IMPROVING THE RESOLUTION OF FRESNEL VOLUME TOMOGRAPHY WITH WAVELENGTH-DEPENDENT VELOCITY SMOOTHING

Siegfried R.C. Rohdewald, Intelligent Resources Inc., Vancouver B.C., Canada

Abstract

We demonstrate improvement in resolution of subsurface P-wave velocity tomograms incorporating Fresnel Volume Tomography and Wavepath Eikonal Traveltime inversion (WET) by engaging Wavelength-Dependent Velocity Smoothing (WDVS). We interpret synthetic traveltime data for Sheehan 2005 Broad Epikarst model to obtain sharper imaging of layer boundaries with WDVS. We use our default 1D-gradient starting model and a layered refraction Plus-Minus method starting model. Also we show improved resolution using WET+WDVS for a field survey using 9 shots into 24 channels.

WDVS is most beneficial for profiles shorter than 100m with traveltime paths not much longer than a few wavelengths. WDVS will not help if reciprocal traveltime picking errors are too large. WDVS requires the exact specification of the used recording geometry.

Sheehan 2005 Broad Epikarst Model Synthetic Data Interpretation

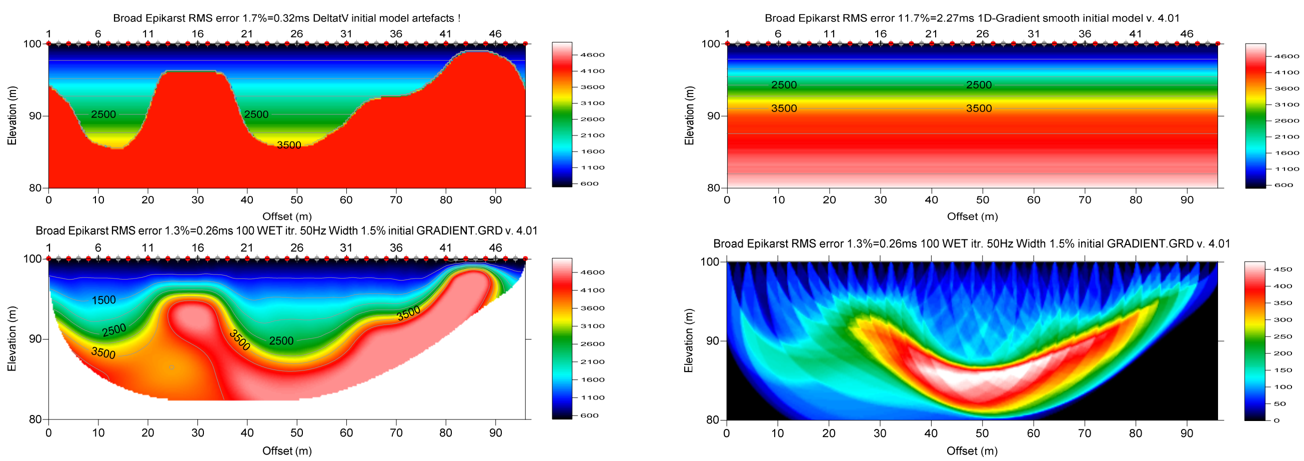

Figure 1: Top: Broad Epikarst model (left) and 1D-gradient starting model (right).
Bottom: 100 Steepest-Descent WET iterations using WDVS at 400Hz and 1D-gradient starting model (left). WET wavepath coverage plot using unit wavepaths per pixel (right).

In Fig. 1 we show WET inversion (Schuster, 1993) of the synthetic traveltime data modeled for the Broad Epikarst model (Sheehan, 2005). We use our default 1D-gradient starting model obtained by laterally averaging the pseudo-2D DeltatV velocity (Sheehan, 2005). We enable WDVS (Zelt, 2016) for WET inversion (Rohdewald, 2020a). We use a WET wavepath width of 1.5% and minimal WET smoothing. Note the too low basement velocity where the wavepath coverage is lower (Fig. 1 Bottom).

