# Imaging the Earth's Refraction Interfaces by Refraction Migration

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## ABSTRACT

We present a procedure for migration of refraction data. The physical concepts of this procedure are similar to those in the reflection prestack depth migration. Migrating refraction data for the near-surface structure imaging, the algorithm migrates refractions to the refractor and therefore determines the location and shape of it. Kirchhoff migration (KM) and least-squares migration (LSM) algorithm is tested on synthetic data generated for the fault model by using ray-tracing approach. In general, LSM is superior than the KM as the KM images suffer from artifacts due to coarse sampling, geometric spreading, defocusing and attenuation. Results obtained from the synthetic data validate this situation for refraction migration. Taking consideration of that not enough research has been conducted on refraction migration using LSM, we believe that our preliminary results with synthetic data example suggest new directions of research on this topic.

## INTRODUCTION

Typically, refraction arrivals are used to determine the shallow structure of the earth. This is important, because determination of deeper structures depends upon knowing the effects of near-surface region, Often a shallow image cannot be formed from reflections recorded in a standard exploration reflection survey, but information about the shallow region can be obtained from refracted arrivals (Palmer, 1981).

Migrating refraction data using downward continuation algorithms has been studied by a number of authors in an attempt for the near-surface structure imaging ((Hagedoorn, 1959; Hill, 1987; Zhang and Toksoz, 1987)). However, until now, there have been no studies on the effectiveness of integral based approaches and LSM applied to refraction data.

In this report, we test the KM and underdetermined iterative LSM using synthetic data generated from the ray-tracing, which accounts for only the first arrivals. We also present how coarser sampling of source-receiver affects the images of KM and LSM.

## KIRCHHOFF MIGRATION

In the refraction migration, the key idea is to restrict to smearing of a refraction to be along a refraction wavepath. The refraction imaging formula is given by the following equation:

$$m(x,z) = \sum_{s}\sum_{g} d(x_s, x_g, \tau_{sx} + \tau_{xg} - \tau_{sg}) \tag{1}$$

where d(xs,xg,t) is the refraction data (all arrivals muted but refractions) for a shot at s and a geophone at g; $\tau_{sx}$ is the time it takes to go from a source at s to a subsurface point at x, and $\tau_{sg}$ is the actual refraction time to go from the source at s to the geophone at g. All sources and receivers are on the surface and the second time derivative of data is assumed. The traveltimes are calculated from the ray-tracing method.

## LEAST-SQUARES MIGRATION

The least-squares migration seeks to minimize the $l_2$(least-squares) norm of the data residuals. We define an objective function as follows:

$$E = \frac{1}{2}(\mathbf{d}^{est} - \mathbf{d}^{obs})^T(\mathbf{d}^{est} - \mathbf{d}^{obs}), \tag{2}$$

where $\mathbf{d}^{est}$ denotes the estimated refraction data from the forward modeling and $\mathbf{d}^{obs}$ stands for the recorded refraction data. We may evaluate the gradient by taking partial derivatives of equation2 with respect to the reflectivity model yielding:

$$g_i = \frac{\partial E}{\partial m_i} = [L^T(Lm_0 - d)]_i \tag{3}$$

Where $m_0$ is the estimated reflectivity model, L represents the linearized forward-modeling operator and g is the gradient, which can be used any gradient based optimization method to update the reflectivity. In this study, iterative LSM is applied separately to each shot gather to get prestack migration images. For the updating reflectivity, conjugate gradient method is used.

## RESULTS

The data is generated for traces recorded by 300 evenly distributed geophones and there are 300 sources separately excited at each geophone location to give a total of 300 common shot gathers (CSGs). The geophones and sources are placed on the surface. 50 Hz source frequency is chosen. The velocity model is shown in Figure 1. The velocity of the first layer is of 1000 m/s and the velocity of the second layer is of 2000 m/s.

