Migration of non-zero-offset sections for a constant velocity medium

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Abstract

The first step in migrating a zero-offset seismic section $p(h=0,y,t)$ via the Stolt (1978) or Gazdag (1978) algorithms is a two-dimensional Fourier transform over midpoint y and time t. Assuming that the midpoint transform is performed first, we show that migration of non-zero-offset ($h \neq 0$) sections may be accomplished by replacing the temporal Fourier transform with the more general transform:

$$q(k_y,\omega) = \int dt \; p(h,k_y,t) \, A^{-1} \, e^{i\omega t A}$$

where

$$A \equiv A(h,k_y,\omega) \equiv \left[1 - \frac{4h^2}{v^2t^2}\left(1 - \frac{v^2k_y^2}{4\omega^2}\right)\right]^{1/2}$$

and where ω is temporal frequency, k_y is midpoint-wavenumber, h is half-offset, and v is velocity assumed constant. $q(k_y,\omega)$ is then migrated as if it were the two-dimensional Fourier transform of a zero-offset section. One can readily verify that the general transform reduces to the Fourier transform in the limit of zero-offset $h = 0$, and that it reduces to the Fourier transform of normal-moveout-corrected data in the limit of zero-dip, $k_y = 0$. In fact, the above transform is accurate for all offsets and all dips.

Introduction

Let $p(h,y,t,z=0)$ denote the seismic wavefield recorded at the the earth's surface $z=0$ as a function of half-offset h, midpoint y, and time t. We define the migration of this data as the mapping from $p(h,y,t,z=0)$ to $p(h=0,y,t=0,z)$, a process which can be performed by first extrapolating the wavefield $p(h,y,t,z=0)$ to obtain $p(h,y,t,z)$ and then extracting the zero-offset and zero-traveltime section $p(h=0,y,t=0,z)$. The extrapolation step can be performed via

$$p(k_h,k_y,\omega,z) \ = \ e^{ik_z(k_h,k_y,\omega)z} \ p(k_h,k_y,\omega,z=0) \tag{1a}$$

where k_z is the "double square root" (DSR) extrapolation operator defined by

$$k_z \ \equiv \ \frac{-\omega}{v}\left\{\left[1 - \frac{v^2}{4\omega^2}(k_y - k_h)^2\right]^{1/2} + \left[1 - \frac{v^2}{4\omega^2}(k_y + k_h)^2\right]^{1/2}\right\} \tag{1b}$$

v is the earth velocity which we assume constant, and $p(k_h,k_y,\omega,z)$ is the Fourier transform of $p(h,y,t,z)$ defined by

$$p(k_h,k_y,\omega,z) \ \equiv \ \int dh \ e^{-ik_h h} \int dy \ e^{-ik_y y} \int dt \ e^{+i\omega t} p(h,y,t,z)$$

Integrating over ω and k_h and Fourier transforming over k_y (ignoring 2π normalizations) yields

$$p(h=0,y,t=0,z) \ = \ \int dk_y \ e^{+ik_y y} \int dk_h \int d\omega \, p(k_h,k_y,\omega,z)$$

We refer the reader unfamiliar with the concepts associated with these equations to several tutorial papers in SEP-25 (Claerbout,1980,p.285-315).

Several authors, including Judson et al (1978) and Yilmaz and Claerbout (1980) have noted the difference between migrating before stack via equations (1) and the more conventional process of migrating a common-midpoint (CMP) stack of normal moveout (NMO) corrected data. The difference (i.e., the error in conventional processing) is, to first order, proportional to $k_h^2 k_y^2 / \omega^4$ (Yilmaz and Claerbout,1980). For $k_y = 0$ (zero-dip) or $k_h = 0$ (zero-offset), the conventional process is accurate. But seismic data typically contains energy at non-zero k_y and k_h, so the above mentioned authors developed clever additions to conventional processing which they called "Devilish" or "pre-stack partial migration" (PSPM).