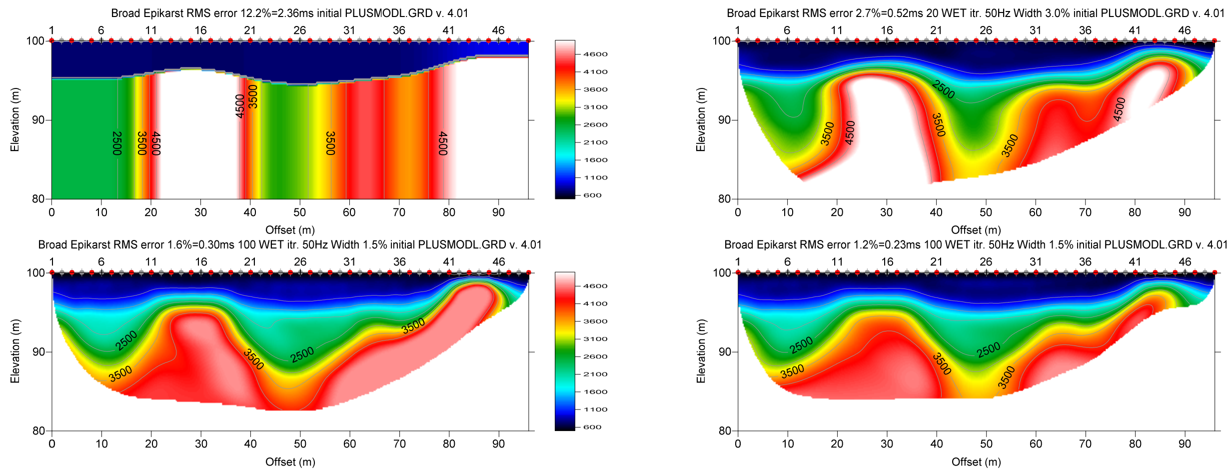

Figure 2: Top: Plus-Minus starting model (left). Smooth inversion with Plus-Minus starting model and WDVS engaged (right). Bottom: 100 Steepest-Descent WET iterations using Plus-Minus starting model with WDVS activated (left). Same WET inversion as shown at left but without WDVS (right).

In Fig. 2 we show WET inversion of the same synthetic traveltime data as shown in Fig. 1 with the same WET settings but using our Plus-Minus method layered refraction starting model (Rohdewald, 2020a). Plus-Minus apparent velocity below anticlines is unrealistically high (Fig. 2 Top left). Note the lower velocity contrast at top-of-basement (yellow to red color transition) with velocity increasing more gradually with depth when disabling WDVS (Fig. 2 Bottom right). The anticline flanks are modeled more steeply with WDVS engaged (Fig. 2 Bottom left) as with 1D-gradient starting model (Fig. 1 Bottom left) and as in true model (Fig. 1 Top left).

