Application of an Eigenimage filter to attenuate both surface-related and short period internal multiples on data from onshore Texas

J. De Wildt,[1] R.K. Oldfield[2] and R. Silva[2] illustrate the use of an Eigenimage filter to attenuate different types of multiples arising from land seismic data acquired in Texas.

In the absence of velocity discrimination between the primaries and multiples (apparent primaries), a common-midpoint (CMP) stack may contain both primaries and apparent primaries (multiples). Such multiples may originate as surface related multiples as well as from within layer boundaries to create internal (or peg-leg) multiples. Attenuation of short period peg-leg multiples poses an additional challenge particularly when their periodicity is shorter than the wavelet length. The attenuation of such multiples requires both a priori interpretive information to identify the multiple-generating primaries and a robust technique to attenuate these multiples.

An Eigenimage filter is ideally suited for the attenuation of short period peg-leg multiples when their periodicity is shorter than the wavelet length and has the advantage of not requiring an accurate specification of a velocity depth model to describe the multiple generating primaries. Having identified the multiple-generating primaries on, for example, a CMP stack section, a targeted Eigenimage filter is applied to the pre-stack data to attenuate both surface related multiples and internal multiples. Subsequent prestack time migration and velocity analysis after migration on a land data set from the Gulf Coast demonstrates effectively the ability of the Eigenimage filter to attenuate both surface related and internal multiples.

Background

It is well known to the practitioner in the art of multiple attenuation that there is no single technique that can be applied to seismic data in order to attenuate multiples. In practice one technique is often followed by a different one in order to achieve the overall objective of attenuating multiples.

The skill of the practitioner lies in determining whether the earth models used in a particular multiple attenuation technique match the earth model from which the seismic data is physically acquired. Any mathematical technique, such as seismic migration or multiple attenuation, will have to create a model of the earth for which that particular technique is designed to work. Unfortunately the Earth does not lend itself to be easily modelled.

Short period peg-leg multiples generated between the Base Cretaceous Unconformity (BCU) and the shallow water layer in the North Sea are known to interfere with target horizons below the BCU. Due to the shallow water layer, there is little or no velocity discrimination between the peg-leg multiples and the primaries. Deconvolution, the traditional technique used to attenuate short period multiples is ineffective in this situation because the period of the peg-leg multiples are too short compared to the wavelet length. In the example used in this paper, a land data set is selected to illustrate the generation of short period multiples by a shallow sequence of shale-sandstone in seismic data from the Gulf Coast. This shallow shale-sandstone sequence is responsible for generating short period internal multiples as well as surface-related multiples. These multiples do not respond to conventional techniques of multiple attenuation as there is very little velocity discrimination between primary and multiple and the periodicity of the multiple is shorter than the wavelet length. An Eigenimage filter is used successfully to attenuate both these types of multiple.

Geological setting and multiple generator interpretation

The land data set used in this example to attenuate surface and peg-leg multiples is from a 3D survey from onshore Texas. The multiples present in the PSTM (prestack time migration) stack shown in Figure 1 are those that remain after the application of deconvolution. Radon demultiple was not applied due to the lack of velocity discrimination between primary and multiple. The deconvolution applied was ineffective due to the periodicity of the short period multiples being short compared to the wavelet length. The

---

[1] *Spectrum Geo Inc, 16225 Park Ten Place Ste.300 Houston, TX 77084, USA.*
[2] *Spectrum Geo Ltd, Spectrum House, 56 Goldsworth Road, Woking, Surrey GU21 6LE, UK.*
Corresponding author, E-mail: ron.silva@spectrumasa.com

presence of surface-related and internal multiples is attributed to a shallow sequence of shale-sandstone between 1.3 and 2.0 sec TWT (two-way travel time). This sequence contains various lithologies and the bedded units of sandstone within this sequence will give rise to impedance contrasts causing the high amplitude reflections observed on the PSTM stack. More importantly, the distinct boundaries seen within this shale-sandstone layer gives rise to the surface-related and internal multiples observed on the PSTM stack seen between 2.3 sec and 4.0 sec that mimic the shape of the shale-sandstone sequence.

