RAYFRACT Tutorial specific to IGT line 14 :

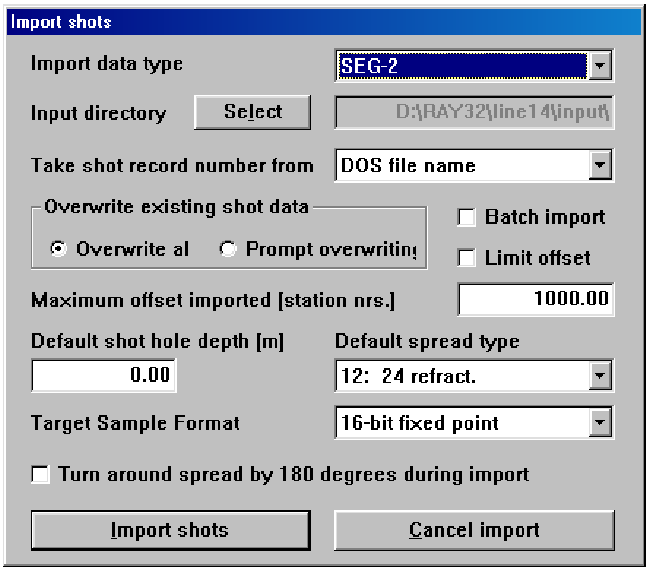
The seven SEG-2 formatted shot sorted binary trace data files and the Interpex Gremix .GRM file used to import first breaks as described below are available on our ftp server, at http://rayfract.com/tutorials/LINE14.ZIP . Please enter this address into the URL address field at the top of your web browser and hit ENTER. Please note that we recommend to record 10 or more shots per profile, for reliable interpretations with our Delta-t-V and WET inversion methods.

Creating a new Rayfract profile, importing the SEG-2 trace files and the Gremix header data :

This tutorial describes how to import and process Geometrics Strataview SEG-2 formatted shot files l14-1.dat, l14-2.dat, l14-3.dat, l144.dat, l14-5.dat, l14-6.dat and l14-7.dat, together with Gremix header data as available in file line14.grm. The shorthand notation File|New Profile means : select item „New Profile“ in menu „File“. User dialog interface items such as names of text fields, buttons, titles etc. are printed in *italic*.

Start up Rayfract and select File|New Profile. Be sure that the current directory as displayed above the directory selection box is your \RAY32 root directory. Now enter „line14“ or similar in the top left text field *File name*. Then hit RETURN. Now select Header|Profile. Enter text strings into the three top left edit fields *Line ID*“, *Job ID* and *Instrument*. Then enter the profile spacing of 2.5 (minimum distance between adjacent receiver stations, in meters) into the text field *Receiver spacing*. Now hit RETURN. Confirm the prompt as now displayed with RETURN.

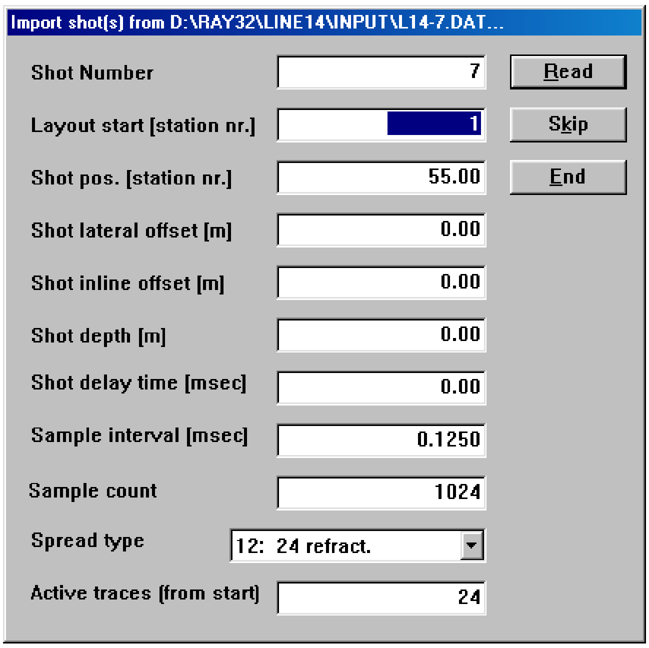
Now create a subdirectory named „INPUT“ or similar, in directory \RAY32\LINE14. Do this from within your Windows Explorer or in a DOS box. Copy the seven .dat input files l14-1.dat etc. into this new subdirectory. Copy the Gremix file line14.grm into that directory as well.



