Introduction

In 2015, Polarcus acquired its first penta-source (5-source) towed streamer survey off the north-west coast of Australia (Hager et al 2015). This proof-of-concept has led to the acquisition of subsequent penta-source surveys, primarily in the Arabian Gulf. The shallow water carbonate environment found there requires a densely sampled dataset providing high levels of horizontal and vertical resolution to image the thin stratigraphic sedimentary layering. These high levels of resolution are provided by 6.25 x 6.25 m penta-source 3D spatial sampling.

A case study of a penta-source survey, acquired offshore UAE in 2019, will be outlined in this abstract. In addition to the high-resolution towed streamer acquisition, ocean bottom nodes (OBN) were deployed under in-field infrastructure to produce a seamless and contiguous 3D dataset covering approximately 1,000 km² around four active offshore oil and gas fields in the Emirate of Dubai.

Survey Design

Several factors influenced the design of the survey. There is significant infrastructure in “Field One” and “Field Two” that sit adjacent to the north-west border of the survey full fold area (Figure 1). Even though this would affect coverage and line changes, sail line azimuth was chosen to be NW-SE as the geology predominantly dips from West to East.

Figure 1 (A) Regional map showing the survey location (green polygon) in the Arabian Gulf offshore Dubai, UAE. (B) Survey map displaying the active fields with the primary streamer survey full fold polygon (green outline); boxing-in streamer area (yellow); OBN source grid (red); and OBN receiver patches (blue).

The primary seismic objectives were the Asmari, Mishrif and Thamama geological targets, with depths ranging from 1 to 4 km. A streamer offset of 6 km was selected in order to image down to the Thamama limestone. With the data acquired in continuous recording mode, the shot interval of 8.33 m was configured such that unblended seismic data would be recorded within the 3 seconds TWT window beneath the seafloor, which contained the primary targets.

The subsurface is carbonate with thin subtle structures of between 10-30 m in thickness - so resolution, bandwidth and spatial sampling were clear objectives. The survey was designed to properly sample the subsurface in the crossline direction to image high frequency shallow targets, dipping events, diffractions and a variety of coherent noise modes. Compared to a conventional dual-source high-resolution configuration, such as 10 x 50 m x 6 km dual source and 12.5 m shot interval, which provides 6.25 x 12.5 m bins and 1,536,000 traces/km², the penta-source 8 x 62.5 m x 6 km configuration delivers 6.25 x 6.25 m bins, and a trace density of 1,844,000 traces/km². This not only aids processing routines such as noise attenuation, demultiple and velocity analysis, but the dense sampling means improved illumination of geological features and enhanced imaging of shallow...
targets and dipping events. Critically, using two fewer streamers significantly de-risked the operation while maintaining a 250m sail-line efficiency.

The acquisition configuration was designed to achieve safe operations in the shallow 20-50 m water depths. The equipment was deployed at 6 m source depth and 10 m streamer depth to optimize a broadband response and subsequent deterministic deghosting of the data, where the influence of source and receiver ghosts on the wavelet are removed, therefore recovering both low and high frequencies. The 8 streamers at 62.5 m separation geometry maintained a balance of operational efficiency while minimizing the loss of recording of water bottom and shallow sub-surface reflections on the outer streamers due to narrow critical angles. This avoided an acquisition footprint that could not be handled by regularization of the data in processing.

There are several obstructions within the prospect, with four platforms in “Field Three” and two platforms in “Field Four”. To collect data underneath obstructions a dual vessel “undershoot” acquisition technique is often executed, with a streamer vessel and a source vessel sailing either side of the obstruction to close the gaps in coverage. However, this comes with a compromise of poor water bottom and near sub-surface imaging due to the physical offset between the streamers and source vessel. In this geological setting - with the high velocity shallow targets - this compromise was not acceptable.

Instead, it was decided to integrate a two-step approach to address the gaps in coverage. Firstly, and after acquisition of the primary main azimuth streamer lines, the streamer vessel would acquire a series of oblique lines around the infrastructure, referred to as “boxing-in operations”. Once the streamer coverage was completed, an OBN survey was designed to provide multi-component (4C) narrow-azimuth 3D infill in the areas that could not be acquired by the streamer vessel.

There would be three OBN patches, one in “Field Three”, one in “Field Four” and one to complete coverage where “Field One” had restricted vessel manoeuvrability. The ocean bottom seismic acquisition was designed to provide homogeneous offsets and azimuth to the surrounding streamer data, so that the two datasets could be merged into a single seamless multi-seismic volume. The fixed node patches were to deliver a natural bin grid of 12.5 x 12.5 m. This would be achieved with receiver station interval of 50 m, receiver line interval 225 m, with an overlaying parallel shot grid 25 x 25 m (Figure 2). The source lines were extended in the inline direction by 3 km on each side of the patch (runouts) and the receiver lines were minimum 6 km to satisfy the offset and fold requirements.