CAMP1 Field Data Interpretation with WET and WDVS

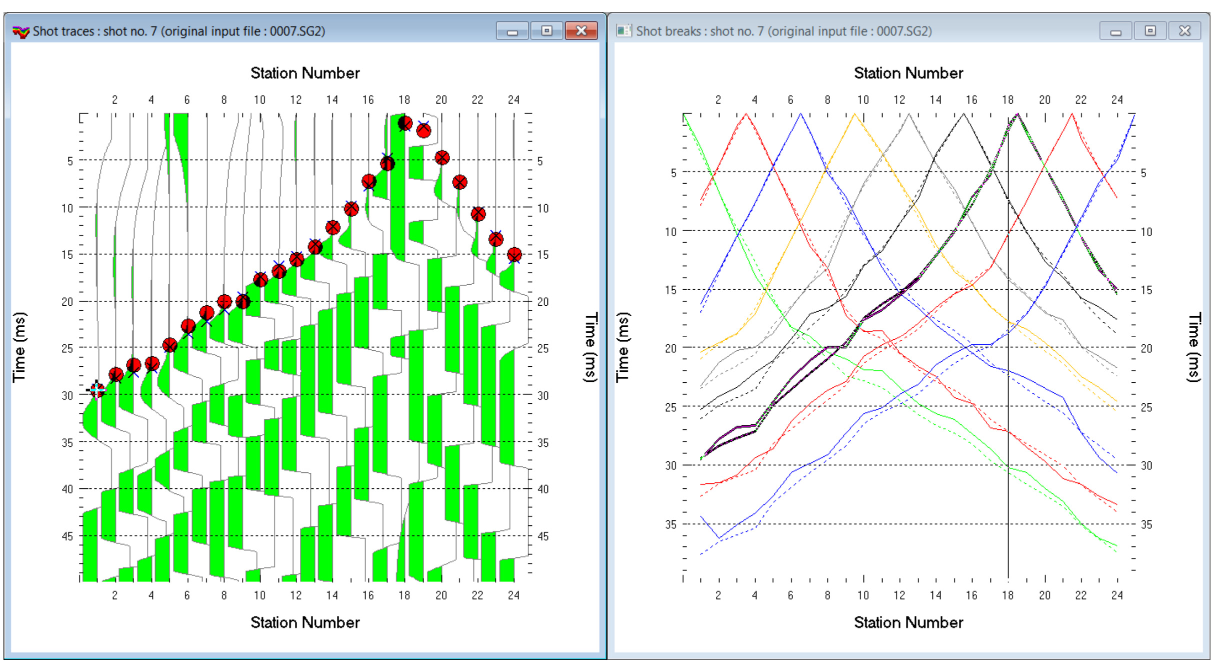

Figure 3: Sample shot record (left). Picked times (solid) and WDVS modeled times (dashed) at right. Note the high signal-to-noise ratio of first breaks (left).

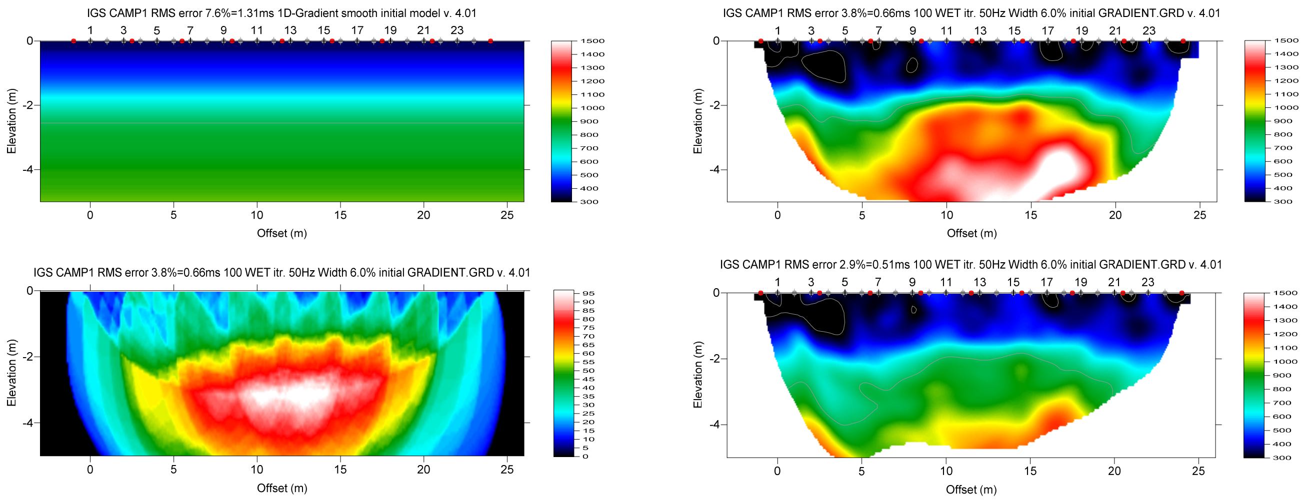

Figure 4: Top: 1D-gradient starting model for line CAMP1 (left). 100 Steepest-Descent WET iterations using WDVS at 150Hz with 1D-gradient starting model (right). Bottom: WET wavepath coverage plot obtained for tomogram shown at top right. Unit is wavepaths per pixel (left). Same WET settings as used to produce tomogram at top right but without WDVS (right).

In Fig. 4 we show WET inversion (Schuster, 1993) of the picked traveltime data for field survey CAMP1 (Rohdewald, 2020b). We again use our default 1D-gradient starting model obtained by laterally averaging the pseudo-2D DeltatV velocity (Sheehan, 2005). We use a WET wavepath width of 6% and minimized WET smoothing: smooth every 10th WET iteration only. We engage WDVS at 150Hz (Zelt, 2016) for WET inversion (Fig. 4 Top right). Note the lower velocity contrast at top-of-basement (elevation -2m) when disabling WDVS (Fig. 4 Bottom right).