Data analysis

Figure 2, showing a supergather, constant velocity stacks, and semblance panel, demonstrates the proximity of the multiple velocities to the potential primary velocities at

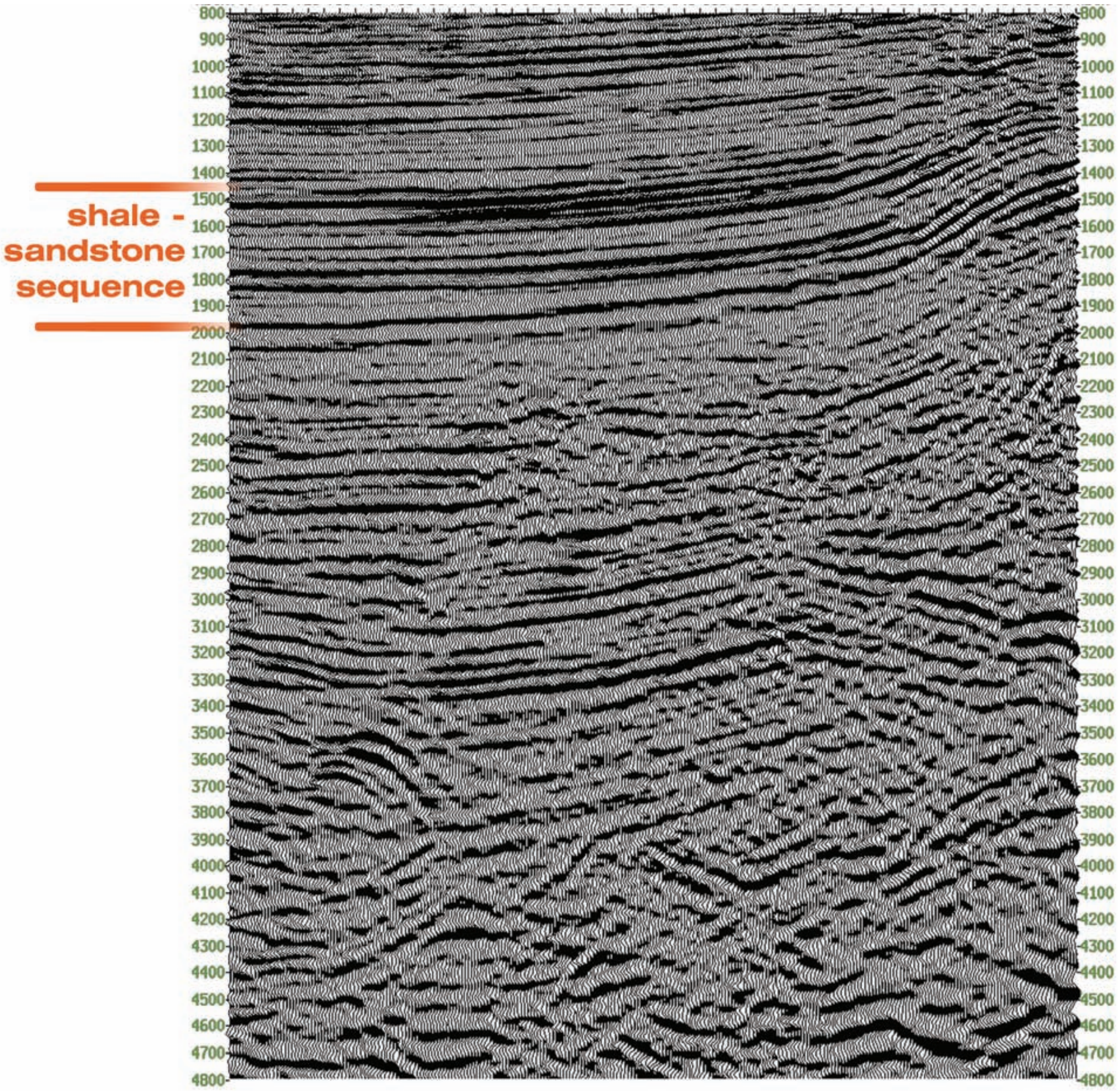

***Figure 1** PSTM stack of the land data set after standard processing, including spiking deconvolution to attenuate short period multiples. Radon demultiple was not applied (see text). The shallow shale-sandstone sequence responsible for the internal and surface relate multiples is indicated by arrow. Observe the high amplitude events due to the impedance contrast that characterize this sequence. The surface-related and internal multiples clearly mimic this sequence and appear on the PSTM section between 2.3 and 4.0 Sec TWT.*

