IXRefraX Shootout Tutorial

Interpretation of SAGEEP 2011 "Shootout" refraction tomography data using IXRefraX

Description

There was a special "Blind Test" refraction tomography on Monday afternoon 11 April 2011 at the SAGEEP meeting in Charleston. Colin Zelt (czelt@rice.edu) generated a dense data set comprised of a 100-geophone spread and 101 shots and offered it to anyone who wanted to interpret it with refraction tomography. Approximately 10 speakers responded with models. The "true" model was not revealed until the very end of the session.

This data set is well suited for interpretation with the commonly used seismic tomography methods. It is not designed for use with time-delay methods such as the Generalized Reciprocal Method, as the interior shots are very densely spaced and there are no far shots. However, for completeness, we will show here how to interpret these data with GRM. Then, we will trim the data set to be more suitable for GRM and reinterpret it in a separate presentation.

Acknowledgements

The author would like to acknowledge the co-chairs of the

Seismic Refraction Shootout: Blind Test of Methods for Obtaining Velocity Models from First-Arrival Travel Times:

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Import & Interpretation Sequence

❑ Use File/Create Spread to import data.

❑ Examine data using flat refraction interpretation to estimate layered model.

❑ Use Calculate/Estimate Model to generate a 2-D model of the section.

❑ Use Calculate/Estimate Layer Assignments and Estimate Reciprocal Times.

❑ Use Calculate/GRM Interpretation to generate GRM Section.

❑ Examine velocities and velocity analysis curves to find discontinuities.

❑ Regenerate GRM section after assigning discontinuities

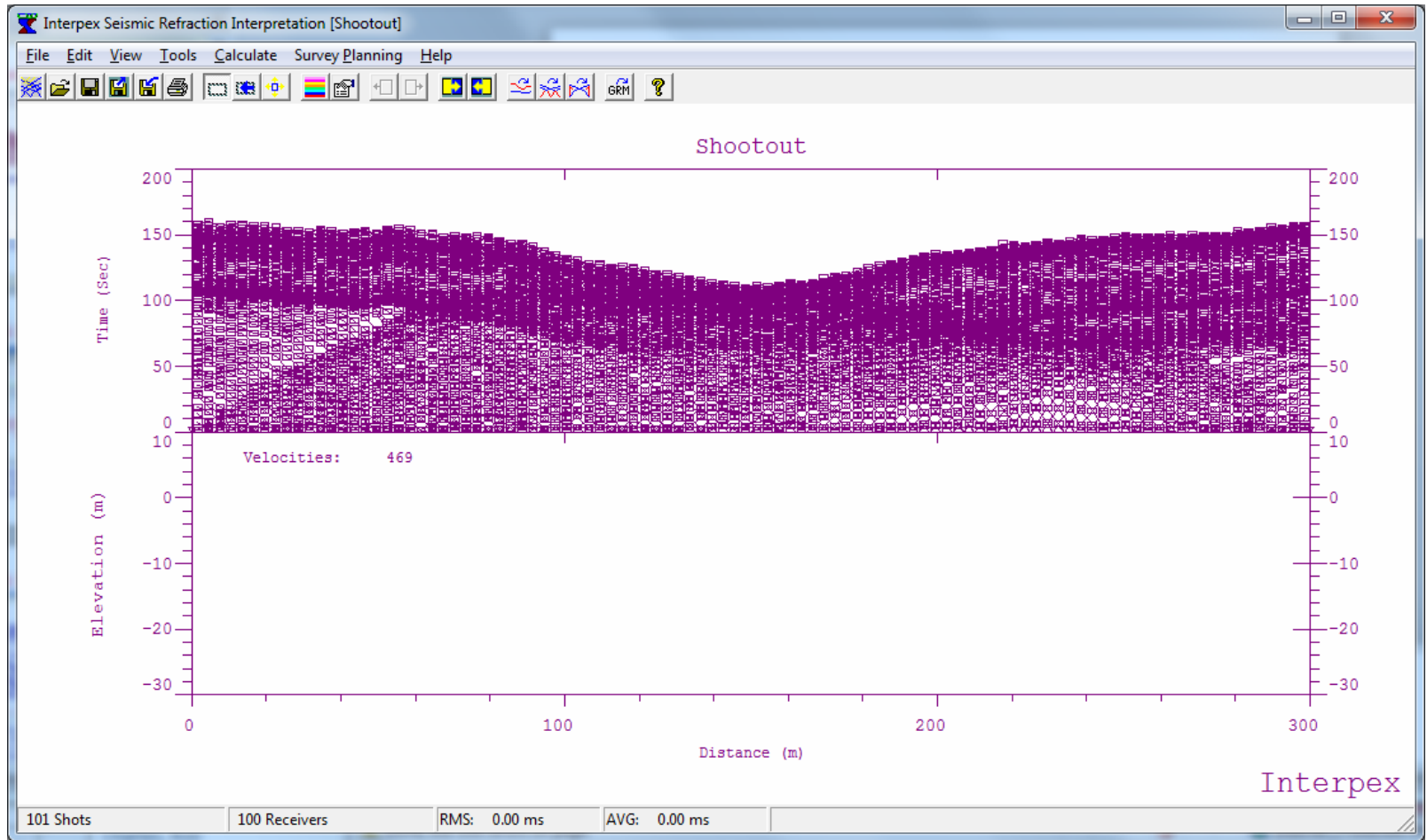# Use File/Create Spread to import data.
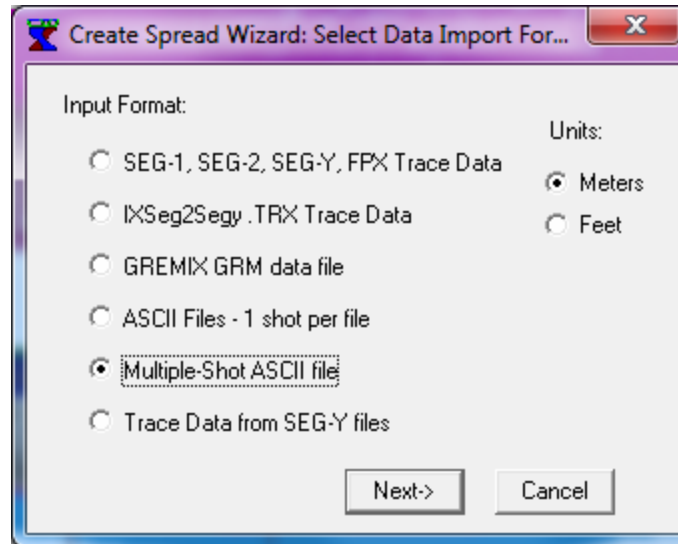
First, select input format. (If using unlicensed version, this is not available. Open keyed Shootout.RFX demo file instead).

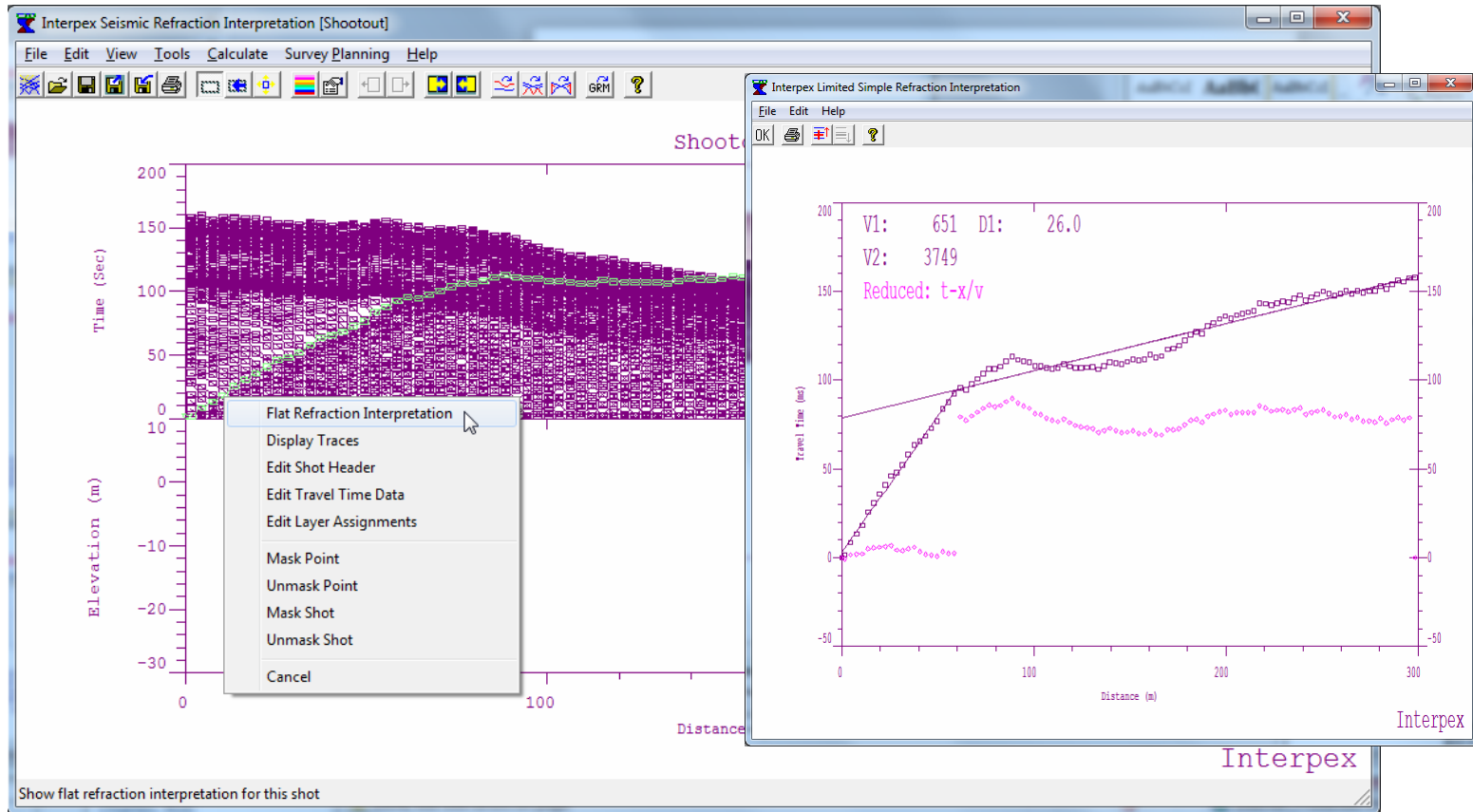# Use File/Create Spread to import data.
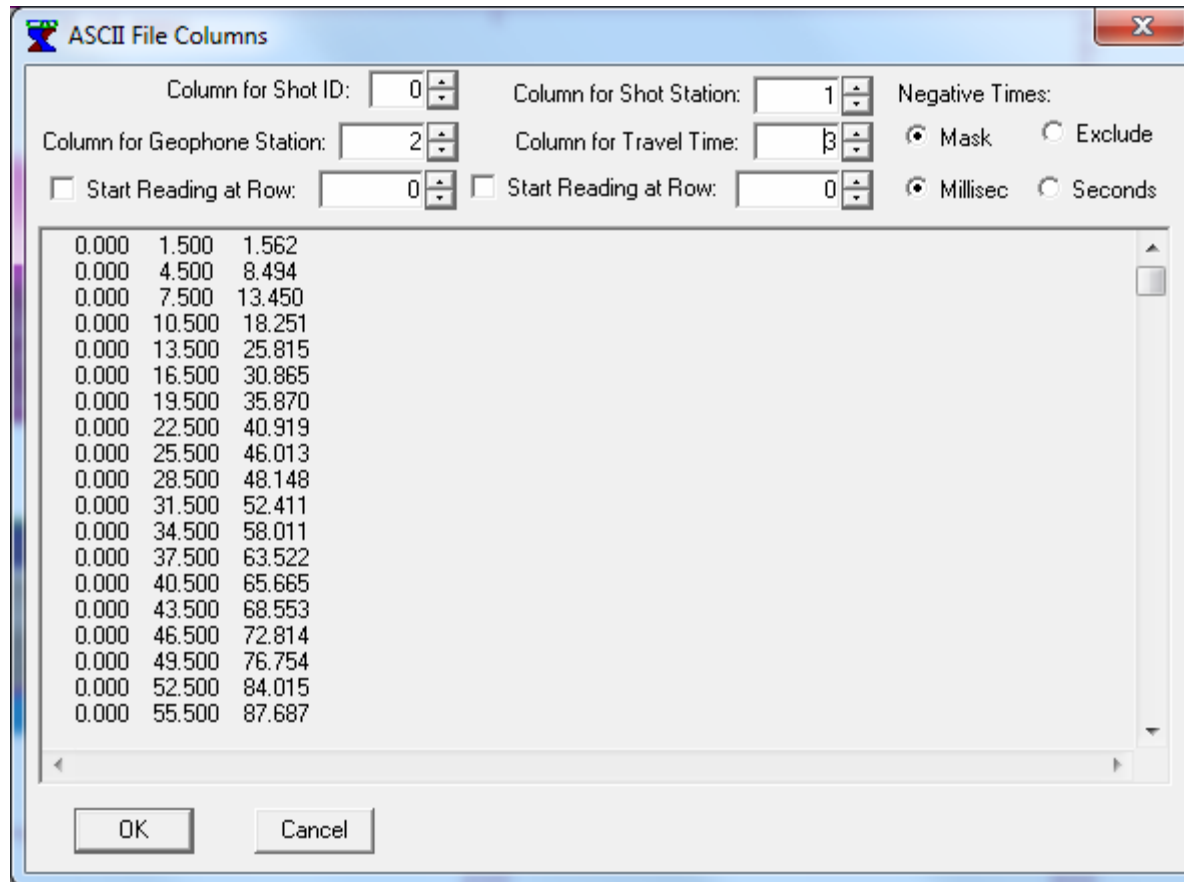
Second, select file and then be sure columns are set correctly.

