Z-99 MULTIPLE ATTENUATION AFTER MIGRATION

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1 Abstract

Multiples can be suppressed in the angle-domain image space after migration. Primaries and multiples have different angle-domain moveout, therefore they can be separated using techniques similar to the ones employed in the data space prior to migration. We use Radon transforms in the image space to discriminate between primaries and multiples. This method has the advantage of working with 3-D data and complex geology. It offers an alternative to the more expensive Delft approach.

2 Introduction

The current most robust multiple attenuation techniques exploit moveout discrepancies that exist between primaries and multiples. For relatively simple geology, NMO correction efficiently flattens the primaries and leaves the multiples curved which can then be separated in the Radon domain. It has been recognized that NMO and Radon transforms are not optimal when complex wavefield propagation occurs in the subsurface since the moveout of primaries and multiples cannot be describe with simple functions (parabolic or hyperbolic) anymore (Bishop et al., 2001).

One method that takes complex propagation effects into account is the Delft approach (Verschuur et al., 1992). This technique has the advantage of working with the surface data only and for any type of geology. Thus, it is often the method of choice for multiple attenuation in complex geology. To be accurate, the Delft method requires a very dense coverage of sources and receivers. If this condition is relatively easy to meet in 2-D, it becomes much more difficult to fulfill with 3-D surveys.

A powerful multiple attenuation technique takes complex wavefield propagation into account, and then uses moveout discrepancies to remove multiples. To achieve this goal, we first propose using prestack depth migration as our imaging operator. In this process, *both* primaries and multiples are migrated, after which they are transformed to angle gathers using standard techniques. In the angle domain, primaries are flat and multiples are curved, mimicking the situation we have after NMO for simple geology. We propose mapping the angle gathers into a Radon domain where the signal/noise separation can be achieved. This method has the potential to work with 2-D or 3-D data, and it is also much cheaper than the Delft approach, although it can still handle complicated geologic media.

3 Angle transform

Angle-domain common image gathers (ADCIGs) are decompositions of seismic images in components proportional to the reflection magnitude for various incidence angles at the reflector. Given correct velocities and migration algorithms, primaries map into flat gathers and multiples map into events with moveout.

ADCIGs are useful for multiple suppression because events imaged with the wrong velocity show substantial moveout, which allows us to discriminate between primaries and multiples. ADCIGs also describe the reflectivity at the reflection point, independent from the actual structure for which they are computed, so they capture most 3-D propagation effects at every individual CIG.

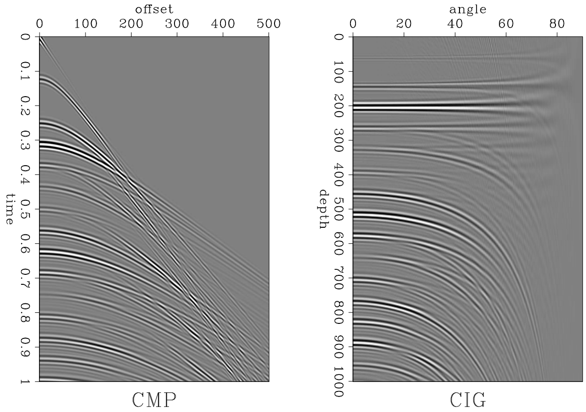


Figure 1: Simple synthetic model. A data-space CMP (left) and a corresponding image-space CIG (right).

4 Multiple suppression

Multiple attenuation with Radon transforms (RT) are popular and robust methods (Foster and Mosher, 1992). These techniques use the moveout discrepancy between primaries and multiples in order to separate them. Usually, the multiple attenuation is carried out with CMP gathers after NMO correction. The NMOed data are mapped with a parabolic Radon transform (PRT) in a domain where primaries and multiples are separable.

One desirable property of a Radon transform is that events in the Radon domain be well focused. The RTs can be made sparse in the Fourier domain or in the time domain. In our implementation of the RTs, we use a time domain formulation with a Cauchy regularization.

A generic equation for a Radon transform in the angle domain is $z(q,\gamma) = z_0 + q\ g(\gamma)$, where z_0 is the zero-angle depth, γ the angle, q is a curvature parameter, and $g(\gamma)$ is a function that represents the moveout in the CIGs. The modeling equation from the Radon domain to the image domain is

$$d(z,\gamma) \ = \ \sum_{z_0}\sum_{q} m(z_0,q)\delta\left[z_0-(z-q\ g(\gamma))\right]. \tag{1}$$

At first order, we can assume that $g(\gamma) = \gamma^2$, which shows that Equation (4) corresponds to the definition of a parabola. However, Biondi and Symes (2003) demonstrate that for ADCIGs, a better approximation is $g(\gamma) = tan(\gamma)^2$.

