Near-Surface Corrections for Complex Structure Imaging

Jie Zhang and Oz Yilmaz, GeoTomo LLC*

Summary

In complex structure imaging problems, near-surface corrections often play critical roles. For processing land data from mountainous areas, using the first-arrival 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 only the down-going one-way statics from the actual shot and receiver locations to a floating intermediate datum, and then perform subsurface imaging from this intermediate datum. This approach avoids the complexity in selecting a replacement velocity for up-going statics when the lateral velocities vary significantly. We shall demonstrate in a real case that the proposed approach improves the data quality for the subsurface imaging.

Introduction

Near-surface corrections are often critically important for both prestack and post-stack land data processing. 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 evident effects due to the near-surface complexity are often displayed in both the first-arrivals and the reflections, such as broken first arrivals or the non-hyperbolic moveout behavior in reflections. Although local or residual refraction statics may help improve the continuity of the first arrivals, it may not help improve the reflection data in some situation when the refraction and reflection vary in inconsistent manner. We illustrate this problem by using a synthetic model as shown in Figure 1. The near-surface anomaly occurring in the middle of the model has been observed at two different receiver locations in the first arrivals (see Figure 2). If we derive refraction residual statics using the first arrivals, then the reflection statics will be mapped to two wrong locations. However, in a different situation as shown in the model in Figure 3 where the anomaly is shallow, the refraction anomaly occurs at the same location that reflection should be influenced. In the second case, then the residual statics is helpful. Therefore, applying refraction residual statics alone without knowing anything about the structures is valid only for very shallow near-surface anomalies.

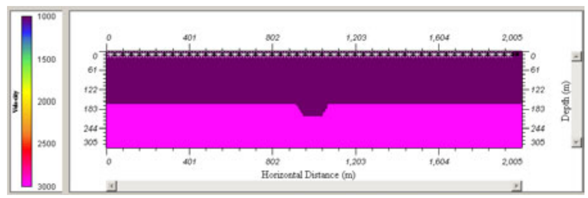

Figure 1: synthetic near-surface model with an anomaly.

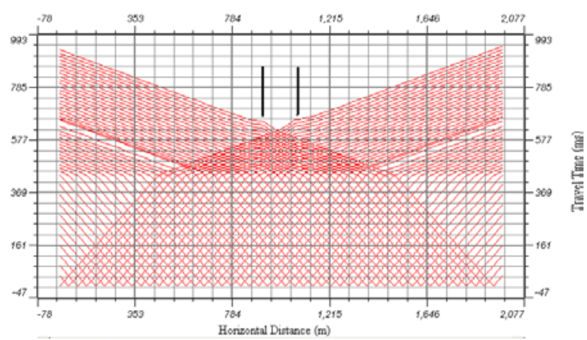

Figure 2: first-arrival traveltimes for the above model. Note the single anomaly in the model produces moveout effects at two receiver locations.

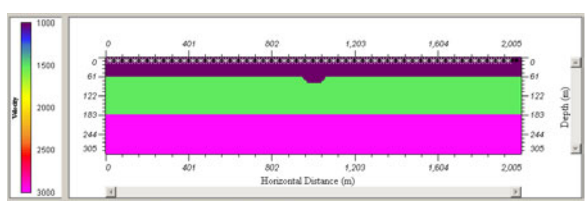

Figure 3: synthetic near-surface model with a shallow anomaly and a deep refraction interface.

Near-Surface Corrections

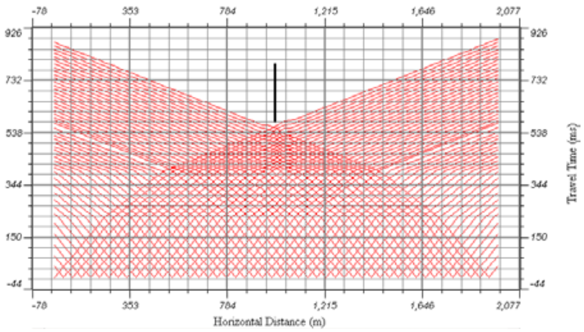

Figure 4: Calculated first-arrival traveltimes for model in Figure 3, and note that the model anomaly appears at the receivers at the same horizontal locations.

In situation shown in Figure 2, we must apply a model-based method to invert the observed anomaly in data and produce a velocity structure with the proper physical location and magnitude of the anomaly. Without this velocity model, we cannot directly convert the traveltime anomaly to the reflection statics solutions. Therefore, we choose to use both tomostatics solutions and the refraction residual statics solution.

Near-Surface Correction Method

In the case of complex near-surface problems where the base velocity varies laterally, our approach is first to invert the near-surface velocity structures using a nonlinear first-arrival tomography method. And then we derive an intermediate datum that separates the near-surface area and subsurface, and calculate down-going statics to the intermediate datum. Instead of going back to a flat or floating datum with a constant replacement velocity, we choose to stay at the intermediate datum, and the subsurface depth imaging will start from the intermediate datum. This concept is illustrated in Figure 5.

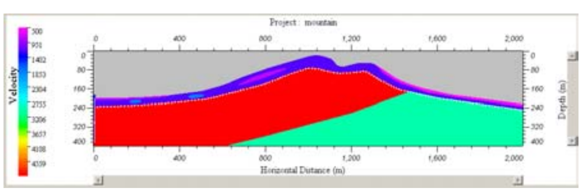

Figure 5: Schematic near-surface model showing the lateral velocity discontinuity in the base of the near-surface area. A dashed line separates the near-surface area and the subsurface.

