Chapter 5. Summary and Conclusion

Summary

Starting with a one-dimensional model and several simplifying assumptions, a method was developed for dealing with multiple reflections involving the near perfect reflector at the free surface. Solutions for the practical problems relating to estimating the source waveform and computational efficiency were presented. An application of the single-channel algorithm to a section of field data demonstrated the successful elimination of seafloor and pegleg multiples. This example also confirmed the underlying assumption that the disturbing multiples were those involving the free surface reflection.

Extending the analysis to waves in two dimensions, the approximation that the subsurface behaves as an acoustic medium allowed describing the seismic wave field as a scalar potential governed by the scalar wave equation. Based on a number of numerical and theoretical considerations the wave equation was split into two separate partial differential equations: one governing the propagation of upcoming waves and a second describing downgoing waves. This was accomplished by transforming the wave equation into two separate coordinate frames; selected such that the desired solution is discriminated as a slowly varying function of depth. Having developed the equations for propagation in homogeneous media, the required coupled equations for velocity inhomogeneous regions were obtained. Following this, arguments were presented for neglecting the transmission coefficients and the intrabed reflection term in the equations.

Stating the initial-boundary value problem in terms of a known reflector model and initial disturbance, finite difference approximations were formulated to numerically integrate the surface reflection seismogram.

The forward algorithm was developed and economizing gating techniques were described. Use of the algorithm was illustrated with several reflector models. In the simple point scatterer case the computed arrival times were compared with ray path travel times. The forward solution to more complicated models were in qualitative agreement with intuition and experience observing field data.

The inverse problem was defined and placed in the context of reflector mapping. The causal directions of propagating waves in time and space were related to the downward continuation of surface data. The basic reflector mapping principles were discussed and used to develop a general reflection coefficient estimator. The inversion algorithm was illustrated using the results of the 2-D forward calculation as the surface boundary conditions. Finally, the theoretical and numerical requirements of the inversion technique were related to current field recording parameters and geometries.

Conclusion

The one-dimensional algorithm represents a new and interesting approach toward eliminating multiple reflections in situations where wave effects are negligible. While the field example illustrated its use in moderately deep water, the theory is valid for shallow water multiples as well. The basic requirements are obtaining an estimate of the source waveform and recording and preserving reflected (vertical) amplitudes.

The two-dimensional forward algorithm presents an economical technique for obtaining time dependent solutions of the wave equation, including diffracted multiple reflections, for an arbitrary number of complex-shaped reflectors. Additionally, we may simulate these results due to an arbitrary initial surface disturbance. The primary limitation is the angular bandwidth modelled. For the reflection seismic geometry this will not usually cause difficulty. However, solutions involving wide-angle reflections will necessarily be involved additionally with consideration of angular dependent reflection coefficients, refractions and shear waves.

There are a large number of effects observed on field data; some of which are subtle (variable reverberation period, amplitude diffusion) and others dramatic (obvious focusing and diffraction). Still others are simply confusing. When these effects are the result of multiple reflected waves the interpretation is not, in general, aided by migrating these waves as primaries. The inversion technique of this thesis was predicated on the belief that diffracted primary and multiple waves represent useful information. The numerical examples have illustrated that at least theoretically we may attempt a direct, time dependent inversion of reflection seismic data. Thus, within the framework of this theory we may be able to model subtle, dramatic and confusing multiple reflections. Perhaps the greatest practical information lies in the confusion.

The unresolved question then concerns testing of this hypothesis by applying the proposed inversion method to field data meeting all the prescribed requirements. The final result may well indicate that this approach places requirements on the data which are fundamentally too severe or impossible to meet in practice. The possibility must then be explored of combining a wave theoretic, deterministic approach (such as this) with statistical methods. The strong belief is that dramatic results may be expected where reflector mapping techniques are based on theory consistent with the entire reflected wave field.