Summary

A new method is developed for estimating the seismic wavelet from seismic data acquired in offshore areas without wells. Our method is essentially an improvement of the one proposed by Foster et al (Geophysics, 1997), which involved combining two independent methods in order to increase the reliability of the estimated wavelet.

One important requirement of the proposed method is that the near field signatures generated by the air guns forming the source array are recorded during the survey so that the depths and the geometry of the air guns, the reflection coefficient of the sea surface and the far field signature of the seismic source can be determined (Safar, 1998, 1999). Another requirement is a Q value for modeling the earth’s absorption, which is determined from the seismic data.

The main feature of the proposed method is that we do not need the assumption that the seismic wavelet is minimum phase. The method is tested using 3D migrated data acquired around a logged well in the North Sea. The accuracy of the proposed method is evaluated by comparing the estimated seismic wavelet with those derived from the statistical and well to seismic matching methods.

Introduction

Recently Foster et al (1997) proposed a method for estimating the seismic wavelet for the purpose of zero-phasing seismic data without wells. It consists of a combination of two independent methods for deriving the seismic wavelet, namely the physical modeling and the statistical extractions. The main objective is to increase the reliability of the estimated seismic wavelet. This is because one method should compensate for the shortcomings of the other method.

The new methodology proposed in this paper differs from that discussed by Foster et al (1997): the physical modeling is combined with only one part of the statistical method, which does not require the assumption that the seismic wavelet is minimum phase. Another important difference is that the far field signature, which is crucial for the physical modeling method, is determined from the near field signatures recorded during the survey.

Acquisition and Processing

In 1995 a 3D survey of UKCS Quad 15 was carried out for Enterprise Oil by Geco-Prakla using the Geco Gamma vessel, which was fitted with the Trisor source signature estimator (SSE) system. The Trisor SSE system is capable of calculating the far field signature for each shot from the recorded pressure field in the vicinity of each element forming the seismic source array. This array was dual air-gun array – Flip/Flop (Port array and Starboard array). Each array consisted of two non-identical sub arrays with each sub array having six elements. The element nearest to the vessel consisted of 3 identical air-gun clusters whereas the remaining five elements were single air guns.
The 3D survey was acquired using six 3000m streamers separated by 100m crossline with each streamer having 240 groups with separation of 12.5m between two adjacent groups. The six streamers were placed at a depth of 6.5 m.

The initial part of the processing sequence, which was carried out on board the Geco Gamma vessel, consisted of resampling the data from 2 ms to 4 ms after applying a zero phase anti-alias filter (5 Hz/18 dB – 90 Hz/72 dB). Subsequently the following steps were applied: a spatial anti-alias filter and trace drop; source designature to minimum phase using a “library” far field signature, scaling T to the power 1.9, 2 zone predictive deconvolution before stack 20/300ms and 24/300ms.

Seismic Wavelet Estimation

The estimation of the seismic wavelet is essentially obtained using the physical modeling method, which requires a far field signature of the seismic source and a Q value for modeling the earth’s absorption.

The determination of the far field signature requires knowledge of the depths of the air-guns, the air-gun-hydrophone geometry and the reflection coefficient of the sea surface, which are determined (Safar, 1999) from the recorded near field signatures when the air-guns were fired individually. The effective depths of the port and starboard arrays, obtained from the amplitude spectra of the far field signatures synthesized from the measured near field signatures using the depths of the air-guns, were 6.5m and 6.25m respectively. However, the depth of the arrays specified in the contract was 5m. Fortunately, the “library” for field signature used for source designature to minimum phase was obtained at a depth of 6m instead of 5m.

