PS Application of Illumination Compensation to Irregular Surface Areas Imaging*

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Abstract

Many oil and gas reservoirs are located in the areas with irregular topography, which offers a big challenge for traditional horizon-based depth migration algorithms in the mountain areas. The limited acquisition aperture widely exists in the real seismic acquisition system. It would be more serious in the area with irregular topography. Based on our previous study, in this paper, we have done some further study and analysis about acquisition-aperture correction to improve the image quality in irregular surface area.

Pre-stack depth migration turns out to be a valid way to get better image of these area. Migration with data acquired on surface with irregular topography can be extrapolated from the highest surface based on one-way wave field propagator. We fill the area (fictitious layers) between the highest surface level and the irregular surface with near surface velocity. At every depth, the corresponding seismic data are added if receivers or sources exist. In addition, a filter was introduced to eliminate the migration noise in the fictitious layers. We use the local-cosine-bases (LCB) beamlet propagator, which improves the image quality at the near irregular surface area because of its windowed reference velocity. We apply the local exponential frame (LEF) decomposition to obtain the image and amplitude correction factor in local wave number domain and then transform them into local angle domain after all the shot summation. The influence of irregular topography has been eliminated during the continuation process.

We test our method with Canadian overthrust irregular surface model (Model94) which has the highest elevation nearly 1,800 meters. Compare with the imaging results without aperture correction and with Auto-vertical gain control (AGC), it has significant improvement in image quality, especially, the deep weak illumination area. Comparison about the amplitude versus angle (AVA) response before and after the acquisition aperture correction also shows the validity of our method.

Because of the local reference velocity used in beamlet propagation, the image near the irregular surface has some improvement. After the aperture correction, the image of deep weak illumination area became clearer. Therefore, acquisition aperture correction can also be a good way for us to improve image quality in area with irregular topography.

Application of Illumination Compensation to Irregular Surface Areas Imaging

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1 Abstract

Lots of oil and gas reservoirs are located in the areas with irregular topography which offers a big challenge for traditional horizon-based depth migration algorithms in the mountain areas. The limited acquisition aperture widely exists in the real seismic acquisition system. It would be more serious in the area with irregular topography. Based on our previous study, in this paper, we have done some further study and analysis about acquisition-aperture correction to improve the image quality in irregular surface area.

Migration with data acquired on surface with irregular topography can be extrapolated from the highest surface based on one-way wavefield propagator. We fill the area (fictitious layers) between the highest surface level and the irregular surface with near surface velocity. At every depth, the corresponding seismic data are added if receivers or source exist. Also, a filter was introduced to eliminate the migration noise in the fictitious layers. We borrowed the local-cosine-bases (LCB) beamlet propagator which improves the image quality at the near irregular surface area because of its windowed reference velocity. Local exponential frame (LEF) decomposition was used to obtain the image and amplitude correction factor in local wavenumber domain and then transform them into local angle domain. The influence of irregular topography has been eliminated during the continuation process.

We test our method with Canadian overthrust irregular surface model (Model94) and one real data in China. Because of the local reference velocity used in beamlet propagation, the image near the irregular surface has some improvement. After the aperture correction, the image of deep weak illumination area became clearer.

2 Introduction

Irregular topography offers a big challenge for traditional horizon-based stacking methods during migration and imaging in the mountain areas like western China. There are some ways to eliminate the influence of irregular surface. Reshef (1991) proposed a method by depth migration from the highest irregular surface and added the data where receivers exist. Beasley and Lynn (1992) proposed a "zero-speed layer" concept, which would also remove the impact of irregular surface by inserting a virtual layer with low speed between the irregular surface and datum surface, However, it is not stable in area with sharp irregularity.

