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Wide Azimuth Tow Streamer Acquisition: from Exploration to Field Development

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Summary

Marine 3D wide-azimuth towed streamer acquisition methods have provided signifiant improvments in seismic imaging of deep water sub-salt reservoirs in the Gulf of Mexico. The intial surveys were designed to provide very dense trace sampling. Subsequent to these successful field specific surveys, wide- azimuth acquisition designs have been developed to allow cost effective use of the technique over large areas for exploration objectives. This paper will describe a "sparse" acquisition configuration that has been derived from the source / receiver geometry used on the Mad Dog survey for BP. This design allows a full suite of data densities from the initial first pass for the exploration objectives to successively appended additional data acquired through the appraisal and management phases of field development.

Introduction

The first wide azimuth towed streamer surveys shot in the Gulf of Mexico were targeted at overcoming seismic imaging difficulties at specific sub-salt reservoirs like Mad Dog (Michell, et al) and Shenzi (Howard and Moldoveanu). These surveys were designed to densely sample the sub-surface from a grid of surface shot locations that would generate a set of seismic data traces with a wide range of offsets and azimuths relative to a set of receivers towed from a multi-streamer 3D seismic vessel. As the preliminary images from these early wide azimuth acquisition efforts were presented at various technical meetings and workshops, it quickly became apparent that the wide azimuth data were providing superior sub-salt images compared to conventional narrow azimuth towed streamer data acquired over the same areas. With that in mind, a number of contractors looked for ways of reducing the considerable acquisition efforts applied on the field development programs while maintaining the main imaging benefits of the wide azimuth technique. The motivating objective for designing a technically viable, cost effective, "sparse" wide azimuth towed streamer acquisition method is the ability of applying the technique over large areas as a valuable tool in the exploration for deep-water sub-salt prospects, not just in the Gulf of Mexico but worldwide.

To that end, a marine wide-azimuth acquisition configuration has been designed that will produce +/- 8,100 m inline split- spread sampling with 2,000 m of cross-line offset on a 150 m by 500 m shot grid with just a single pass of the acquisition spread. Additionally, the same shot locations can be reoccupied on a second pass to append an extended range of cross-line offsets to the can be covered economically for exploration purposes and then additional data can be appended to extend imaging quality through the appraisal and development stages of new discoveries.

Method

Conventional 3D marine towed streamer surveys employ single or dual sources at the head of a linear array of receivers composed of multiple streamer cables arranged side by side. This type of source/ receiver geometry produces a very narrow range of azimuth sampling at all but the very near offsets (Figure 1). This type of narrow azimuth acquisition geometry does not do a very good job of sampling the 3D seismic wave- field and in areas of structurally complex geology the limited azimuth sampling generally leads to poor seismic images.

In order to increase the range of azimuths sampled with marine streamers, especially in the cross-line direction, a source, or a set of sources, has to be positioned somewhere to the side of the streamer- spread (Figure 2).

For the Mad Dog survey, BP designed an acquisition configuration with sources located at the front and rear edge of an 8,100 m long by 4,000 m wide receiver grid. As this spread moves along a shot line, the rear source eventually occupies a shot location sampled with the front source. The two shots at the same location produces a gather of traces with +/- 8,100 m of inline offset and 4,000 m of cross-line offset (Figure 3).

In order to produce a streamer receiver grid 4,000m wide, the BP design envisioned a vessel towing thirty-two (32) streamers with an inter-streamer separation of 125 m. However, since there are no seismic vessels capable of towing a streamer spread that large, the full receiver grid was built up from successive passes of a vessel towing eight (8) streamers separated by 125 m (Threadgold, et al). Therefore, each 1000 m increment of cross- line offset required a dedicated transit of the streamer vessel for each shot-line. In the case of the Mad Dog survey, the streamer vessel sailed through the survey area four times for each shot- line.

Initial images resulting from the Mad Dog and Shenzi surveys were first made public during industry workshops in the summer of 2006. Comparisons to images from the same areas generated from conventional narrow azimuth streamer surveys showed a dramatic improvement in sub-salt image quality from the wide azimuth acquisition. This increase in image quality has generated a lot of interest across the industry in using these non- conventional marine acquisition techniques for a variety of applications in provinces all over the world.

However, for these techniques to be widely adopted the time and cost of acquisition has to be shortened and lowered compared to the time and cost of the first surveys. With that in mind many contractors have come up with wide azimuth acquisition designs that can be applied over large areas and at lower costs then those applied on the early field specfic surveys. The main efficiency feature of all of these new designs is to reduce the number of passes the acquisition spread has to complete to acquire a desired range of crossline offsets.