PSPM plus conventional processing is not, however, equivalent to full migration before stack. PSPM as described by Yilmaz and Claerbout is just the first order correction to conventional processing, the error increasing with larger offsets and steeper dips. The purpose of this paper is to describe a method for migrating non-zero-offset sections which, for a constant velocity medium, is accurate for all offsets and all dips.

Two-step migration of $p(h,y,t,z=0)$

We first rewrite the DSR extrapolation of equations (1) as follows:

$$q(k_h,k_y,\omega_0,z) = e^{ik_z(k_y,\omega_0)z}\, q(k_h,k_y,\omega_0,z=0) \tag{2a}$$

where k_z is redefined by

$$k_z(k_y,\omega_0) \equiv \frac{-2\omega_0}{v}\left[1 - \frac{v^2k_y^2}{4\omega_0^2}\right]^{1/2} \tag{2b}$$

and ω_0 is defined by

$$\omega \equiv \omega_0\left[1 + \frac{v^2k_h^2}{4\omega_0^2}\left[1 - \frac{v^2k_y^2}{4\omega_0^2}\right]^{-1}\right]^{1/2} \tag{3}$$

That the two definitions of k_z are equivalent can be verified by direct substitution. Our motive for redefining k_z in terms of a new frequency ω_0 is that equations (2) represent the conventional extrapolation we would use for zero-offset sections. Therefore, we consider ω_0 to be the Fourier dual of zero-offset traveltime t_0.

Because we typically do not record zero-offset sections, we need equation (3) to transform recorded frequency ω (or time t) to zero-offset frequency ω_0 (or time t_0). In other words, we use equation (3) to transform the recorded data $p(k_h,k_y,\omega,z=0)$ to zero-offset data $q(k_h,k_y,\omega_0,z=0)$. To perform this transformation, let

$$p(h,y,t,z=0) \equiv f(h,y,t,t_0=0)$$

and let

$$q(h,y,t_0,z=0) \equiv f(h,y,t=0,t_0)$$

Then, think of equation (3) as a dispersion relation representing a partial differential equation which enables us to compute $f(h,y,t,t_0)$ from $p(h,y,t,z=0) = f(h,y,t,t_0=0)$. Finally, extract the $t=0$ portion $q(h,y,t_0,z=0) = f(h,y,t=0,t_0)$. All together,

$$q(k_h,k_y,t_0,z=0) = \int d\omega\, e^{-i\omega_0(k_h,k_y,\omega)t_0}\, p(k_h,k_y,\omega,z=0)$$

or, using equation (3),

$$q(k_h,k_y,t_0,z=0) = \int d\omega_0 \left[\frac{d\omega}{d\omega_0}\right] e^{-i\omega_0 t_0}\, p[k_h,k_y,\omega(k_h,k_y,\omega_0),z=0] \tag{4}$$

By inspection,

$$q(k_h, k_y, \omega_0, z=0) = \left[\frac{d\omega}{d\omega_0}\right] p[k_h, k_y, \omega(k_h, k_y, \omega_0), z=0] \tag{5}$$

We now show that $q(h=0, y, t_0=0, z)$ computed via the two-step method of equations (2) and (5) equals $p(h=0, y, t=0, z)$ computed via the one-step method of equations (1). In fact, we can prove the stronger statement

$$q(h, y, t_0=0, z) = p(h, y, t=0, z)$$

From equation (1a)

$$\begin{aligned} p(k_h, k_y, t=0, z) &= \int d\omega\, e^{ik_z(k_h, k_y, \omega)z} f(k_h, k_y, \omega, t_0=0) \\ &= \int d\omega\, e^{ik_z(k_h, k_y, \omega)z} \int d\omega_0\, f(k_h, k_y, \omega, \omega_0) \end{aligned}$$

and from equation (2a)

$$\begin{aligned} q(k_h, k_y, t_0=0, z) &= \int d\omega_0\, e^{ik_z(k_y, \omega_0)z} f(k_h, k_y, t=0, \omega_0) \\ &= \int d\omega_0\, e^{ik_z(k_y, \omega_0)z} \int d\omega\, f(k_h, k_y, \omega, \omega_0) \\ &= p(k_h, k_y, t=0, z) \end{aligned}$$

Therefore, the subsurface image obtained using equations (2) and (5) is identical to that obtained using equations (1).

