# PRE-STACK PARTIAL MIGRATION

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## Abstract

Conventional seismic data processing can be improved by removing the degrading effect of wide offsets on dipping events so that they stack coherently. A procedure to achieve this improvement is proposed here, which is basically a "partial" migration of common offset sections prior to stack. It has an advantage over "full" migration before stack in that, in the case of the latter, the final product is a migrated section. However, the pre-stack partial migration provides the interpreter with a high quality common midpoint (CMP) stack section which can be subsequently migrated. An unmigrated CMP stack is a preferred intermediate product because velocity estimation is usually not completely accurate. The resulting migrated section may have events that are difficult to correlate with others.

The theory of pre-stack partial migration is based on the double square root equation, which describes seismic imaging with many shots and receivers. The double square root operator in common midpoint space can be approximately separated into two terms, one involving only migration effects and the other involving only moveout correction. This separation provides an analysis of conventional processing. Estimation of errors in the separation yields the equation for pre-stack partial migration.

Extension of this theory for separable approximation to incorporate lateral velocity variation yields a significant term proportional to the product of the first powers of offset, dip and lateral velocity gradient. This term has potential application in estimating lateral velocity variation. Finally, the three-dimensional development of the theory for the double square root equation and related operators is introduced.

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# *INTRODUCTION*

The geophysicist who is involved in the seismic interpretation of field data from the foothills region of the Rockies is quite aware of the problem with dipping beds - they require adjustment on stacking velocities. The junior geophysicist whose first assignment is processing data from the Gulf of Mexico, an ideal place for testing exploration techniques, occasionally wonders why some events are hardly visible on common midpoint stack even though they are present on most common offset sections.

Conventional processing is robust enough to handle seismic field data from many different parts of the world. Even in areas with flat beds, however, offsets can be large enough to accommodate for accurate velocity estimation. Large offsets can have a degrading effect upon common midpoint (CMP) stack. Moreover, in regions of complex structural setting, conventional processing has difficulty in delineating steeply dipping events. The underlying reason for all this is related to two crucial assumptions upon which conventional processing is based. The first assumption is that the classic NMO equation is derived for the stratified earth (zero dip) model. This allows one to apply moveout correction to each CMP gather, independently. The other assumption is that the CMP stack is equivalent to a zero-offset section, which in turn is considered to be generated by putting sources on reflectors and turning them on at t=0 and continuing the resulting upcoming wavefield to the surface using half the medium velocity. This makes it possible to migrate the stack section with wave extrapolation techniques.

In recent years, considerable attention was given to tackling the problem with CMP stack so that steeply dipping events could be delineated. Gardner et al (1974) described a procedure to simultaneously migrate and do velocity analysis of seismic data using an experimental model. Sattlegger (1975) and Dohr and Stiller (1975) demonstrated on some field data the success of migration before stack to produce a more enhanced section of the earth. Doherty and Claerbout (1976) developed the early wave equation methods to downward continue moveout-corrected seismic wavefields for a more reliable velocity estimation in a non-layered earth. Sherwood et al (1976) implemented a migration before stack procedure by adjusting velocities for offset and successfully applied it on field data from the Gulf of Mexico. However, it was realized that *full* migration of each individual common offset section is computationally costly. Additionally, but also more importantly, such a procedure does not yield an unmigrated CMP stack section as an intermediate product. Also, velocity estimation provides only limited accuracy. An unmigrated CMP stack section helps the interpreter a great deal in resolving spurious events on a migrated section due to inaccurate velocities. Finally, Judson et al (1978) presented a procedure which produced an unmigrated CMP stack section in which steeply dipping events are enhanced. Even though the theory of this procedure, namely "Devilish," is based on coarse ray approximations, it produced encouraging results from a particular field dataset. In this thesis, we propose a systematic procedure, based on the wave equation, which will improve conventional processing by removing the effect of wide offsets and correcting for dipping events so that they stack coherently. The process is basically a ***partial*** migration of common offset sections prior to stack.

We start Chapter 1 with a discussion of the fundamental problem of reflection seismology, namely seismic imaging. The task is to reconstruct the reflectivity of the earth over the (x,z)-plane given the wavefield recorded at the surface P(x,0,t). To accomplish this task, one needs to downward continue the recorded wavefield and pick out the reflectivity at zero traveltime. However, the situation is a bit more complicated for a real seismic experiment which involves many shots and receivers. Here, we must downward continue both shots and receivers. When the shot and the receiver coincide we are at the reflecting point at zero traveltime.

A mathematical description of seismic imaging is given by the double square root equation (DSR). All migration techniques are offshoots of this equation. In fact, it turns out that conventional processing is based on an approximation to the double square root equation. Imposing the zero-dip and zero-offset assumptions, we separate the double square root operator into two terms, one involving the zero-dip moveout correction applied in offset space and one involving the migration of zero-offset section applied in midpoint space. We will study the response characteristics of the DSR equation and its separable approximation (Sep), and observe the problems related to zero-offset and zero-dip assumptions.

We will begin Chapter 2 by formally defining the deviation operator (Dev) as the difference between DSR and Sep, which is effectively the error involved in the separation of the double square root operator. The recognition of a significant term in the difference will yield an equation for ***pre-stack partial migration***. A wide variety of model experiments and field data example will demonstrate the fact that conventional CMP stack is considerably improved by incorporating this procedure into the mainstream of seismic data processing. In particular, the mute zone during stack is considerably reduced, a better imaging is achieved by migration after stack, and dipping events can be delineated much more successfully.

In Chapter 3, we will extend our theoretical analysis on separation of the double square root equation to the case of lateral velocity variation. We will discover an unfamiliar term that is a function of offset, dip, and lateral velocity gradient. A simple experiment on field data, in which a lateral velocity gradient of roughly (500 ft/sec)/1000 ft was measured, shows that this term may be used for estimating lateral velocity variation. In particular, it is potentially useful in the statics problem where the near-surface lateral velocity gradient is often significant.

Finally, in Chapter 4, we will extend the theory of the double square root equation to three-dimensional recording geometry. Here, one has to downward continue a two-dimensional array of shots and receivers. The separable approximation to the three-dimensional DSR equation suggests strong coupling of wavenumbers that are associated with inline and crossline directions. The deviation operator also takes a form that is rather difficult to implement. The 3-D extension is basically meant to introduce problems related to 3-D seismic recording which is one of the future directions exploration seismology will take.