the same location caused by this shallow shale-sandstone sequence. In this instance, constant-velocity stacks were the most useful way for discriminating between the multiple and primary velocity trends. The multiple energy from surface related multiples and internal multiples caused by the shallow shale-sandstone sequence dominates the semblance display, and it is difficult to determine which reflections were the primaries and which were the multiples on the supergather. The *rms* velocity range at which both both trends were very close to one an other was generally

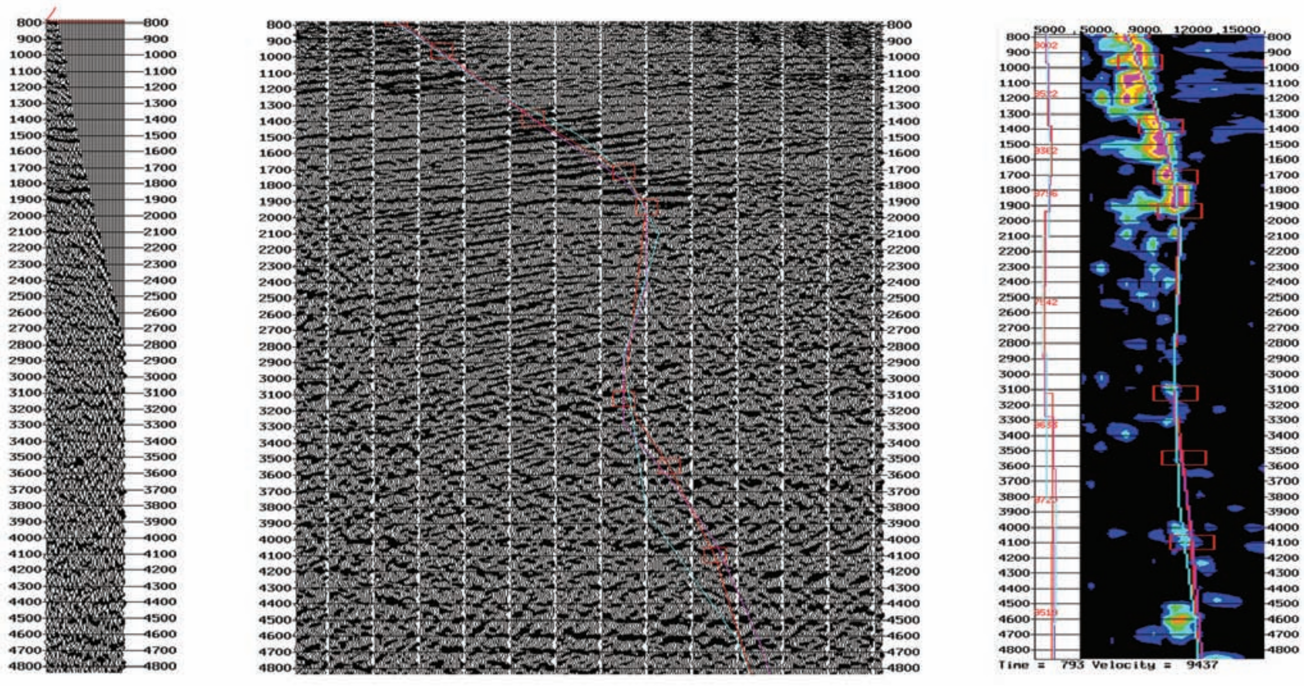

***Figure 2** Velocity analysis after PSTM prior to the application of the Eigenimage filter. The displays from L to R are: supergather, constant velocity stacks, and the semblance panel.*