So why should we use the two-step approach of equations (2) and (5)? One disadvantage of the one-step migration before stack implied by equations (1) is that no intermediate results such as common-midpoint stacks are produced. As noted by Yilmaz and Claerbout (1980), "an unmigrated CMP stack section helps the interpreter a great deal in resolving spurious events on a migrated section due to inaccurate velocities." Equation (5) provides the desired CMP stack section while maintaining the accuracy of full migration before stack; just integrate $q(k_h, k_y, \omega_0, z=0)$ over k_h. Because the extrapolation defined by equations (2) is independent of k_h, this integration may be performed before or after migration via equations (2).

The transformation represented by equation (3) deserves closer examination. Stolt (1979) noted that NMO correction corresponds to the frequency domain transformation from ω to ω_n defined by

$$\omega \equiv \omega_n \left[1 + \frac{v^2 k_h^2}{4\omega_n^2}\right]^{1/2} \tag{6}$$

Note that $\omega_0 = \omega_n$ for $k_y = 0$; i.e., equation (6) is a zero-dip version of equation (3). Now, suppose we had recorded a zero-offset section $q(h=0,y,t_0,z=0)$ for an earth with one dipping reflector with dip ϑ. In the frequency domain, all the energy in $q(h=0,k_y,\omega_0,z=0)$ would lie along the line given by

$$\sin\vartheta = \frac{vk_y}{2\omega_0}$$

The well-known substitution of $v/\cos\vartheta$ for v in equation (6) will again make equations (3) and (6) equivalent. However, for an earth with reflectors of different dip (or truncated reflectors or point scatterers), no single cosine correction to velocity is valid. The strength of equation (3) is its validity for all zero-offset emergence angles, i.e., all

$$\cos^2\vartheta = 1 - \frac{v^2k_y^2}{4\omega_0^2}$$

Converting a single non-zero-offset to zero-offset

In addition to the disadvantage of one-step migration already noted, namely the lack of an intermediate CMP stack, a further disadvantage is the implied necessity of dealing with all offsets and all midpoints simultaneously. The latter disadvantage also applies to the transformation of equation (5). We would rather map each non-zero-offset independently to zero-offset, just as we attempt to do with NMO correction. Such a mapping would be essential, for example, if only a single non-zero-offset section were available. We derive the desired mapping in this section.

Using equation (5), we may express the transformation from $p(h,y,t,z=0)$ to $q(h=0,y,t_0,z=0)$ in the following way:

$$q(h=0,y,t_0,z=0) = \int dh\ g(h,y,t_0,z=0) \tag{7a}$$

where $g(h,y,t_0,z=0)$ is defined by

$$g(h,k_y,\omega_0,z=0) \equiv \int dk_h \left|\frac{d\omega}{d\omega_0}\right| e^{-ik_h h} p[h,k_y,\omega(k_h,k_y,\omega_0),z=0] \tag{7b}$$

Equation (7a) is CMP stacking, so the transformation (7b) from $p(h,k_y,\omega,z=0)$ to $g(h,k_y,\omega_0,z=0)$ represents a pre-stack partial migration (PSPM) which, unlike that described by Yilmaz and Claerbout (1980), includes NMO correction and, more importantly, is exact for all offsets and all dips. Note that each constant-offset section in equation (7b) is treated independently but that computation of the zero-offset section requires the integration over h of equation (7a).

