Chapter 6. Summary and Conclusion

Summary

A velocity estimation procedure which allows accurate velocity estimates to be made regardless of reflector geometry has been presented. The key idea of this procedure is to migrate the data before it is used to estimate velocity.

Here wave equation techniques were used to perform pre-estimation migration. In adopting a particular realization of the wave equation migration method, several simplifying assumptions were made. It was assumed that the subsurface is an acoustic medium containing only two-dimensional reflectors. This assumption allowed the use of a two-dimensional scalar wave equation to describe wave propagation. Additionally, it was assumed that the subsurface is such that multiple reflections are not significant.

Because previously published downward continuation equations were designed to model nearly vertical wave propagation, new equations valid for wide angle reflections were developed. As a first step in deriving the migration equations to be used in estimating velocity, a downward continuation equation which governs wide offset reflections generated by a single source was found. A finite difference calculation illustrated the properties of each term in this downward continuation equation. When source-receiver directivity effects were ignored this continuation equation reduced to a form similar to the previously published equations. The same calculation also indicated that wide offset reflection data can be accurately migrated with the simplified equation.

Using the techniques and insights gained from the study of the single source geometry, an equation which can be used to downward continue multi-offset sections was derived. This equation contained terms which explicitly coupled common offset sections during migration. Numerical experiments demonstrated that for many commonly encountered reflector and recording geometries, this coupling has an almost imperceptible effect on the migrated data. Additionally, synthetic data examples showed that continuation equations which neglect this coupling, model even second order effects like structurally caused moveout.

Study of some velocity estimates showed that many of the difficulties associated with estimating velocities from seismic data recorded over nonhorizontal reflectors can be traced to the fact that such data need not resemble, in detail, the earth structure over which they were recorded. On the basis of this study it was concluded that multi-offset section migration equations are just the tool needed to improve velocity estimates. Two synthetics demonstrated that, unlike estimates based on surface data, velocity estimates based on correctly migrated data exhibit no velocity diffusion effects and are independent of reflector dip and curvature. Following this, arguments stating that migration should improve velocity estimates even when an incorrect velocity is used for the migration, were presented. It was also noted that if velocity is assumed to be constant over a receiver cable length, velocity estimation programs designed for use on surface data can be applied to migrated data without modification. An additional synthetic illustrated that good velocity estimates can be made with incorrectly migrated data.

A final synthetic illustrated that downward continuation can be used to allow accurate velocity estimates to be made from no record data recorded over an earth in which the reflectors are random functions of midpoint and depth. Theoretical considerations showed that for reasonable data parameters downward continuation of random earth data could be expected to increase the semblance of that data along the true velocity hyperbolic by factors of approximately 50%.

Lastly, the velocity estimation procedure was applied to some field data recorded over a Gulf Coast diapir. These data contained regions where the reflections had good lateral coherence and regions where lateral coherence was poor. These latter regions were used to illustrate velocity estimation in no-record-areas. Estimates based on the coherent data illustrated the usefulness of migration in suppressing both diffusion effects and structurally caused residual moveout. The estimates made in the incoherent portions of the data sometimes showed minor improvements after migration. However, usually migration had no dramatic effect on the estimates. The very minor differences between the migrated and surface estimates were thought to be due to the lack of significant interference effects in that portion of the test data.

Conclusion

As stated in chapter 1, the objectives of this thesis were to demonstrate that velocity estimates could be improved by the use of downward continuation and that the problems resulting from migrating the data with an incorrect velocity could be overcome. The results of chapter 5 demonstrate that these objectives have been realized both for synthetic and field data. There we showed that continuation improves estimates because it suppresses both the Levin effect and velocity diffusion. We also found that the fact that continuation velocities might be incorrect presents no great difficulties.

In the course of fulfilling the main objectives of this thesis we developed several additional techniques. One new capability we have gained is the ability to downward continue multi-offset sections. This ability is useful not only for our velocity estimation applications but also for improving the quality of stacked sections. The equations developed in chapter 4 can be used to migrate before stack and hence, can be used to reduce the destructive interference of signal which occurs when complex surface data are stacked.

The ability to estimate accurate velocities from some types of no record data is another capacity that we have gained along the way. If sufficient no record data fitting our three dimensionally arbitrary reflector model exists, this ability may turn out to be the fundamentally most important development of this thesis.

Although they were developed only as an introduction to the section continuation problem, the profile results developed in chapter 3 might in the long run be more useful than the multi-offset continuation equations. Recall that a 15° dip assumption was used heavily to reduce the number of terms appearing in the final section continuation equation. Study of random earth data showed that the real payoff of downward continuation occurs only when effective dips are greater than 15°. Thus, really dramatic improvements in velocity estimates resulting from downward continuation can be achieved only if the 15° assumption is relaxed by including, or at least estimating, some of these discarded terms. Unfortunately if this is done there is a distinct possibility that the resultant finite difference algorithms may become complex and that computation costs will increase dramatically. If this is the case it may become more economical to migrate many fold multi-offset sections by using the simple profile equations of chapter 3 to migrate the data generated by each shot separately. In any event, all the equations necessary for migrating any or all of the data in a multi-offset section are contained in this thesis.