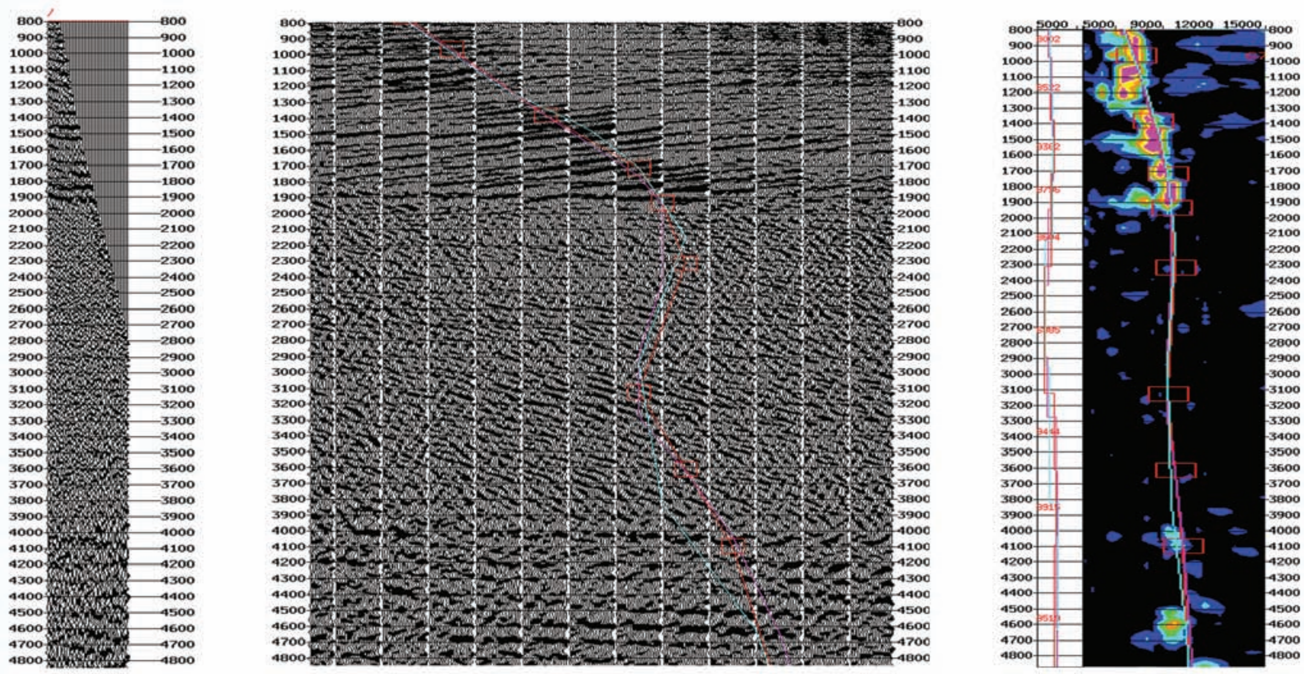

***Figure 3** Velocity analysis, at the same spatial location, after PSTM and after the application of the Eigenimage filter. The displays from L to R are: supergather, constant velocity stacks, and the semblance panel.*

between 2100–2600 m/sec, and between 1.5–4.0 seconds. In many instances the multiples and primaries moved-out at the same velocity. The distinct multiple velocity trend seen on the semblance panel between 2.3 sec and 4.0 sec, totally dominated the required primary trend.

Eigenimage filter for multiple attenuation

The Eigenimage filter used on this data example is based on the work by Kneib and Bardan (1997) who applied the technique proposed by Freire and Ulrych (1988) to attenuate water layer bourne internal multiples. The methodology adopted in this paper is similar but the application is to land data where the multiple generating mechanism is replaced by a shallow shale-sandstone sequence. The processing sequence can be summarized as follows:

1. Interpret the primary and its associated surface related and internal multiples.
2. Flatten these events.
3. Compute the covariance matrix within a specified window.
4. Determine the dominant eigenvectors of the covariance matrix.
5. Subtract the dominant eigenimage(s) from the data in common offset domain.
6. Reverse the flattening process of stage 2.