We may avoid the interpolation of $p(h,k_y,\omega,z=0)$ in equation (7b) by rewriting that equation as

$$g(h,k_y,\omega_0,z=0) \;=\; \int dt\; p(h,k_y,t,z=0) \int dk_h \left[\frac{d\omega}{d\omega_0}\right] e^{i\omega(k_h,k_y,\omega_0)t\,-ik_h h} \qquad (8)$$

We should perform the data-independent integration over k_h analytically. Differentiating equation (3) with respect to ω_0 yields

$$\frac{d\omega}{d\omega_0} \;=\; \frac{\omega_0}{\omega}\sec^2\vartheta - \frac{\omega}{\omega_0}\tan^2\vartheta$$

where

$$\sin\vartheta \;\equiv\; \frac{vk_y}{2\omega_0}$$

So the integral we wish to evaluate is

$$I \;\equiv\; \int dk_h \left[\frac{\omega_0}{\omega}\sec^2\vartheta - \frac{\omega}{\omega_0}\tan^2\vartheta\right] e^{i\omega(k_h,k_y,\omega_0)t\,-ik_h h} \qquad (9)$$

Unfortunately, an exact evaluation of this integral can only be expressed in terms of hyperbolic Bessel functions. Assuming that we would ultimately use asymptotic approximations to these functions, we may approximate I directly using the method of stationary phase. The phase of the integrand is stationary at that $k_h = \hat{k}_h$ for which

$$\frac{\partial\omega}{\partial k_h}(\hat{k}_h,k_y,\omega_0) \;=\; \frac{h}{t}$$

Partial differentiation of equation (3) with respect to k_h yields

$$\hat{k}_h \;=\; \frac{4h\cos^2\vartheta}{v^2 t}\,\omega(\hat{k}_h,k_y,\omega_0) \qquad (10)$$

or, solving for $\hat{k}_h$,

$$\hat{k}_h \;=\; \frac{4h\,\omega_0\cos^2\vartheta}{v^2 t}\left[1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right]^{-1/2}$$

Equation (10) may also be derived in the manner of Yilmaz and Claerbout (1980). Suppose we Fourier transform a CMP gather. The most significant contribution in (k_h,ω)-space from data near a point (h,t) in the gather would occur along the line given by $k_h/\omega = dt/dh$ where t is the dip-corrected traveltime given by

$$t = \left[\frac{4\cos^2\vartheta}{v^2} (z^2 + h^2) \right]^{1/2}$$

Differentiating yields

$$\frac{k_h}{\omega} = \frac{4h\cos^2\vartheta}{v^2 t}$$

which is equation (10).

The integrand of equation (9) evaluated at the point of stationary phase $k_h = \hat{k}_h$ is (after some algebraic manipulation)

$$\left(1 - \frac{4h^2}{v^2t^2}\right) \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{-1/2} e^{i\omega_0 t \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{1/2}}$$

and the complete stationary phase approximation to I is [see, for example, Carrier, Krook, and Pearson (1966)]

$$I \approx A\, e^{i\omega_0 t \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{1/2} + i\,\mathrm{sgn}(\omega_0)\frac{\pi}{4}}$$

where

$$A \equiv \left(\frac{8\pi |\omega_0| \cos^2\vartheta}{v^2 t} \right)^{1/2} \left(1 - \frac{4h^2}{v^2t^2}\right) \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{-5/4} \tag{11a}$$

which enables us to approximate equation (8) as

$$g(h,k_y,\omega_0,z=0) = \int dt\; p(h,k_y,t,z=0)\, A\, e^{i\omega_0 t \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{1/2} + i\,\mathrm{sgn}(\omega_0)\frac{\pi}{4}} \tag{11b}$$

Toward the goal of mapping a single non-zero-offset section to zero-offset, we choose to replace the transformation (11) with

$$A \equiv \left(1 - \frac{4h^2}{v^2t^2}\cos^2\vartheta\right)^{1/2} \tag{12a}$$

$$g(h,k_y,\omega_0,z=0) = \int dt\; p(h,k_y,t,z=0)\, A^{-1}\, e^{i\omega_0 t A} \tag{12b}$$

The differences between equations (11) and equations (12) lie in the amplitude factor and the $\pi/4$ phase shift. Our preference for equations (12) stems from their conventional behavior in the limits of zero-offset and constant-dip. For zero-offset, $g(h=0,k_y,\omega_0,z=0)$ is simply the Fourier transform of $p(h=0,k_y,t,z=0)$; therefore, as we might hope, PSPM defined by equations (12) does nothing to a zero-offset section.