# Use File/Create Spread to import data.

Press OK and view imported data. Note shots are very dense (one per geophone) and there are no far shots.
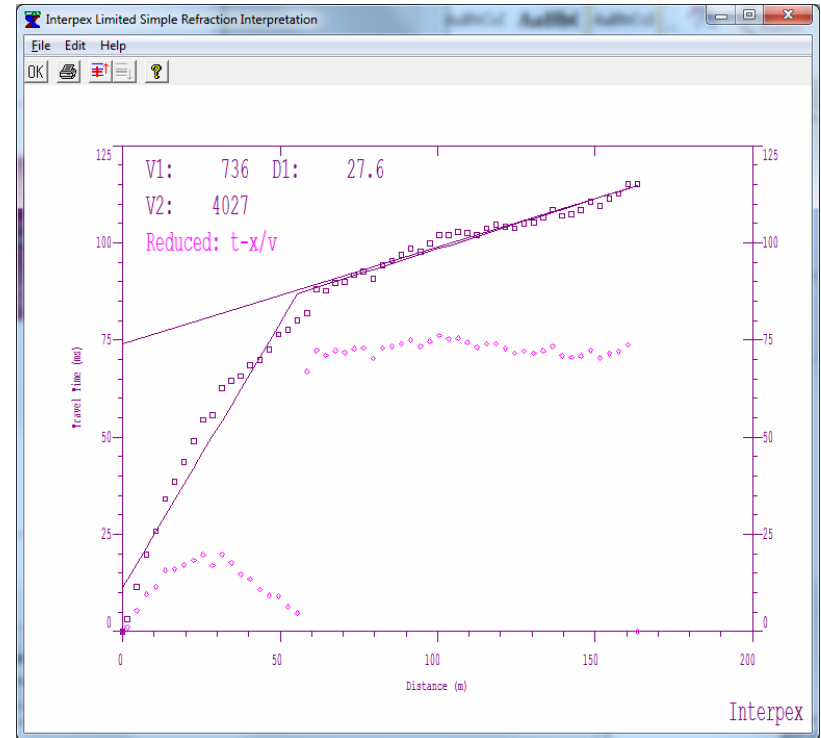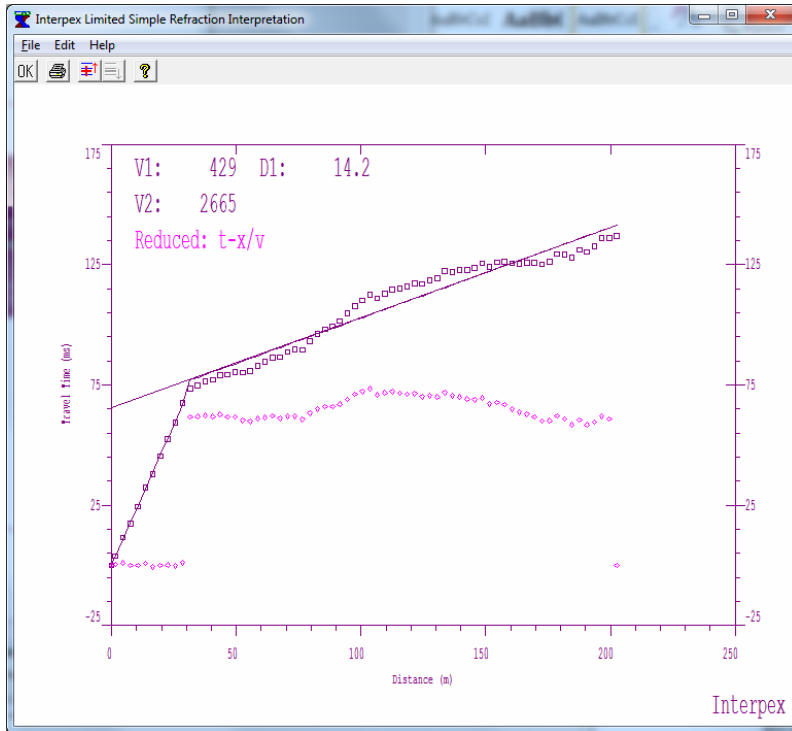
Examine data to estimate model.

Right-clicking on a travel time curve pops up a menu. Select Flat Refraction Interpretation to estimate velocities and depths from Slope-Intercept analysis. For interior shots, click on a point to the right or left of the shot to interpret the respective side using SI analysis. Here we see the results for forward shot at 0 m.

Examine data to estimate model.
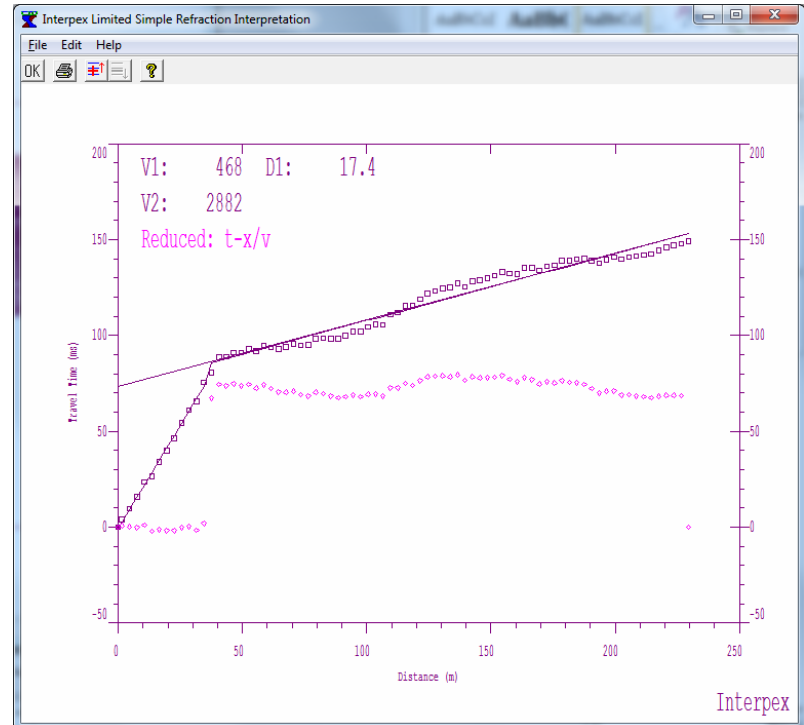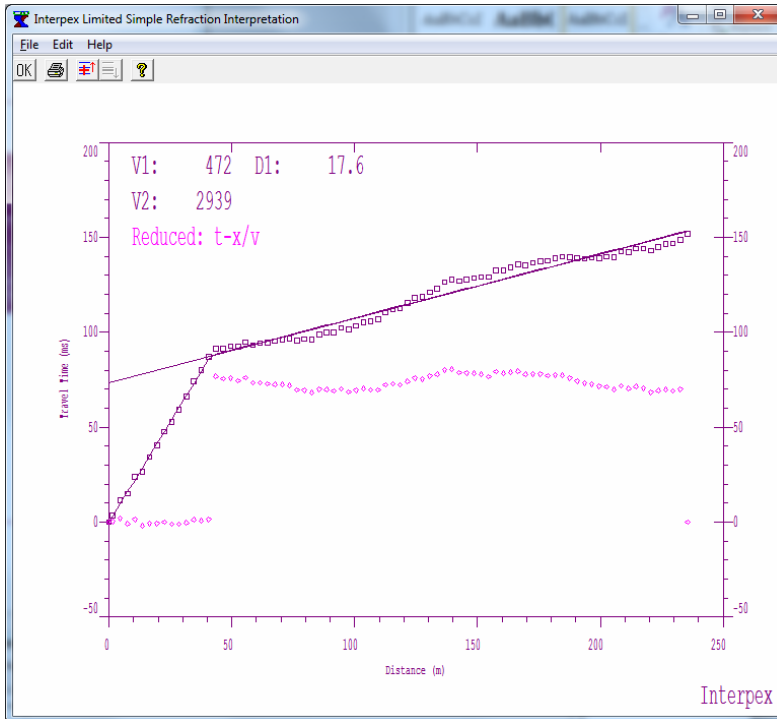
Examine a number of the travel time curve segments, trying to determine the number of layers, their velocities and thicknesses, Be careful to look at curves which are most representative of a layered earth. Here we see the results for forward shots at 55.5 m and 85.5 m.
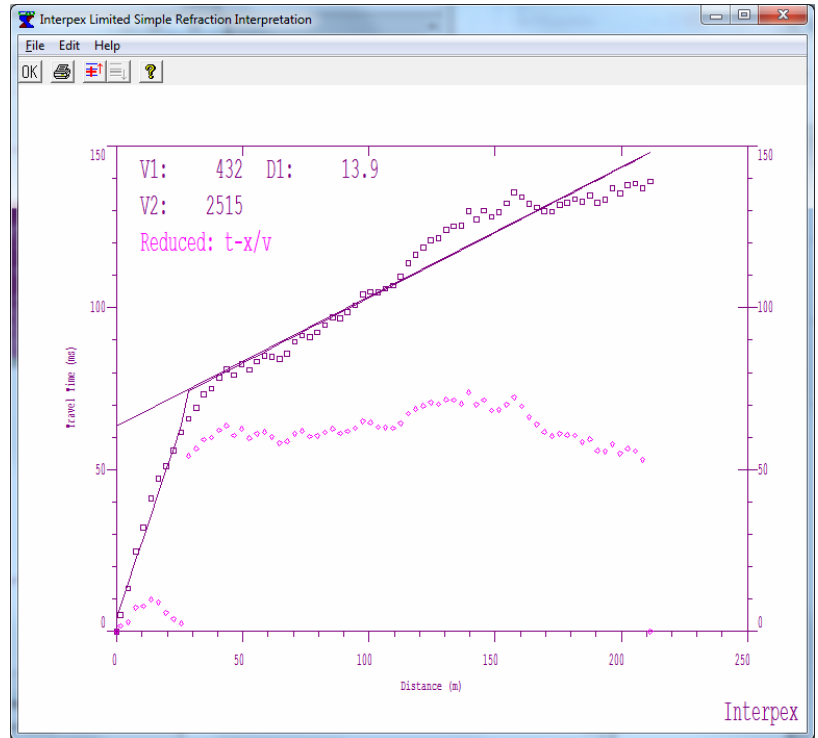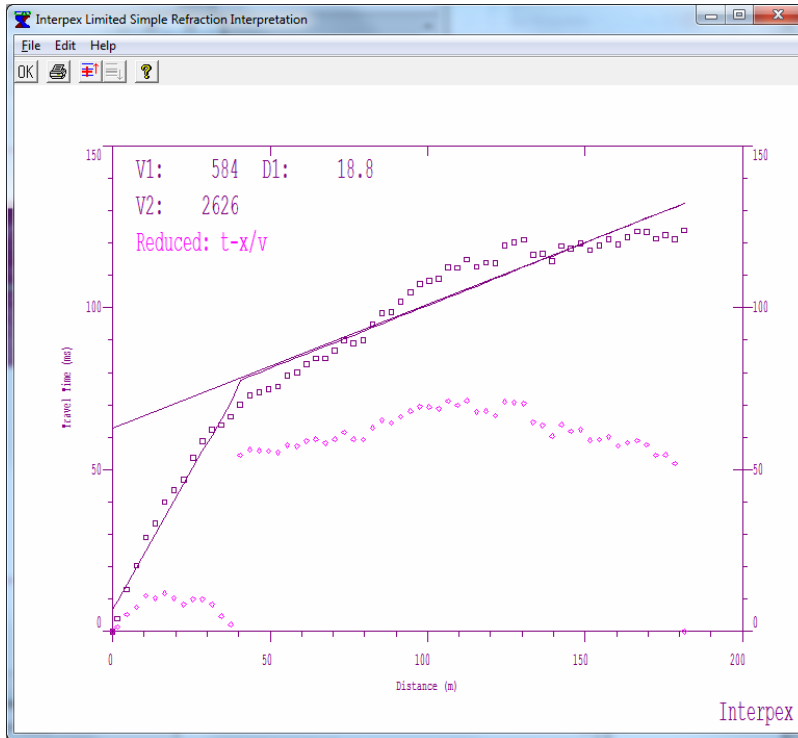
Examine data to estimate model.

