Diffraction imaging using geometric-mean reverse-time migration

Jianhang Yin, Nori Nakata*
ConocoPhillips School of Geology and Geophysics, University of Oklahoma

Introduction

According the the classic Snell's law, we can assume that a specular reflector illuminated by an incidence wave responds and reflects the energy mainly in one direction, whereas a point diffractor acts as a secondary source and radiates the energy in all directions.

Most methods of diffraction imaging are based on this assumption.

Nori Nakata and Gregory C. Beroza (2016) introduced a new method of reverse-time migration using the geometric mean as an imaging condition (GmRTM) for the locations of passive seismic sources, which can be applied for diffraction imaging due to the similarity to active-shot RTM.

Methodology

Mathematical preparation

We start with simple forward wave propagation from a seismic source location $\vec{x}_s$ to the position underground.

$$W_s(\vec{x},t) = F^{-1}\{S(\vec{x}_s,t)G(\vec{x},\vec{x}_s,t)\} \quad (1)$$

$W_s(\vec{x},t)$: Wavefield extrapolation of Source
$S(\vec{x}_s,t)$: Source function
$G(\vec{x},\vec{x}_s,t)$: Green's function

Then we backward each recorded data in reverse time.

$$W_{r_i}(\vec{x},t) = F^{-1}\{D_i(\vec{x}_{r_i},t)g^*(\vec{x}_{r_i},\vec{x},t)\} \quad (2)$$

$W_{r_i}(\vec{x},t)$: Wavefield extrapolation of recorded data i
$D_i(\vec{x}_{r_i},t)$: Recorded wavefield
$g^*(\vec{x}_{r_i},\vec{x},t)$: The complex conjugate of the approximated Green's function

Imaging condition for conventional RTM.

For the RTM algorithm using the cross-correlation imaging condition.

$$I_{RTM}(\vec{x}) = \sum_t \{W_s(\vec{x},t)\sum_i W_{r_i}(\vec{x},t)\} \quad (3)$$

Imaging condition for GmRTM

For the GmRTM algorithm.

$$I_{GmRTM}(\vec{x}) = \sum_t \{W_s(\vec{x},t)\prod_i W_{r_i}(\vec{x},t)\} \quad (4)$$

