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Gini 3D High Productivity Blended Acquisition – A case study from the Delaware Basin

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Summary

High density, high productivity surveys that utilize blended acquisition techniques in the Middle East have established the next step in land acquisition survey design and operations. The Gini 3D survey, acquired in the summer of 2018 in the Delaware Basin, provided a test area for which this type of design and acquisition could be tested and compared with traditional operations used onshore US. The test was planned to be operationally efficient & cost effective (in terms of equipment), specifically the goal was to improve trace density as much as we could while staying within realistic commercial prices (within 20% of the original cost). The second purpose was to prove that resulting blended acquisition can be more effective than traditional designs in terms of imaging. Operationally the test exceeded expectations and with processing still ongoing, initial results show that the two designs are comparable.

Introduction

Recent acquisitions in North Africa (Saleh et al., 2017; Yanchak et al., 2018) along with processing tests (Pastori et al., 2016) have proved that high density surveys do provide uplift in data quality compared with traditional survey designs which rely on multiple vibrators per fleet. The move to single vibrator, higher trace count and, in particular, increased source density has also necessitated the move to autonomous vibrator shooting, using blended acquisition techniques.

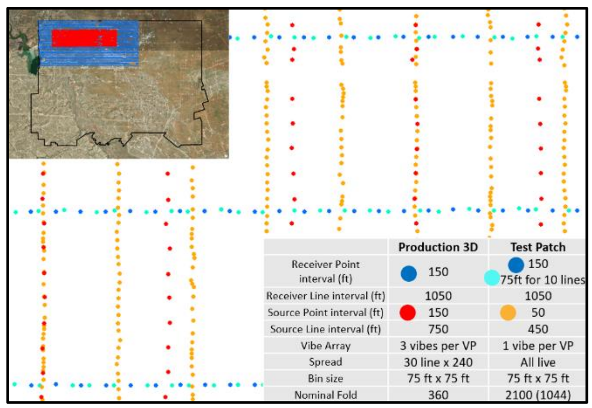
In many areas in the US, permitting costs and damage claims are one of the primary costs of the overall project expenses for the survey, often exceeding the actual cost of the recording crew. As a result, acquisition in the US has been slower to follow the high source effort, carpet-shooting trends that are more commonly seen in the Middle East, due to the costs and difficulties associated with permitting landowners and paying damages.

The Delaware Basin is one area where limitations on source density can be explored further. This basin has traditionally been difficult to image due to the scattering effect of the near surface (Maley and Huffington, 1953), and could be improved with higher trace density and increased fold.
This is one reason why a test was considered in this area to see if a move to single autonomous vibrator acquisition could provide equivalent data quality to a traditional survey design and acquisition, while still being cost effective for operations.

Design and Planning

In recent years, with advances in nodal acquisition, equipment movement is getting faster and cheaper. Vibroseis has become more mainstream in most areas, and due to the cheaper per shot cost relative to explosive sources, source effort has also been reduced to a single sweep. Together with slip sweep acquisition this has improved productivity and allowed for tighter source and receiver spacings.

The Gini 3D production survey was acquired with vibroseis over a total area close to 500 sqm. Trace density was higher than legacy surveys by a factor of 2.2 with WAZ design and receiver and source point spacing of 150 ft and line spacings 1050 ft and 750 ft respectively.



	Production 3D	Test Patch
Receiver Point interval (ft)	150	150 75ft for 10 lines
Receiver Line interval (ft)	1050	1050
Source Point interval (ft)	150	50
Source Line interval (ft)	750	450
Vibe Array	3 vibes per VP	1 vibe per VP
Spread	30 line x 240	All live
Bin size	75 ft x 75 ft	75 ft x 75 ft
Nominal Fold	360	2100 (1044)

Figure 1: Location of the test within the survey area, and the design and layout parameters for the production and test.

The test area was a patch design in the North West corner of the survey with a receiver extent of 108 sqm and source patch in the middle of 26 sqm, resulting in a CDP coverage area of close to 60 sqm. The design for the test patch (Figure 1) utilized the existing production spread with a receiver patch made up of 36 receiver lines of 345 stations, and a central source patch of 118 source lines by 272 VPs spaced at 50 ft. To add extra variety for 5D interpolation and regularization, extra receivers were interleaved on the middle 10 receiver lines. The source lines alternated regular 50 ft spacing and randomized spacing on a 17.5 ft grid.
As all the receivers in the patch were live, the fold exceeded 2200 per bin, however when restricted to the same spread as production, the equivalent fold was 1044 in a 75 x 75 ft bin vs 360 for production.