One method being adopted in the Gulf of Mexico is to use lateral separations between mulitple sources to generate crossline offsets instead of building up wide receiver arrays with multiple passes of a streamer vessel towing a sub-set of the desired final receiver patch. Figure 4 shows a schematic of a design using four (4) source vessels. Two sources are arranged at the front and rear edge of a receiver spread composed of ten (10) 8,100 m long streamers with a lateral separation of 100 m between streamers. These sources produce the first 1,000 m of cross-line offset. The other two sources are located in the same front-to-back formation but with a lateral offset of 1,000 m relative to the first set of sources. These sources produce the next set of cross-lines offsets between 1,000 m and 2,000 m. So, with this configuration 2,000 m of cross-line offset can be acquired with one pass of the acquisition spread compared to two passes required on the Mad Dog survey. On a shot-line per shot-line bases this technique reduces the required number of sail-lines by a factor of two.

This four-source technique also allows additional cross-line offsets to be appended to the first pass data by making a second pass with the streamer vessel being positoned an additional 2,000 m from the source vessels compared to the first pass. The sources are then naviagted to the existing shot locations and the additional lateral offset between sources and receivers will add cross-line offsets between 2,000m and 4,000m to the existing shot gathers.

Conclusions

During the last year a number of images from towed streamer wide azimuth surveys have been presented at industry workshops and technical conferences. In all cases, comparisons with images generated from conventional narrow azimuth surveys show a significant uplift in wide azimuth image quality, especially below salt.

The four source technique presented above is an example of an acquisition configuration designed to provide the major benefits of wide azimuth imaging in time and cost efficient fashion. For exploration objectives datasets incorporating 2,000 m cross-line offsets can be acquired with only one pass of the acquisition spread.

As exploration discoveries are made, additional data acquisition efforts at existing shot locations can produce a wider range of cross-line offsets and/or closer spaced shot lines to enhance image quality to meet appraisal and development requirements.

Acknowledgments

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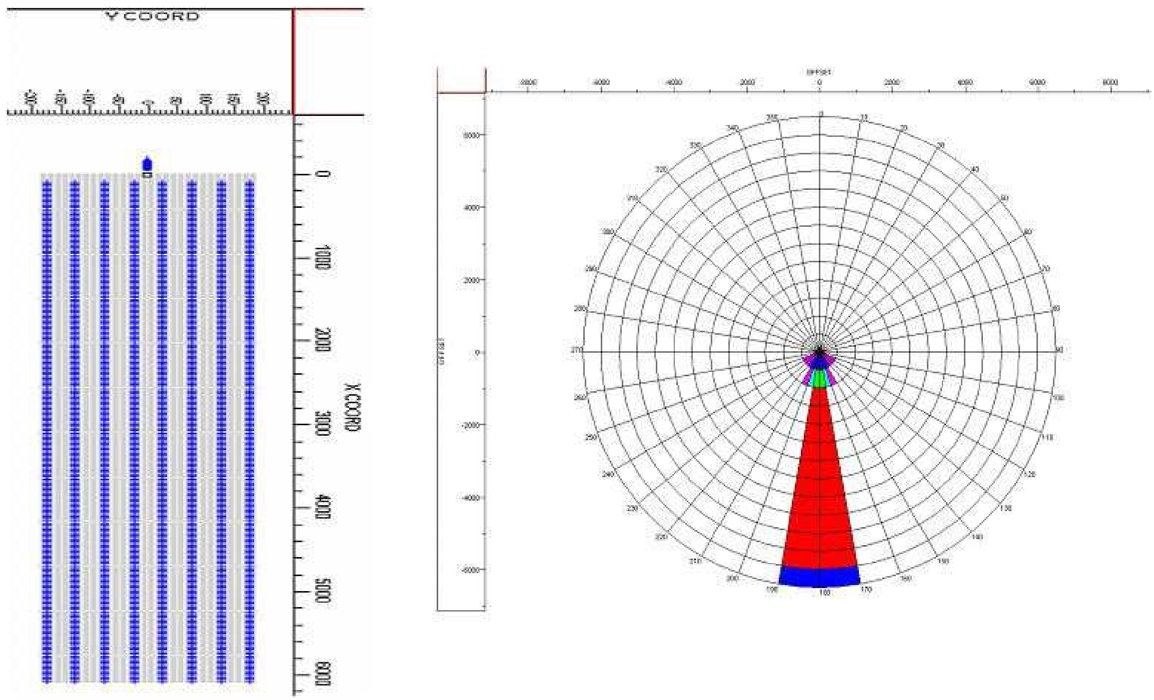

