A fast method for accurately determining 3-D refraction static corrections

Erick Adam* and Bernd Milkereit
University of Toronto, Toronto, ON
49 Fayence, Gatineau, QC, J8T 7B7
eadam@physics.utoronto.ca

ABSTRACT
Conventional methods of computing refraction static corrections require picking first arrivals on several traces and many iterations of traveltime inversions. Furthermore, the amount of time required to pick first arrivals increases as the quality of the data decrease and automatic picking algorithms require more assistance from the data processor. Obtaining accurate refraction static corrections becomes even more important when processing data with low signal-to-noise ratio because residual static correction algorithms do not perform well.

The method that we propose simplifies the refraction static correction problem by solving the shot and receiver static corrections independently. We first estimate the short wavelength component of the static correction while the long wavelength component is attributed to the refractor velocity variations. The receiver static corrections are derived from the first break pick times from only a few shot gathers. The shot static corrections are obtained, after the application of the receiver static corrections, by picking a single stacked trace per shot gather. The first break time can be predicted for all shot receiver pairs and then serve as input data to more sophisticated algorithms to derive a realistic near surface velocity model.

This simple and fast method was applied to a 3-D survey acquired for base metal exploration that consist of about 1000 shot points recorded by up to 1983 receivers. In the survey area near surface conditions and data quality are highly variable making first break picking difficult.

Introduction

The importance of deriving accurate refraction static corrections to obtain high-quality seismic section has long been recognized. It is also known that the accuracy of the static correction largely depends on the quality of the first break pick times which in turns depends on the overall quality of the seismic data. Consequently, obtaining accurate refraction static corrections for a large 3-D dataset of variable data quality can be challenging and time consuming.

Since the arrival of the generalized inversion of first break pick times (e.g. Hampson and Russell, 1984), most of the advancement in the field of refraction static corrections have focused on either automating the picking of first breaks (e.g. Coughlin, 1996) or avoid first break picking altogether (Hatherly et al., 1994). The inversion of first break pick times has the ability to produce an accurate model of the near surface and the quality of the model will depend on the consistency of the first break picking. As first break picking can be tedious and time consuming, deriving refraction static correction without first break picking (Hatherly et al, 1994) can be quite attractive. A drawback of the fully automated method, lies in the absence of a near surface model as the output.

Tomographic traveltime inversion studies (Dahlen, 2002) suggests that time delays observed in the seismic wavefield are caused by heterogeneities that are close to the receivers. Heterogeneities that are far from the receiver do not affect the seismic arrivals as the waves "heal" quite rapidly. These observations are opening the way to fast and accurate methods of estimating refraction static correction with minimal first break picking. The objective of this paper is to propose a new methodology that combines the accuracy of the generalized linear inversion of first break pick times (Hampson and Russell, 1984) with the speed and limited processor intervention of the fully automated methods (e.g. Hatherly et al., 1994). The effectiveness of the method is illustrated on a 3-D dataset acquired for base metal exploration.

The Trillabel 3-D seismic experiment

The Trillabel 3-D seismic experiment has been acquired to locate deep nickel-copper deposits at depths. The survey geometry, geological setting, and results have been presented by Milkereit et al. (1997, 2000). The survey area is characterized by highly variable near surface conditions and difficult access. The surface elevation and survey geometry are shown in Figure 1. The relatively weak seismic reflectivity, typical for the area, is partly compensated by acquiring high fold seismic data. For this survey almost all receivers (up to 1983 channels) were live during data acquisition. For a large number of seismic traces, poor signal-to-noise ratio makes automatic first break picking inefficient and requires frequent interventions from the data processor. It is the large number of traces to picks (~2 millions) and the variable data quality that prompted the search for a more efficient method of evaluating the refraction static corrections.