The same sweep was used for both the production and test; a broadband EmphaSeis 3-96 Hz, 30 sec sweep. The

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production data was acquired with four fleets of three vibrators using slip sweep acquisition (12s slip). The test data was acquired with autonomous single vibrator stakeless blended acquisition, with individual vibrators shaking independently, and no control or triggering from the recording system.

In terms of imaging expectations, it was envisioned that the test data would be on par with the production data even though signal source estimate calculations (Meunier, 2011, p116, equation 24) were theoretically 3dB down compared with the production data. It was hoped that the higher density would outweigh the blending and single vibrator limitations in terms of energy per shot point, as had already been seen in other tests undertaken in the Middle East (Huo, 2011).

Field Operations

Acquisition of the test data was carried out after production had finished in the NW section of the survey area.
Although the test acquisition was acquired into a patch, the main aim of the test was to see if single autonomous vibrator acquisition could be used in the field and if the increase in trace density accounted for the loss in single VP strength; not to compare equipment rotation along with the single vibrator acquisition. As the spread was fully laid out by the end of block, the field crew was also not limited by equipment rotation for the production patch of sources that was acquired in the same area as the test.

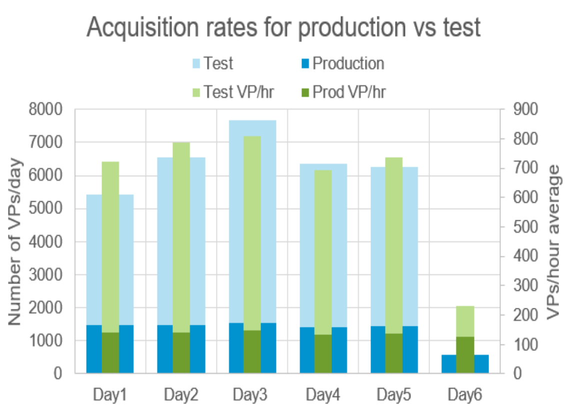

Figure 2: Daily production rates for the same area that was acquired for the 3D survey vs test area, including average VPs per hour.

It was assumed that by going to single vibrator acquisition compared to the array of three vibrators, the rate of acquisition would at least triple, with maneuverability of single vibe fleets also allowing for faster acquisition rates. There were 15 active single vibrator fleets for the test, whereas normal production used up to four fleets of three vibrators.

As the test recording was autonomous, the recorder was not triggering the source, and the vibrators were starting whenever they were ready. Hence, one of the main requirements for the test was to record the GPS time for each record. This meant recording the GPS timestamp of the start of the sweep in every vibrator was paramount, so the data could be deblended in processing. This was achieved with the force 3 vibe electronics, with the force files also being recorded into nodes that would act as auxiliary channels for every vibrator.

A couple of problems occurred during the acquisition, with a different sweep being used on a couple of vibes (vibrator signatures were recorded, so this was not a major problem), and also one vibe that didn’t record any force files one day. Timing information for the sweeps were available, however for consistency, the VPs were acquired again.

Production rates exceeded expectations and the crew achieved a maximum production in excess of 800 VPs per hour during a 10-hour period (Figure 2) even though they shut down early that day due to weather. This proved that even in areas with facilities, having multiple fleets of vibrators that are autonomous does allow for faster and more efficient movement around obstacles.
The area of the test was acquired in the same amount of time as the production area, even though there were four times the number of VPs.

Processing and Results

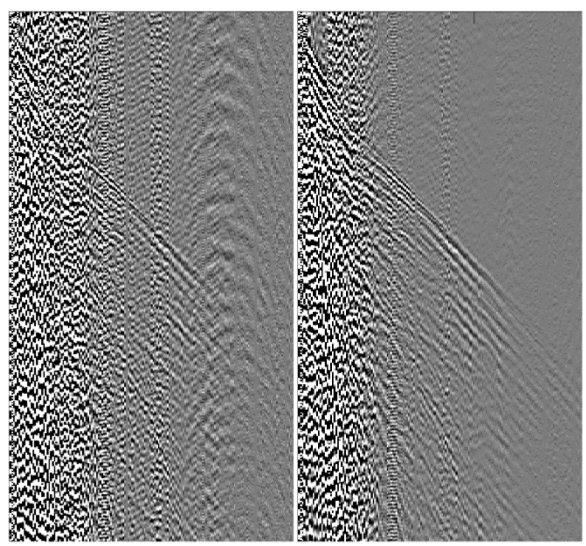

Figure 3: Raw correlated shot comparison between single vibroseis (left) and 3-vibe array (right).

