Chapter 1. Problems Solvable with Wave Stacks

In this chapter we make mention of some of the more general classes of problems which we believe can be successfully handled using wave stacks. Not all of the problems mentioned here are treated in this thesis. Some, such as the estimation of strong lateral velocity variations, are more or less straightforward extensions of the formalism contained in Chapters 2 through 4. Others, such as prediction and elimination of diffracted sea floor multiple reflections represent concurrent research by my coworkers.

Migration through Regions of Strong Lateral Velocity Variation

Migration involves the imaging of a subsurface reflector. To do this effectively, we must know the shape of the downgoing wave front immediately before it encounters the reflector, and we must also know the shape of the upcoming wave front immediately after the reflection. The image of the reflector then becomes the net change in the shape of these two wave fronts.

In a constant velocity medium this is a straightforward procedure. When the data has been plane wave stacked, we know that the downgoing wave was a plane wave immediately above the reflector. The shape of the upcoming wave can be inferred from downward continuation of the surface data by wave equation techniques.

For a migration through a region of strong lateral velocity inhomogeneity, consideration must be given to transmission effects on both the upcoming and downgoing wave. Those of the upcoming wave are effectively handled by pre-existing wave equation methods of

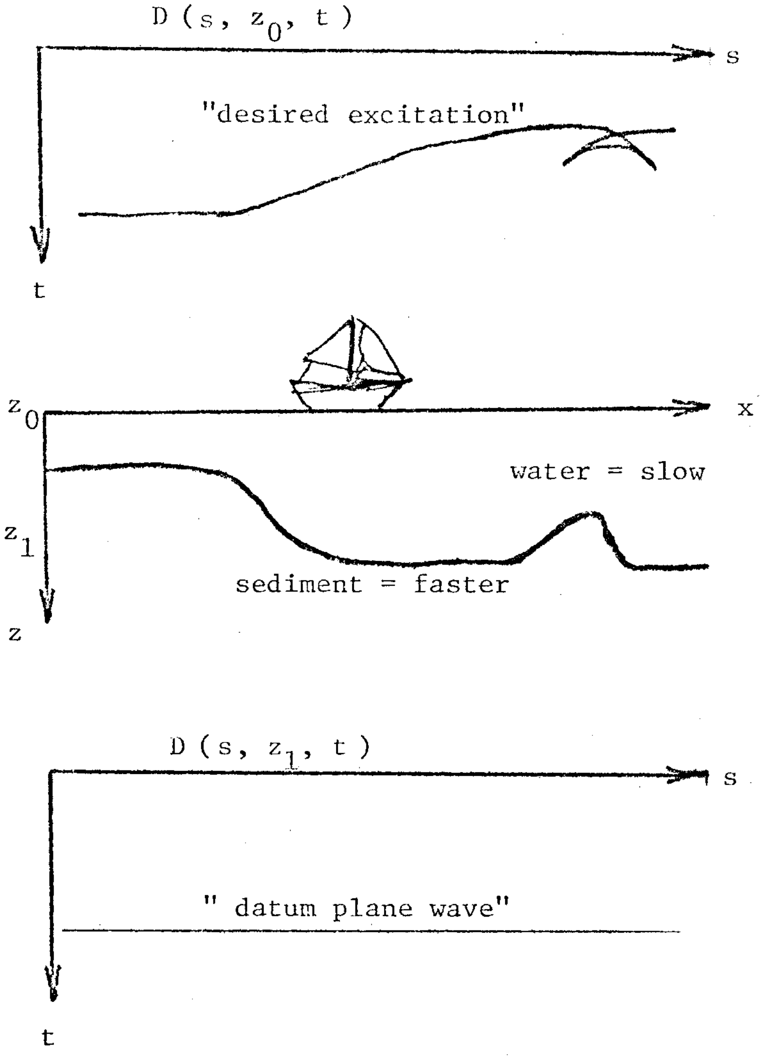

Figure 4.8. In order to achieve a downgoing plane wave at the datum depth z_1, another wave "desired excitation" must be initiated at z_0. The "desired excitation" may be computed by projecting the "datum plane wave" up through the sea floor topography.

downward continuation. Wave stacks now have allowed us to develop a method for handling these effects on the downgoing wave. The wave stack can be generalized so that a plane wave front (or a wave front of any shape) is created at some datum provided the velocity function $v(x,z)$ above this datum is known. Figure 4.8 is reproduced here from Chapter 4 to illustrate this principle.