Due to the limited seismic data acquisition aperture in reality, the inverse-propagated waves cannot completely recover the scattered wave field and will render distortion to the amplitude of the image. This problem may even worse in area with irregular topography. Wu et al. (2004) proposed an amplitude correction method in the local angle domain (LAD) for aperture correction. Wavefield decomposition into LAD can be done by local slant stack (LSS) (e.g., Xie and Wu 2002; Xie et al., 2004, 2006). Their numerical examples showed significant improvement in the images. Beamlet decomposition (e.g., Wu et al., 2000) can decompose the wavefield into local waves, which are simultaneously localized in the space and direction. It is faster to obtain the LAD image and amplitude correction factor (Cao and Wu 2008) by decomposition in the local wavenumber domain (LWD) using LEF decomposition (Mao and Wu 2007).

We apply the aperture correction in LAD to imaging in areas with irregular topography. We filled with near surface velocity in the area between the highest surface datum and the irregular surface. Based on the LCB beamlet propagator (Wu et al., 2000; Wang and Wu, 2002; Luo and Wu, 2003; Luo and Wu, 2005; Wu et al., 2008), continuation of the wavefield begins from the highest surface datum and seismic data are added where the level intersect receivers. At each depth, LEF decomposition was used to obtain the LWD image and aperture correction factors. And then transform them into LAD where amplitude correction is performed. In order to test the validity of our method, examples of amplitude correction for imaging using the typical irregular topography model Model94 (Gray and Marfurt, 1995) are shown. The image after amplitude correction has shown clearly improvement in deep area compared with the one with the image after AGC.

3.1 Continuation from irregular topography

The source and receivers spread along the irregular surface at different elevation in the area with rugged topography (Figure 1). Based on the LCB beamlet propagator, wavefield continuation starts from the highest irregular surface horizontal datum. At each depth, the corresponding seismic data was added if there exist located receivers. For the source wavefield continuation, the source data will be added if source exist there. So the wavefield at each location actually consists of two parts, one is the wavefield extrapolated from upper layer and another is the exist wavefield .

$$u(x_s, z, w) = P[u(x_s, z-\Delta z, w)] + u_e(x_s, z, w) \qquad (1)$$

where P is the one-way LCB beamlet operator that extrapolate a wavefield from depth z-△z to depth z level. Wavefield continuation starts from the highest elevation where z=0. The fictitious layer between highest elevation and irregular surface filled with near surface velocity V_F. During the continuation, there is a localized reference velocity in each beamlet window (Figure 1) which leads to higher calculation accuracy. The influence of irregular surface can be eliminated during the process of continuation. We also introduce a filter as equation 5 shown to eliminate the migration noise in the fictitious layers

$$u(x,z) = u(x,z)\,filter(x,z) \qquad (2)$$

$$filter(x,z) = \begin{cases} 0, & (x,z) \in Fictitious\ \ layer \\ 1, & (x,z) \in Others \end{cases} \qquad (3)$$

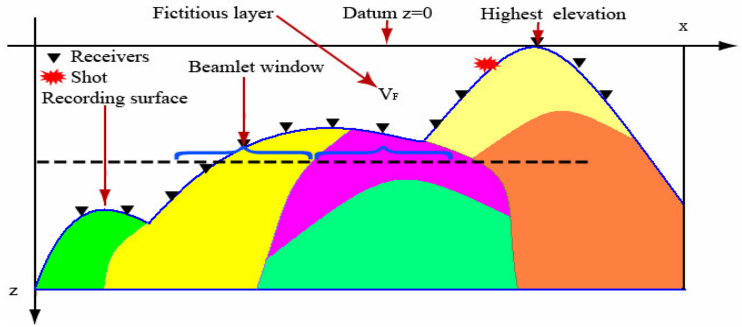


Figure 1. The acquisition system along the irregular topography. The datum located at the highest elevation plane. There are near surface velocity filled in the fictitious layer. At each depth, in beamlet window, it has localized reference velocity.