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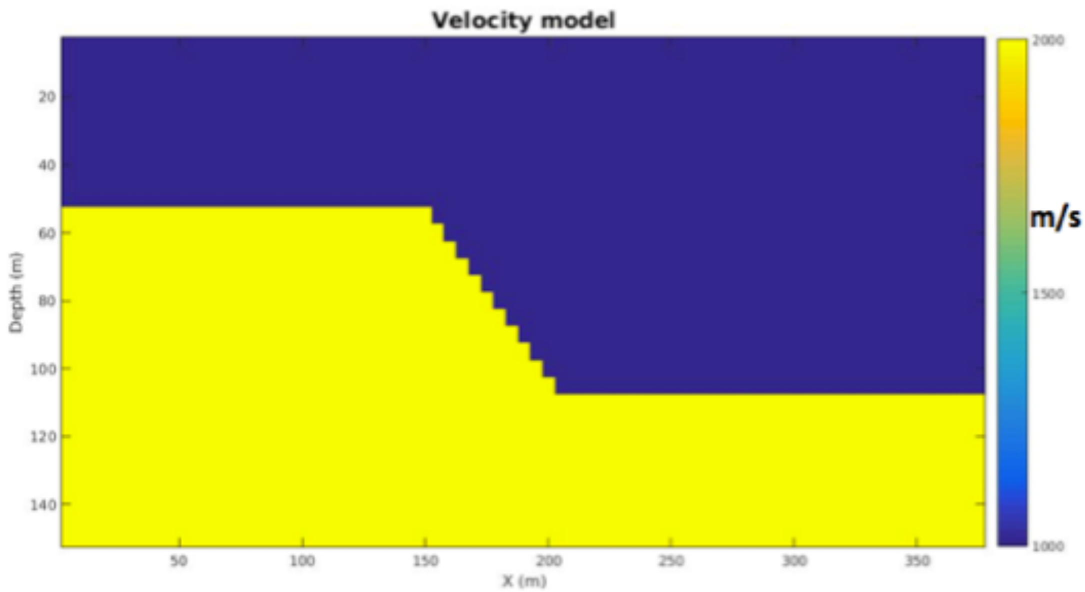


Figure 1: fault layered velocity model

Figure 2 shows both Kirchhoff and least-squares migration images. It is evident that LSM image show an improvement over standard migration image, which suffer from migration artifacts.   3 shows convergence history for LSM. We now test the migration algorithms using poor source and receiver sampling. We retain every sixth trace so that the migration images will contain aliasing artifacts as shown in 4.LSM image has fewer aliasing artifacts as opposed to the standard migration. This is because the migration artifacts are forward modeled at each iteration to give corresponding artifacts in the predicted data. Such data domain noise increases the misfit error, so the LSM image will tend to find the refractor with fewer aliasing artifacts. . .

## CONCLUSION

We tested KM and LSM for delineating refraction interface on synthetic data generated by using ray-tracing. The numerical results show that LSM provides a high

