Hexasource compact source acquisition for improved imaging in an OBC campaign across the Edvard Grieg field

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Summary

The popularity of using more and smaller sources, often referred to as distributed source acquisition, has grown over the last few years. The standard towed marine seismic source is now more often triple or more, compared to large dual-sources just a few years ago. This paper presents a full hexasource small compact array acquisition test compared to a standard large dual-source setup in an OBC setting. Results are very favourable, especially in the shallower part of the data. Further processing is expected to push this spatial uplift all the way down and into the reservoir zone at 1900ms. In order to study the effect of simultaneous or blended acquisition, the test data was acquired with two small sources per sail line pass and each line was acquired 3 times. This way, three sail lines can be combined and blended into a single full hexasource line with 1.8s shot point interval.

Introduction

This paper describes and presents a full 3D OBC field test using a hexasource small compact seismic air-gun array. The topic of using smaller, more compact arrays was addressed in a similar setting by Dhelie et al. 2017, but this was merely along a single 2D shot line and the source configuration used was not optimized. The inherent three dimensional focusing effect from a point like source output was also challenging to investigate in a 2D setting. This 2018 field test used a full hexasource compact array design as well as covering a small 3D swath of data, consisting of four full conventional shot lines and 12x2 hexasource lines. With six sources, replicating a dual-source setup of 12.5m flip/flop, the six sources must be fired within 25m to retain the fold of the data. This requires a shot point interval of only 4.16m (25m/6) or approximately 1.8s at 4.5 knots. Deblending the shot data is therefore a pre-requisite for this technique to match the dual-source setup. In order to study the blending and deblending, this field experiment was designed and acquired using only 2 sources, but each line was shot three times. This way we possess a dataset with 5.5s clean unblended records, that can be mixed or blended into any shot interval close to 1.8s to match the subsurface location in a real hexasource acquisition setup.

Improving seismic resolution of OBC data at the Edvard Grieg field

The Edvard Grieg field is situated in the North Sea, some 200km west of the city of Stavanger. The water depth is ~110m and the field was discovered in 2007 by Lundin Norway. Throughout the last 10 years, a number of seismic campaigns and tests have been performed in order to improve the seismic image quality. The reservoir is at approximately 1900m depth (1800ms TWT) and as such, overcoming the loss of high frequencies due to attenuation (Q) is not a trivial task. Most of the various seismic technologies tested, GeoStreamer, BroadSeis, OBC Q-Marine, IsoMetrix to name a few mostly address the receiver side (Lie et al. 2016 and Dhelie et al. 2014). It was not until 2016 when we performed the first point source tests that we started to investigate and challenge the seismic air gun setup. Motivated by some encouraging 3D site survey results acquired with very small seismic sources (~160in^3) we decided to investigate and test using compact smaller air gun arrays for a conventional large OBC survey (Dhelie et al. 2017). Results and further investigation of smaller point sources led us to perform a new test this year using even smaller and more compact point-like sources compared to our initial designs. The conceptual idea is simply that we believe that by distributing the same source inventory from a single large ~3500in^3 source covering 15x15m area, provides a much improved image if used as 6 or more sources of ~1000in^3 each covering only 1x6m. A small point source design will avoid spatial smearing of the output signal and increase the possibility of retaining higher frequency signal at 1900ms TWT.

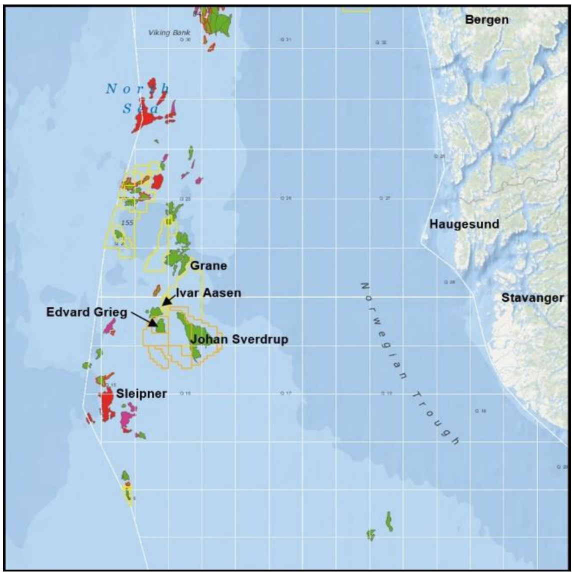

***Figure 1** Map showing the location of the Edvard Grieg field. The field is located on the Utsira High in the North Sea.*