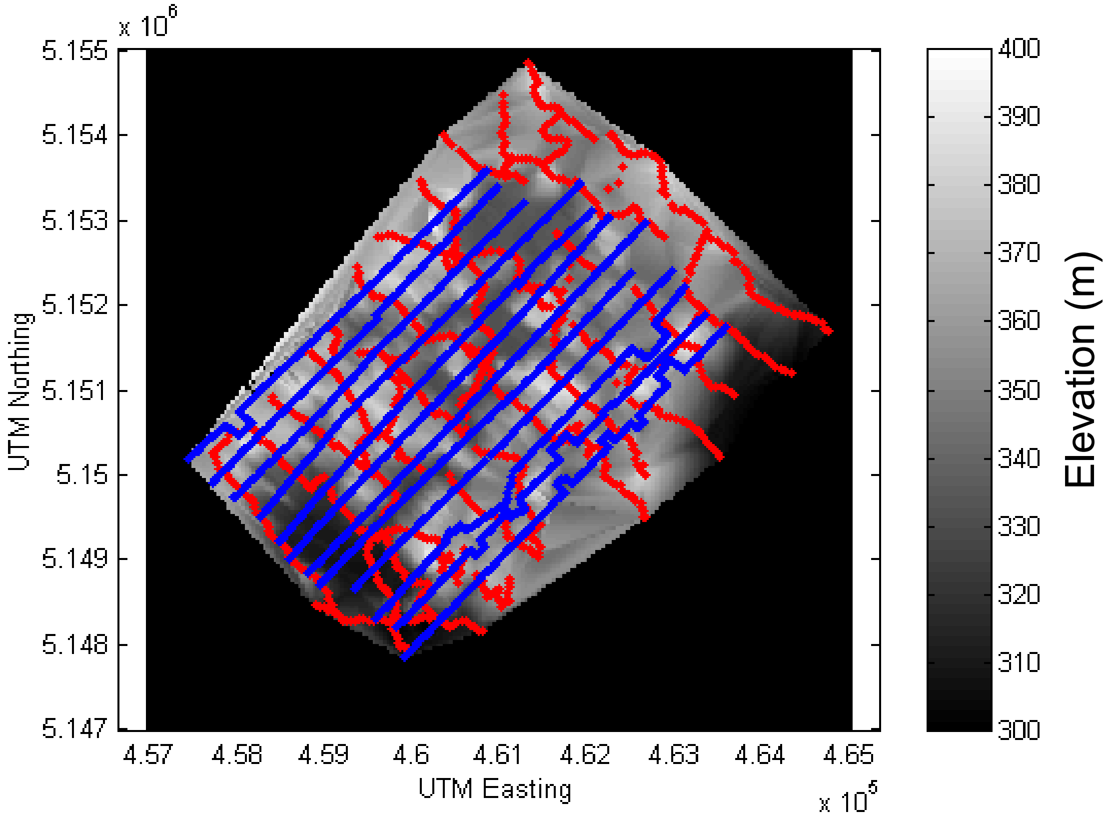

Fig. 1: Location map of the Trill 3-D area. Receiver locations are indicated in blue and the shot locations are in red. The gridded surface elevation is also indicated in metres above the mean sea level.

The refraction static correction method

Our proposed refraction static correction method requires to determine the average velocity over the survey area. Knowing the large scale velocity variations also help the static correction algorithm by explaining the long wavelength refraction static component. *Fig. 2* shows the complete seismic dataset binned (30 m bin size) as a function of source-receiver offset. On Figure 2, clear ground roll energy and S-wave direct arrivals can be observed and the slope of the P-wave direct arrival is giving the average velocity of the refractor (5850 m/s). More details of the refractor velocity can obtained by performing a similar analysis on subsets of the data.

The velocity field derived from first break analysis (*Fig. 2*), without first break picking, is used to reduced the seismic data. *Fig. 3* shows a portion of a shot gather reduced using a single velocity of 5850 m/s with the red line indicating the first break pick times. From the tomographic inversion study (Dahlen, 2002), we attribute the short wavelength delays to the near receiver variations (i.e.

overburden thickness). The long wavelength variations are attributed to the refractor velocity variations over the seismic survey area.

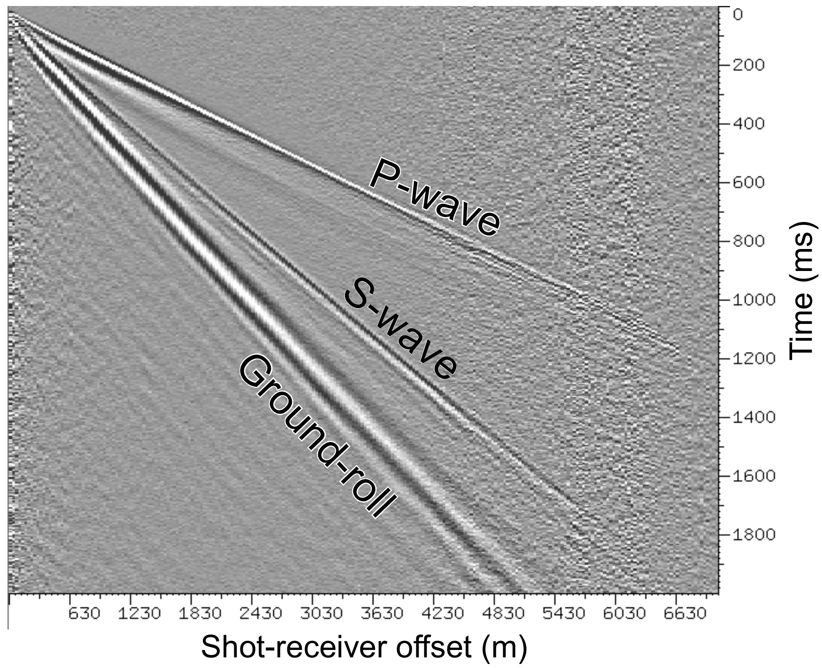

Fig. 2: Partial stack of all the seismic data of the Trillabel 3-D survey binned (30 m bin size) as a function of source-receiver offset distances. Dominant seismic waves are indicated.