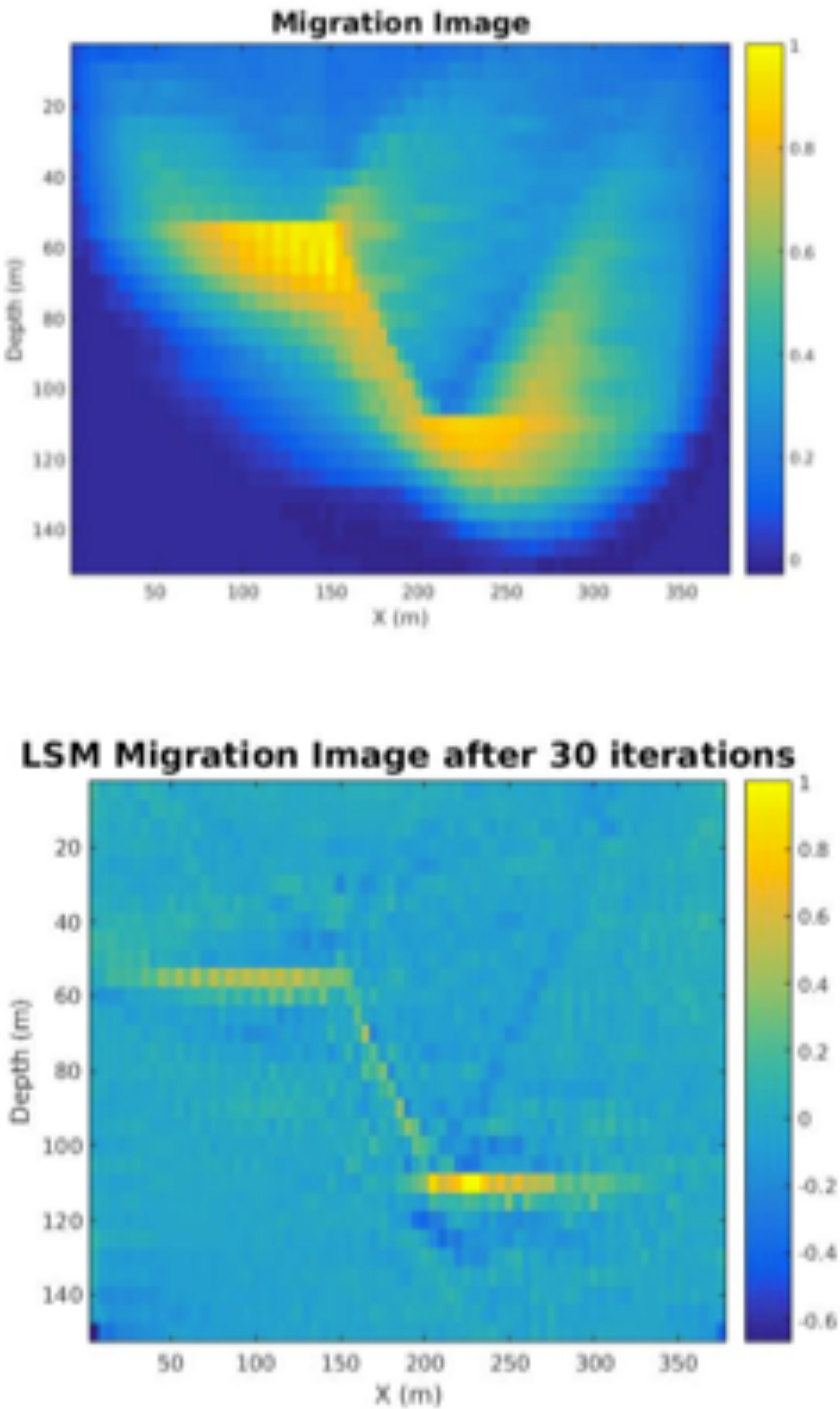


Figure 2: (TOP) Kirchhoff migration image and (bottom) least-squares migration image after 30 iterations.

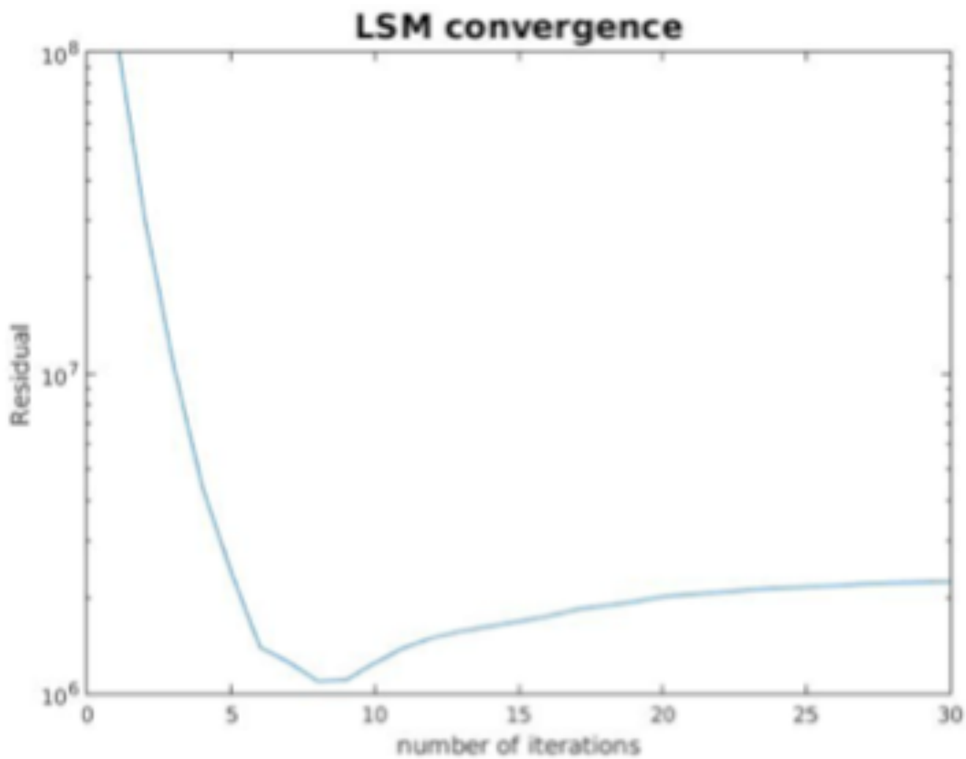


Figure 3: convergency history of LSM. There is no improvement on misfit after the eighth update

