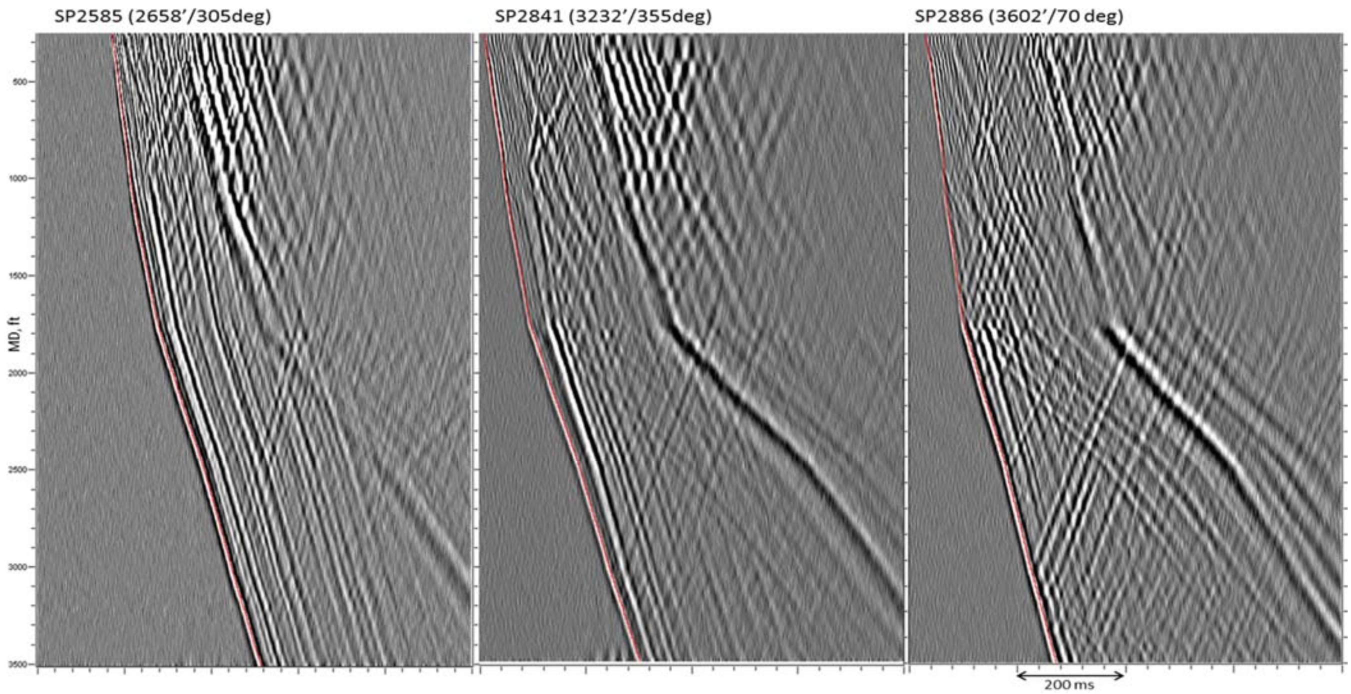

Figure 6. Common source gathers a three difference azimuths showing varying Ps and diffraction energy content.

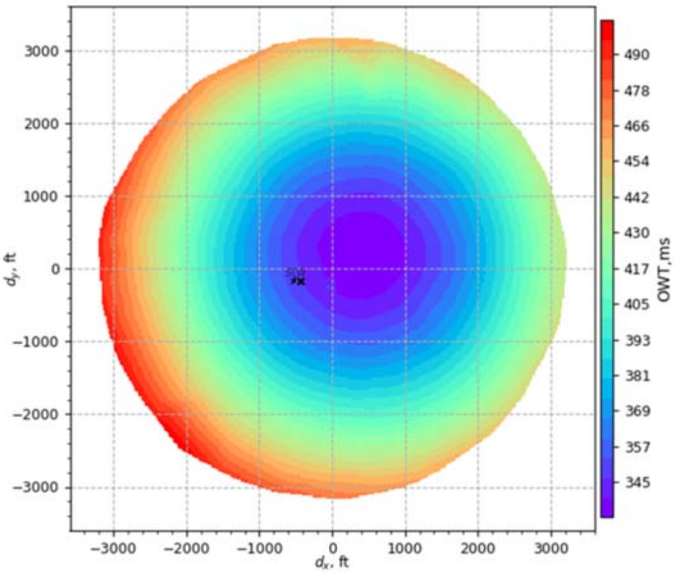

Figure 7. 3DVSP transit time QC map for receiver at 3010 ft MD, just below the target Unit-B.

4. QUICK RESULT

The quality of this first DAS 3DVSP recorded for hydrate research is very good. Checkshot time-depth function obtained from the VIVSP tied very well with the acoustic logs. Seismic matching between the logs-VSP-surface seismic is also very good. Initial 3DVSP processing result has revealed some structural features. which were not obvious on the surface seismic. This gave confidence to utilise DAS VSP for the geo data well and production well planning.

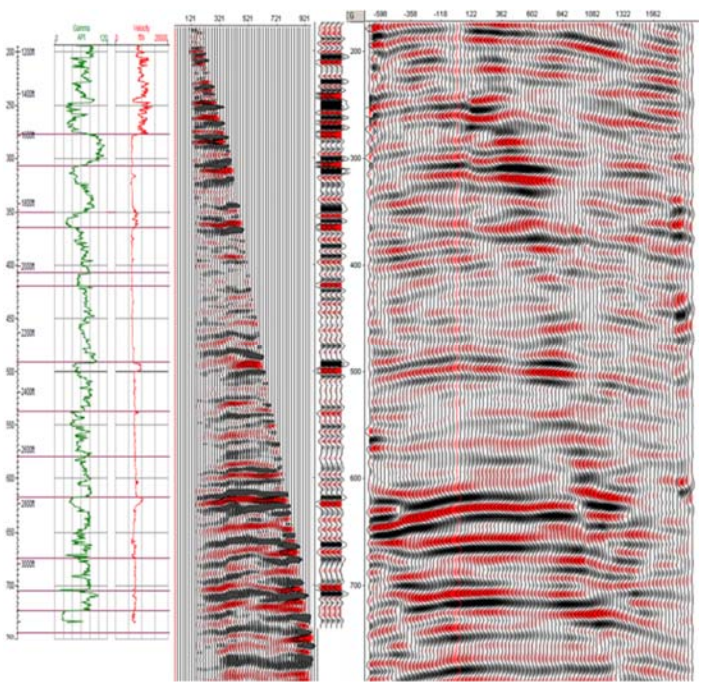

Figure 8. From left to right are the LWD logs, VIVSP high resolution P image, synthetic seismogram created from the compressional acoustic logs and 3DVSP CDP mapping result in same well plane.

5. CONCLUSION

We have presented here briefly the acquisition of the largest onshore DAS 3DVSP for Methane Hydrate research. Careful pre-survey planning and collaboration from all parties involved at the well site are keys to the success of this survey. Despite the extreme conditions and additional source effort requirement, 98% of the survey points were recorded within the tundra opening time frame. Although not presented here in detail, initial processing of the DAS VSP data have shown great potential by revealing the sub-fault system that are not presented in the surface seismic data.

6. ACKNOWLEDGEMENTS

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