3.2 Aperture correction in local dip-angle domain

Local image matrix (LI M) calculated during the migration is distorted from local scattering matrix (LSM) due to the acquisition aperture limitation and propagation paths effects. The amplitude correction factors can be obtained in LAD (Wu et al., 2004) or LWD (Cao and Wu et al., 2008) to restore the LSM by the correction. Since it is more efficient to obtain the wavefield in the LWD than in the LAD, we calculate the Green's function in the irregular topography acquisition system and obtain the amplitude factor in LWD. It can be written as equation (4) ,

$$F_w(x,\xi_m,\xi_n)=2\sum_{x_s}\left|G_I^*(x,\bar{\xi}_m;x_s)\right|G_F(x,\bar{\xi}_m;x_s)\cdot\left\{\int_{A(x_g,x_s)}dx_g\left|G_F(x,\bar{\xi}_n;x_g)\right|^2\right\}^{1/2} \quad (4)$$

Local image matrix (LIM) Where "*" stands for complex conjugate; x stand for (x, z); ξ_m and ξ_n are the source and receiving wavenumber respectively; G_I is the Green's function used in the i maging process; G_F is the Green's function used in forward modeling; $A(x_g, x_s)$ is the spatial receiver aperture for a given source. Then transform the amplitude factor matrix F_w and image matrix L_w into local dip-angle domain expressed as F_a and L_a. The image matrix after amplitude correction can be expressed as follows,

$$L(x,z,\theta)=L_a(x,z,\theta)/(F_a+\varepsilon) \quad (5)$$

4.1 Aperture correction on irregular topography model

We exemplify the method using the 2D Canadian overthrust synthetic dataset. This model consists of a number of faulted and folded layers. It is a typical mountainous region. Figure 1a and figure 1b are the velocity model and its elevation. The model is 25000 meters long and the highest elevation is nearly 1800m. The top of the model is in 2000m above the sea level and the bottom of the model is 8000m below sea level. So the total depth of the model is 10000m.

Shots and receivers all located at the irregular surface as blue line shown in Figure 1b which is the receiver distribution of the 141st shot. Figure 1c shows the or iginal shot r ecords, from which we can see the obvious distortion of the event caus ed by the ir regular topography. We extrapolate downward the wavefield from the top of the model with LCB propagator. The images and factors are obtained in LWD (Cao and Wu, 2008) with LEF decomposition (Mao and Wu, 2007) and then transform them into local dip-angle domain where the aperture correction is performed.

As examples, figure 3 is 0 degree dip-angl e domain amplitude correction factor, image and image after amplitude correction. For the reason of limited acquisition aperture, the deep layers don't have enough illum ination resulting in weak image energy for deep targets (figure 3b). After the aperture correction with the factor (figure3a), the deep structure image has significant improvement (figure 3c). Even some of small faults have clearer images.

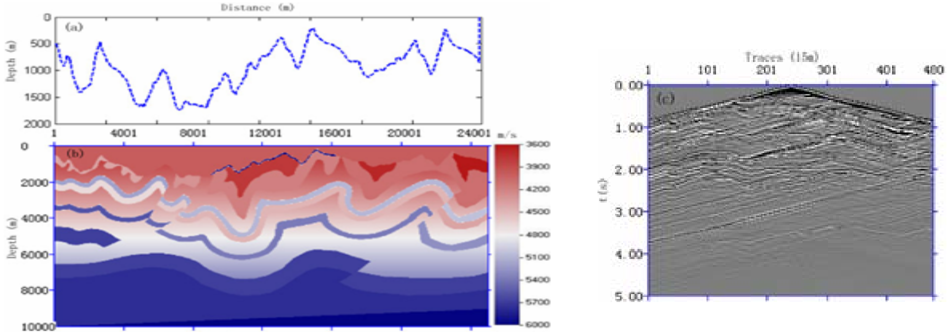


Figure 1. Irregular topography model. (a) is elevation of irregular surface; (b) is the velocity model; (c) is single shot records

