Advanced Seismic Acquisition and Imaging Using Gemini Extended Frequency Source Technology in Complex Geological Environments

Introduction

The last five years have been notable for the commercialisation and increased utilization of low frequency sources. Wolfspar® (Dellinger et al., 2016) and the Tuned Pulse Source (TPS) (Ronen and Chelminski, 2017) have been designed to provide low frequency data for Full Waveform Inversion (FWI). Others, such as the Gemini extended-frequency source (Brittan et al., 2020) are designed to generate low frequencies and higher frequencies. The Gemini technology is based on a single-element (8000 cu. in.) source design that generates low frequencies down to ~1.5 Hz for FWI while preserving the mid-frequency range of the seismic bandwidth for sub surface imaging, making it suitable as the sole source for a range of exploration objectives. It produces significantly less energy above 800 Hz compared to conventional airgun arrays, lowering the impact on marine mammals. Here we review our recent experience and results using Gemini in conjunction with deep tow multisensor streamers in large scale exploration surveys in the Eastern Mediterranean and West Africa, and with sparse OBN geometries in the Gulf of America.

Combining deep tow multisensor streamers with extended frequency sources

Several projects have recently demonstrated the value of combining extended frequency sources and deep tow multisensor streamers deployed in innovative seismic acquisition solutions, including the utilisation of hybrid source solution in extended long offset acquisition (see Shell-PGS-ION press releases, 2021) and one-sided wide azimuth (WAZ) (Donaldson et al., 2024) configurations. Following three successful seismic surveys in the Eastern Mediterranean, another survey using the one-sided WAZ technology was acquired offshore Angola in early 2025 (Widmaier et al., 2025). Twelve 10 km long streamers towed 150 m apart and a total of six Gemini sources were deployed.
Results show improved imaging in a range of complex environments including the pre-Messinian interval in the Eastern Mediterranean and the complex salt regimes of West Africa. Figures 1A-1D show the preliminary migrated images from the Angola survey. Imaging uses an acoustic FWI model derived from the narrow azimuth shots alone and is compared to one that uses the narrow- and wide-azimuth shots combined. These early results shows that the introduction of wide-azimuth data improves both the illumination of events underneath the salt, shown by the orange arrows, and the velocity updates within and beneath salt, shown by the blue arrows.

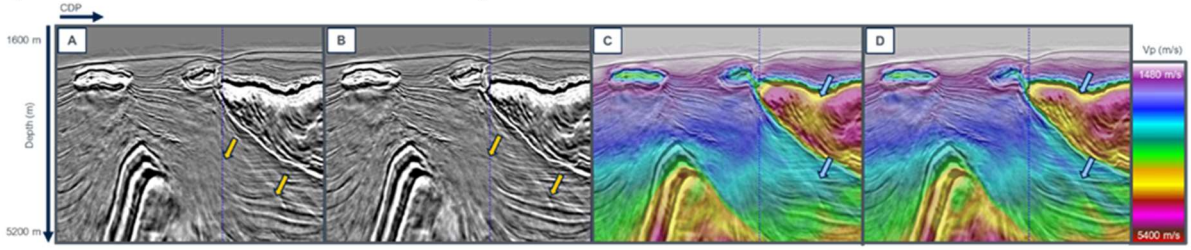

Figure 1 *A: KPSDM with an NAZ FWI model; B: KPSDM with a NAZ+WAZ FWI model; C: aFWI model using NAZ data; D: aFWI model using NAZ+WAZ data.*

The omni-directional nature of single-element sources simplifies de-signature, de-bubble and FWI. Integral to the success are a stable wavelet and an accurate estimate of the wavelet using near field hydrophone (NFH) data. Figure 2 shows the wavelet stability achieved during the Angola survey, as well as the close correspondence between the NFH data (SBS-CS) and the data derived wavelet.

Sparse OBN surveys with extended frequency sources

A key consideration in OBN acquisition is source-side efficiency. Leveraging the experience of wide tow sources for streamer acquisition, recent OBN surveys in the Gulf of America (GoA) have increased both the number sources and the spread width to increase efficiency (Figure 3).

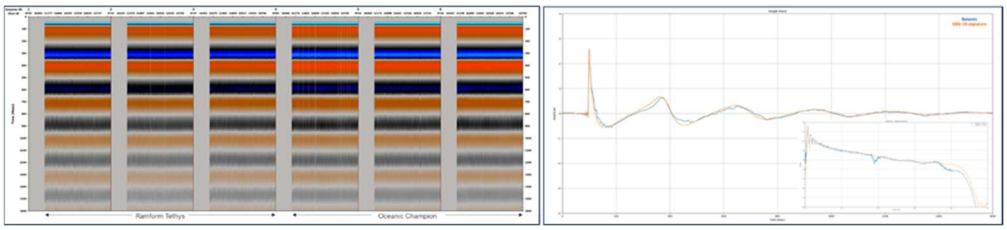

Figure 2 *Left: Sequence of shot-by-shot far fields for each of the six Gemini sources. Right: Average far field signature compared to the wavelet derived from the seismic data.*

Dual or triple source acquisition using conventional sources on a 50 m x 100 m shot grid has been common for deep water sparse OBN surveys until a few years ago. Single-element sources compared to standard source arrays reduce operational complexity and enable wider tow of multiple sources. Further optimization of the air delivery has recently enabled wide-tow quad source acquisition with 100 m source separation, resulting in a 50 m x 100 m shot grid. This means a 33% source-side efficiency gain in addition to increased low frequency output for FWI compared to the conventional triple source operations in the GoA.

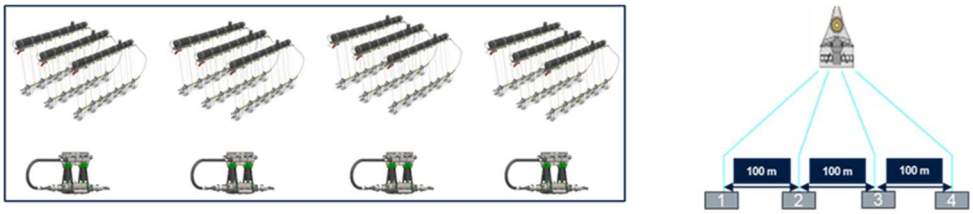

Figure 3 *Leveraging the flexibility of single-element sources: Four Gemini replace four standard source arrays (left) and enable an effecient wide-tow quad configuration for sparse OBN (right).*

Conclusions

Utilisation of low and extended frequency source technology in seismic exploration is rapidly increasing. We have shown how extended frequency source technology combined either with innovative streamer geometries or sparse OBN enables improved imaging in complex geological settings. The single-element nature of the Gemini source reduces towing complexity and enables more efficient wide-tow multi-source acquisition solutions.

References

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