Equation (1) can be rewritten as $\mathbf{d} = \mathbf{Lm}$, where $\mathbf{d}$ is the image in the angle domain, $\mathbf{m}$ is the image in the Radon domain, and $\mathbf{L}$ is the forward RT operator. Our goal now is to find the vector $\mathbf{m}$ that best synthesizes, in a least-squares sense, the data $\mathbf{d}$ *via* the operator $\mathbf{L}$. We, therefore, want to minimize the objective function $f(\mathbf{m}) = \|\mathbf{Lm}-\mathbf{d}\|^2$. We also add a regularization term that enforces sparseness in the model space by imposing a Cauchy distribution on $\mathbf{m}$:

$$f(\mathbf{m}) = \|\mathbf{Lm}-\mathbf{d}\|^2 + \epsilon^2\sum_{i=1}^{n} ln(b+m_i^2), \tag{2}$$

where n is the size of the model space, ϵ and b two constants chosen a-priori: ϵ controls the amount of sparseness in the model space and b relates to the minimum value below which everything in the Radon domain should be zeroed.

5 Examples

Our first example corresponds to a synthetic model with flat reflectors and $v(z)$ velocity. The left panel in Figure 2 is a representative CMP. The right panel depicts a corresponding CIG. Most of the energy

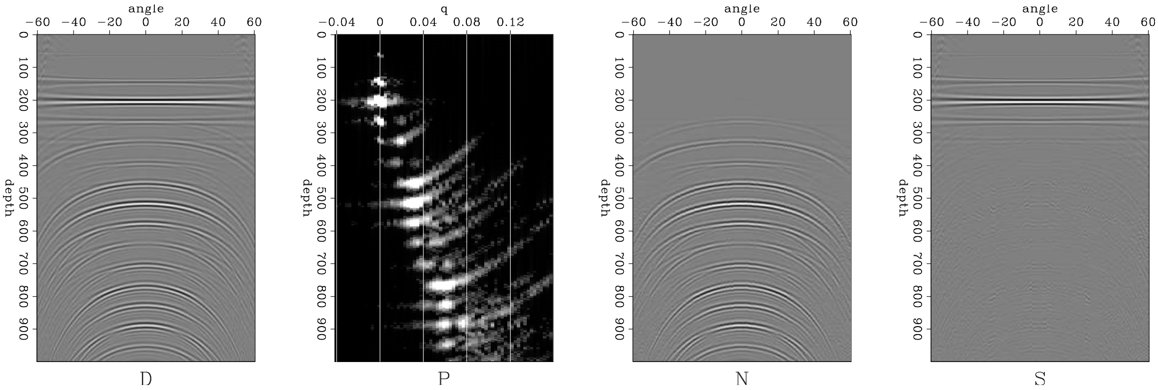


Figure 2: Synthetic example for S/N separation in the image space: (D) data in the image domain; (P) data in the Parabolic Radon domain; (N) multiples (noise); (S) primaries (signal).

in the gather is represented by multiples, described by non-flat moveout.

Figure 2 shows from left to right: (D) the data = primaries + multiples, in the image space; (P) the data transformed to the Radon domain, where the flat primaries are represented in the vicinity of $q = 0$, in contrast to the multiples at non-zero q; (N) the multiples isolated in the Radon domain and transformed back to the image domain; (S) the primaries left after subtraction of the multiples (N) from the data (D). Figure 3 shows a comparison between RT using the parabolic equation $g(\gamma) = \gamma^2$ (left), and the more accurate tangent equation $g(\gamma) = tan(\gamma)^2$ (right), where the events are much better focused.

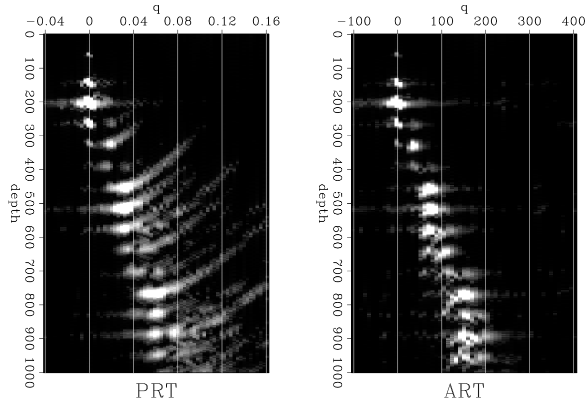
We also apply our technique to a Gulf of Mexico dataset. Following the pattern used in the preceding example, Figures 4 and 5 show our multiple analysis at two different locations in the data. The first figure, corresponds to an area away from the salt body, while the second one corresponds to a region under the salt. From left to right, we present the data (D), the Radon domain (P), the noise (multiples) (N), and the signal (primaries) (S).