Continuing across the spread, we look at curves approximately evenly spaced along the spread.
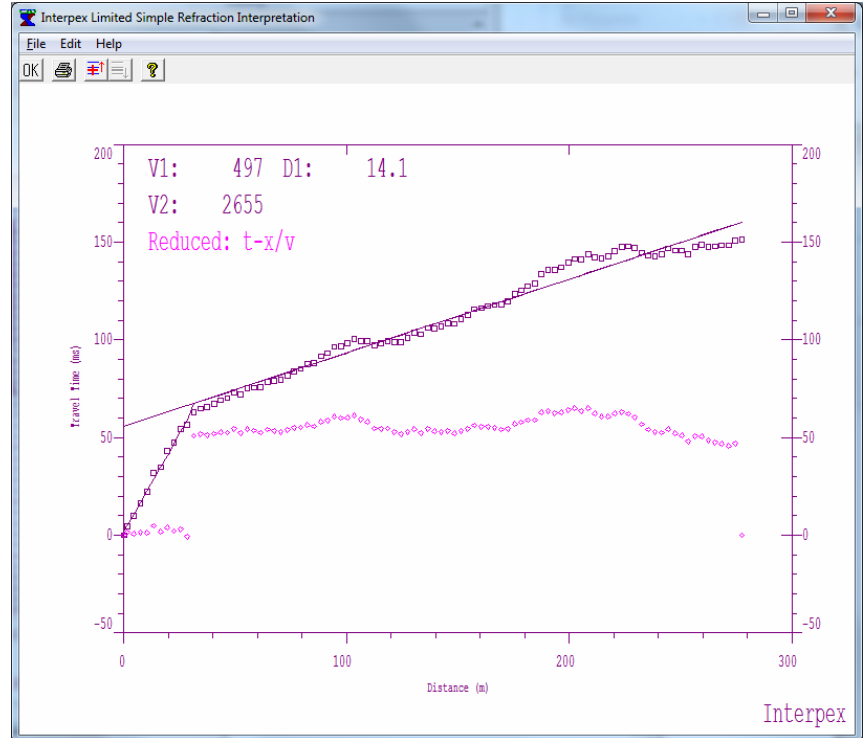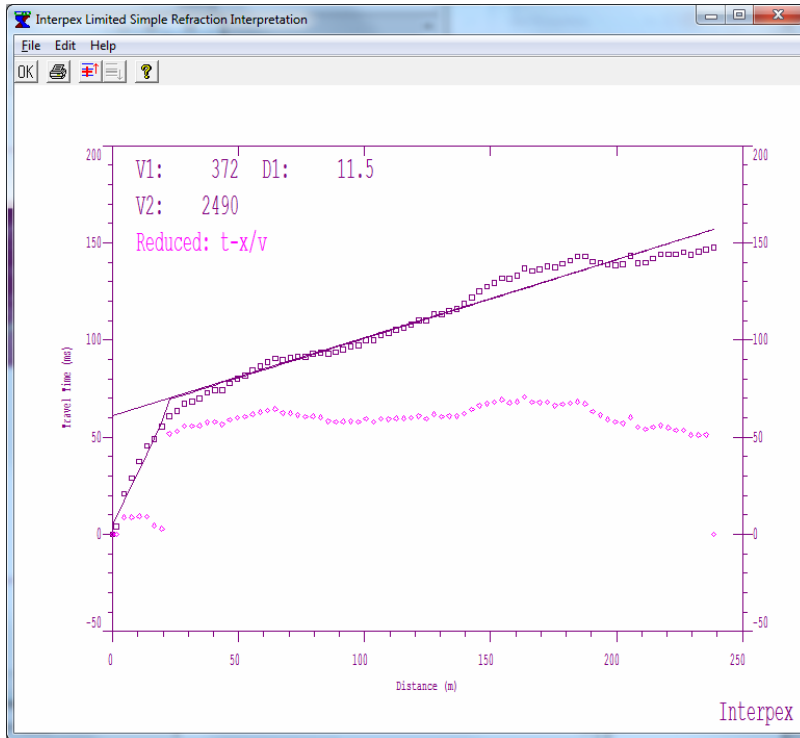**Here we see the results for forward shots at 115.5 m and 145.5 m.**

Examine data to estimate model.

Continuing across the spread, we look at curves approximately evenly spaced along the spread.
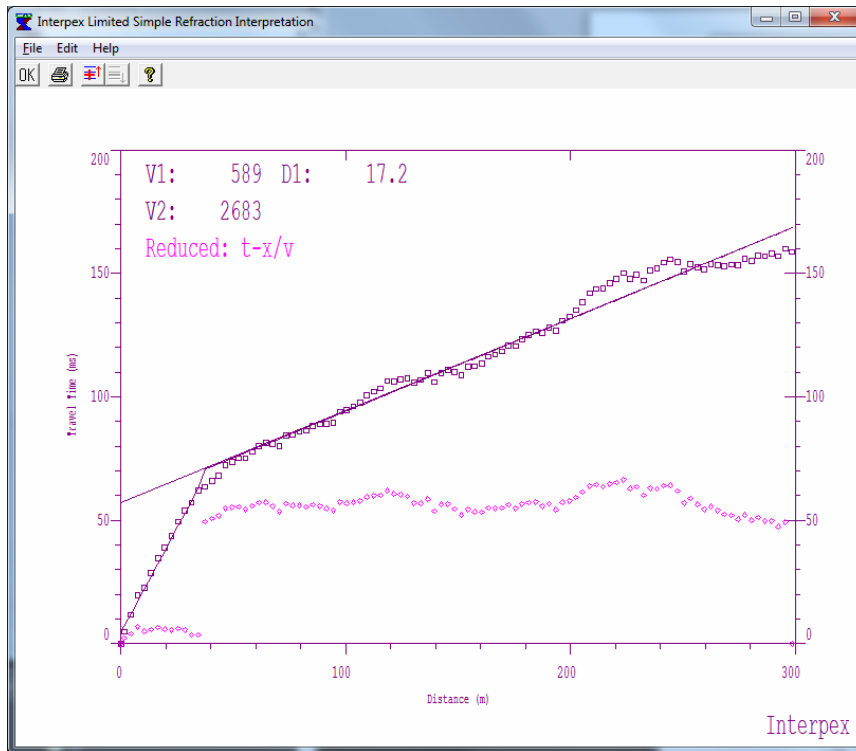**Here we see the results for reverse shots at 175.5 m and 205.5 m.**

Examine data to estimate model.

Continuing across the spread, we look at curves approximately evenly spaced along the spread.
Here we see the results for reverse shots at 235.5 m and 265.5 m.

Examine data to estimate model.

POSITION	V1	V2	D1
0	651	3749	26
55.5	472	2939	17.6
85.5	468	2882	17.4
115.5	429	2665	14.2
145.5	736	4027	27.6
175.5	584	2626	18.8
205.5	432	2515	13.9
235.5	372	2490	11.5
265.5	497	2655	14.1
298.5	589	2683	17.2
AVG	502	2852	17.83

Finally we reach the end of the spread.
Here we see the results for reverse shots at 298.5.
The table on the right shows a summary of the results. Average velocities
were determined by averaging the slowness rather than the velocity.

Estimate the Model
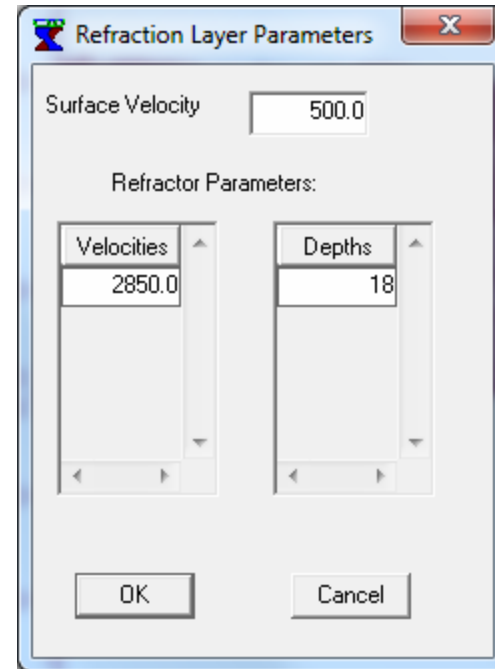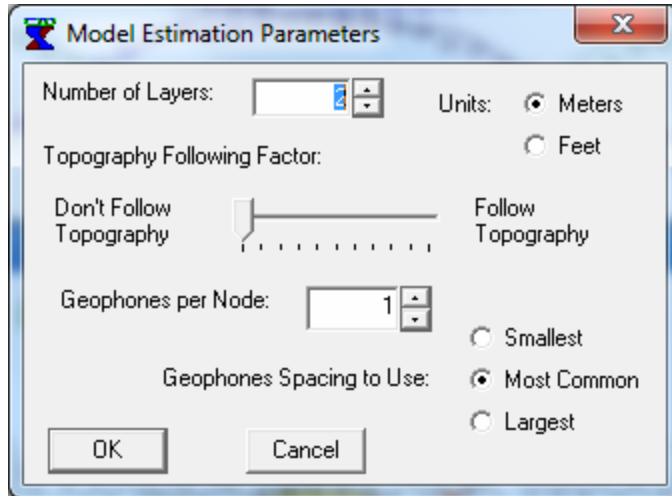
Use Calculate/Estimate Model to select number of layers, topography following factor and the number of geophones per node in the model. Then we press OK and enter the average velocities and layer thickness from the previous slide.