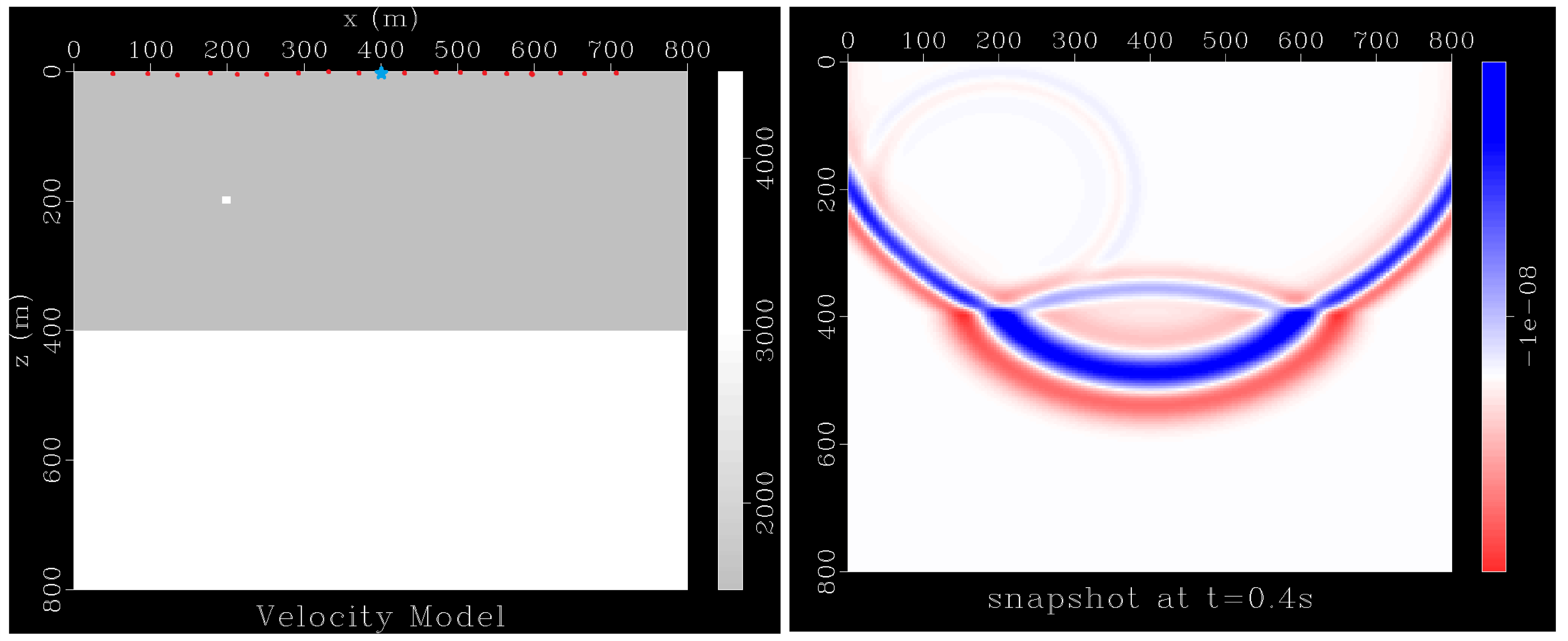

Fig 1. (a) Acoustic velocity model. The blue★and the red dots indicate the location of the source and receivers, respectively. We can see there is a diffractor at (200,200) m, and a reflector along the z=400 m. (b) Snapshot at 0.4s, we arrow indicated the diffracted wave which propagates in all directions like a source underground.

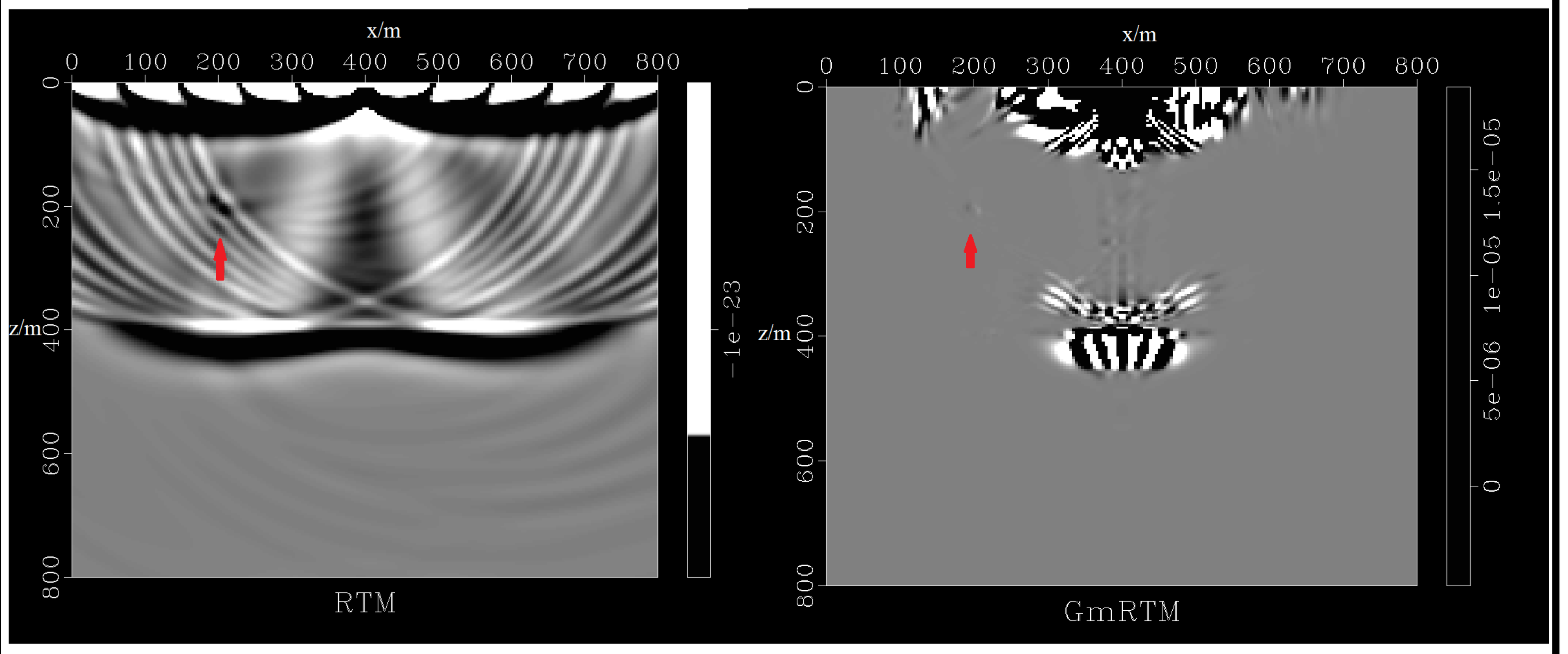

Fig 2. Result of (1) conventional RTM using cross-correlation imaging condition. (b) GmRTM. The red arrow indicates the location of the diffractor underground.

