Exploration OBN Survey Design

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Summary

The low-frequency sources developed in the last two decades such as Wolfspar® (Dellinger et al., 2016) and the Tuned Pulse Source (TPS) (Ronen and Chelminski, 2017), have been designed to provide lower frequency data for Full Waveform Inversion (FWI). Others, such as the Gemini extended-frequency source (Brittan et al., 2020) are designed to give both low frequencies for FWI and higher frequencies for imaging. As they utilize larger chambers, the new sources require longer refill times and have other operational characteristics that affect survey design compared to traditional air-gun arrays. We describe how we iterate over survey design practices when working with low frequency sources in exploration settings. We illustrate this process using a recent sparse OBN survey in the Gulf of America (GoA).

Introduction

The low-frequency sources developed in the last two decades such as Wolfspar® (Dellinger et al., 2016) and the Tuned Pulse Source (TPS) (Ronen and Chelminski, 2017), have been designed to provide lower frequency data for Full Waveform Inversion (FWI). Others, such as the Gemini extended-frequency source (Brittan et al., 2020) are designed to give both low frequencies for velocity model building with FWI and higher frequencies for imaging. These new sources also enable improved imaging of deeper targets in areas of salt and volcanic basins. However, as they utilize larger chambers, they require longer refill times and have other operational characteristics that affect survey design compared to traditional air-gun arrays.

Here we describe how we iterate over survey design practices when working with low frequency sources in exploration settings. We illustrate this process using a recent sparse OBN survey in the Gulf of America (GoA) where we maximize shot sampling in the field by using quad-tow sources, while still acquiring long-offset, full-azimuth data with improved efficiency. This survey is the first sparse OBN survey acquired with an extended-frequency source in a quad-tow configuration and a relatively dense shot grid of 75 m x 75 m.

Method

Exploration survey design starts with the exploration targets. However, even for sparse OBN projects in the GoA or any other well established hydrocarbon province, the input data for survey design will contain large model uncertainties, especially below salt and for older, deeper sediments closer to the economic basement. Managing this uncertainty in the survey design process leads to the iterative approach described here.

Step one is to establish an initial set of parameters, including the minimum required offsets for FWI, the desired azimuthal coverage, clean record length, and shot and receiver density. This can be done using a variety of workflows, from simple 2D and 3D raytracing, FWI kernels (Tshering et al., 2024), to full 2D and 3D FD modeling and migration workflows (Cvetkovic et al., 2014). The environmental and regulatory requirements, which can sometimes be restrictive, are also considered at this point.

For large volume low and extended frequency sources (Gemini: 8,000 in^3 and TPS: 28,000 in^3) the shot spacing, compressor capacity and air delivery systems all determine refill times and need to be considered when designing the survey. Using the previously determined initial parameters, refill times are estimated using vessel-specific information. Furthermore, differences between vessel capabilities, even within the same fleet or vessel provider, also affect sampling decisions. A final set of constraints comes from need to deblend the blended signal by leveraging a natural or induced dithering scheme. The vessel, refill and dithering information all contribute to a proposed shooting configuration that is evaluated using another pass of modelling. This iterative loop of survey design involving parameterization coupled with information exchange between expert teams, leads to optimal solutions that achieve model building and imaging objectives and deliver on environmental, regulatory and operational goals.

Case study

The Amendment IV survey in the Mississippi Canyon and Ewing Banks area of the GoA represents the fourth phase of Amendment sparse OBN surveys. It draws on experience from previous phases as well as current industry trends and features extended frequency sources, long offsets and dense shot coverage.

Node spacing and required offsets come from real and synthetic data decimation studies specifically built for the eastern parts of the GoA. Nodes are placed on a 1,000 m by 1,200 m grid with possible infill nodes on a denser grid based on node availability. For the offset requirement, we observe that 20 km of shot halo will allow for 25 km of minimum-maximum offsets within the node patch. We tested several source geometries with a combination of real and synthetic data (Huang et al., 2025) and decided on a final 10 km and 20 km halo interleaving source lines (Figure 1 (a)).

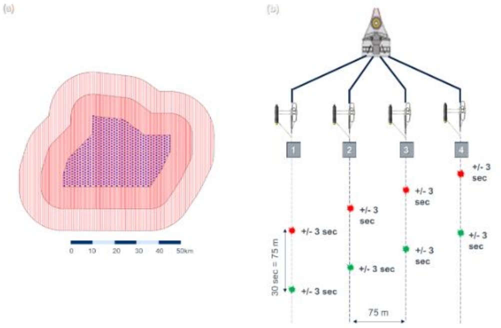

***Figure 1**: Amendment Phase 4 geometry - (a) node (blue) and shot (red) position map, with node outline and 10km and 20km respective shot halo. (b) Shooting configuration with quad-tow Gemini.*

For the source spacing, we started with a shot grid of 50 m by 100 m, which has been used on most sparse OBN surveys in the GoA. There should be no issue maintaining the above-mentioned grid using two vessels with a triple source configuration. However, source efficiency can be improved by 33% if four sources (quad-tow) are used. In order to evaluate this, we first tested quad-towing capabilities for two different vessels. Based on refill tests, it was determined that either 70 m at 2000 psi or 50 m at 1,850 psi could be achieved. After further normalization of the air-delivery system and compressor capacity between the vessels a 75 m by 75 m source grid at 2,000 psi with a nominal vessel speed of 4.7 knots was selected. A synthetic modelling exercise with a checkerboard model showed that the difference in FWI updates between 50 m x 100 m shot spacing and the proposed 75 m x 75 m spacing is negligible.

For the shooting scheme, a flip-flop-flap-flup configuration was used. For the dithering scheme, a workflow based on Maiza and Hodges 2024 was modified to allow a large maximum dither of +/- 2.5 seconds to preserve low frequencies and allow optimal de-blending.

Conclusions

Designing a survey to maximize the use of FWI and extended-frequency sources in exploration settings presents a problem best solved in an iterative manner. We show how this was achieved for an OBN survey in the GoA. Following the growth of acoustic and elastic FWI workflows, where low-wavenumbers (coming from low frequencies and long offsets) are required to build an accurate model, and combined with their environmental benefits, we see increased use of extended-frequency sources not just in exploration but in production settings: 3D and 4D OBN as well as NAZ streamer surveys

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