Modeling of the compact source array

Conventional marine air gun sources are design and optimized around a few key items. Maximizing the peak-to-bubble ratio, maintaining a few large cluster guns and having enough spare guns to be able to swap guns if some should fail. Reducing the source from ~3000in^3 down to less than ~1000in^3 will naturally inflict on some of these criteria. With fewer guns, maintaining the peak-to-bubble ratio is difficult as less variation between single gun volumes will lead to less variation in the bubble times. In order to maintain the low frequency output strength, it is important to keep at least one large cluster gun

~250x2. For practical purposes and to save gun reconfiguration time, moving many guns around was deemed unnecessary for this test, but in order to focus the source output, including the effect of the source ghost, it was necessary to reduce the source depth from 8 to 5m. Therefore, the experiment involved recovering the full dual-source gun arrays, reconfiguring them from 2x3147in^3 down to 2x875in^3 as well as swapping the depth ropes from 8 to 5m. The resulting compact single string used consisted of only 5 guns, providing a total single source volume of 875in^3. Figure 2 shows the source layout of both the large conventional air gun string and the small compact 875in^3 used for the hexasource acquisition. The conventional dual-source consisted of three sub-arrays with an areal size of 15x15m whereas the hexasource single string only occupies 1x6m.

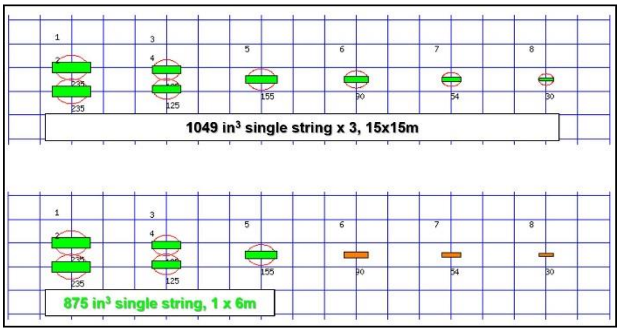

Figure 2 *Airgun source layout comparison between a single conventional large sub-array and the compact 875in^3 5-gun sub-array used for the hexasource acquisition.*

Full scale 3D hexasource field test

The field test described in this paper was performed directly following and during a larger ongoing OBC 4D campaign across the Edvard Grieg field in 2018. Figure 3 shows the conventional large source positions compared to the hexasource shot positions. There are 3 times as many hexasource shot locations, as there are dual-source locations. The receivers were placed on the seafloor with 200x25m spacing and recorded as 4C, Pressure, X, Y and Z. In order to obtain a fully unblended dataset the hexasource setup was acquired as 12.5m flip/flop shooting, using two single small sub-arrays, interleaved and acquired as three individual sail-line passes. Each sail line was shifted 2 x xline source distance, to simulate a full hexasource towing configuration. These three passes are then blended together to form a single complete hexasource line. The nature of this acquisition design allows us to have at hand the unblended data prior to performing blending and subsequent deblending in processing. The drawback is of course that the background noise level will be recorded three times and as such by blending the data in processing the background noise level with be added together instead of being recorded only once. Details of how blended acquisition improves the signal-to-noise ratio can be found in Berkhout and Blacquière, 2013.