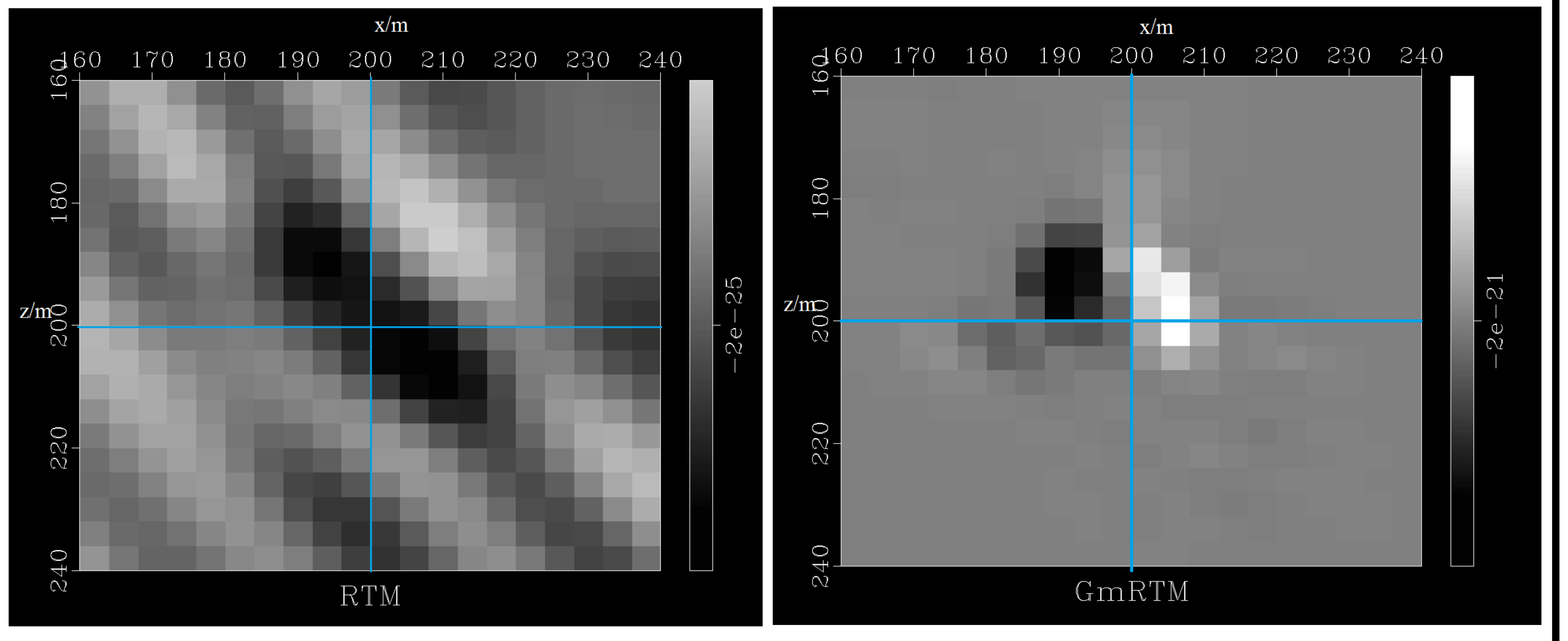

Fig 3. Images around the diffractor(200,200) obtained by (a) conventional RTM (equation 3), (b) GmRTM (equation 4). The blue solid lines show the depth and horizontal location of the diffractor.