Figure 1: Conventional narrow azimuth marine geometry and resulting trace offset distribution

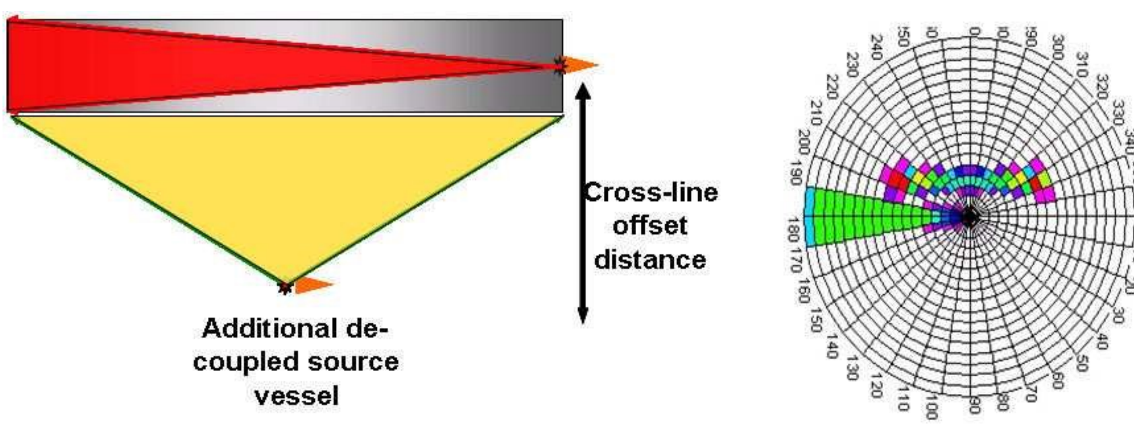

Figure 2: Placement of lateral source produces traces with crossline azimuths and offsets.