For comparison, in both Figures 4 and 5 we include one more panel (C) which represents the same image gather obtained by migration of the signal obtained by multiple suppression in the data space using a high resolution HRT with Cauchy regularization. The image space multiple suppression creates cleaner CIGs, compared with the data space method.

6 Conclusions

Multiples can be suppressed in the angle-domain, after migration. For a given velocity model, primaries and multiples have different moveout in the image space, and therefore they can be separated

Figure 3: Radon transform of angle-domain CIGs using the parabolic equation (left) and the tangent equation (right).



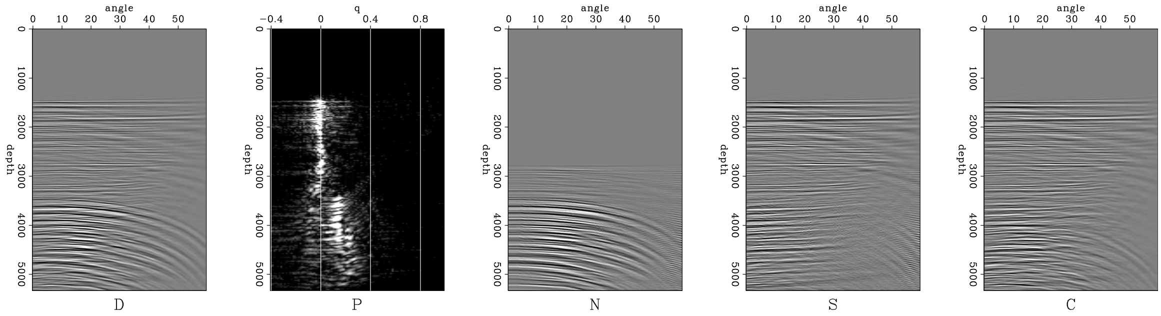


Figure 4: Gulf of Mexico example. S/N separation in the image space: (D) signal + multiples (data); (P) data the Parabolic Radon domain; (N) multiples (noise); (S) primaries (signal) separated in the image space; (C) primaries (signal) separated in the data space.

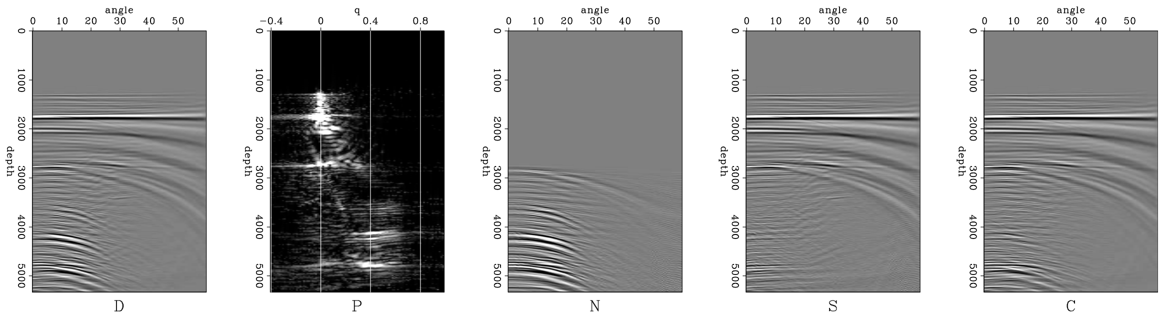


Figure 5: Gulf of Mexico example. S/N separation in the image space: (D) signal + multiples (data); (P) data the Parabolic Radon domain; (N) multiples (noise); (S) primaries (signal) separated in the image space; (C) primaries (signal) separated in the data space.

using similar techniques as the ones employed in the data space, prior to migration. We use Radon transforms, although these methods are neither unique, nor ideal.

Because we are using prestack depth migration, this method takes into account the effects of complex wavefield propagation in the same way that the Delft approach does. However, our proposed scheme has the potential to be affordable with 3-D data and cheap to apply. Therefore, for complex geology, this method stands between multiple attenuation in the data space with Radon transforms and the Delft approach where multiples are first predicted and then subtracted.

7 REFERENCES

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