The approach used by Foster et al (1997) for determining the average value of Q consisted of matching the seismic wavelet obtained by physical modeling to the seismic wavelet derived by the statistical method, which assumes that the seismic wavelet is minimum phase. In fact, a much better approach for determining the Q value is to match the high frequency part of the amplitude spectrum of the seismic wavelet derived by physical modeling to that of the statistically derived seismic wavelet and consequently avoid the minimum phase assumption. We use the same approach used by Foster et al (1997) for deriving the amplitude spectrum of the statistically derived seismic wavelet from the seismic data. This consisted of using the multiple coherency function (White, 1972, 1973 and personal communication) for separating noise from coherent signal and then smoothing for removing any geological information. Fig 1 shows the statistically derived average signal spectrum using 20 x 20 traces around a well over the time windows of 1000 – 1500 ms and 1700 – 2100 ms. It can be seen from Fig.1 that the signal spectrum for the time window 1700 – 2100 ms, which is the target zone, has a peak at a frequency of 14 Hz indicating a very high earth absorption. A Q value of 40 is obtained when matching the high frequency part of the signal spectrum shown in Fig.1 for the time window of 1700 – 2100 ms to that of the seismic wavelet derived by the physical modeling method.

Discussion

In order to check the accuracy of the estimation of the seismic wavelet using the proposed method, the seismic wavelet is also derived using the statistical and the well to seismic matching (White, 1980, Walden and White, 1984 and see also Van de Coevering, 2000 for overview) methods.

The estimation of the seismic wavelet using well to seismic matching essentially involves the determination of the impulse response of the transfer function of the matching operator, which is required so that the broadband synthetic seismogram and a segment of the processed seismic data are matched. Unlike the statistical method, the well to seismic matching does not require the assumptions that the seismic wavelet is minimum phase and the reflection sequence is white. This means that the polarity and the onset time of the estimated seismic wavelet are the same as those of the seismic wavelet in the seismic trace segment. Fig.2 shows three seismic wavelets derived by the three methods. It can be seen from Fig.2 that the seismic wavelet estimated by the statistical method differs significantly form those derived by the new method and the well to seismic matching method (White, 1980 and White and Walden, 1984). The important difference is that about 20 ms of the front of the statistically derived seismic wavelet is missing. This may explain the reason for the mistie, which is usually found between the synthetic seismogram, generated using the statistically estimated seismic wavelet, and the seismic data. It is worth pointing out that the missing part of the statistically derived seismic wavelet was also observed by Porsani and Ursin (TLE, 2000) when comparing the statistically
derived seismic wavelet with that derived using mixed phase statistical method (Geophysics, 1998 and Geophysical Prospecting 1999).

A comparison between the seismic wavelet estimated by our proposed method and that estimated by the well to seismic matching method displayed in Fig.2, shows that the early part of the well to seismic matching derived seismic wavelet is in fact processing noise (the early part is that part which occurs before the first trough). This is because the first peak of the seismic wavelet is not physically plausible. The onset times and the shapes of the first two lobes of the estimated seismic wavelets agree fairly well. However, there is a significant difference between the tails of the estimated seismic wavelets. A possible explanation for this difference is that less attention is paid (White, 1980) in estimating the seismic wavelet’s tail than that paid in estimating the main lobes. It can be deduced from Fig.2 that the seismic wavelet is not minimum phase. This means that the attempt during processing to convert the seismic wavelet to a minimum phase wavelet was unsuccessful. On the other hand, the new proposed method for estimating the seismic wavelet makes not only the attempt to convert it into minimum phase but also the current idiotic specifications for the source performance unnecessary.

Conclusion

The new method developed in this paper for the purpose of zero-phasing seismic data acquired in areas without wells is believed to be more reliable in reducing uncertainty in the seismic wavelet estimation than that proposed by Foster et al (Geophysics 1997). This is because the statistical method, which is an essential part of their proposed method, is shown to be unreliable.

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References


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**Fig 1:** Average signal spectrum of 20 by 20 seismic traces around the well location for a time window of 100-1500 ms (black) and 1700-2100 ms (red).

**Fig 2:** Comparison of the wavelets derived using different methods: (TOP) the matching operator, (MIDDLE) the modeled wavelet and (BOTTOM) the autocorrelation wavelet.