Improving Marine Acquisition Efficiency and Quality

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Introduction :

In marine acquisition the seismic vessel sails up and down adjacent parallel lines towing more than eight floating cables at typically 100 m spacing or less. Each cable contains several thousand hydrophones (insea microphones) to record reflections from the geological layers down to 10 km beneath the vessel. An even distribution of recording positions (coverage) is considered to yield the best image. However, since this ideal situation cannot be achieved without extreme costs, less complete coverage criteria are accepted. During acquisition, sea currents may move the cables behind the vessel to the side. This is called feathering. It will also cause a corresponding shift in recording positions, leaving the original positions with no measurements. After the vessel has sailed along all predefined lines, a coverage map is produced to show which positions have and do not have enough measurements. This is the basis for the so-called infill shooting, i.e. the acquisition of additional lines to fill in the holes.

For coverage below these specifications, additional infill lines must be acquired to supplement the coverage. These specifications are normally made for offset ranges along the cables. The offsets close to the vessel contain more high frequency signal and their position is more easily controlled; hence the specifications are relatively tight. For long offsets the signals are more of low frequency and the cables may feather due to the ocean currents; hence the specifications for the long offsets are more relaxed and full coverage is not required. The coverage specifications typically set by operator require:

90% of full coverage for near quarter of the streamer
90% of full coverage for second quarter of the streamer
90% of full coverage for third quarter of the streamer
70% of full coverage for fourth (far) quarter of the streamer

This shall be achieved after removal of bad traces and shots and duplicate offsets and 10-15% flexible binning. The flexible binning allows for including in the counting those traces, which just are outside the actual bin.

This can easily be justified bearing the accuracy of the navigation in mind. However, these specifications are not consistent with the requirement of even coverage. The acceptable situation may arrive, that 30% of the far offsets are missing. There is no guarantee, that the missing seismic data can be replaced by means of interpolation, because no information is available about the position of the surrounding seismic data, which could be used for the interpolation. Hence, this type of quality control does not really give us control over the data quality.

Coverage control for controlling seismic Data Quality

CGG promotes a different way of monitoring coverage. Since proper multi-channel pre-stack processing requires a complete data set, the requirement is for 100% of the nominal fold. The concept is based on a further development of coverage specifications, originally proposed by Shell in the nineties, combined with innovations in the seismic processing technology.

There has always been a need to interpolate over missing or edited recordings. Traditionally, linear interpolation using the neighbouring recordings or more advanced sinc-interpolators have been used. Presently, multi-dimensional and wave-equation-based interpolation filters are becoming available. Nevertheless, the distance, over which seismic data can be interpolated reliably, has its limits. This distance is controlled by the quality of the interpolation filter. It is well known, that near offsets contain more high frequencies than far offsets. Hence, acceptable holes or missing traces at near offsets cannot be as large as for far offset traces. Typical limits for interpolation at different offset ranges are defined:

Nears : 1 column
Near Mids : 2 columns
Far Mids : 3 columns
Fars : 4 columns

Obviously, these distances may need to be verified for the actual survey in cooperation with the responsable oil company.

CGG promotes monitoring coverage using static bins and approximately full fold, i.e. approximately 100% of nominal coverage, but it includes the maximum distance of quality-preserving interpolation in the assessment of any infill shooting. If after consideration of these maximum interpolation distances still some data is missing in the bins, we know, that interpolation over a longer distance cannot be done anymore without unacceptable loss of data quality. Hence, infill shooting is needed.

Figure 1 and 2 show the coverage for the far offset range using the traditional and the proposed coverage concept. The proposed concept indicates that any missing coverage can be interpolated without unacceptable loss of seismic quality. The traditional coverage plot not only shows areas with insufficient coverage in white, but it also shows more seriously areas in blue as being accepted, while perhaps only 70% of the nominal coverage has been achieved and the remaining 30% may not be available.