Figure 3 shows the comparison between a shot recorded from a single vibroseis point versus a 3-vibe array. As less

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energy is sent into the ground, the signal-to-noise ratio is not as good on raw shot from the test data as it is on the production survey.

However, it is expected that the denser shot point grid should be able to compensate for the lower signal strength. The success of such acquisition allowing each vibroseis to sweep independently obviously depends on how well we can separate energy coming from each shot point. For deblending, we used the approach presented by Guillouet et al. (2016) making use of curvelet transforms and promoting sparsity in output data. Figure 4 shows a shot before/after deblending and the blended energy removed.

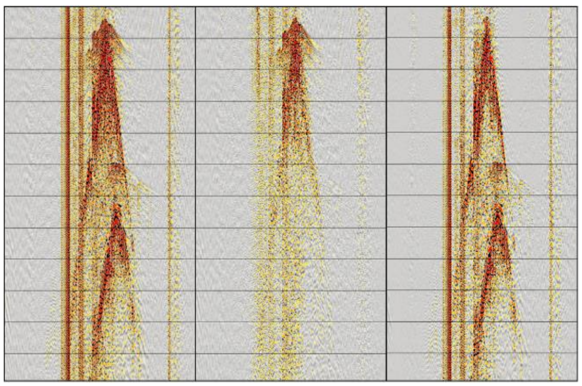

Figure 4: Raw correlated shot before deblending (left), after (middle) and difference (right).

After some basic processing (denoise, surface consistent scaling and deconvolution), the test imaging sequence initially involved a post-stack migration to get preliminary results in a timely fashion. The slip-sweep baseline production data was trimmed to the test area and processed in parallel with the same processing sequence for a comparable reference product.

Figure 5 shows the migrated stack of the simultaneous survey on left and the slip-sweep baseline data on right. The denser test data, despite the use of single vibroseis, clearly shows better S/N ratio and resolution, especially for shallow reflections. Shallow signal continuity is enhanced due to higher trace density and reduced source interval providing better near offset population.

The purpose of the Fast-Track processing was to quickly assess signal quality and reflection continuity with autonomous single vibroseis survey, where refraction & reflection statics, along with velocities were mostly derived from the production slip-sweep baseline. The next step will be to evaluate whether first break & velocity picking can be reliably performed on lower energy shot records. Using recommendations from other similar surveys, data might be stacked into super shots or super gathers to provide stronger and more continuous refractions and reflections.

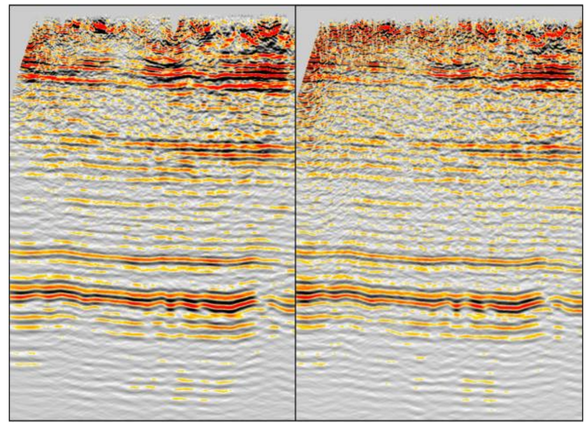

Figure 5: Fast track post-STK migrated volume of simultaneous shot survey (left) and baseline slip-sweep production data (right). The denser test data, despite single vibroseis points and blended seismic, exhibits better signal continuity, especially in shallow.

Conclusions

Operationally the test was a success with production rates exceeding expectations, and field operations progressing smoothly. The test proved this type of acquisition is feasible in the lower 48.
In terms of pre-processing, the deblending process was successful in separating the blended acquisition data. In terms of imaging, the shallow data looks better as expected with the higher fold. Utilizing the production processing flow, and applying this to the test data shows comparable reflection quality.
More work needs to be completed on the final processing comparison to optimize individual workflows to access how well independent processing would compare on each dataset.

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