An inversion process will find the best possible fit from these starting values.

Results of Model Estimation
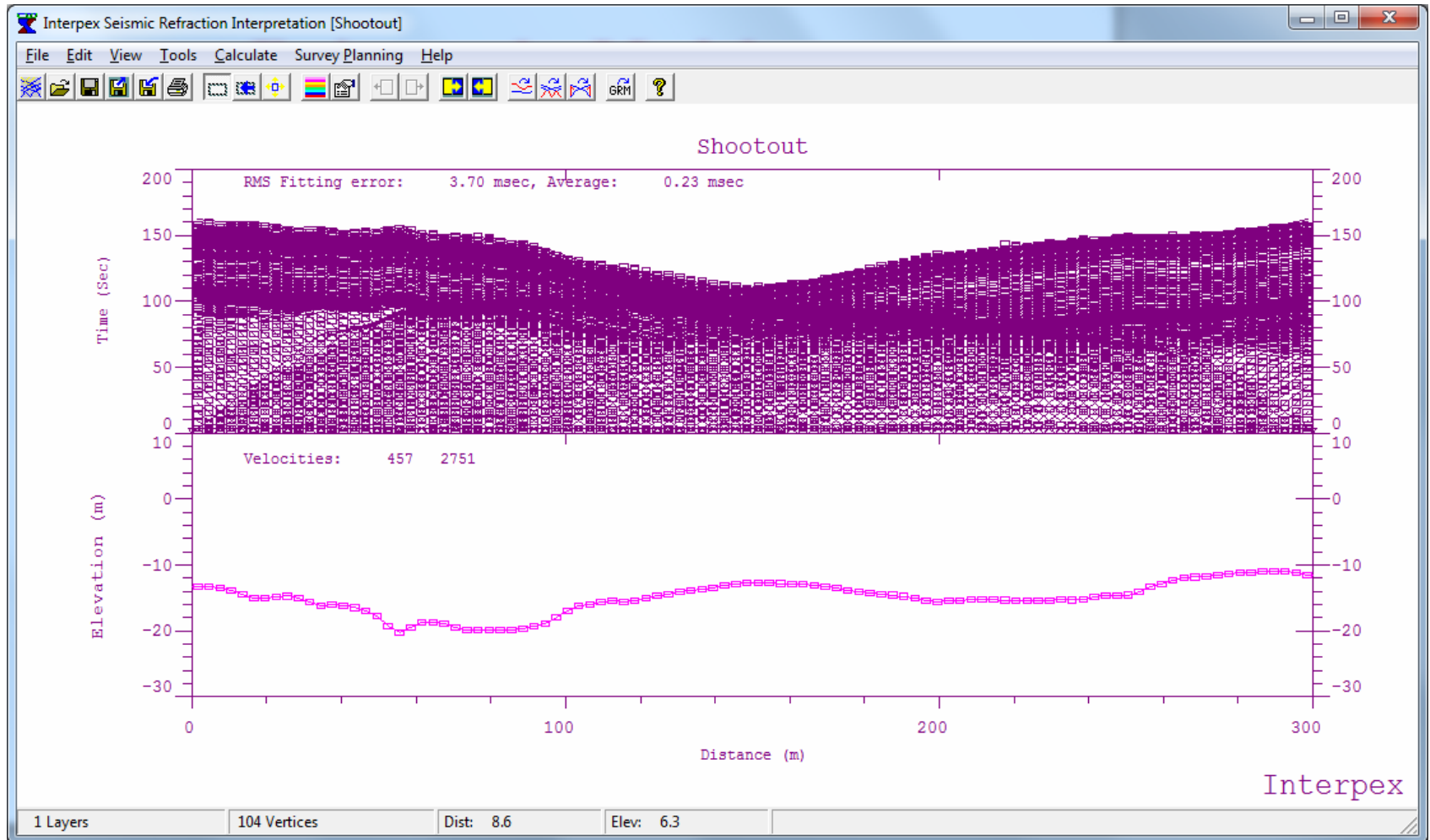
When the iterations are finished, the final result is displayed. Remember, the layer velocities are constant across the section. RMS fit is 3.7 ms, compared with about 1 ms or so for the tomography results presented in the oral session.

Estimated Layer Assignments
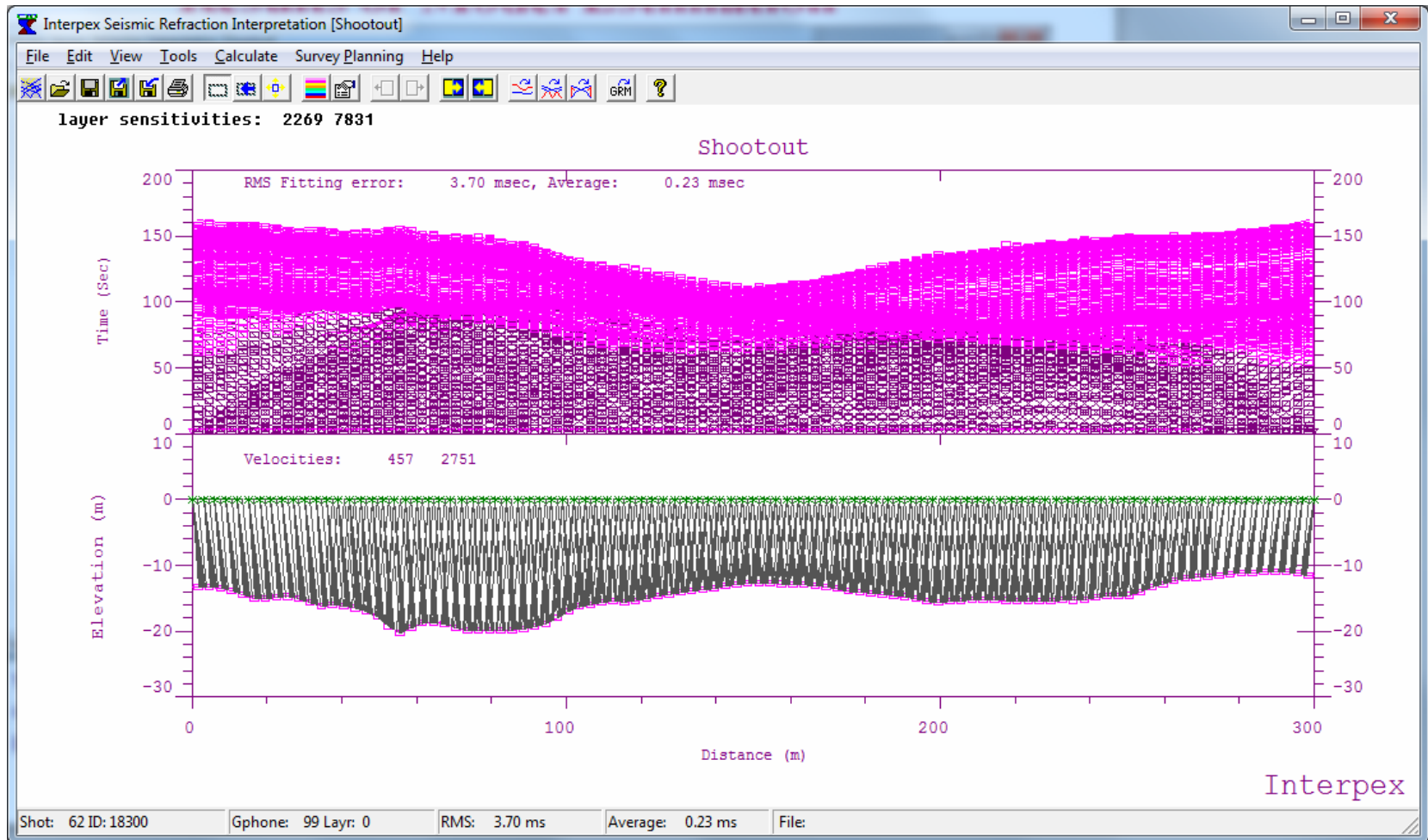
GRM requires that each arrival be assigned to a layer. This is done automatically using the 2-D model results. Note the rays are displayed and that the color of the travel time data points reflects the layer assignment. Reciprocal times between shots are also estimated automatically.

Alternative Methods of Performing GRM Analysis
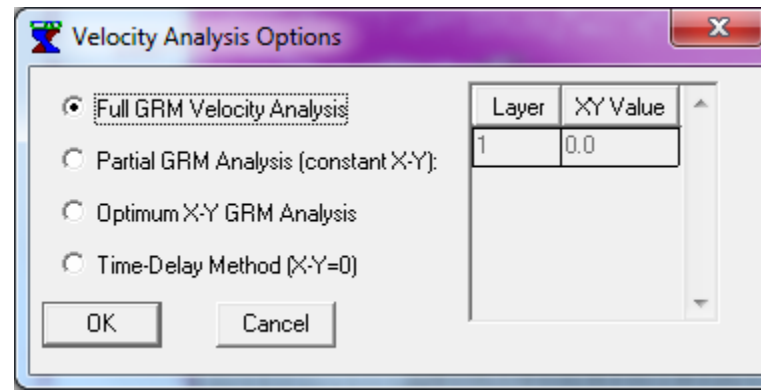
Full GRM analysis uses the existing X-Y values to perform the analysis for each pair of curves. The starting point for these values comes from the 2-D model.

Partial GRM analysis allows you to specify an X-Y value for each refractor.

Optimum GRM analysis performs a two step process. First, the analysis is performed using the Time-Delay method (X-Y=0). The depths of the layers are used during this step to find the X-Y values and the analysis is run again using these values.

Time-Delay method uses X-Y=0 for all layers.

The GRM analysis can be carried out in several ways, depending on your choices. We will use the full GRM analysis in this presentation.

Perform GRM Analysis
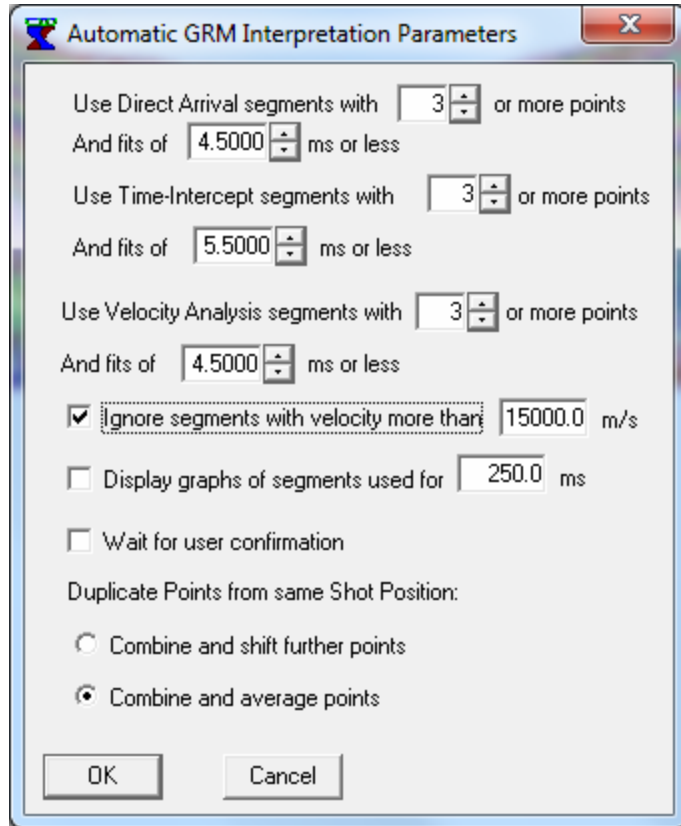
We start the GRM interpretation by including as much data as possible.