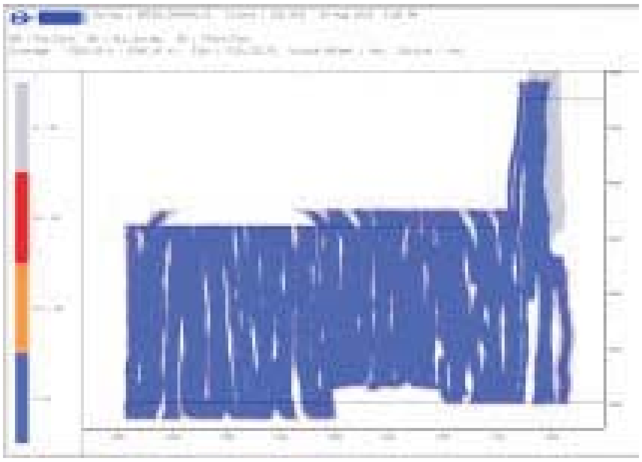

Fig.1 : traditional coverage plot (far offsets)

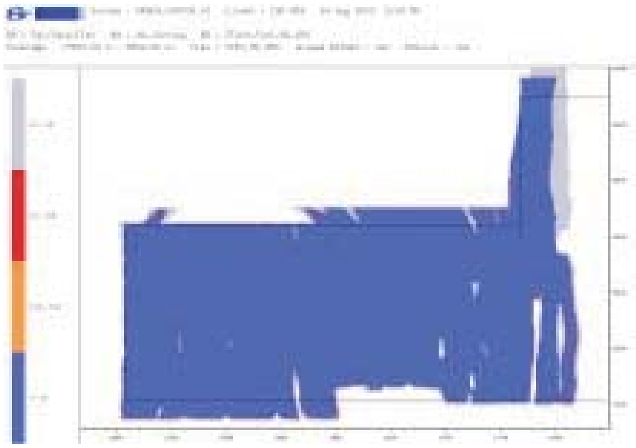

Fig.2 : proposed coverage plot (far offsets)