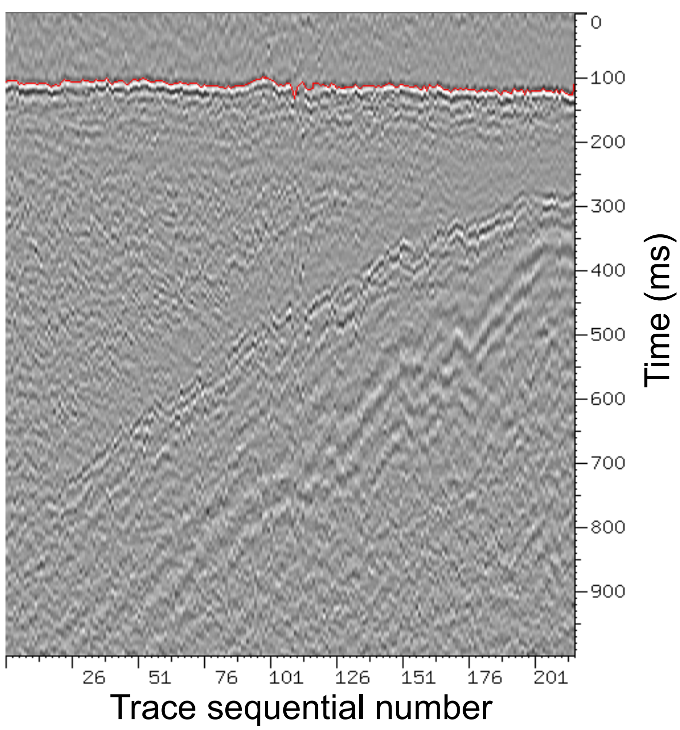

Fig. 3: One receiver line from shotpoint 10001 reduced using a velocity of 5850 m/s. The first break pick times are indicated in red.

The time shifts required to flatten the first breaks can be directly attributed to the receiver static correction. Note that in the case of the Trillabel survey, most of the geophones where active during data acquisition, thus picking first breaks on a single shot gather following a rapid estimation of the refractor velocity, produces a set of receiver static corrections. For this analysis, the best shots with the largest number of receivers are selected. In order to minimize the effects of inhomogeneities far from the receiver, shotpoints from the periphery of the survey are used.

The receiver statics corrrection derived from the shotpoint (shot 10001) shown in *Fig. 3* have been applied to another set of shotpoints to assess the effectiveness of the method. As an example, shot 5094 is shown on *Fig. 4* without static corrections. After applying the receiver static correction derived from shot 10001 to shot 5094, we obtain the data shown on *Fig. 5*. Clearly, this new method allows a rapid estimation of receiver static corrections since they were obtained from picking only one shot (i.e. 1983 seismic traces). The quality of the refraction correction can be assessed by reducing the data and identify residual long wavelength statics.

In a similar manner, the shot refraction static correction can be obtained after the receiver static correction have been applied. By stacking reduced shot gathers, the shot refraction static corrections can be obtained with only a single pick time per shotpoint. This new method of evaluating refraction static corrections thus requires picking of only a subset of the traces. Because, it is not necessary to pick first break on every shot gathers, the data processor can choose the best shot gather to perform the analysis.