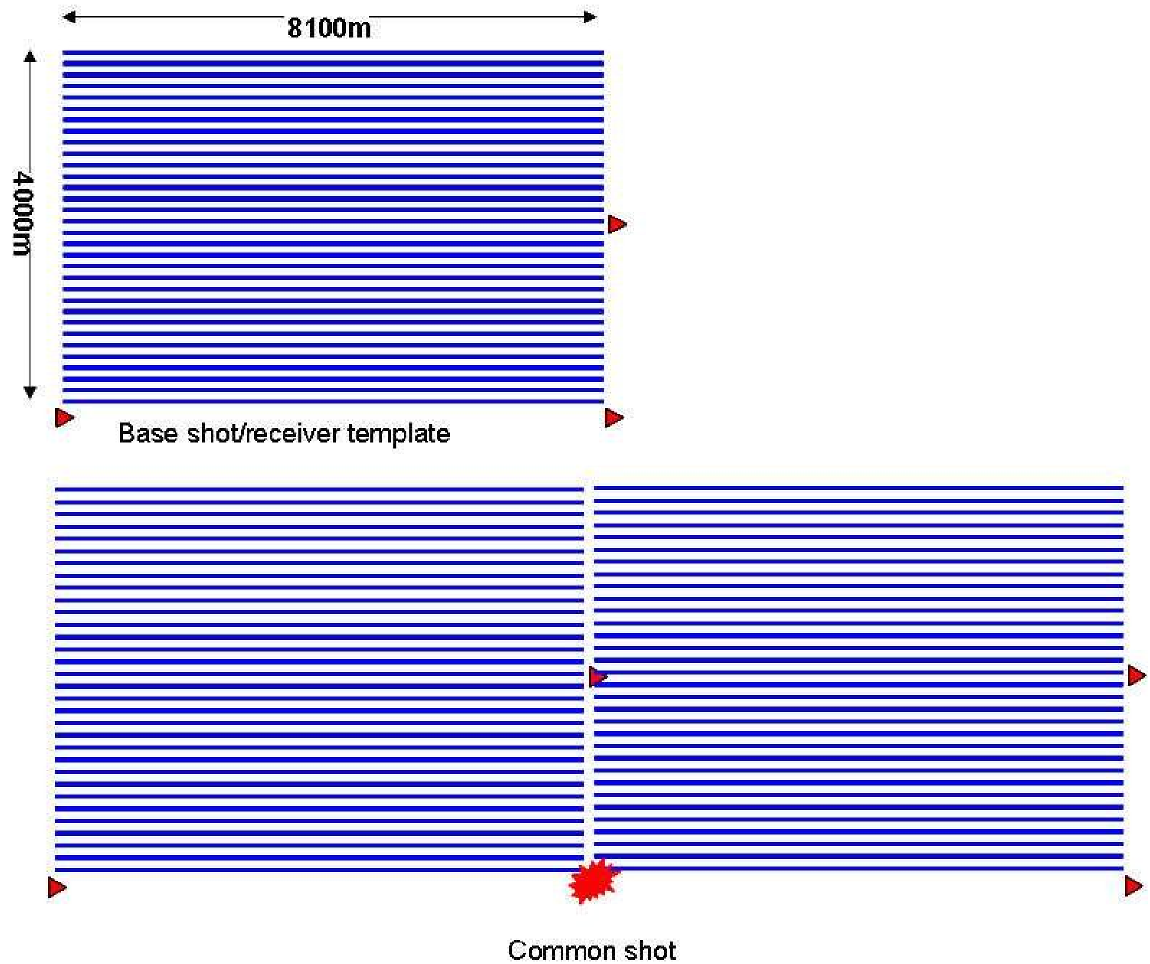

Figure 3: BP WATS Source and receiver geometry

Four Source Wide Azimuth Acquisition

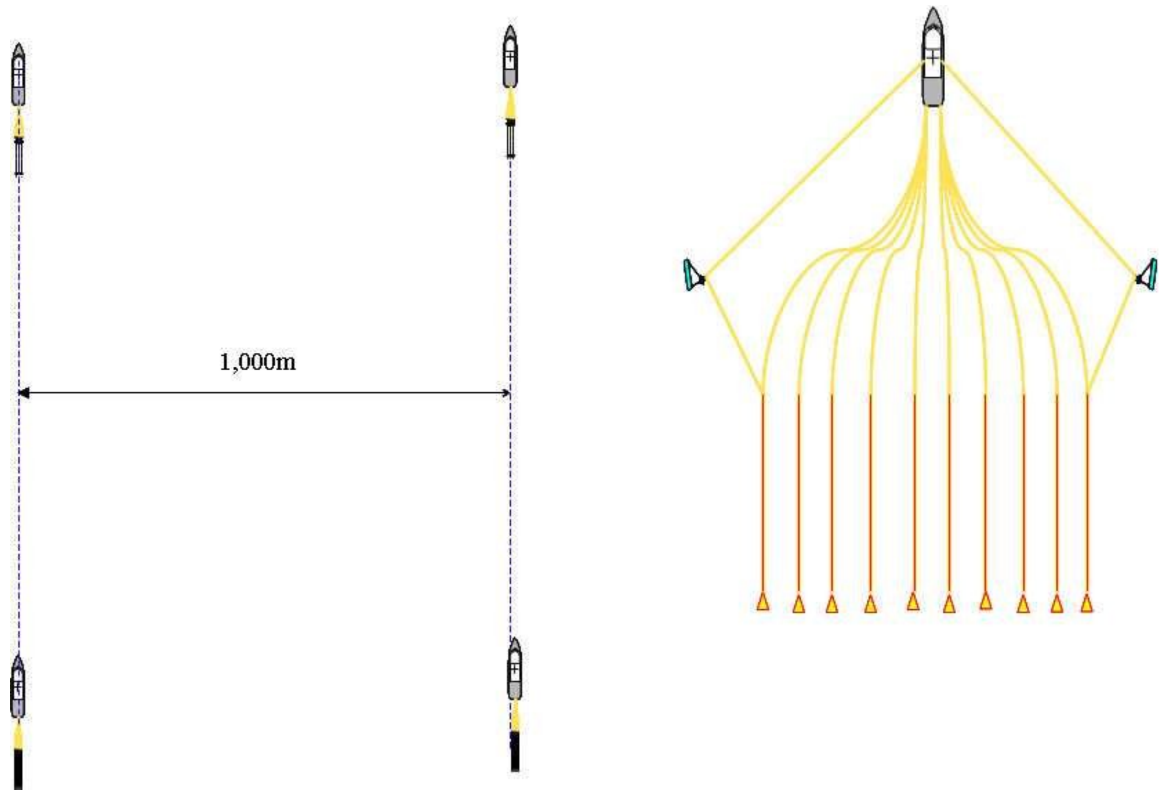

Figure 4: Four source vessel wide azimuth geometry.