For zero-dip, $\cos\vartheta = 1$, the change of variable

$$t_n = \left[t^2 - \frac{4h^2}{v^2} \right]^{1/2}$$

in equations (12) yields

$$g(h,k_y,\omega_0,z=0) = \int dt_n \; p(h,k_y,\sqrt{t_n^2 + 4h^2/v^2},z=0) \; e^{i\omega_0 t_n}$$

In other words, for zero-dip, PSPM defined by equations (12) is just conventional NMO correction. Furthermore, if all reflectors have dip ϑ_0, then the same change of variable with v replaced by $v/\cos\vartheta_0$ demonstrates that equations (12) again yield the expected transformation.

How do we justify the use of equations (12) in light of the fact that the stationary phase approximation of I and, hence, equations (11) are asymptotically exact in the limit $t \to \infty$, h/t *fixed*? We have no rigorous justification, but note from their zero-offset and constant-dip behavior that equations (12) apparently transform each non-zero-offset section to a zero-offset section; i.e., $g(h=h_0,y,t_0,z=0)$ in equation (12b) is the zero-offset section derived from the constant-offset section $p(h=h_0,y,t,z=0)$. In contrast, equations (11) should yield a zero-offset section $q(h=0,y,t_0,z=0)$ only after integrating $g(h,y,t_0,z=0)$ in equation (11b) over an infinite range of h [recall equation (7a)]. Because the available range of offsets is typically limited, equations (12) represent the preferred transformation. Indeed, equations (12), unlike equations (11), are accurate even if only one constant-offset section is recorded, as the next section demonstrates with a synthetic example.

A synthetic example

The transformation (12) is best illustrated by its time-variable impulse response. Plotted in Figure 1 is a synthetic non-zero-offset section $p(h=20,y,t,z=0)$ containing eight evenly spaced impulses. For simplicity, we have chosen all sampling intervals equal to unity and velocity $v = 2$. Geometrical optics predicts this section to be the result of recording with $h = 20$ over an earth with semi-elliptical reflectors given by

$$\frac{(y - y_p)^2}{\left[\dfrac{v^2 t_p^2}{4}\right]} + \frac{z^2}{\left[\dfrac{v^2 t_p^2}{4} - h^2\right]} = 1 \qquad (13)$$

where $p(h=20,y,t,z=0)$ contains impulses at (y_p,t_p).

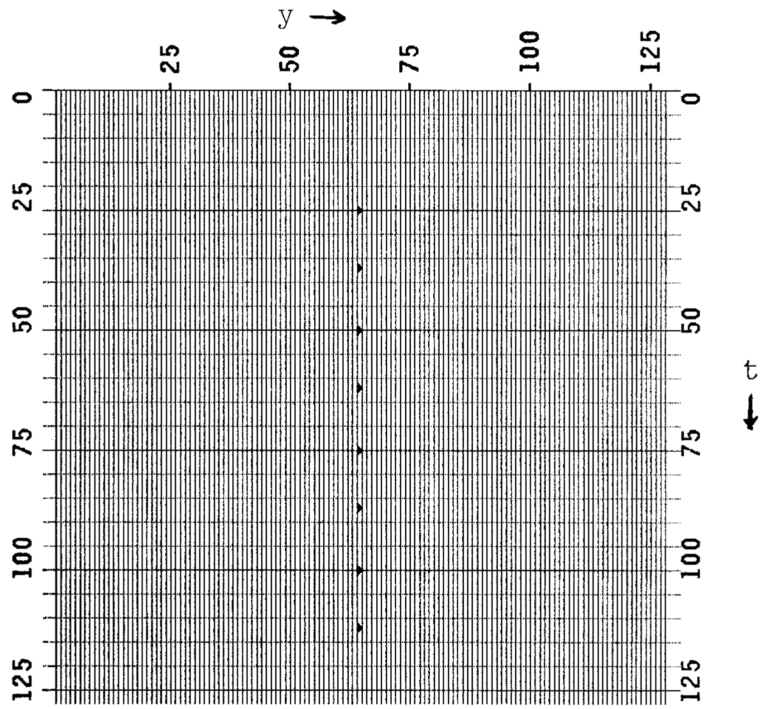

FIG. 1. Synthetic non-zero-offset section $p(h=20,y,t,z=0)$. This section would theoretically be recorded over an earth with semi-elliptical reflectors.