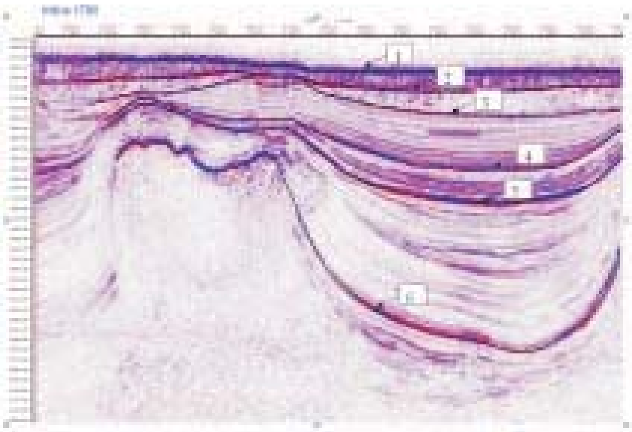

Fig. 3 : seismic section with salt structure

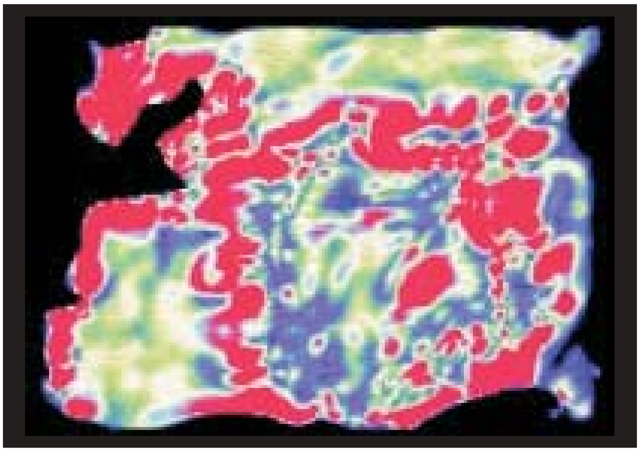

Fig. 4 : sub-surface illumination

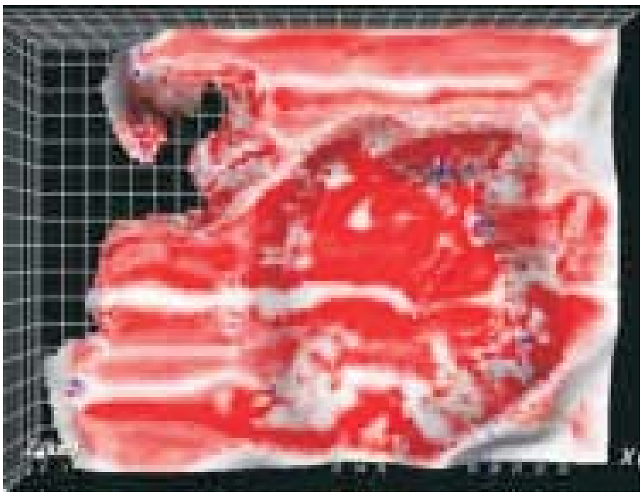

Fig.5: horizon PSDM amplitude map

From covereage VIA sub-surface illumination to horizon amplitudes

The acoustic waves do not follow straight lines due to variations in the geological layers. In addition, these layers are not flat, but are deformed into complex structures. Figure 3 shows how a salt diapir has pushed the layers upwards, leaving a sedimentary basin between neighbouring salt domes. As a result, the even coverage at the surface does not give an even illumination of the subsurface interfaces. Especially in the case of steep salt flanks, as in figure 3, shadow zones may occur, corresponding to parts of the subsurface, which have not been illuminated and hence do not give reflections. This is illustrated in Figure 4 using seismic modelling with a simulated zero-feather acquisition yielding the ideal 100% coverage. Nevertheless, there are significant areas, where the subsurface horizon 6, as indicated in Figure 3, has not been illuminated.

Using the same modelling software the sub-surface illumination can be expressed in simulated PSDM prestack depth migration amplitudes. It gives a preview of the seismic data quality to be expected from the real acquisition. This is demonstrated in Figure 5 for the 3D data set of Figure 3, where only the prime lines without infill are used for the computation of the PSDM horizon amplitudes of horizon 6. The white areas correspond with the areas where infill shooting is needed; for example the white traverse in the middle from left to right. When this traverse drops into the depth in the basin, the width of the traverse gets smaller. This may be caused by the fact that the migration aperture is wider in the depth of the base than at the top of the salt dome towards the left. The migration process may contribute to filling the holes. CGG has pioneered this technique to estimate final reflection amplitudes during acquisition. It then becomes possible to judge more reliably, whether sufficient seismic data has been acquired and which infill lines will contribute best to the final image. Hence, acquisition will be more cost-effective and final data quality may be improved.

Noise filter and extended weather window

During marginal weather, turbulence around the cables causes hydrophones to record an increase in noise. Since this noise will mask the weak reflection signals, acquisition has to stop. This is obviously very costly. It seems a shame to halt seismic acquisition in marginal weather, if it can be proven that the additional noise can be removed and the signal fidelity preserved. For onboard seismic processing, CGG uses its proprietary noise filter, SPARN, an abbreviation for Signal Preserving Attenuation of Random Noise. Obviously, removal of noise should not lead to removal of signal. Figure6 shows part of a noisy recording on the left.

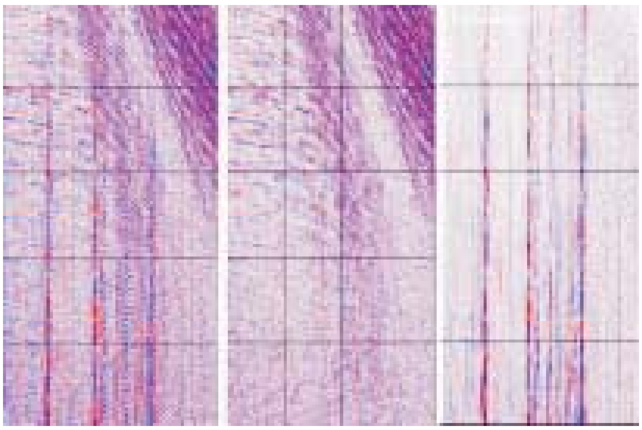

Fig. 6 : SPARN noise filter

The middle panel shows the recording after application of the noise filter and the right panel shows what has been filtered away. It confirms that no signal has been removed. The introduction of this filter in the onboard processing yields a timely and cost-effective acquisition for the benefit of CGG's clients.

Conclusion :

Modelling and processing techniques are available before the start of the survey to allow definition of acquisition parameters and so-called specs to ensure that the required seismic data quality can be obtained. Similar techniques are available during the acquisition to monitor that the pre-defined quality indeed is achieved.

References :

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1994 – Brink, M., Result-oriented marine seismic acquisition, First Break, vol. 12, no. 7.

2004 – Brink, M. et al., Infill decisions using simulated migration amplitudes, presented at SEG in Denver.