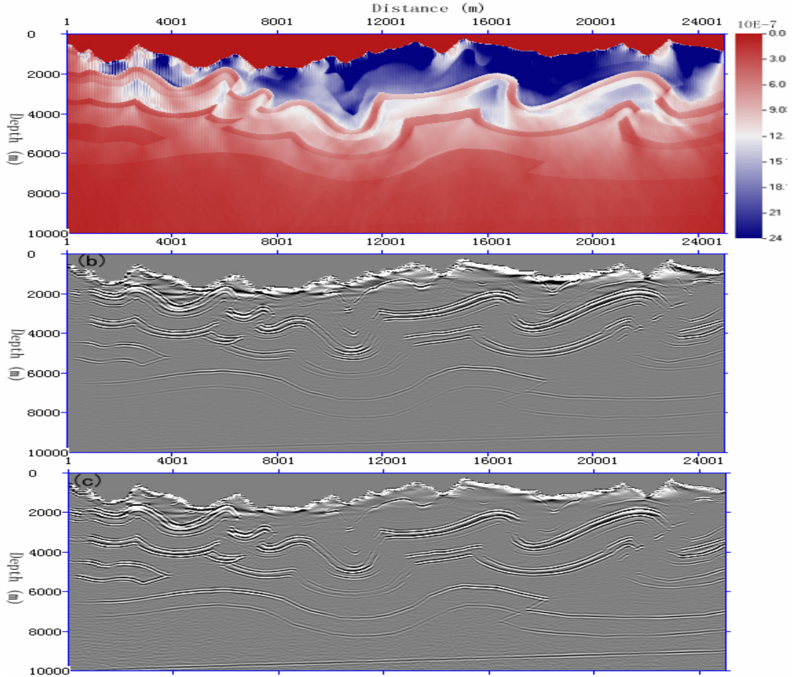


Figure 3: The amplitude correction factor and image for 0 degree dip angle:
(a) the amplitude correction factor;
(b) the image without amplitude correction;
(c) the image after amplitude correction.

We compare the image obtained from conventional one-way migration (Figure 4a), t he image get from LCB migration (Figure 4b) has some improvement at the irregular surface area for the reason of windowed background reference velocity. Both of them have weak illumination in deep area. For comparison we compensate the image with vertical gain control AGC factor. After stack all the images with amplitude correction in local dip-angle domain, we obtain the final image as figure 4c shows. It is obvious that the amplitude balance and image quality is better than the single compensation with AGC and the deep structure image has significant improvement.

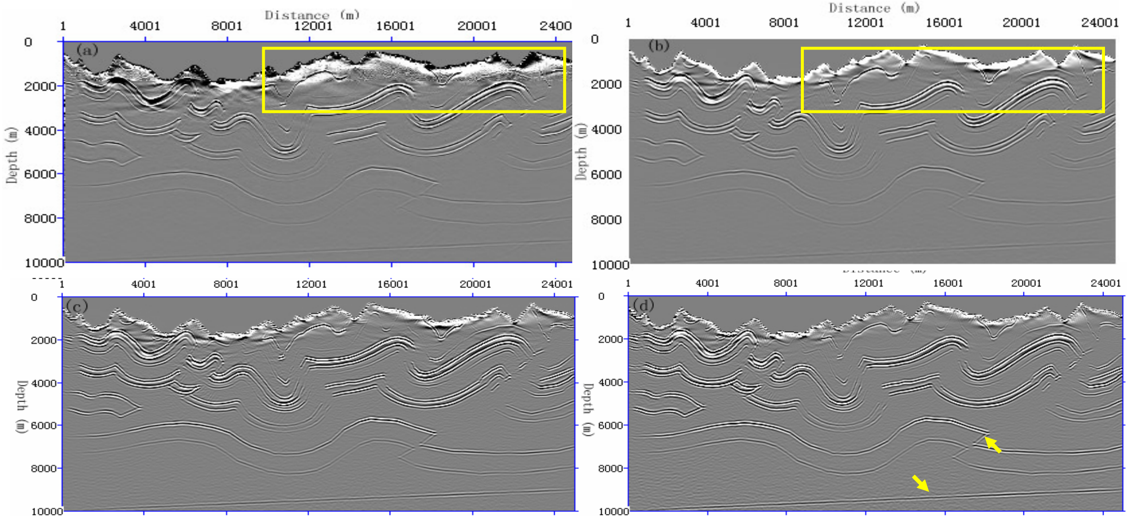
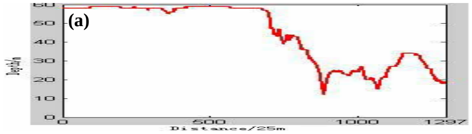


Figure 4: The comparison of final image with different method:
(a) the image using conventional one way migration;
(b) the image using LCB beamlet migration;
(c) total strength of the image after acquisition aperture correction in the local dip-angle domain.