A plane wave (for example) is desired at some depth, z_1 . This depth is below a known strong lateral velocity inhomogeneity. Methods of wave field extrapolation using the scalar wave equation can be used to predict the wave field necessary at the surface to produce the desired wave front at depth. This "desired excitation" is then synthesized from conventional data at the surface by methods of wave front reconstruction discussed in the next chapter.

By combining the downward continuation of the upcoming wave with synthesis of a desired downgoing wave at any depth, the entire experiment is thus downward continued through an arbitrary and known velocity, $v(x,z)$. In this manner a complete and rigorous migration procedure is attainable.

Estimation of a Laterally Variable Velocity

When the lateral velocity variation of an interval at depth is unknown, the method of the previous section can be generalized to its estimation.

Methods of statics analysis yield a high lateral velocity resolution in the near surface because the experiment (i.e., both shots and geophones) is at virtually the same depth as the region of velocity inhomogeneity. Indeed, if the entire experiment is downward continued to some datum, and then an interval velocity estimate made between that datum and a reflector at slightly greater depth, the result will be the same high lateral resolution of velocity.

The tools for this estimation of a lateral velocity inhomogeneity at depth are developed in this thesis for data which has been slant plane wave stacked. In Chapter 3 a method for interval velocity estimation is presented, and in Chapter 4 downward continuation of both shots and geophones is described.

Angle-Dependent Reflection Coefficients

Field data which was plane wave stacked for this thesis (see Chapter 2) clearly exhibited angle-dependent reflection coefficients. The wave stacks which were done synthesized downgoing plane waves at various propagation angles, and as a result permitted easy identification of this angle-dependent feature.

Observation of angle-dependent reflection coefficients is often difficult on common midpoint gathers because of low signal strength on the raw data, and of course impossible on common midpoint stacks because of the summation over all angles. In a plane wave stack, however, the coherent sum includes only that reflected energy which is produced from a single illumination angle. This results in a partial coherency stack that has an enhanced signal to noise ratio that can facilitate amplitude measurement.

Angle-Dependent Transmission Coefficients

Any angle-dependent reflection coefficient has an associated angle-dependent transmission coefficient. A reflector, such as a "bright spot", may exist for which the transmission effect is strong enough so that amplitude measurements on deeper events are affected.

If an angle-dependent transmission coefficient can be estimated, a proper migration through this region can be done when the data has been plane wave stacked. This is not possible in common midpoint stacked data where these angle-dependent effects are smeared by the summation over all angles. The discussion in Chapter 4 following equation (4.16) treats this matter in more detail.

Angle-Dependent Waveforms

It is a practical reality that the shot waveform is angle-dependent. This is generally due to the angle-dependent antenna response of the shot and geophone arrays, but can also be due to angle-dependent sedimentary resonances.

The effectiveness of many data processing algorithms is enhanced by a shot waveform which is uniform throughout the seismic section. An example of this is in the prediction and subtraction of sea floor multiples.

By means of the slanted plane wave stack, an entire seismic section can be generated by downgoing energy of a single illumination angle. This will tend to create uniformity in the shot waveform.

Diffracted Sea Floor Multiples

The wave equation can be used to predict and therefore subtract the effect of sea floor reverberations. This is a particularly attractive method when the sea floor is of sufficient curvature to produce a diffracted wave front upon reflection.

Riley (1975) showed that a theory for predicting diffracted multiples of an incident vertical plane wave could be developed, but that it was inappropriate for dealing with such multiples on common midpoint stacked data. Riley's theory can in principle be generalized to an incident plane wave of any angle, and therefore can be applied to slanted plane wave stacked sections.

These stacks are described in detail in Chapter 2, but no treatment of diffracted multiples is included here as it is the content of concurrent thesis research.