The result $g(h=20,y,t_0,z=0)$ of PSPM via equations (12) is plotted in Figure 2a. The computer program used to generate this zero-offset section is given in the appendix. Note that NMO correction alone could not have produced Figure 2a. Because only one offset was assumed to be available, $q(h=0,y,t_0,z=0) = g(h=20,y,t_0,z=0)$.

Figure 2b contains the result $q(h=0,y,t_0=0,z)$ of applying Gazdag's (1978) phase shift migration to $q(h=0,y,t_0,z=0)$ of Figure 2a. The semi-elliptical shape of the reflectors is obvious and one can readily verify using equation (13) that the lengths of the major and minor axes are correct. As expected, the eccentricity decreases with increasing vt_p.

For additional examples of PSPM via equations (12), we refer the reader to the following paper in this report by Ottolini.

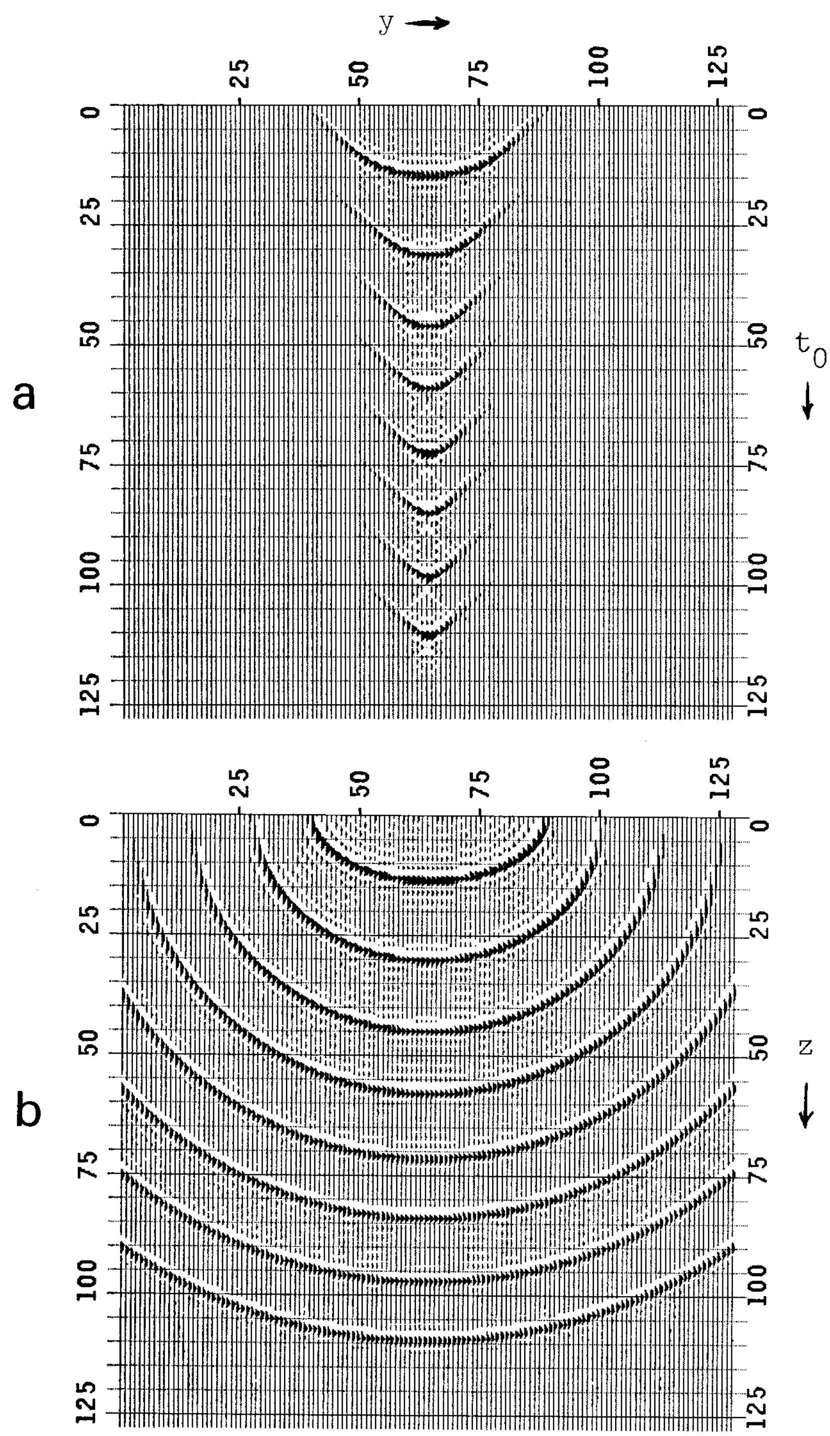

FIG. 2. (a) the zero-offset section $q(h=0,y,t_0,z=0)$ derived from the non-zero-offset section $p(h=20,y,t,z=0)$ in Figure 1 via equations (12) using the computer program in the appendix; and (b) the result $q(h=0,y,t_0=0,z)$ of migrating $q(h=0,y,t_0,z=0)$ using a phase shift algorithm. Note the semi-elliptical shape of the reflectors.

Conclusions

The reader should verify that the transform described in the abstract is just a notationally simpler version of equations (12). The frequency-domain, constant-velocity migration algorithm for non-zero-offset sections resembles that for zero-offset sections, the only difference being in the transform from time to frequency. Assumptions of small offset or small dip are unnecessary, and the data may be left in offset coordinates. In particular, transformation to radial coordinates (Ottolini, 1981) is not required. Offset coordinates are particularly attractive when only a few offsets are recorded.