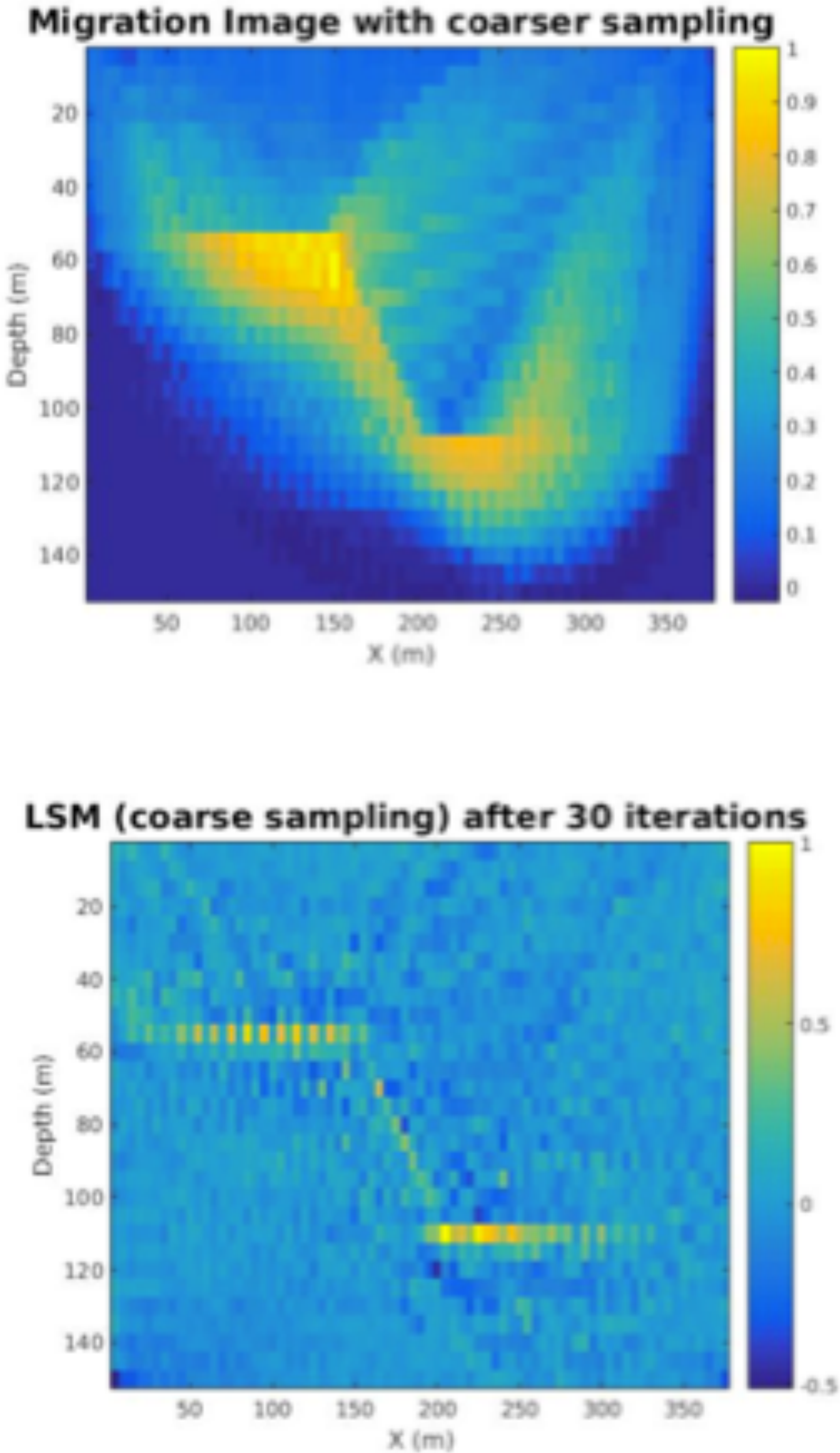


Figure 4: migration images with coarser sampling. (Top) Kirchhoff migration image and (bottom) least-squares migration image after 30 iterations.

quality image than the standard migration. We also showed that LSM is less sensitive to poor source and receiver sampling. But the methods that we presented here are undoubtedly applicable to more complex cases, such as multi layer structures if refraction data from the deep layers are available. Therefore, we are hopping to apply LSM to real data to better image refraction interfaces.

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