Imaging from the intermediate datum is due to the fact that the concept of the replacement velocity fails in situation as shown in Figure 5. Using any constant replacement velocity will add an artificial layer in the subsurface velocity model. The connection between the near-surface area and the subsurface is not physically valid.

The above approach is almost like performing migration from the actual shot and receiver locations with the near-surface velocity model included. However, we separate the near-surface area and the subsurface, and apply the near-surface one-way statics to correct the non-hyperbolic moveout or broken events first. In addition, we apply the refraction residual statics derived after the tomostatics is applied. The data is then better conditioned for the subsurface imaging. Directly migrating data from the actual shot and receiver locations will result in poor images due to broken events even with the use of an accurate near-surface velocity model. For the same reason, wave-equation datuming may not be able to maintain reasonable data quality as well for the subsurface imaging.

Therefore, our near-surface correction method for the complex near-surface area includes the following steps: 1) apply tomography approach to obtain an accurate near-surface model; 2) derive a floating intermediate datum that separate the near-surface area and subsurface; 3) calculate one-way statics from the actual shot and receiver locations to the intermediate datum using the tomography model; 4) apply the tomostatics to the long-offset refraction traveltimes, and then smooth the corrected refractions and derive residual statics; 5) apply both tomostatics and the refraction residual statics to the data.

Real Data Applications

We demonstrate the above method using a real example from a mountain area in Yumen, China. The survey was performed in an area with significant topography variations. We designed a fixed recording array in the field and a total number of 141 shots were recorded. For details, see Yilmaz *at al.* (2005).

It appears that the near-surface correction becomes a major issue in this case. Not only because of topography variations and the near-surface velocity complexity, also the high-velocity subsurface intrusion causes difficulties for the conventional concept of "replacement velocity" in statics corrections.

We shall apply the approach that we described above and obtain both tomostatics and refraction residual statics problems. Figure 6 shows the tomography solution.

Near-Surface Corrections

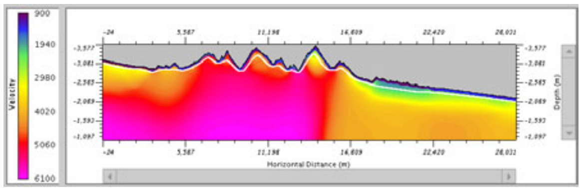

Figure 6: Tomography velocity solution for the near-surface area.

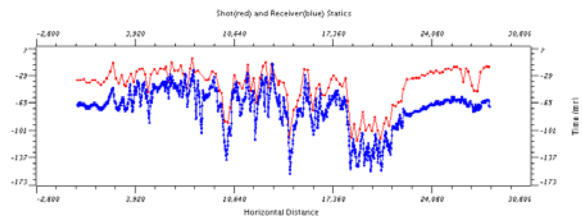

Figure 7: The sum of the tomostatics and the refraction residual statics. Shot statics in red, and the receiver statics in blue.

In Figure 6, we also draw an intermediate datum in white below the low velocity zone. We calculate the tomostatics solutions down to the curve, and then apply the statics to the long-offset refractions. We further calculate the refraction residual statics from the corrected refractions. Finally we apply both tomostatics and the refraction residual statics to the data. Figure 7 shows the sum of the two statics solutions.

The following two figures show the differences of a shot gather before and after the total statics applied.

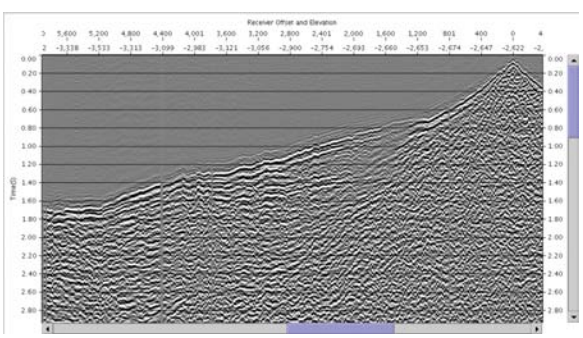

Figure 8: A shot gather before statics is applied.

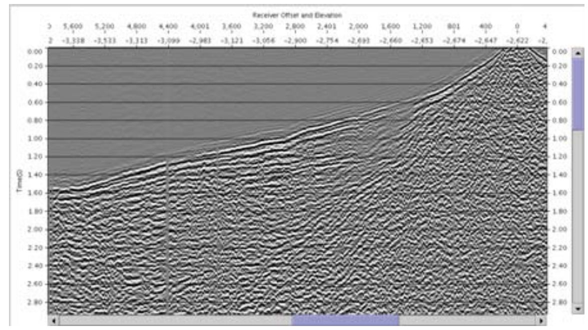

Figure 9: A shot gather after statics is applied.

The above results demonstrate the effectiveness of the near-surface corrections in this situation.

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

We thank PetroChina for providing the seismic data used in this case study and granting us the permission to publish the results.

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.

Yilmaz, O., Zhang., J., and Yan, S. X., 2005, Acquisition and processing of large-offset seismic data: a case study from Northwest China, Expanded Abstract, submitted to 75th Ann Internat. Mtg., 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.

EDITED REFERENCES

Note: This reference list is a copy-edited version of the reference list submitted by the author. Reference lists for the 2005 SEG Technical Program Expanded Abstracts have been copy edited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

Near-Surface Corrections for Complex Structure Imaging

References

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

Palmer, D., 1980, The generalized reciprocal method of seismic refraction interpretation: SEG.

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

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