The dialog shows that the surface velocity will be determined from segments with at least 3 points and an RMS error of fit to a line of 4.5 ms or less.

Slope-Intercept results require a length of 3 points and RMS fit of 5.5 ms or less.

GRM velocity analysis segments require at least 3 points and RMS fit of 4.5 ms or less.

We will ignore segments with a velocity of more than 15,000 m/s.

Velocity analysis graphs will not be displayed.

Duplicate points (overlap) will result in a shift of the far offset data.

The next step is to interpret the data using the GRM method, now that layer assignments have been made for each travel time point and the reciprocal times between each shot pair have been estimated.

Slope-Intercept and GRM Velocity Analysis Statistics

The surface velocity was determined from 169 segments with 3 to 15 points and RMS fit of 0.5 to 6.5 ms. Of 200 segments, 169 were used, 31 were discarded.

Refractor velocities were determined from 160 segments with 3 to 91 points and RMS fit of 0.2 to 6.5 ms. Of 179 segments, 160 were used ad 19 were discarded.

There were 2,848 velocity analysis segments with 1 to 76 points and RMS fit of 0.0 to 1.2 ms. 2539 of these were used and 309 were discarded (for too few points).

This information is useful in case too many segments were discarded. You can rerun the GRM analysis with revised parameters.

In this case, we purposely included too many segments to see what was present in the data, with intention to revise later.

This dialog shows the statistics from the automatic Slope-Intercept and GRM analyses.
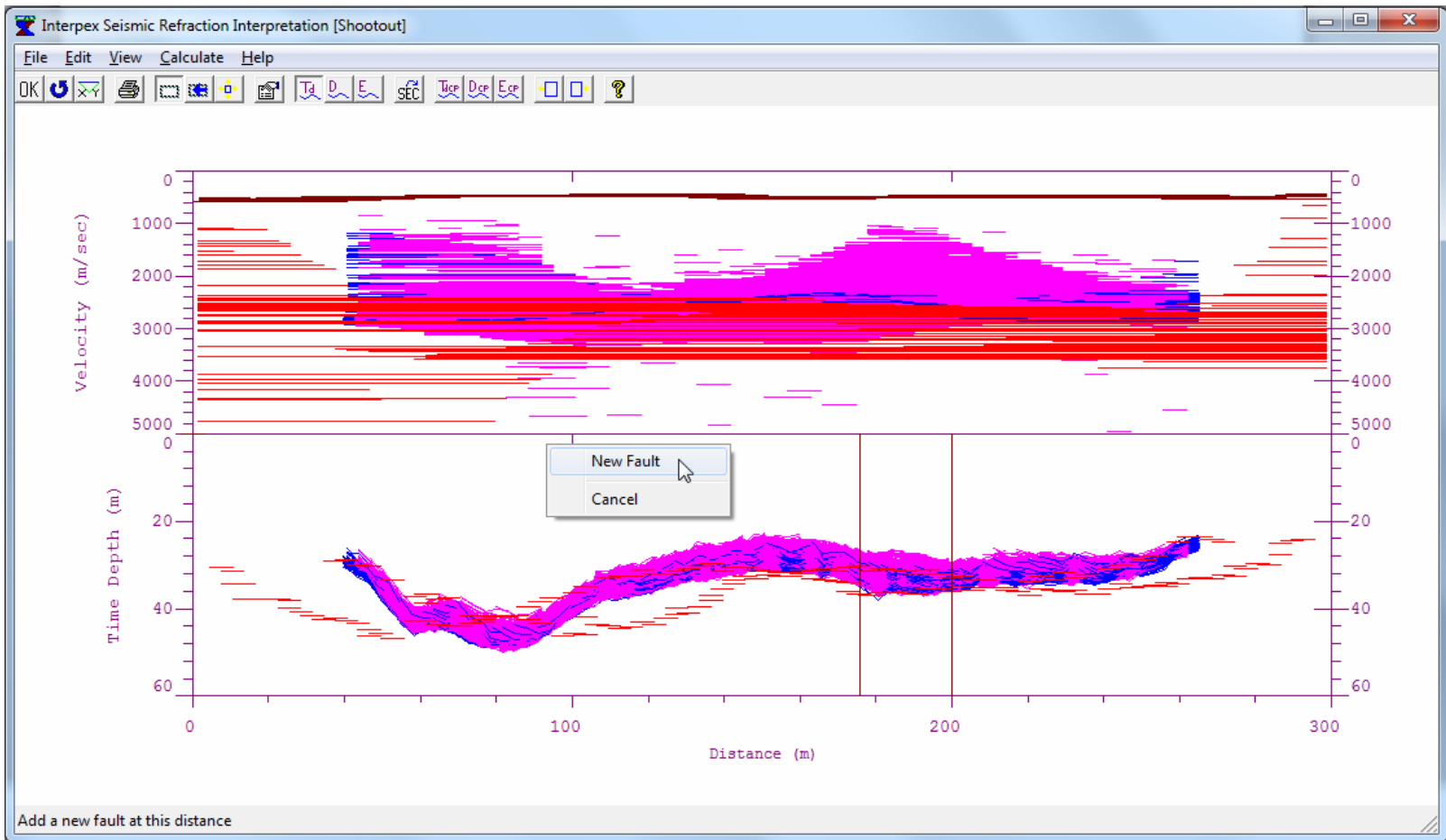
GRM Velocity & Time-Depth Results
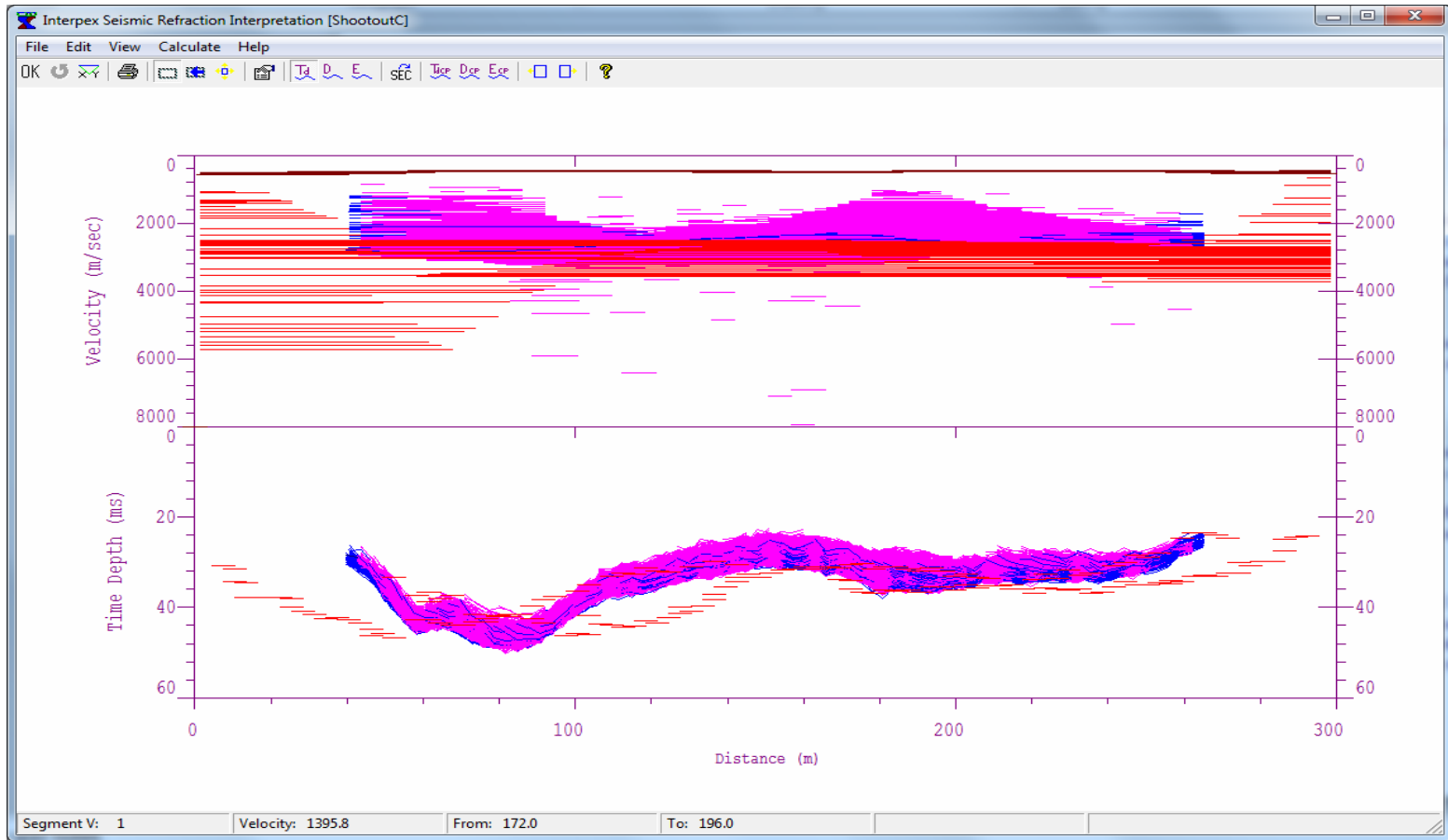
The velocities are shown on top with time-depths shown below. Red lines on both graphs are slope-intercept results for the refractor and the rest are GRM results. Darker lines at the top of the velocity graph are surface velocities determined from slopes of the direct arrivals. We will now adjust the velocity display with the zoom tool to limit it to 5,000 m/s.

