Identifying and suppressing noise in seismic data from the Gippsland Basin (Australia)

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Figure 1. Current seismic exploration in the Gippsland Basin is hindered by strong noise beneath the Latrobe Group coal sequence. In this experimental seismic section the noise interference brings about the sudden lack of lateral continuity in reflections beneath 1.5 s thus increasing the exploration risk. We attempted to characterize this noise using elastic synthetic seismograms to model field records in the vicinity of a well. The accuracy of our synthetic tie then allowed us to interpret these noise contributions and to perform controlled tests upon a number of noise suppression methods.

Figure 2. Elastic synthetic seismograms were computed using the reflection matrix method (Kennett, 1980) for a highly detailed depth model. We defined layers in the depth model and obtained their $V_p$ values by blocking the checkshot corrected sonic log using a pattern recognition algorithm (Kerzner, 1986). We used a compaction trend to account for the shallow region not logged and averaged the density log over the layers defined during the blocking. Typical Poisson’s ratios ($\sigma$) for each formation were combined with a linear depth trend to construct an “artificial $V_s$ model. Our feasibility study revealed this approach to be quite accurate when tested using a $V_s$ log from another well. $Q_p$ and $Q_S$ were increased in the water layer and compaction zone to provide a closer match to the direct wave’s amplitude response.
Figure 3. Our synthetic/data matching procedure only corrected the synthetic for the main wavelet differences using the coal sequence reflections as the reference. We did not account for source directivity, airgun bubble effects or differences in frequency content. Amplitude scaling and bandpass filtering were applied to enhance deeper reflections.

Figure 4. Key events in the synthetics and field data are labeled using these abbreviations.

D  Sea floor reflections
MC  Miocene carbonate reflections
CS  Coal sequence reflections
CS SM1 First coal sequence surface multiple
NZ1 Mode converted interbed multiples
NZ2a Long-period multiples between CS and MC
NZ2b P/SR reflections between CS and MC
NZ2c SS reflections between CS and MC
NZ3 Surface related long-period multiples

* Note: all labels plotted at upper right onset of event(s)

Figure 5. Interleaved CMP gathers (supergathers) were compared to the synthetics because they contain the full range of offsets with events that are likely to be reflected from near the well log, even under conditions of moderate dip. Super-gather 842 is located almost directly above the well and is highly consistent with neighboring supergathers. It is dominated by strong refractions and guided waves including S-wave refractions associated with the Miocene carbonates.
Figure 7. The spliced stack display contains the synthetic and adjacent supergather after minimal processing through to stack. Once again, the match is exceptional especially at the coal sequence (1.2-1.6 s) and its surface multiples (2.5 s, 3.7 s). Amplitude discrepancies at the Miocene carbonates are probably due to the greater guided-wave interference in that part of the supergather. Using the additional synthetics we confirmed the persistence of three separate noise zones in stacked data from the Gippsland Basin. The synthetic computed without mode conversions suggested that S-wave reflections account for the majority of stacked signal in the target zone (1.3-2.2 s).

Figure 6. The elastic synthetic seismogram provides an excellent overall match to supergather 842, particularly at the coal sequence and its surface multiple. Intrinsinc anisotropy probably accounts for the amplitude and timing discrepancies at the far offset P- and S-wave refractions. We interpreted the elastic synthetic using additional synthetics (based on variations of the depth model and the synthesis method) to identify several regions containing noise reflections. For example, a synthetic computed without mode conversions revealed the importance of S-wave reflections for offsets greater than 800 m and helped to identify S-wave refractions. These results suggest that S-waves play a much greater role in marine seismic reflection studies than is commonly thought.
Figure 11. Noise interpretation in the semblance domain allowed us to use the depth model’s RMS velocity function to guide velocity picking away from the well. It is important to note the distinction between a “well-log RMS velocity function” and a “depth model RMS velocity function” as only the latter reveals where primary reflections should be picked in the elastic synthetic and the matched field data. Our model-based velocity analysis of the experimental seismic line produced only subtle changes in the stack amplitudes although these changes may have significant impact upon the interpretation. The reflector at 1.9 s, lying in the midst of the NZ2 long-period multiples, now appears with much greater continuity as a gently dipping structure.

C onclusions. Using detailed elastic modeling we found S-wave reflections and long-period multiples generated between (and within) the coal sequence and Miocene carbonates to be the most troublesome noise contribution in the target zone. Lateral variation of the noise interference is largely due to structural variation in the Miocene carbonates. We used the elastic synthetic to improve velocity analyses and are currently testing processing solutions to the noise problem. In particular, $\tau - p$ domain processing methods appear likely to bring about further improvements in stacked data quality. We are confident that our techniques will find wider applicability in the modeling, inversion and noise suppression of field data from other exploration permits.