Select File|Import data... . Rayfract will display the *Import shots* dialog as imaged at left. Be sure to adjust the edit fields as displayed :

Specify the correct Rayfract input directory by clicking on button *Select*. Then navigate to your \RAY32\LINE14\INPUT directory, specify file type .DAT, select one .DAT file and hit RETURN. Be sure that the list box *Take shot record number from* is set to entry „DOS file name“. Now click on the list box below label „Default spread type“, and select the entry „12: 24 refract.“. This spread type defines a non-equidistant receiver spread type, as customary in refraction seismic recording.

If you need to define your own spread type, please refer to the online help.



Now start the import of the SEG-2 trace files by clicking on button *Import shots* or hitting RETURN. In the following, the *Import shot* dialog will be displayed, once for each shot record to be imported.

The default station number value for the first receiver station as displayed in text field *Layout start* is 1. Shot positions as specified in the SEG-2 trace header are transformed into station numbers relative to the layout start of the spread automatically. The *Receiver spacing* as specified above will be used for this transformation.

So shot position 137.5 for shot file l14-7.dat for the receiver spread starting at position 2.5 (in meters) is transformed into the station number 55, based on the receiver spacing of 2.5 meters as specified above. For details, please see online help (rightmost Rayfract™ menu „Help“, item „Contents“) chapter „Station numbers and spread types“.

Just hit RETURN or click on the *Read* button once for every shot header displayed.

Importing first breaks and elevations from the Gremix .GRM file

If ABEM .FIR or Geometrics .BPK files are located in the input directory as specified above, the first breaks as contained in these pick files will be imported automatically for each shot being imported as above. Rayfract assumes that these files are named l14-1.fir / l14-2.bpk for shot file l14-1.dat etc.

Elevations along the line may be specified in a .COR ASCII file formatted as the sample file \RAY32\DOC\COORDS.COR. Such a file may then be imported with File|Import Coordinates.

Since first breaks and elevations have been specified with the Interpex Gremix/Firstpix software for this sample profile already, you may import the resulting .GRM header data file into Rayfract with File|Update from Gremix .GRM files... . Select this item and specify the line14.grm file located in directory \RAY32\LINE14\INPUT.

Delta-t-V inversion of the first breaks

First make sure that Depth|Output Horizontal Offset of CMP pos. in meters is checked. If not so, select that menu item to check it. Then select Depth|Delta-t-V method (CMP Velocity vs. Depth). When the *Parameters for Delta-t-V method* dialog is displayed, just hit RETURN once to accept the default parameter values.

Once the inversion has been carried out, Rayfract will store the results into a comma-separated value file named DELTATV.CSV into directory \RAY32\LINE14. You may grid and contour the station nr.-depth-velocity triples contained in this file with Surfer or a similar scientific data plotting package. Please follow these instructions (assuming you are using Surfer version 8) :

Visualization of the resulting initial tomogram with Surfer

Start up Surfer and select Grid|Data. Then select file \RAY32\LINE14\DELTATV.CSV. Change values for the two edit fields in *column # of Lines* for rows *X Direction* and *Y Direction* to 600 and 187, respectively. This will ensure that grid cells are small and about quadratic, a prerequisite for raytracing and tomography processing. Adjust *Y Dir. # of Lines* until the *Y Dir*. size of the cell (row spacing, as indicated in the previous column) optimally matches the *X Dir*. size of the cell i.e. column spacing. Now click on the OK button, of the *Scattered Data Interpolation* dialog.

Once Surfer announces with three beeps that the gridding / kriging of the data (Delta-t-V output) has been done, select Grid|Blank... and then file \RAY32\LINE14\DELTATV.GRD. Then select file \RAY32\LINE14\SEIS32.BLN as Surfer Boundary File. This file specifies the line geometry in Surfer compatible format. Now specify \RAY32\LINE14\DELTATV.GRD as output file. Confirm the prompt to overwrite the existing DELTATV.GRD.