GRM Velocity & Time-Depth Results
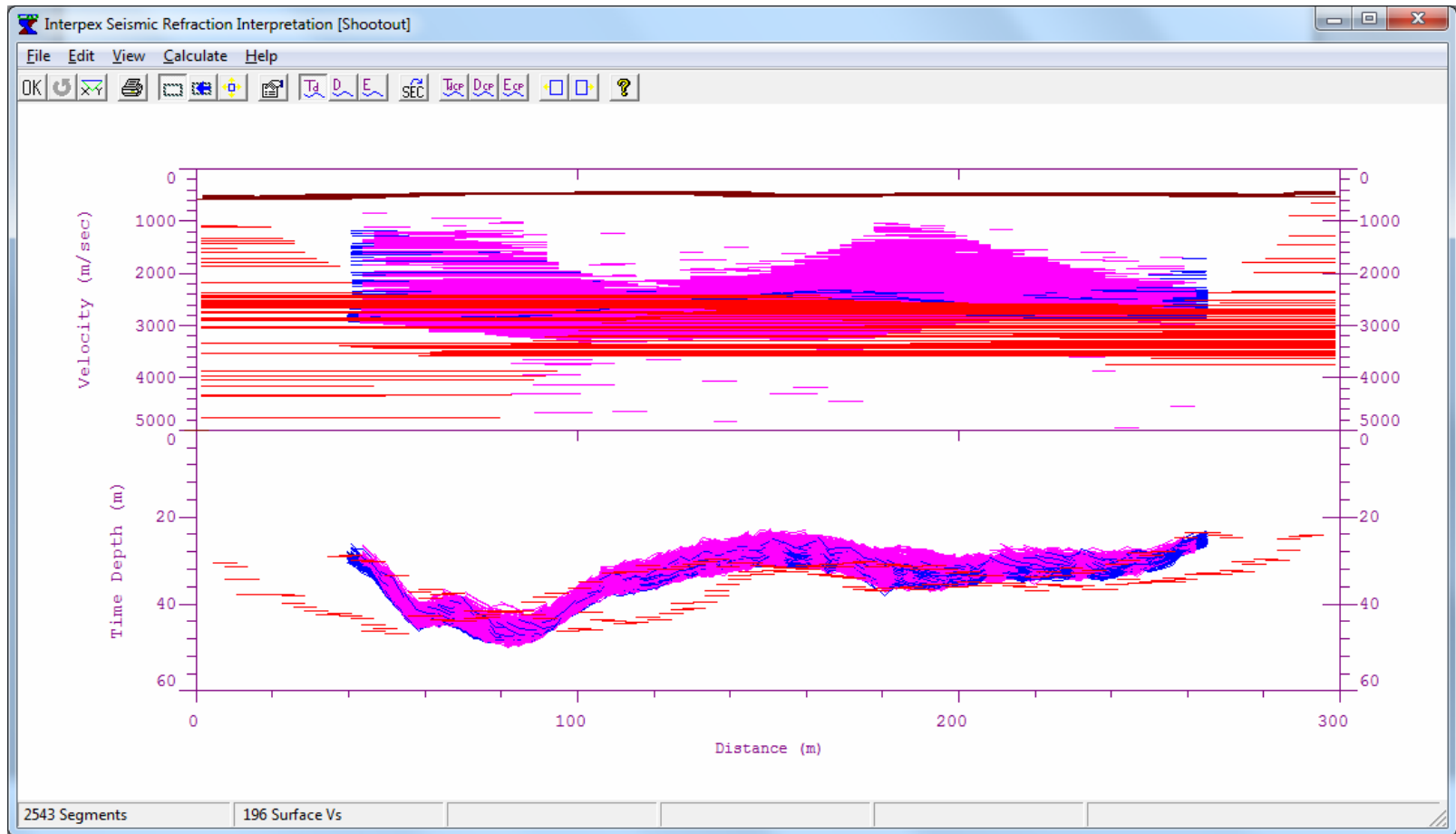
There are two distinct zones of low velocity, one between 40 and 90 m and another between 175 and 200 m approximately. The time-depth curves are pretty consistent, which indicates that our assignment of arrivals to layers is correct. In order for the GRM velocity analysis to be performed correctly, we will insert discontinuities at about 90, 175 and 200 m.

Insert Discontinuities at Velocity Changes

Introduce discontinuities in the velocity analysis by right clicking at the desired location and selecting "New Fault" from the pop-up menu. Menu shown is for inserting a discontinuity at about 90 m.

GRM Velocity & Time-Depth Results
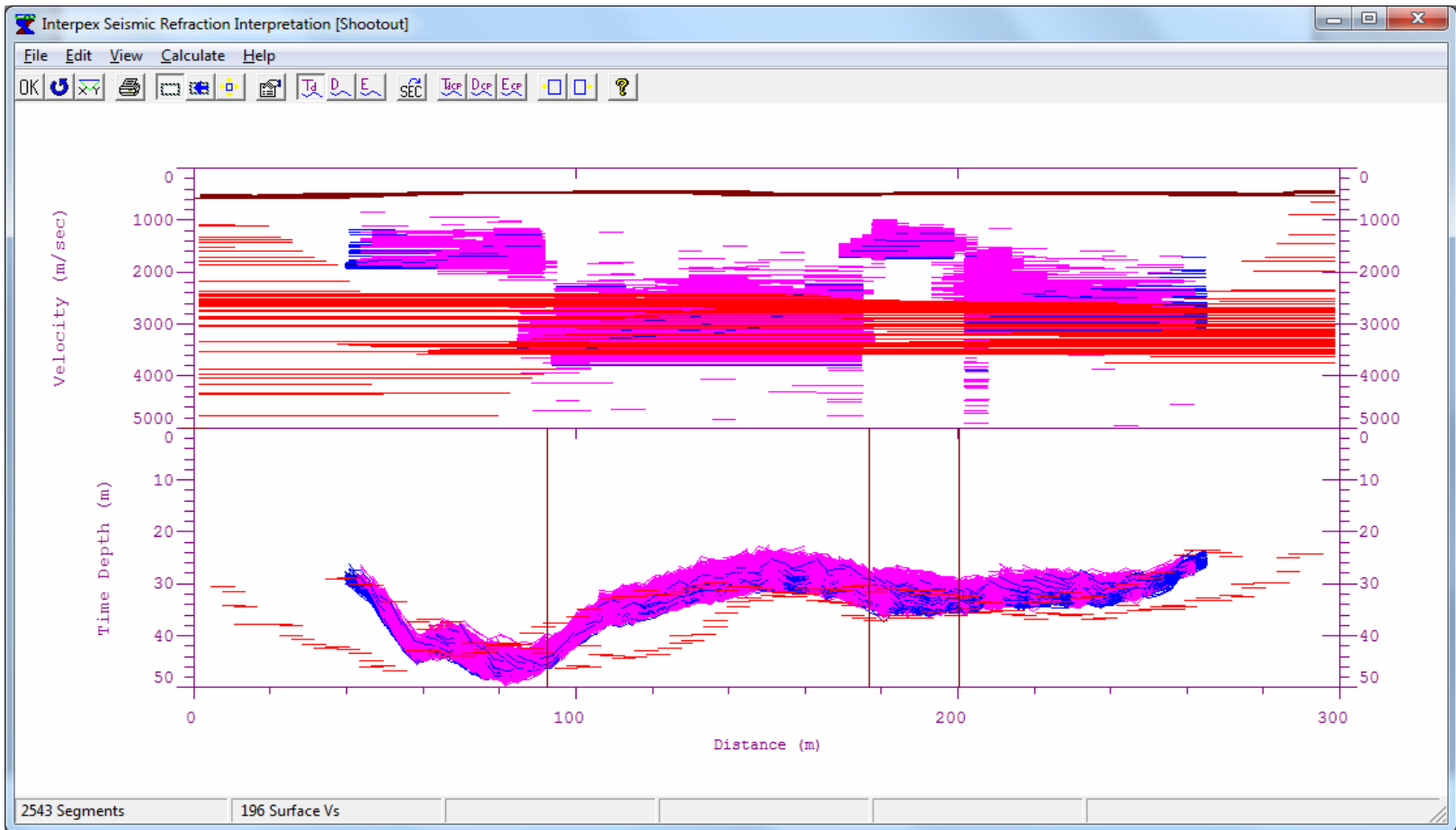
Refresh the GRM analysis after introducing the discontinuities. This shows a much improved display but the discontinuity at 200 m need to be repositioned a bit to the right.

Reposition Faults to Match Display
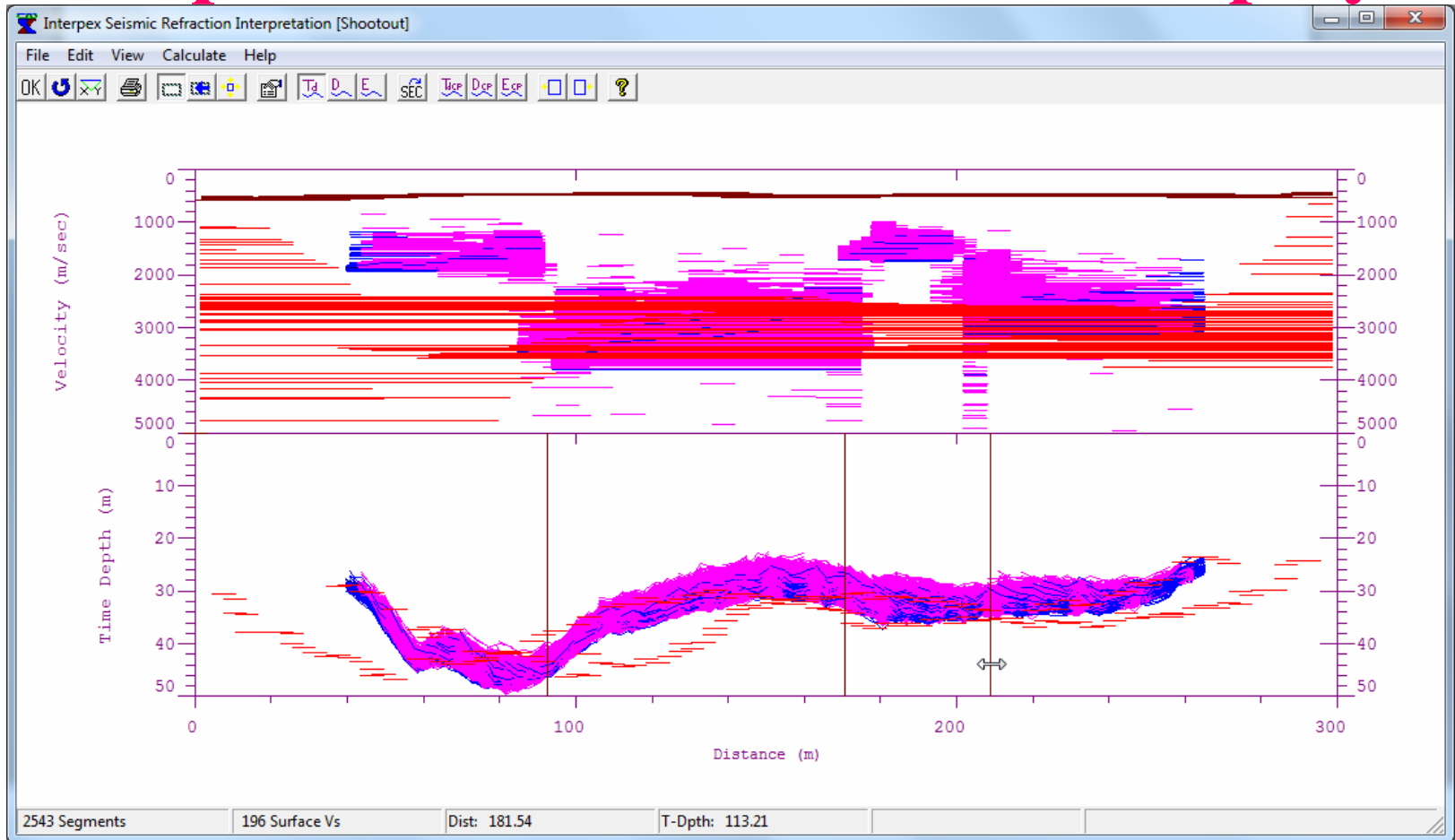
When you point the mouse at a discontinuity, the cursor changes to E-W arrow. Press and hold the mouse button to move the discontinuity laterally. Here we have moved the two right discontinuities to about 170 and 210 m.