Equations (2) and (3) provide the foundation for the results of this paper. Previous treatments of the non-zero-offset migration problem, such as that by Deregowski and Rocca (1981), have been based directly on the double square root extrapolation of equations (1) and have required assumptions of small offset or small dip.

Less accurate and, perhaps, less expensive PSPM algorithms, such as that given by Yilmaz and Claerbout (1980), may be derived using equations (3) and (6). Briefly, the NMO correction (6) may be extracted from equation (3) leaving a correction which, to first order (small offset and/or dip), is proportional to $k_h^2 k_y^2 / \omega^4$.

The most serious drawback to the non-zero-offset migration method described in this paper lies in the restriction to constant velocity. The treatment of lateral velocity variations is made considerably difficult by Fourier transforming over midpoint, but the generalization to depth-variable velocity should be easier. Ottolini (following paper) has attempted to treat $v = v(z)$ by replacing v in equations (12) with a root-mean-square velocity. As expected, this approximation breaks down for large offsets or dips. An exact generalization to depth-variable velocity must be based on a simultaneous use of equations (2) and (3). To date, the author's attempts to exactly treat $v = v(z)$ have resulted in algorithms too expensive to be practical.

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Appendix

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# Ratfor [Rational Fortran (Kernighan and Plauger, 1976)] program
# to convert a non-zero-offset section to a zero-offset section
implicit undefined (a-z)
integer*4 it,iy,iw0,iky,ikyn,ikynyq,ny,nt,nky,nw0,itmin,iw0min
real*4 q(130,128),ky,dy,dt,dky,dw0,v,h,h2ov,twopi,w0,t,tmin,tmtm,arg,vkyo2
real*4 tt,h2ovs,scale,amp
complex*8 cp(128,128),cq(65,128),cwork(128),cshft
equivalence (q(1,1),cq(1,1))
twopi = 2.*3.141593; ny = 128; nt = 128; nky = ny; nw0 = nt/2+1;
dy = 1.; dt = 1.; dky = twopi/(ny*dy); ikynyq = nky/2+1; dw0 = twopi/(nt*dt);
v = 2.; h = 20.; h2ov = h*2./v; h2ovs = h2ov*h2ov;

