First-Arrival TomoStatics and Residual Statics for Near-Surface Corrections

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Abstract

Summary

In complex structure imaging problems, near-surface corrections often play critical roles. For processing land data from mountainous areas, using the first-arrival traveltime tomography approach to resolve the near-surface structures is often essential. We propose an approach to integrate the near-surface tomostatics solutions and the refraction residual statics as a strategy for making near-surface corrections. In tomostatics calculation, we calculate one-way statics from the actual shot and receiver locations to a smooth floating intermediate datum, and then back to a floating datum with a constant replacement velocity. We shall then apply the tomostatics to the far-offset refractions. From the refraction traveltimes corrected by tomostatics, we invert the short-wavelength shot and receiver residual statics. This two-step statics interpretation approach is ideal for any prestack imaging, since the solutions are both based on the first-arrival traveltimes without any processing involved. We shall demonstrate in several real cases that the proposed approach improves the data quality significantly for the subsurface imaging.

Introduction

Near-surface corrections are often critically important for both prestack and post-stack land data processing. In order to estimate statics correctly, we will need to resolve the near-surface velocity structures well, and that is often not enough. We shall further need to calculate residual statics that is unable to be resolved in tomography. In prestack processing particularly, we obviously cannot follow an approach for resolving residual statics like in the conventional NMO and stacking process. Thus, resolving long-wavelength statics from the first-arrival tomography and short-wavelength residual statics also from the first arrivals is very appealing.

Current near-surface correction approaches in the industry include general reciprocal method (Palmer, 1980), the delay-time method (Gardner, 1939), the first-arrival tomography (Zhang and Toksoz, 1998), and refraction residual methods (Zhu and Luo, 2004). Industry practice often suggests that one must select a method based on the particular near-surface problem that is encountered. For example, if the first-arrival traveltimes display linear moveout and suggest a simple layered structure, then the delay-time method may be enough to solve the problem. However, for the near-surface problems associated with large topography variations and complex subsurface structures, the first-arrival tomography must be first applied to resolve the near-surface complexity, and then applying long-offset refraction residual statics may help further improve the data quality. The refraction residual statics approach is one subtracting refraction traveltime curves by smoothed refractions and then mapping the residuals to sources and receivers. This is a data-based statics solution, while tomostatics is a model-based statics solution. The integration of the two presents a unique approach for overall statics solutions.

Real Data Applications

We shall demonstrate the applications of the above approach with 2D and 3D land examples. Both examples apply tomostatics and residual statics resolved from the first arrivals.

2D Example

The following example is from Sichuan, China. It includes rugged topography and large velocity variations in the near-surface areas. The following figure shows the tomographic velocity model:

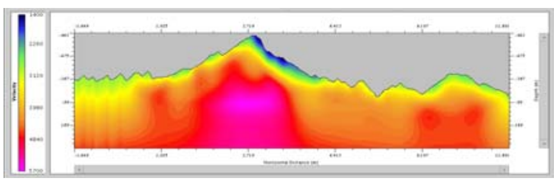

Figure 1. Near-surface velocity model from tomography

From this velocity model, we calculate the long-wavelength statics and then residual statics following the above approach. Here is the statics interpretation result:

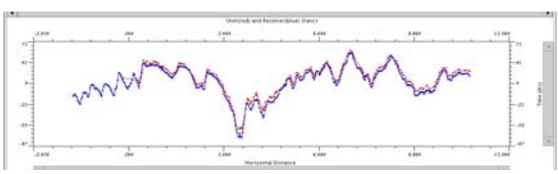

Figure 2. Tomostatics solution

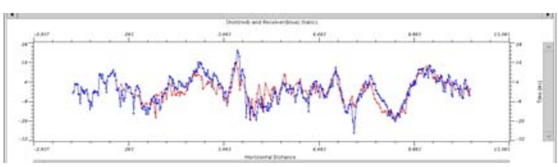

Figure 3. Residual statics solution

Applying tomostatics and residual statics to a shot gather for near-surface correction, here it shows the comparison for before and after:

