Optimizing Infill in Modern 3D Seismic Acquisition

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Abstract

An innovative approach to managing infill in the field, applied consistently over the past three years, has been successful at driving down time spent on prospect, thereby minimizing survey cost and operational exposure. The approach is hinged on existing best practice in data processing, and leverages currently available infield technologies to optimize infill acquisition. Given that infill acquisition on the typical marine 3D survey accounts for up to 25% or more of the total time on prospect (Monk 2010), it stands to reason that this represents a significant opportunity for improving survey efficiency, thereby reducing both cost and overall turnaround time from survey start to data interpretation.

Introduction

During the 3D survey design process a grid of bins is designed with dimensions that honour the geophysical objectives of the survey. An array of sources and receivers (the seismic spread) is chosen to match this grid, such that as it is moved up in the inline and cross-line directions at some interval, bins are populated with a regular distribution of CMP hits or surface-derived coverage. In the marine environment however, the movement of seismic sources and streamers is very dynamic, responding to vessel steering, and more unpredictably, the effects of ocean currents. The result of this movement is less than perfect surface-derived CMP coverage, with empty or low-fold bins requiring additional acquisition, in the form of infill passes, to achieve a contiguous dataset.

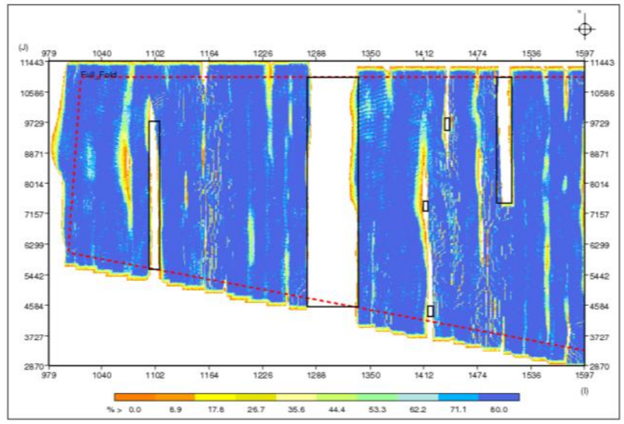

Figure 1: Limited offset coverage plot, with application of hole detection, output from the Integrated Navigation System onboard the vessel

Although recent technological advancements in both source and streamer steering have helped to improve spread response to changing ocean currents, the traditional metrics by which acceptable survey coverage is measured are inconsistent with current geophysical best practice. The method of populating bins with surface-derived CMP coverage described above is geared towards CMP stacking, whereas migration of traces prior to stacking is currently standard practice in data processing. This implies that a more appropriate assessment of 3D coverage in the field would be one that seeks to measure a dataset's suitability for the application of a processing sequence inclusive of prestack migration.

Method

Acceptable sub-surface coverage is achieved when both illumination and seismic wave-field spatial sampling requirements are honoured as calculated from measurements of target depth, velocity, frequency and dip. Monk (2009) described how these parameters relate to the dimensions of Fresnel Zones, pointing out that the surface area of a target illuminated by a single trace increases as a function of source-receiver offset, depth to target, and the maximum frequency of the reflected signal. Spatial Nyquist sampling criteria show sampling interval increasing with average velocity to target, and decreasing with increasing frequency and sine of the dip. When one considers the earth's attenuating effect on higher frequencies with depth and thus offset, and the increasing trend in velocity with depth, it becomes obvious that the farthest seismic offsets and deepest targets are massively over-sampled (Capelle and Matthews 2009). By the same token, care needs to be taken to ensure that shallow, near offset targets are properly sampled and illuminated.

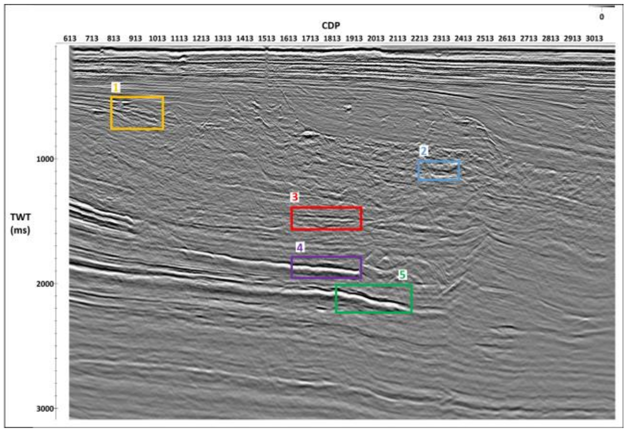

Figure 2: Example seismic section, with application of demultiple, deghosting (broadband), and prestack migration, demonstrating selection of target windows for measurement of frequency spectra.

