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The Effect of Strong Near Surface Scattering on Seismic Imaging: Investigation Based on Resolution Analysis

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Abstract. In land seismic exploration, strong near-surface heterogeneities can cause serious problems in seismic data acquisition and the quality of depth imaging. By introducing random velocity models to simulate velocity fluctuations in the near-surface layer and using the point spread function to characterize image quality, we examine how the scattering generated in near-surface heterogeneities can affect the subsurface image. In addition to the commonly known scattering noises which lower the signal to noise ratio in seismic data, our results also reveal that intermediate scale heterogeneities generate forward scattering which forms phase or travel time fluctuations. Due to intermediate-scale uncertainty in the shallow part of the migration velocity model, these phase changes are carried to the target by the extrapolated wavefields, breaking the zero phase image condition at the image point. This is a primary reason for deteriorated image quality in regions with strong near-surface scattering. If this intermediate-scale information can be obtained and built into the migration velocity, the subsurface image quality can be largely improved. These results can be the basis for further numerical investigations and field experiments. The proposed analysis method can also be used to evaluate other potential methods for dealing with near-surface scattering.

AMS subject classifications: 74J20, 86A15

Key words: Reverse time migration, shallow scattering, velocity model, prestack depth imaging, seismic resolution.

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1 Introduction

Wave equation based prestack migration plays an important role in modern seismic imaging and has gained wide application in oil and gas exploration. However, in land exploration, particularly in certain regions in western China and the Middle East, the near-surface layer is often composed of highly complicated small-scale low-velocity structures (e.g., rough topography, loess, deserts, strongly weathered layers, alluvium). Strong scattering and heavy attenuation generated in this layer bring serious difficulties to seismic acquisition and data processing [1–4]. Illustrated in Fig. 1 is a typical shot record in a region with strong shallow scattering in western China, where deep reflections are almost completely buried in the noise. Many processes are involved in near surface scattering. Because the earth is intrinsically elastic, there are both P-to-P and P-to-S scattered waves, causing reverberations in the shallow low-velocity layer. The undersampling due to sparse acquisition further complicates this process. Many authors have pointed out these effects and investigated related phenomena in either elastic or acoustic models [2,4]. For decades, researchers tested various techniques to mitigate this problem. Based on the assumption that scattering produces random noise, most techniques attempted to suppress scattering effects by stacking, e.g., grouped geophones, long survey lines, wide-line profiling and high-density acquisitions [5–7]. Although these techniques achieved limited successes in certain regions, the problems have not been satisfactorily solved in most cases, particularly in regions with very thick gravel or rough terrain [8].

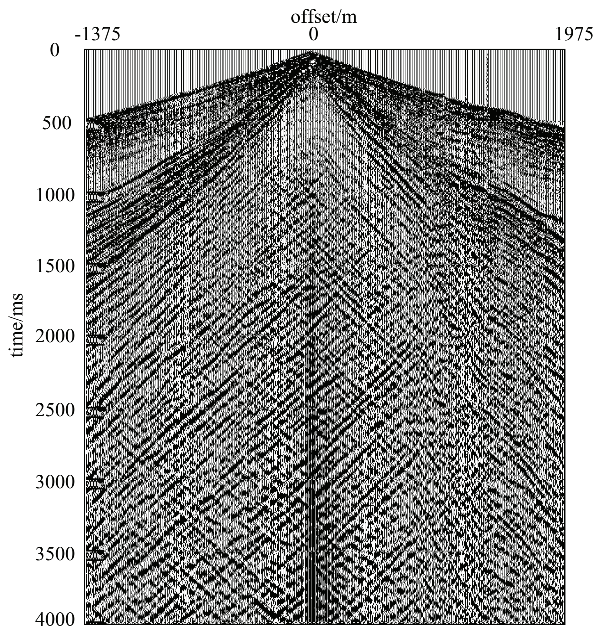

Figure 1: A shot record in a region with strong shallow scatterings in western China.