Refresh GRM Results for New Positions
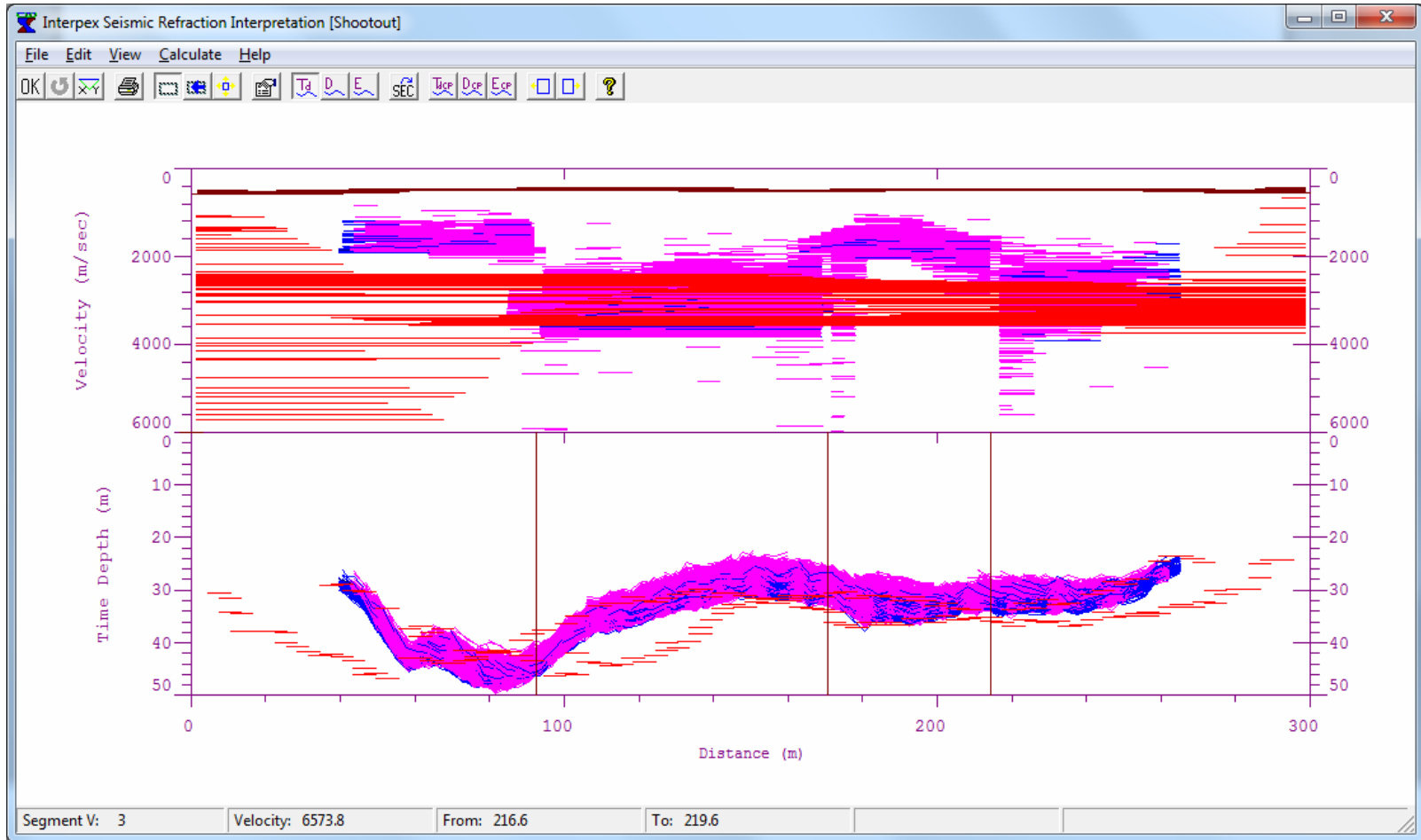
The graph now looks about right. It is time now to redo the GRM interpretation with different parameters so that far fewer segments are included in the analysis.

Refresh GRM Analysis with new Parameters

We now repeat the GRM analysis with our horizontal velocity discontinuities and more stringent restrictions on the segment lengths. We increase the length requirement for direct arrival segments to 9 points and the slope-intercept and velocity analysis segments to 55 points (remember there are 100 geophones). This leaves us with 184 direct arrival segments, 69 slope-intercept segments and 190 velocity analysis segments being retained.

View Results and View Velocity Analysis
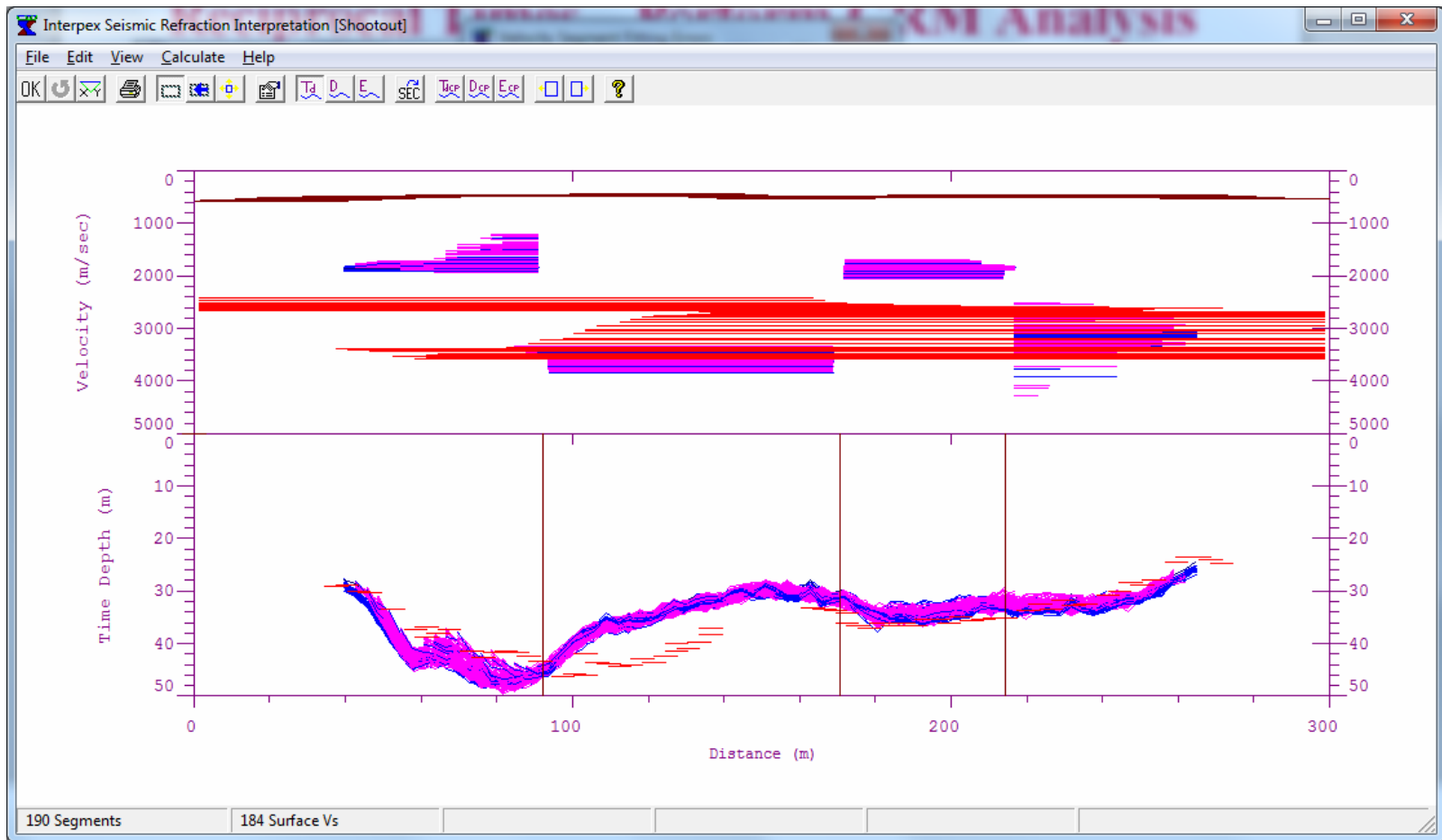
We now have far fewer segments and the discontinuities are in about the right place. It is time now to look at the velocity analysis curves themselves. Point at a time depth segment that seems to span most of the graph range (they "light up" when you point at them) and click to bring up the data, time-depth and velocity analysis curves for that GRM segment.

GRM Velocity Analysis Curves

The velocity analysis curve (upper curve on lower graph) shows the travel time to a point along the refractor. The slope of this curve is the slowness of the refractor. The changes in slope should occur at the discontinuities we have introduced earlier. Note that they are at about the right place but some adjustment is warranted. Press P or N to step through all V/A curves.

GRM Velocity Analysis Curves

Pointing at a velocity discontinuity turns the cursor into an E-W arrow and the discontinuity can be repositioned laterally as before. Position the discontinuities to agree with the breaks in slope of the velocity analysis curves. Us the hot keys P and N or the toolbar/menu options to step through the segments to be sure the discontinuities agree with the slope breaks for most of these curves. If changes are made, refresh the GRM analysis as before after pressing OK to close this window.

Combine Segments to make Composite
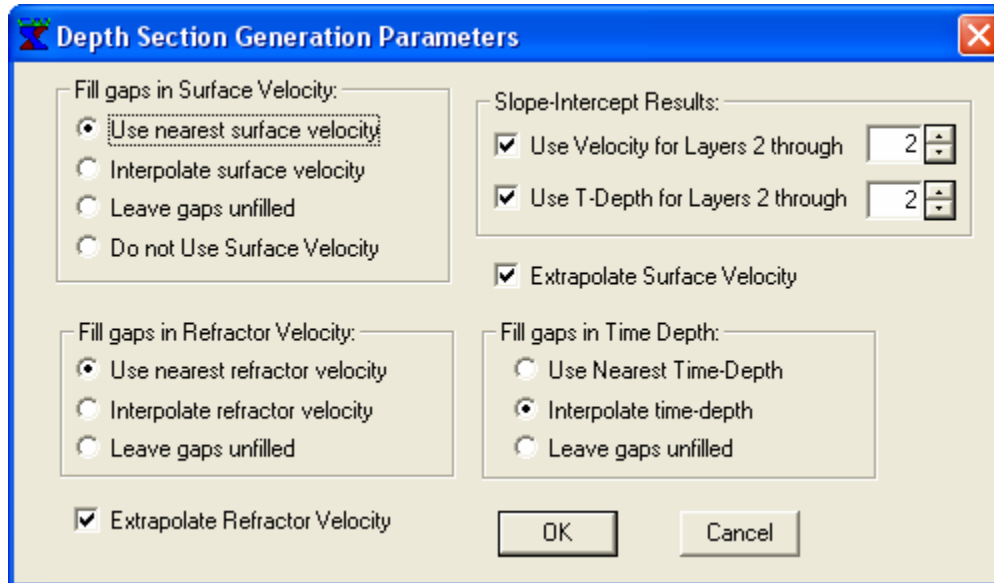
Slope-Intercept Results can be used to fill in missing values for refractors.

Velocities, Time-Depths or both can be used.

Can be used for all layers or just for near-surface layers.

Velocity and Time-Depth profiles may contain gaps.

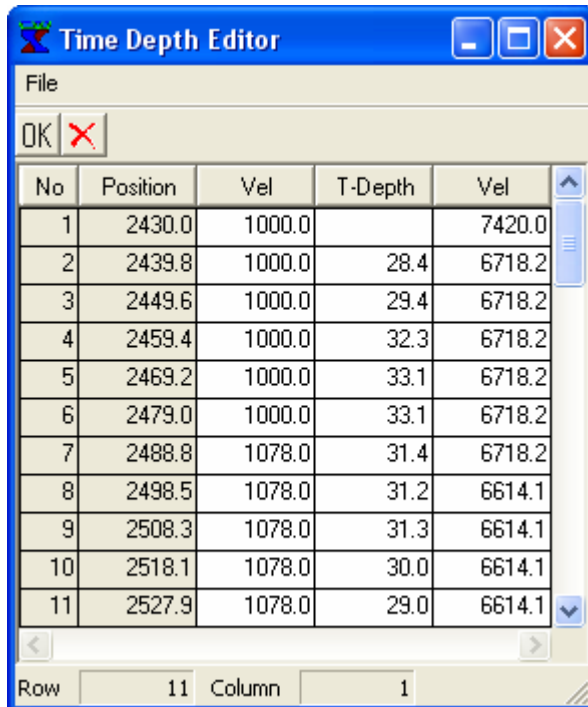**Gaps can be filled by**   **Using the nearest value to the undefined value**

                                         Interpolating to find undefined value

                                         Or, gaps can be left unfilled.