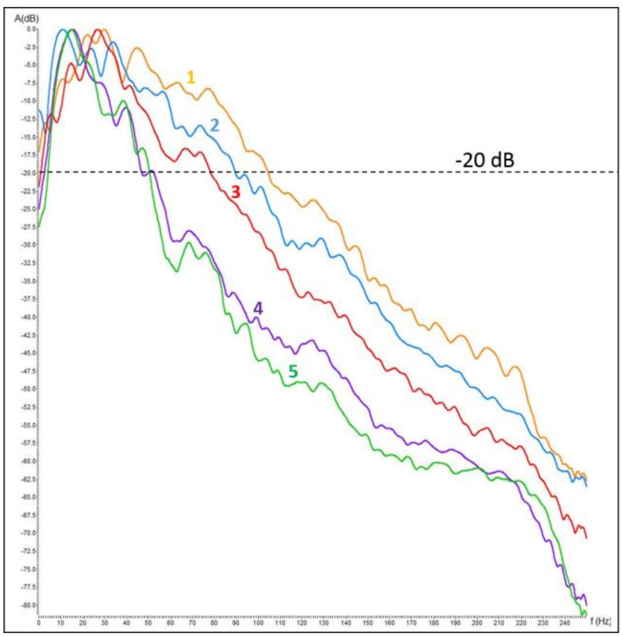

Figure 3: Amplitude spectra measured in the target windows shown in Figure two, demonstrating the effect of the earth's attenuation on the frequency content of seismic targets with depth.

These concepts can be implemented in an Infill Management Plan through the following main elements:

- Spatial sampling requirements and Fresnel Zone dimensions are determined from frequencies, depths, velocities and dips at selected geologic targets. On occasion, this analysis is done on legacy data prior to survey start, however, today's advanced infield processing capabilities (including on-board de-ghosting, de-multiple and pre-stack migration) mean that the most suitable measurements are taken in the field in near real time.
- The seismic source is steered along the pre-plotted seismic lines to ensure sufficient and regular near offset Fresnel Zone Coverage and sampling. This is particularly important when considering that the near offsets contain the full extent of reflection information available in a set of data.
- Use of a "Fan" mode streamer configuration to leverage lower frequencies which dominate with increasing depth and offset, and mitigate large gaps in far-mid and far offset groups.
- Analysis of limited offset cubes in conjunction with coverage plots over corresponding offsets to monitor seismic continuity and dip as a function of Fresnel Zone coverage and sampling.

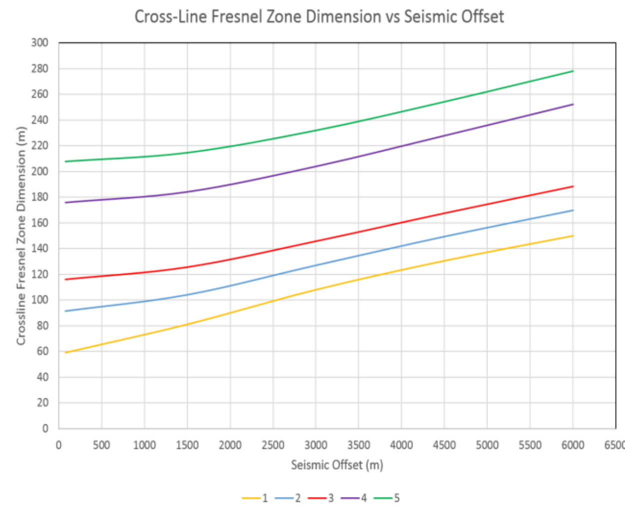

Figure 4: Cross-line Fresnel Zone dimensions plotted as a function of seismic offset and used to define illumination requirements for each target.

Results

The effectiveness of this approach was judged on a combination of 23 multi-client and proprietary surveys acquired around the world. These surveys were all acquired with streamer lengths of greater than six kilometres, longer streamers being affected most by ocean currents, and are representative of the projects acquired to date using the infill management method described. The results were very consistent, with an average infill rate required of 6.8%, and a median rate of 7.5%. When compared to the 25% infill that is regarded as typical in the industry, this represents savings of 11,200 km2 over the course of these 23 projects, the equivalent of acquiring an additional large 3D survey.

Conclusions

We believe there is a misalignment between modern processing techniques and the current CMP-based framework for choosing infill. With an infill management plan based upon sound geophysical fundamentals a significant amount of time and money can be saved during the course of modern multi-streamer 3D surveys.

References

Monk, D. J. (2010, January). Reducing infill requirements using Fresnel zone binning and steerable streamers. In *2010 SEG Annual Meeting*. Society of Exploration Geophysicists.

Capelle, P., & Matthews, P. (2009, June). “Intelligent Infill” for cost effective 3D seismic marine acquisitions. In *71st EAGE Conference & Exhibition*.

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