                                # specify test data (impulses)
cp(25,64) = 1.; cp(37,64) = 1.; cp(50,64) = 1.; cp(62,64) = 1.;
cp(75,64) = 1.; cp(87,64) = 1.; cp(100,64) = 1.; cp(112,64) = 1.;

do it = 1,nt {                  # transform over y
      do iy = 1,ny
            cwork(iy) = cp(it,iy)
      call cfft (cwork,ny,+1)         # ny complex to ny complex fft
      do iky = 1,nky
            cp(it,iky) = cwork(iky)
      }

do iky = 1,ikynyq {                   # for all ky
      ikyn = nky+2-iky                # index for negative ky
      ky = (iky-1)*dky                # note: ky declared real*4
      vkyo2 = v*ky/2.
      iw0min = max(int(vkyo2/dw0+1),2)
      do iw0 = iw0min,nw0 {                 # for all non-evanescent w0
            w0 = (iw0-1)*dw0
            tmtm = h2ovs*(1.-(vkyo2/w0)**2)
            tmin = sqrt(tmtm)
            itmin = tmin/dt+2          # ignore data before tmin
            do it = itmin,nt {         # integrate over time
                  t = (it-1)*dt
                  tt = t*t
                  scale = sqrt(1.-tmtm/tt)
                  amp = 1./scale      # the amplitude factor
                  arg = w0*t*scale    # the phase shift
                  cshft = amp*cmplx(cos(arg),sin(arg))
                  cq(iw0,iky) = cq(iw0,iky)+cp(it,iky)*cshft
                  if (iky > 1 && iky < ikynyq)
                        cq(iw0,ikyn) = cq(iw0,ikyn)+cp(it,ikyn)*cshft
                  }
            }
      }
do iw0 = 1,nw0 {                # transform over ky
      do iky = 1,nky
            cwork(iky) = cq(iw0,iky)
      call cfft (cwork,nky,-1)
      do iy = 1,ny
            cq(iw0,iy) = cwork(iy)
      }
do iy = 1,ny                    # transform over w0
      call rfft (q(1,iy),nt,+1,+2)     # nt/2+1 complex to nt real fft
open(3,file='/scr/hale/g20',status='new',access='direct',form='unformatted',recl=1)
write(3,rec=1) ((q(it,iy),it=1,nt),iy=1,ny)
stop; end
```

SIAM Prize in Numerical Analysis and Scientific Computing

FIRST WINNER: Bjorn Engquist of UCLA

Bjorn Engquist of the University of California at Los Angeles is the first winner of the SIAM Prize in Numerical Analysis and Scientific Computing, SIAM President Seymour V. Parter announced.

The award will be presented at the SIAM 30th Anniversary Meeting, July 19-23, 1982, at Stanford University in Stanford, California.

The SIAM Prize in Numerical Analysis and Scientific Computing is awarded for research in, or other contributions to, numerical analysis and scientific computing during the six years preceding the award.

Engquist was cited by the prize committee for the "richness of ideas in his work on initial value problems, including the construction of absorbing boundary conditions, upwind schemes for conservation laws, stability analysis of matrix products, development of software packages, and applications to seismology and fluid mechanics."

Members of the prize committee are Gene G. Golub, Stanford University; Werner C. Rheinboldt (chairman), University of Pittsburgh; and Burton Wendroff, Los Alamos National Laboratory.

The SIAM Prize in Numerical Analysis and Scientific Computing was established in 1979. Initial funding consisted of an anonymous gift of $2,500, which was matched equally by the SIAM Board of Trustees. A campaign to increase the prize fund through corporate and individual donations is now underway. (Contributions, which are tax deductible, should be made payable to "SIAM Prize in Numerical Analysis and Scientific Computing" and sent to SIAM Prize in Numerical Analysis and Scientific Computing, SIAM, 1405 Architects Building, 117 South 17th Street, Philadelphia, PA 19103.)

The prize will be awarded every three years.

Bjorn Engquist