Chapter 9

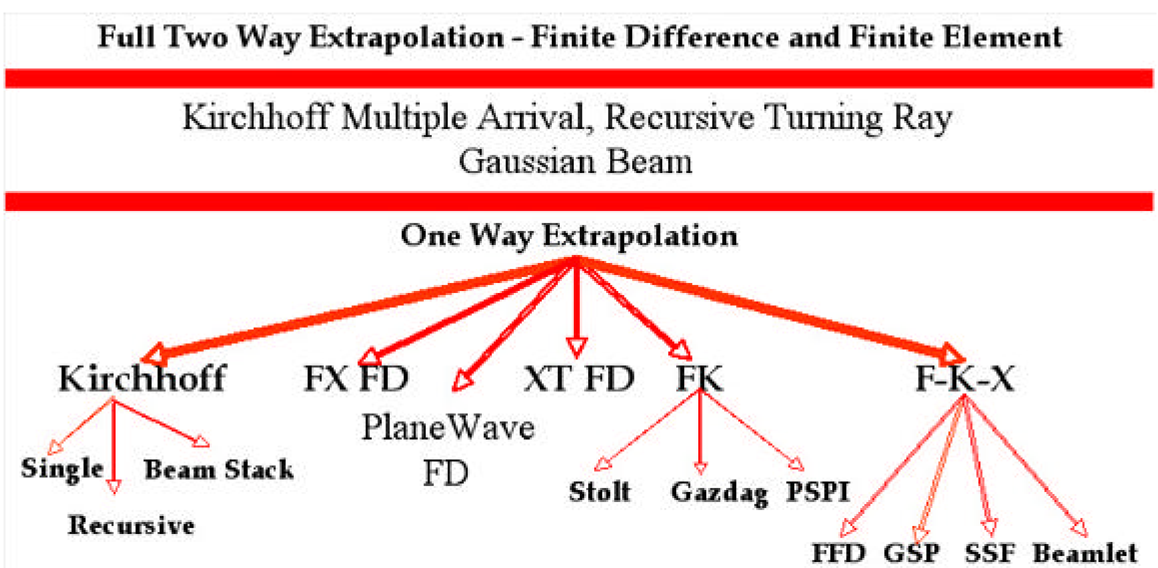
Migration Summary

This chapter briefly summarizes the information about migration presented in previous chapters.

Computational Complexity

The hierarchy of algorithms in Figure 9-1 makes us wonder why this diagram has so many different one-way approaches. Why are there so many one-way methods and so few two-way or almost two-way technologies?

Figure 9-1. The migration algorithm hierarchy



The simple answer is that the demarcation between one-way and two-way methods is one of computational efficiency. That is, one-way methods tend to be significantly more computationally efficient than two-way methods. This statement is certainly a function of algorithm implementation, but it is not a bad rule of thumb. Rumors have it that the Gaussian beam method can be made extremely efficient, and so the rule may be broken in that case. However, because all of the one-way methods function depth slice by depth slice or time slice by time slice, two-way approaches that must compute the entire wavefield at each propagation step usually lose the efficiency battle.

In spite of the apparent complexity of Figure 9-1, there are really only three basic algorithm styles. The first group might be best referred to as raytrace methods, and includes all of the Kirchhoff methods and the Gaussian beam. The second group generally includes methods that image depth slice by depth slice using either finite differences or some form of Fourier domain method. At the top of the hierarchy, the third group does imaging volume by volume. Thus, the computational complexity increases greatly as we move from the bottom to the top in Figure 9-1.

From a more practical viewpoint, raytrace-based methods are by far the most flexible. They can output data anywhere at any desired volumetric level. At some loss of overall accuracy, they can be made far more efficient than any other approach. In the slice-by-slice world, common azimuth methods rule the day. As we move up the accuracy chain, one-way shot profile methods are more efficient than two-way approaches. There is no question that as the computational complexity increases, efficiency decreases, but accuracy improves dramatically.

Velocity Sensitivity

Many geophysicists argue that high technology two-way methods are much more sensitive to errors in the velocity model than any of the one-way approaches. Both mathematical theory and experience contradict this assumption.

Any impulse analysis shows multi-arrival energy is very prevalent below complex geometries defined by anomalously high velocities. Such structures include salt domes and granitic overthrusts but can also be carbonate based.

Since rays, as computed by most raytraces, represent a high frequency approximation, virtually any ray-based migration may be excessively sensitive to sharp velocity discontinuities. This, together with the single arrival assumption, is certainly a major reason that single arrival Kirchhoff methods are extremely poor at imaging below salt.

Most one-way implementations do a much better job of handling multiple arrivals, and so it is not surprising that images produced with these methods are usually better than single arrival Kirchhoff applications. But, because one-way methods have a built-in angle limit, they also have a built in instability.

Two-way methods, or at least those that are above the one-way line in Figure 9-1, have almost no inherent restrictions on velocity variation, angle, or amplitude response. Depending on the implementation, they can produce significant amounts of grid dispersion resulting in something akin to a grid-based anisotropy, but, if that is handled properly, we can be assured that the two-way method will have the least sensitivity to velocity errors.

Amplitudes

The phrase *true amplitude imaging*, as used in this book, really means that, after migration, any amplitude within the imaged volume is directly proportional to reflectivity. There are, of course, so-called *true amplitude one-way methods*, but all of those methods are simply modifications of a one-way method of choice to include some aspect of two-way propagation. Jon Claerbout was the first to propose such a method in his 1986 book, so the idea of making a one-way migration into a two-way migration has been around for some time. However, as far as the author is concerned, the only methods that can be called true amplitude methods are the full two-way method and the Gaussian beam method.

Conclusions

Experience has shown that, given a good implementation, each of the one-way algorithms has a useful place in most, if not all, prestack migration projects. When implemented properly, almost any of the algorithms discussed here will produce a reasonable result. From a hierarchical perspective, the top of the pyramid is dominated by two-way methods. These full wavefield techniques always produce the best result when the velocity model is correct. Moreover, they almost always do a better job than their one-way counterparts when the velocity model is not correct. Moving down the hierarchy tends to reduce the computational complexity at the cost of image quality. Because they leave something out of the imaging process, one-way approaches are also much more sensitive to velocity errors.