4.2 Aperture correction on real data in area with irregular topography

The previous model test shows the validity of our method. Now we apply it to an actual data of an exploration area. Figure 5a shows migration velocity field of the exploration area. Figure 5b is shot recor ds of the actual data. Figure 5c show s the elevation of the irregular surface, in which the location of 0m is the datum and the largest elevati on is 58m, with strong local variation. Figures 6a, 6b ar e the prestack depth migration results for the actual data, which is based on "downward continuation directly", using the con ventional lcb beamlet migration and beamlet migration after aperture correction. The deep layer also get better improvement.



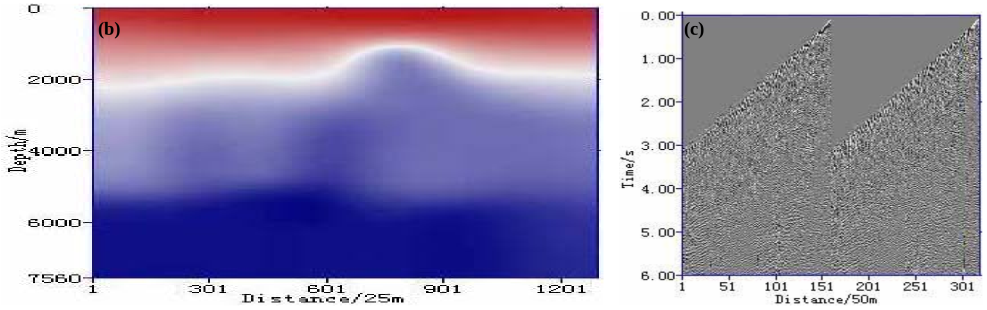


Figure5. rugged surface data of one prospect area
(a) elevation of rugged surfaces; (b)) migration velocity field; (c) original short record.

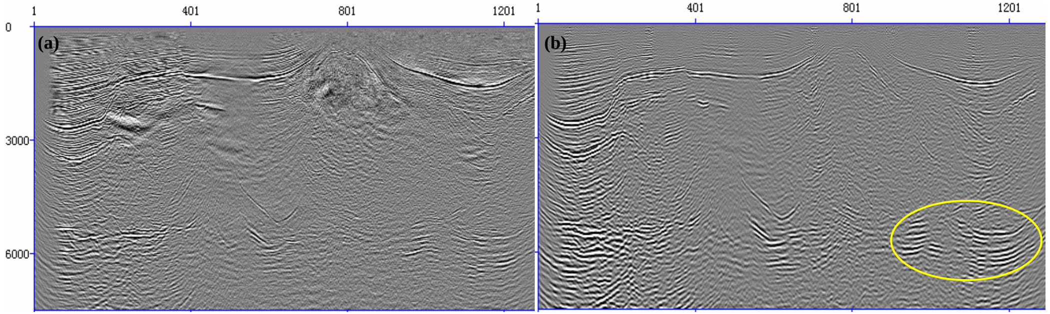


Figure6 irregular surface real data migration
(a) beamlet migration; (b) beamlet migration with illumination compensation.

5 Conclusion

We proposed a method to perform acquisition aperture correction in the local dip-angle domain for area with irregular topography. The irregular surface influence has been eliminated during the process of continuation. Because of the local reference velocity used in beamlet propagation, the image near the irregular surface has some improvement. After the aperture correction, the image quality in deep weak illumination area has been improved significantly. The test of Canadian overthrust irregular surface model illustrated the validity of our method. We also get a better result from the test on a irregular surface real data in China.