Surface velocity can be ignored, and the Average Velocity concept is then used (velocity found from XY value).
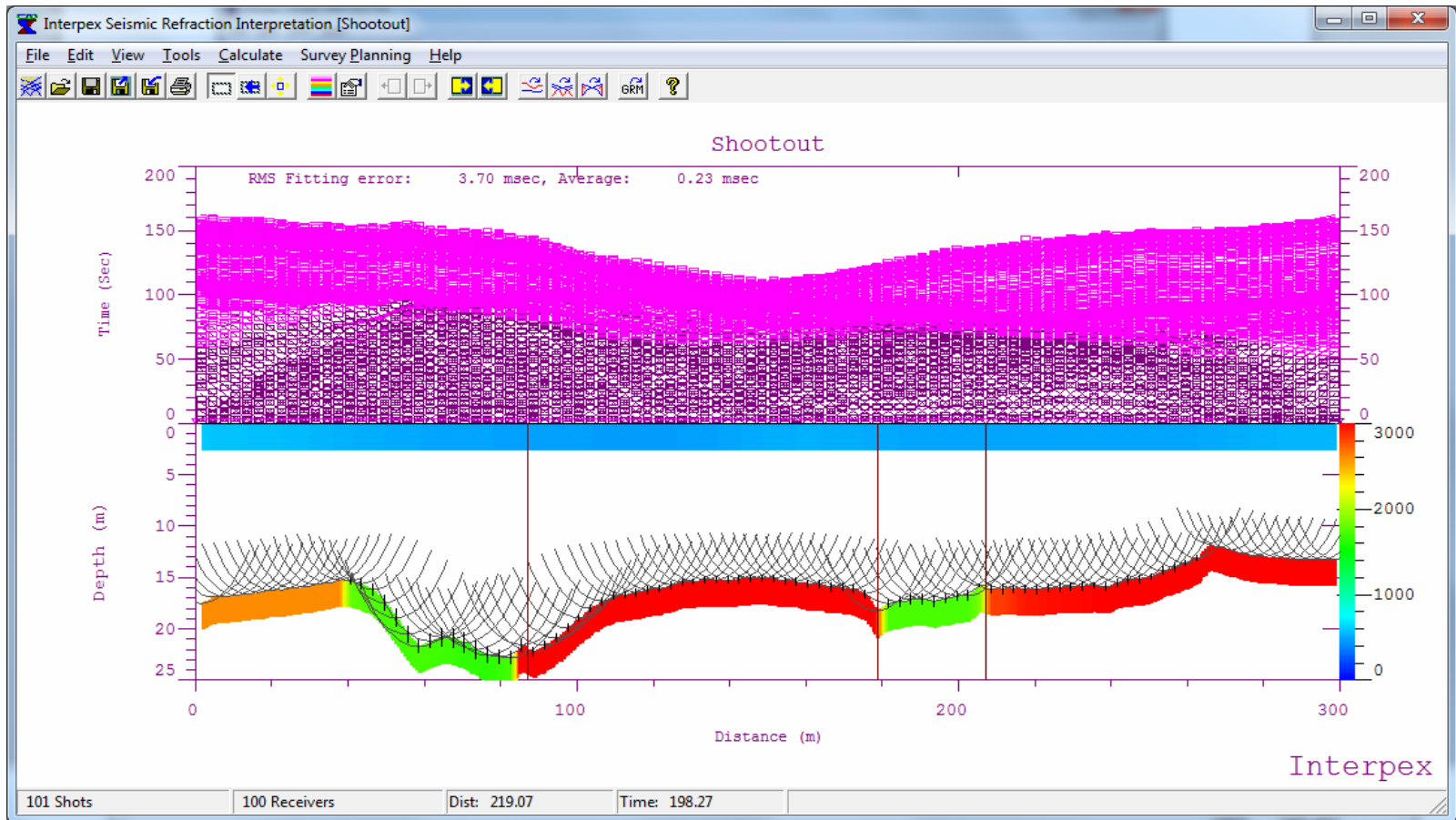
Preview and Edit Section if Desired

Section is shown with gaps where values are undefined.

Velocity and Time-Depth values can be edited.

Press OK to interpolate as selected on previous dialog.

View Composite Section

Composite section is averaged from available results. Vertical lines show error bars where more than one value was averaged to get the composite result. Arcs show wavefronts of rays coming from each position. Colors show velocities.

Add Labels for Velocity
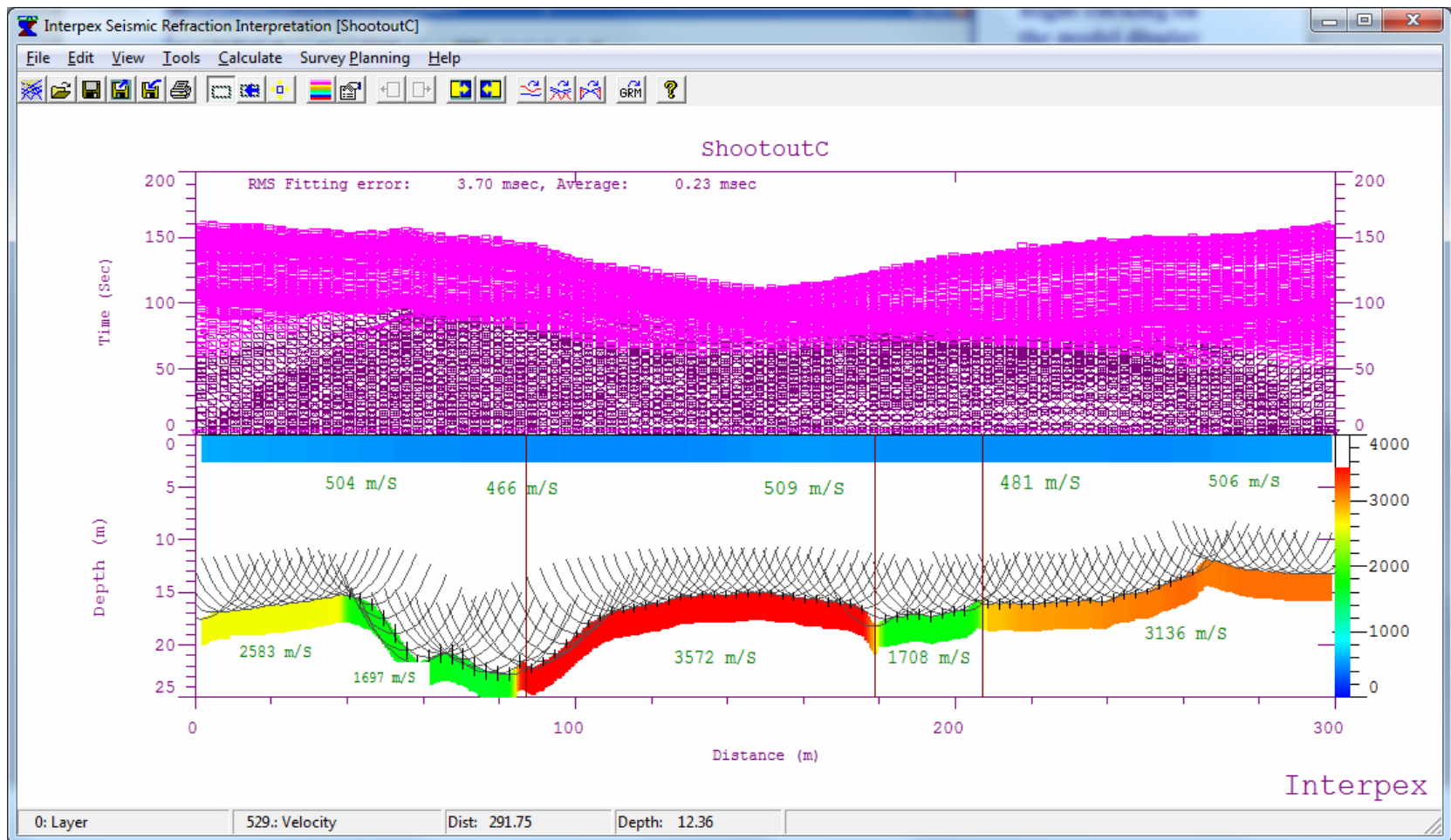
Right-click on a point to add a label or label the velocity. Velocity labels show velocity at label center and this changes if the label is moved.

Discussion
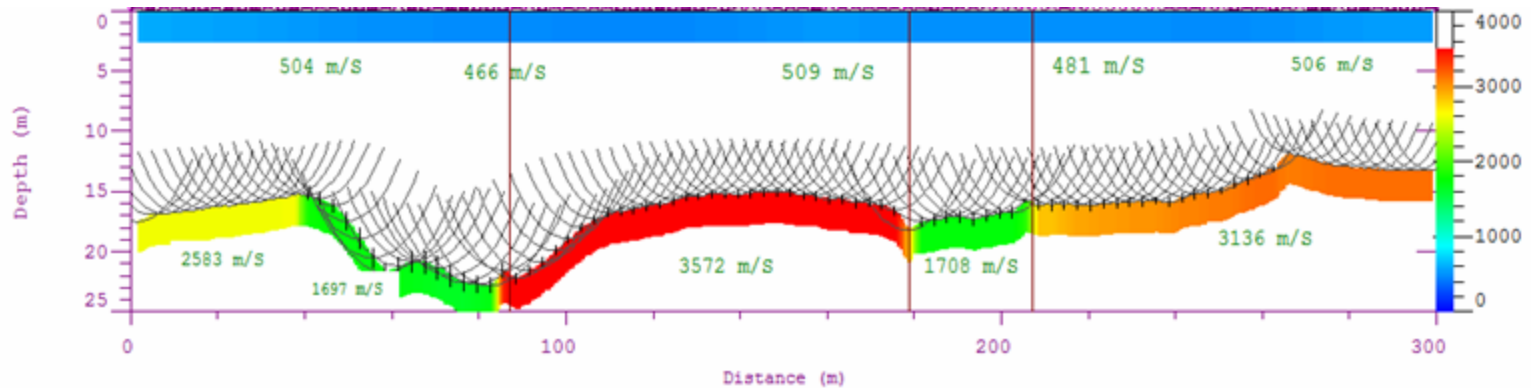
The final section shows a relatively constant surface velocity, with a lower velocity near 80 m and again near 220 m.

The refractor is really not well defined left of 40 m and right of about 265 m because there are no far shots to produce coverage here. Thus the refractor in these regions is likely not correct.

The highest refractor velocities lie between 90 and 180 m and again right of about 210 m. There is a low velocity zone from 40-90 m and another one from about 180-210 m.

The refractor is deepest from about 60-90 m at about 22 m and shallower to the right of 90 m at about 15 m, including the low velocity section.

What lies below the refractor is, of course, not determined by these data since no rays penetrate below that.

Any areas shown in white are pretty much not well constrained.

The data redundancy is far too great to be utilized by a method such as GRM, but it does show the data are consistent.