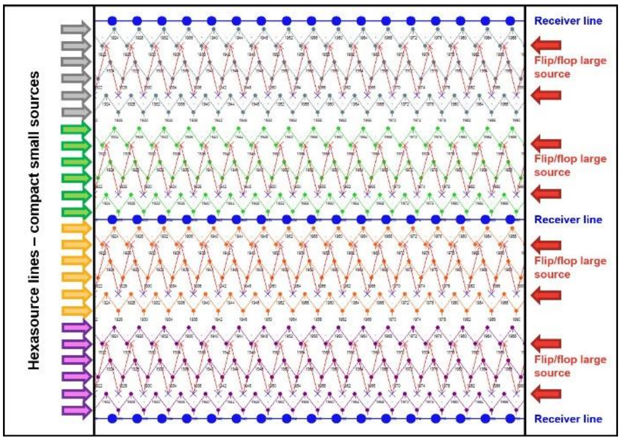

Figure 3 *Source point locations for the hexasource and the dual-source configurations compared in this study. There are 3 times as many hexasource locations as there are dual-source.*

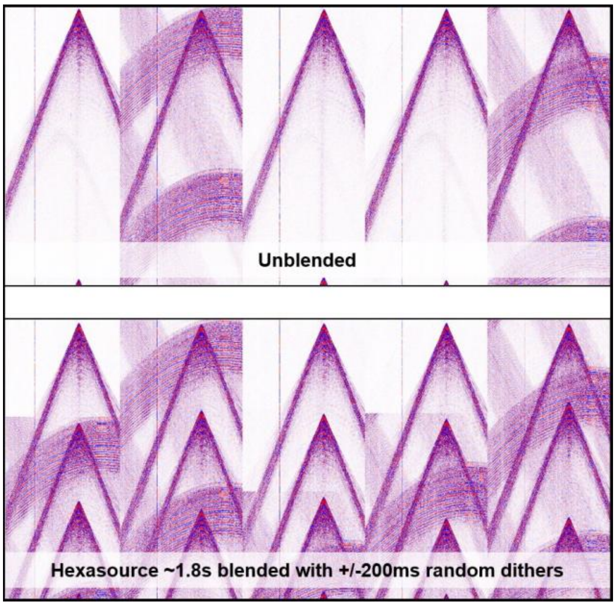

Figure 4 *Shot gathers from the compact small source acquisition as acquired and after hexasource blending.*

The source blending matrix

A major component, and still one with a general concern in the industry today, is the effect of distributed source acquisition when deblending inside the target interval is a pre-requisite. In order to maintain the fold in the CMP domain, it is necessary to retain the shot point interval between each single source fired. For the conventional setup, this was 25m (12.5m dual-source flip-flop). For the hexasource, this needs to be reduced to 25/6=4.16m. In time domain, this represents approximately 1.8s assuming an acquisition speed of ~4.5 knots. With a shot interval of only 1.8s between consecutive sources fired this will lead to overlapping shot records and deblending the data directly in the target level is required to obtain good image results. As this test was performed with only two sources mimicking six sources, we need to blend two and two shot lines into each other with an appropriate blending time. This consisted of measuring the time between each actual shot fired and adding in two other shots from the two other sail-lines to build a new dataset with six sources, blended at 1.8s interval. An additional dither of +/-200ms was added to increase the randomness between the blended shots for optimum deblending. The spatial blending matrix is as such represented as a real hexasource acquisition layout with 50/3=16.66m xline source separation and 25/6=4.16m inline shot point distance. The temporal blending matrix is dependent on the source vessel speed, but at ~4.5 knots this is approximately ~1.8s shot point interval with an additional dither of +/-200ms. Figure 4 shows the hexasource shot gathers as acquired during this test both before and after the blending process. Notice also the seismic interference (SI) noise in the shot gathers that was present during the acquisition. In order to not sum the same SI noise into the hexasource data three times, this must be removed prior to blending the data.