The main assumption in this method is that, after flattening, the multiples can be represented by the dominant eigenimage(s). A direct subtraction was used in this data example as it was known a priori that the multiple and primaries exhibited different dips. In areas where this condition is not satisfied some form of constraint as described by Kneib and Bardan (1997) can be applied to the multiple model prior to subtraction.

Results

Following the application of the Eigenimage filter in the common offset domain, velocity analysis was performed and the display shown in Figure 3 shows the same supergather, constant velocity stacks, and the semblance panel after multiple attenuation. It can be seen that the multiple velocity trend present in the semblance panel (Figure 2) before the application of the Eigenimage filter is not present (see semblance panel between 2.3 and 4.0 sec) indicating that the multiple energy has been successfully attenuated. Also note that the primary velocity trend is identical to the trend used to stack the data before application of the Eigenimage filter. Note the emergence of the underlying primary events that were previously masked by the surface and internal multiples generated by the shallow shale-sandstone layer.

Figure 4 shown below of the PSTM stack after Eigenimage filtering clearly demonstrates the effectiveness of the multiple attenuation and the emergence of the primaries that were originally masked by the multiples.

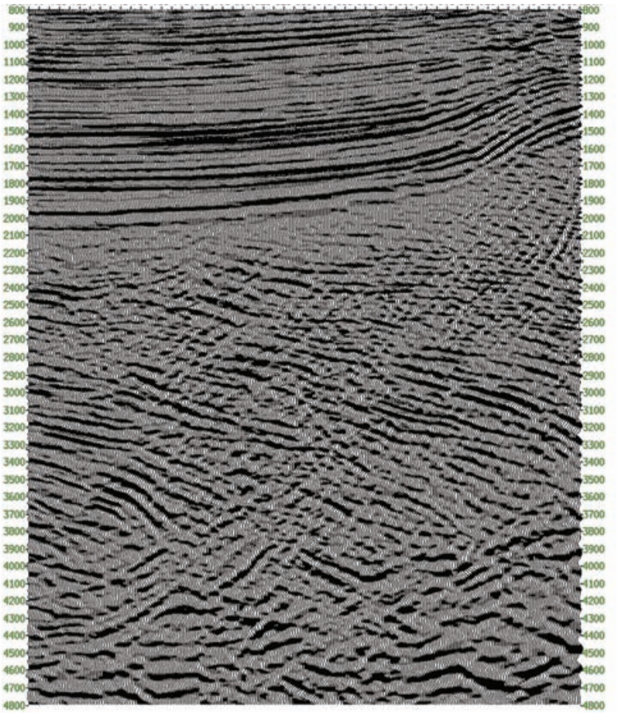

***Figure 4** PSTM stack after Eigenimage filtering. The surface-related multiples and the internal multiples have been successfully attenuated revealing the underlying structure originally masked by the multiples.*

The Eigenimage filtering technique has also been successfully applied in areas where irregular or inadequate spatial sampling can cause the multiples to be spatially aliased making it a robust multiple attenuation technique.

Conclusions

The example selected and the results shown indicate that the Eigenimage filter has a role to play in the arsenal of multiple attenuating tools available to the practitioner faced with the task of attenuating multiples. Provided the seismic data conforms to the underlying mathematical model imposed by the multiple attenuating techniques then a successful outcome can be obtained.

Acknowledgements

The authors would like to thank the management of Spectrum Geo for permission to publish this paper and to their colleagues at Spectrum, in particular to Andy Cuttell, Henk Innemee, and Duncan Woolmer.

References

Freire, S.L. and Ulrych, T.J. [1988] Application of singular value decomposition to vertical seismic profiling. *Geophysics*, **53**, 778-785.

Kneib, G. and Bardan, V. [1997] 3D targeted multiple attenuation. *Geophysical Prospecting*, **45**(4), 701-714.