Once the streamer acquisition was completed, the streamer vessel would recover the streamers and become the source vessel, efficiently acquiring three source lines simultaneously with triple-source (Figure 2). By using the same vessel this meant the penta-source and triple-source had an identical two-string source design with a volume of 2495 in³.

Figure 2 (A) Illustration of the penta-source 8 x 62.5 m x 6 km streamer spread configuration with preplot lines (pink lines). (B) Illustration of the triple-source SX 25 m x 25 m RX 50 m x 225 m OBN configuration with OBN stations (red dots); source points (blue dots); receiver lines (pink lines); and source vessel lines (yellow lines).
Acquisition Overview

Thorough pre-survey planning was implemented to achieve safe and efficient operations. There were several challenges to overcome, such as a high level of marine traffic including commercial shipping, oil field support vessels and fishing activities.

Acquisition started with the primary azimuth towed streamer phase on the eastern swath of the survey around “Field Four” and adjacent to “Field One”, working westwards. Next, the boxing-in lines were successfully acquired around “Field Four”, “Field Three” and “Field One” areas, with numerous close pass approaches safely executed. Since the streamer coverage would guide the required OBN effort, deployment of the OBN started after the streamer acquisition was complete and final streamer coverage was assessed. The streamer survey was completed with 1,186 km² of data acquired, 930 km² of primary azimuth and 256 km² of boxing-in, in 84 days. This was three more days than was originally modelled, in part due to the 34km² increase of the boxing-in program. The success of the boxing-in meant that the OBN area was reduced to 42 km² from the modelled 64 km².

Once the streamer acquisition was completed, the vessel recovered the streamers and reconfigured from penta-source to triple-source in order to acquire the ocean bottom phase of the program. Twin ROV systems were used to facilitate 24-hour subsea OBN positioning operations. Whilst visibility was generally good during the project period, multi-beam sonars were installed to improve the efficiency of operations and accuracy of placement. OBN acquisition started with “Field Three”, followed by “Field One” and finally with “Field Four”. In total, there was 29 operational days of OBN with 24 total production days, matching the survey design model.

Upon completion, the nodes were retrieved from the water bottom by the ROVs, with a 100% recovery success, and were connected to the onboard data management station. Here the node would stop recording and the seismic and ancillary data for each node was downloaded. The cable-free flexible subsea recording 4C system delivered successful acquisition of greater than 99% of trace information.

Conclusions

The 2019 survey sits within the famous Arabian Basin, which contains continental shelf carbonate sediments, and falls into the Thamama Group, which is one of the most productive oil reservoirs in the world.

In an area known for a high level of fishing activity, busy maritime traffic and obstructions (~70% line changes were restricted) it was important to design a survey that would be efficient to acquire and create a seamless multi-seismic volume. Acquiring single-vessel towed streamer acquisition in certain areas with operational constraints, such as in-field infrastructure, will lead to incomplete 3D coverage, with gaps where the streamer vessel cannot pass. Solutions such as single vessel close pass operations can reduce gaps in coverage. A source vessel can be utilized to complete dual vessel operations however this does not fully resolve imaging compromises since there remains poor near-surface imaging caused by lack of near offset data.

Alternatively, the survey can be acquired using an innovative and cost-effective hybrid acquisition design of towed streamer and OBN, deployed within exclusion zones to infill gaps in streamer coverage, for acquisition of a complete and fully imaged 3D dataset (Figure 3 and 4). Multiple sources can be used to acquire high-resolution streamer data and, by using the same vessel to acquire the OBN areas, multiple source lines can be efficiently collected in one vessel pass. The additional benefit is a consistent source design over the full survey area. The high quality and densely sampled streamer data that covers the main area is efficiently acquired and a high quality processed product is delivered, in this case using the extensive compute power of cloud processing, within a short timeframe so that there is no delay in client exploration decisions.
Looking forward, the dataset will be analyzed to compare the single azimuth towed streamer to the areas where there is dual azimuth streamer data and OBN data to determine if there is any improvements in fault definition, highlighting any apparent azimuthal anisotropy, illumination differences with differing azimuth and if a more reliable velocity model can be obtained through multi-azimuth tomography.

Acknowledgements

The authors would like to thank Dubai Petroleum Establishment for granting permission to present this work. The survey was acquired by Polarcus, Sovcomflot and SAE Exploration. The data was processed by Polarcus and WesternGeco.

References