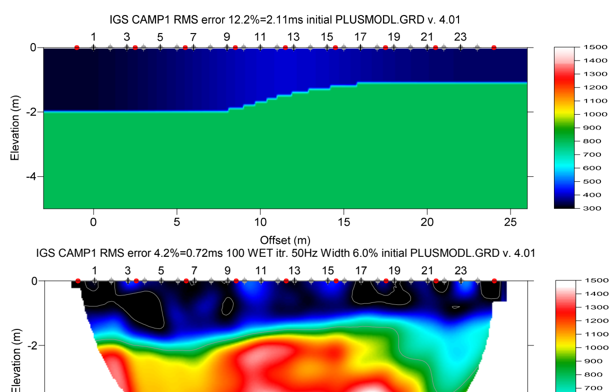

Figure 5: Top: Plus-Minus starting model for line CAMP1. Bottom: WET inversion with WDVS engaged at 150Hz using Plus-Minus starting model.

In Fig. 5 we show WET inversion of CAMP1 traveltime picks with the same WET settings as for inversion shown in Fig. 4 but using our alternative Plus-Minus starting model. We mapped traces to refractors in our Common Mid-Point (CMP) display (Rohdewald, 2020b). Note the close match with (Fig. 4 Top right) obtained with the same WET settings but using the 1D-gradient starting model.

Conclusions

We show that engaging WDVS for WET P-wave velocity inversion can improve the resolution in resulting tomograms. We show this in the examples of synthetic data and field data where the top of the basement is imaged more sharply with stronger velocity contrast between overburden and basement. Also we show that WET+WDVS tomograms are independent of the starting model after 100 Steepest-Descent WET iterations. WDVS shows the most improvement for profile lengths shorter than 100m with traveltime paths not much longer than a few wavelengths. WDVS will not help if reciprocal traveltime picking errors are too large or with errors in recording geometry specification. We have found that increasing the grid cell size can speed up WDVS. Limit the WET velocity to maximum velocity in starting model to suppress a bias towards too high velocities in basement when activating WDVS. This bias gets stronger when lowering the WDVS frequency.

References

Hagedoorn, J.G., 1959, The Plus-Minus method of interpreting seismic refraction sections, Geophysical Prospecting, Volume 7, 158-182.

Rohdewald, S. 2014. Optimized Interpretation of SAGEEP 2011 Blind Refraction Data with Fresnel Volume Tomography and Plus-Minus Refraction. SAGEEP 2014 Expanded Abstract.

Rohdewald, S. 2020a. Broad Epikarst synthetic data inversion. http://rayfract.com/tutorials/epikinv.pdf.

Rohdewald, S. 2020b. CAMP1 field survey interpretation. http://rayfract.com/tutorials/camp1.pdf.

Rohdewald, S. 2020c. NGU Aaknes-1 interpretation. http://rayfract.com/tutorials/Aaknes-1.pdf.

Rohdewald, S., Burton, B., Sheehan, J., Doll, W., 2010, Processing of seismic refraction tomography data, SAGEEP short course notes, Keystone, Colorado, https://rayfract.com/SAGEEP10.pdf.

Schuster, G.T., Quintus-Bosz, A., 1993, Wavepath eikonal traveltime inversion: Theory. Geophysics, Volume 58, 1314-1323.

Sheehan, J.R., Doll, W.E., Mandell, W., 2005, An evaluation of methods and available software for seismic refraction tomography analysis, JEEG, Volume 10(1), 21-34.

Watanabe, T., Matsuoka, T., Ashida, Y., 1999, Seismic traveltime tomography using Fresnel volume approach, SEG Houston 1999 Meeting, Expanded Abstracts.

Zelt, C. A. 2010, Seismic refraction shootout: blind test of methods for obtaining velocity models from first-arrival travel times, http://terra.rice.edu/department/faculty/zelt/sageep2011.

Zelt, C. A., Chen, J., 2016, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., Volume 207, 72-88.

Zelt, C.A., Haines, S., Powers, M.H. et al. 2013, Blind Test of Methods for Obtaining 2-D Near-Surface Seismic Velocity Models from First-Arrival Traveltimes, JEEG, Volume 18(3), 183-194.