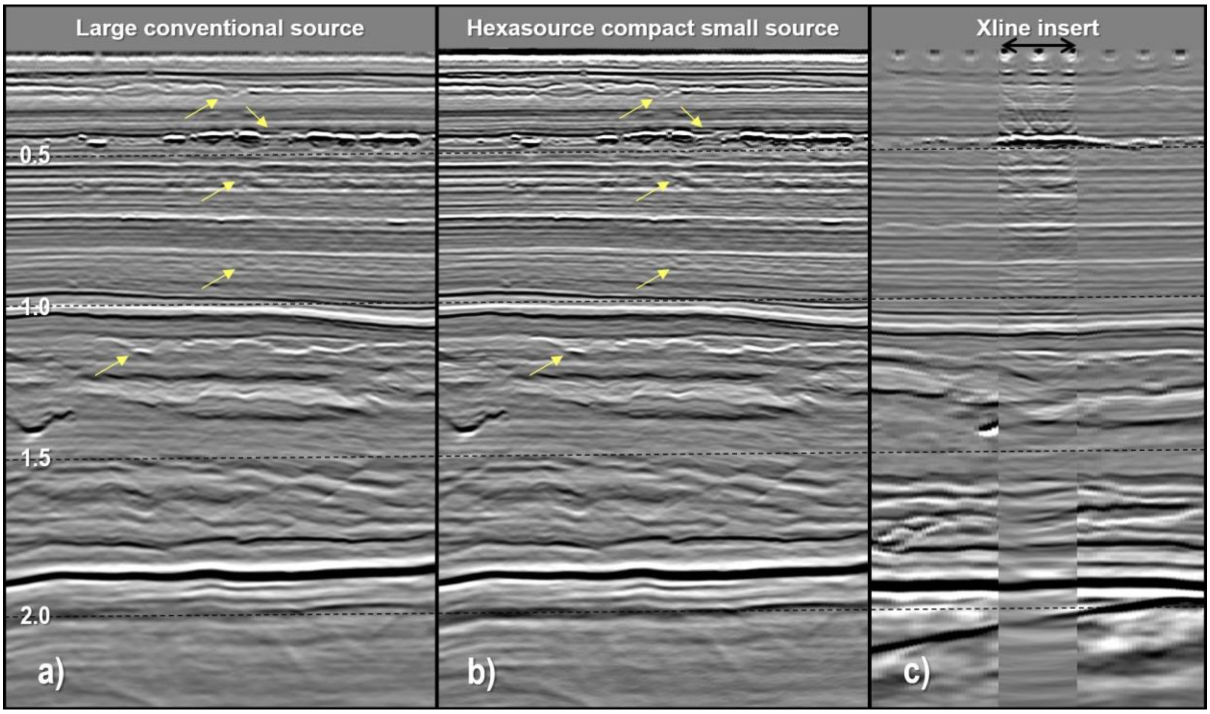

Figure 5 *Inline comparisons between the large dual-source (a) and the compact small hexasource (b) data after 3D migration. c) shows a xline insert from the hexasource into the dual-source. The spatial resolution increase is easily seen in the shallow part, but also quite deep into the data, the improvement is clear. The data is so far only processed using a simplistic sequence and further uplift is expected.*

Results

Due to the nature of the test and the way it was acquired, a substantial amount of data comparisons can be generated and studied. Small vs. large, blended vs. unblended, using larger or smaller bins depending on the number of shot lines used in the blending and also shorter vs. longer dither times. These parameters can again be combined in various ways such that the amount of comparisons and effects to study are almost unlimited. For this paper we have chosen to present a few key items.

Figure 5 shows inline and xline comparisons between the conventional dataset and the hexasource dataset, but processed without any blending or deblending. This should ideally demonstrate the greatest possible uplift using smaller, more compact sources distributed as six dense sources compared to two large conventional arrays. It is clear from the comparisons that there is obvious merit in distributing the same source inventory into six distributed hexasources instead of only two large flip-flop sources. The yellow arrows point towards areas where the hexasource provides greater spatial details compared to the dual-source. The xline insert image, Figure 5c, shows a clear uplift in detail, especially in the shallow part, but also as deep as ~1500ms the uplift is clear.

Conclusions

Distributed source acquisition using six small compact sources (hexasource) has been tested and verified across the Edvard Grieg field in a full 3D OBC setting. The smaller more compact sources increases the spatial detail in the data, specifically down to ~1.5s TWT, however further processing is expected to bring the uplift all the way into the reservoir zone at ~1900ms. Blending and deblending is still in progress but results from previous tests raise no concern over this step. Going forward the industry is likely to see a lot more distributed source acquisition projects using smaller more compact sources for increased spatial resolution in the seismic data. It is worth noting that there is no need for additional or more equipment on the source vessel. It is simply that instead of firing 6 sub-arrays as two large sources, you fire them each as six individual small compact sub-arrays. The lower peak pressure output from the small sources also gives less environmental impact and as such has a positive HSE aspect.

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