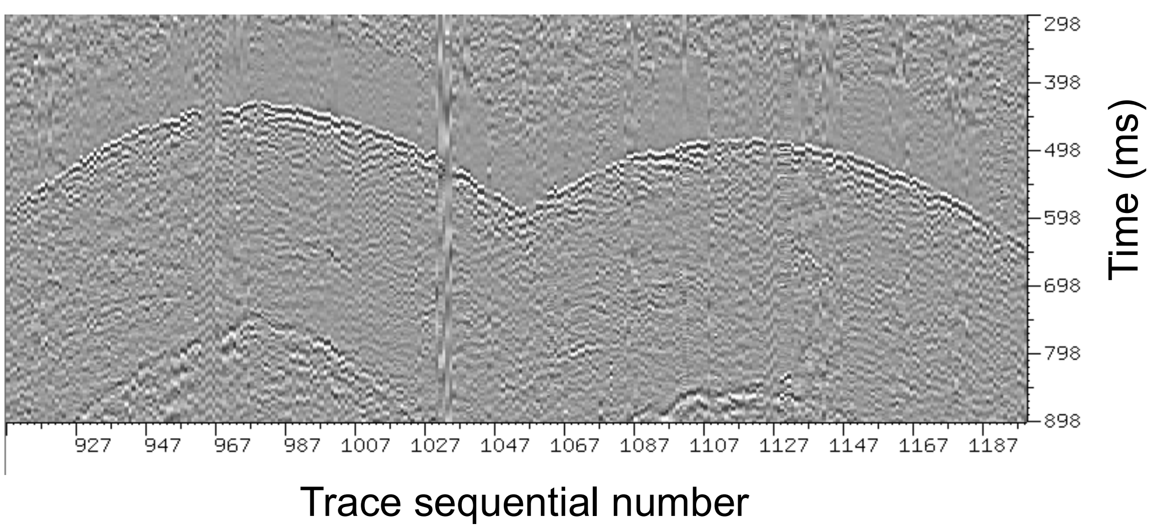

Fig. 4: Two receiver lines from shot gather 5094 with no refraction static correction applied.

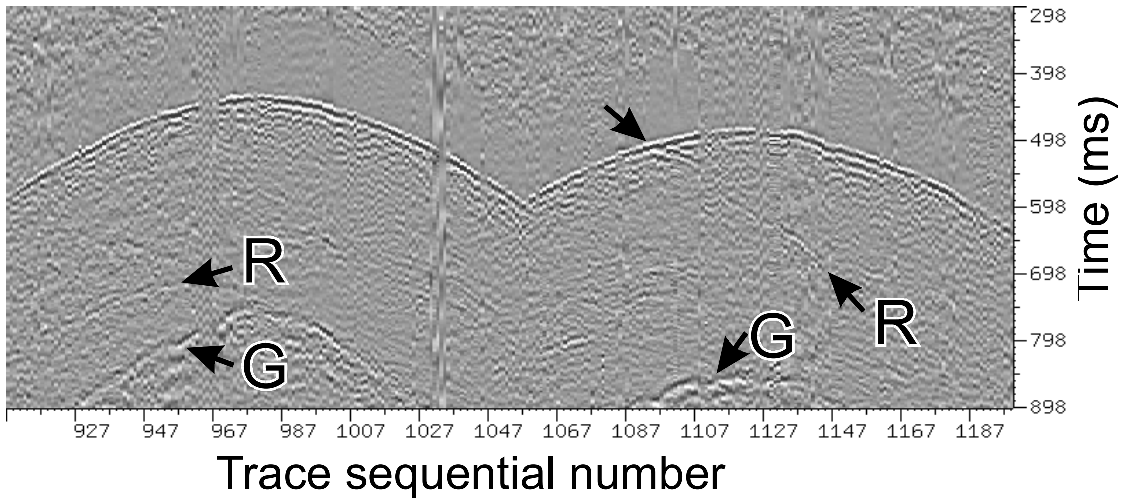

Fig. 5: The same two receiver lines showed on Figure 4 after the application of receiver static corrections derived from the analysis of shot 10001. Two reflections (R) and ground roll (G) are indicated.

Conclusions

We have presented a new method for estimating refraction static corrections. This new approach requires that first breaks be picked on only a subset of the data making it efficient and rapid. A visual inspection of the first break after applying the correction indicates that it is accurate. On the other hand, this method works best with seismic datasets that have a large number of channels live at the same time. Also, in the case where more than the delay times are required, this method can be used to estimate first break pick times for each shot-receiver pairs. This set of first break pick times can serve as the input to the generalized inversion of first break to obtain a realistic model of the near surface.

References

Coughlin, J.P., 1996, First-break algorithm for digitally acquired transient signals. Computers & Geosciences. 22,no. 2, 181-192.

Dahlen, F.A., 2002, Bananas, Doughnuts and Seismic Traveltimes. Eos Trans. AGU, 83(47), Fall Meet. Suppl.

Hampson, D. and Russell, B., 1984, First-break interpretation using generalized linear inversion: J. Can. Soc. Expl. Geophys., 20, no. 01, 40-54.

Hatherly, P. J., Urosevic, M., Lambourne, A. and Evans, B. J., 1994, Simple approach to calculating refraction statics corrections (short note): Geophysics, Soc. of Expl. Geophys., 59, 156-160.

Milkereit, B., Berrer, E., King, A., Watts, A.H., Roberts, B., Adam, E., Eaton, D. W., Wu, J. and Salisbury, M.H., 2000, Development of 3-D seismic exploration technology for deep nickel-copper deposits -- A case history from the Sudbury basin, Canada: Geophysics, Soc. of Expl. Geophys., 65, 1890-1189.

Milkereit, B., Berrer, E.K., Watts, A., and Roberts, B. 1997. Development of 3-D seismic exploration technology for Ni-Cu deposits, Sudbury Basin. In "Proceedings of Exploration 97: Fourth Decennial International Conference on Mineral Exploration". Edited by A.G. Gubins, pp. 439-448.