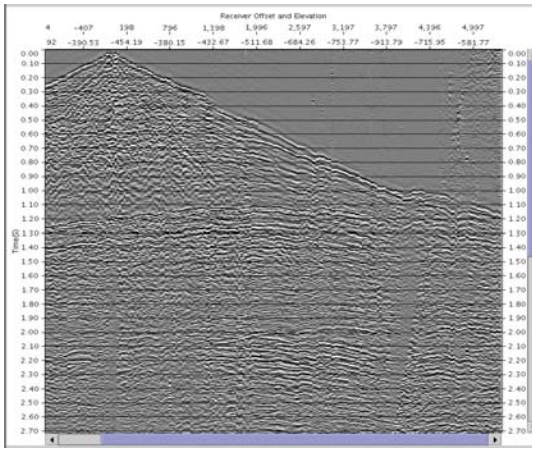

Figure 4. before near-surface corrections

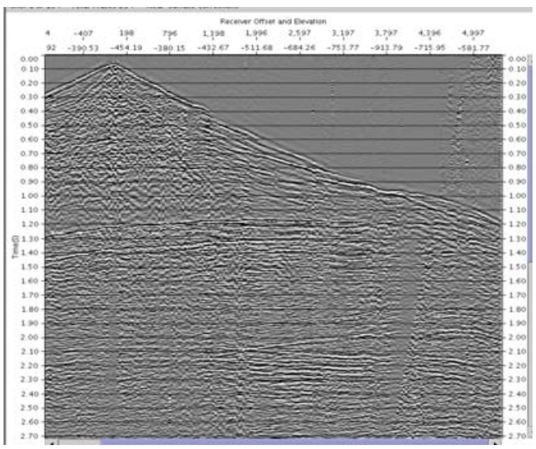

Figure 5. after near-surface corrections

It clearly shows the improvement. The final PSDM image is shown as the follows:

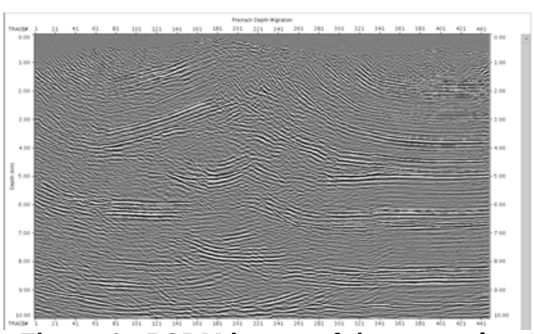

Figure 6. PSDM image of the example

3D Example

A3D case is in the area of Western Texas, USA. The area of the 3D seismic survey covers 135 square miles, and 10,207 shots were made in the field. We picked the first-arrival traveltimes, about 6 millions of picks, and then perform 3D nonlinear traveltime tomography on a Linux cluster. Figure 7 shows the horizontal slices at four different depths of the velocity solution.

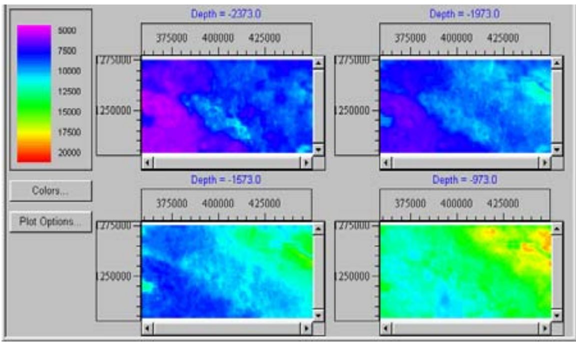

Figure 7. 3D near-surface velocity model

Above solution demonstrates significant lateral velocity variations that cannot be represented by any “layers.” Only tomography approach can resolve those detailed variations vertically and laterally. Also note that the high-velocity intrusion at the surface is also well resolved by tomography, and conventional refraction methods cannot handle structures like that.

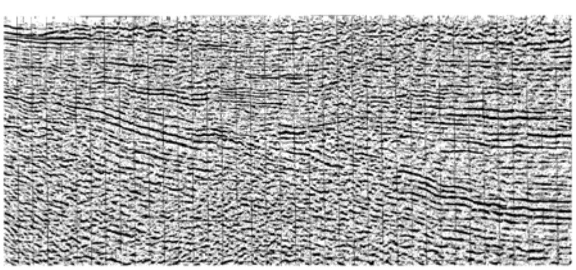

Figure 8. Stack with delay-time statics

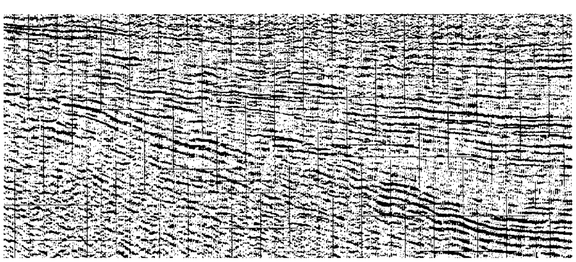

Figure 9. Stack with statics from using the above method

Conclusions

We design a near-surface correction approach for solving the statics problems associated with complex near-surface and complex subsurface structures. This involves the use of one-way tomostatics and refraction residual statics. This also suggests performing migration from intermediate floating datum. Applications to real data produce good results.

Acknowledgements

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References

Gardner, L. W., 1939, An areal plan of mapping subsurface structure by refraction shooting: Geophysics, v. 4., p.247-259.

Palmer, D., 1980, The generalized reciprocal method of seismic refraction interpretation: Soc. Expl. Geophys.

Zhang, J. and Toksoz, M. N., 1998, Nonlinear refraction traveltime tomography: Geophysics, **63**, 1726-1737.

Zhu, W. H. and Luo, Y., 2004, Refraction residual statics (RRS) using far offset data, Geo2004 conference abstract.