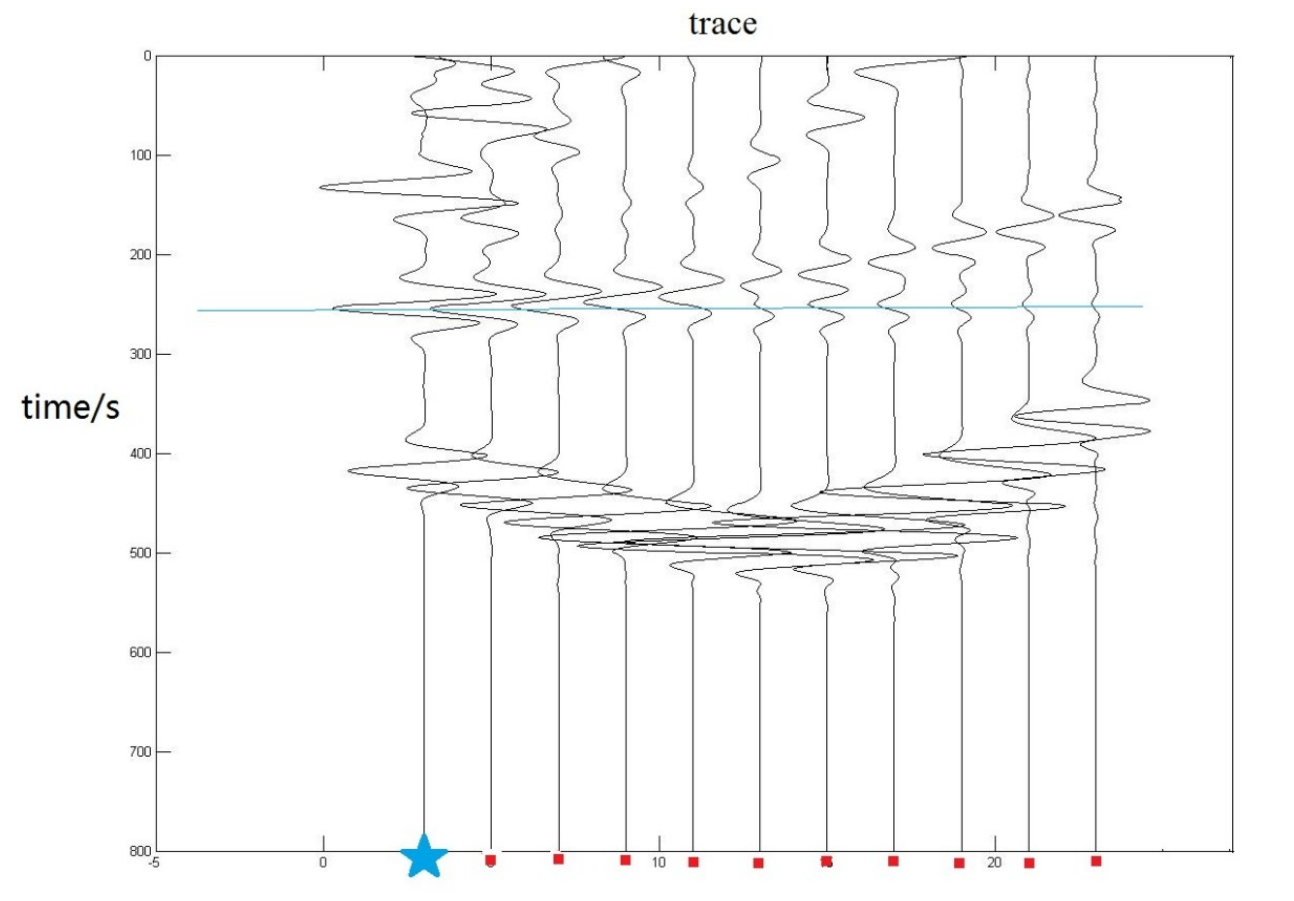

Fig 4. Backward waveform wiggle trace from source and 10 receivers at the location of diffractor. The blue ★indicates the source and red □ indicates the receivers, the blue solid line shows the arrival time of the forward wave from source and backward waves from the receiver.

Conclusion

We introduce GmRTM to image small-scale diffraction objects. Compared with conventional RTM, this method has two advantages:

1. Because the imaging condition of GmRTM requires that all the backward waves from all the receivers have the same arrival time, GmRTM can eliminate the reflection information effectively in the image.

2. GmRTM creates spatially higher resolution diffractor image than conventional RTM.

References

Nakata* N, Beroza G C. Reverse-Time Migration for Microseismic Sources Using the Geometric Mean as an Imaging Condition[M]//SEG Technical Program Expanded Abstracts 2015. Society of Exploration Geophysicists, 2015: 2451-2455.

Silvestrov I, Baina R, Landa E. Poststack diffraction imaging using reverse-time migration[J]. Geophysical Prospecting, 2016, 64(1): 129-142.

For communication email Id: yinjianhang@ou.edu