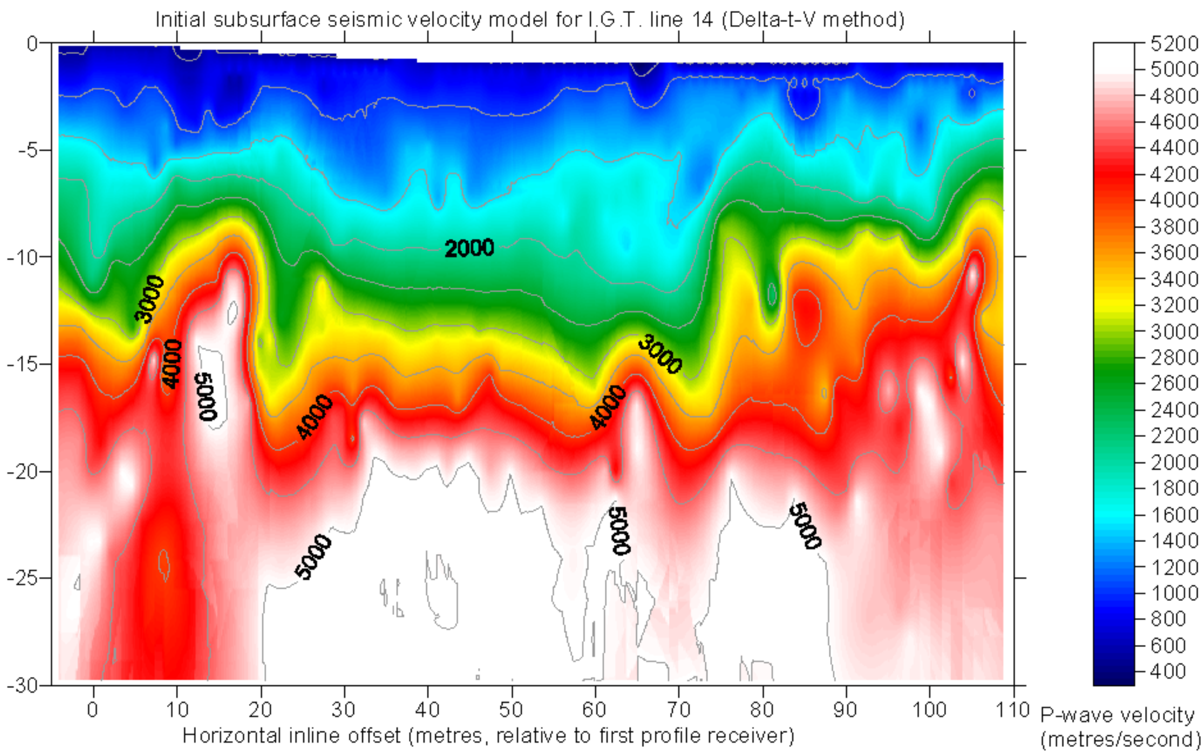
We recommend to use the Surfer 8 Map|Image Map command, instead of Map|Contour Map as described in earlier versions of our tutorials. Select Map|Image Map, and specify above DELTATV.GRD grid file. Double click on the image map generated. Then click on the *General* tab and the *Colors* bar. Now click on the *Load* button and select file \RAY32\REF\RAINBOW2.CLR. Uncheck option *Use data limits* and set *Minimum* to 300 and *Maximum* to 5200 (metres per sec.). Now click on the black color square, directly below label *Color:*. This will enhance the color contrast directly below the topography. Now hit RETURN, and set *Missing Data* to white color. Check options *Interpolate Pixels* and *Show Color Scale*.

Now click on the *Limits* tab and uncheck option *Use Data Limits*. Then set *xMin* and *xMax* to –5.0 and 110, respectively. Set *yMin* and *yMax* to –30.0 and 0.0, respectively. Now click on the *Scale* tab and uncheck *Proportional XY Scaling*. Adjust *X Scale Length* to 6.0 in, and *Y Scale Length* to 4.0 in. Now hit RETURN, and select View|Fit to Window. Next, save the resulting image map with File|SaveAs... and specify filename \RAY32\LINE14\DELTATV.SRF. You will obtain a plot similar to the one shown below.

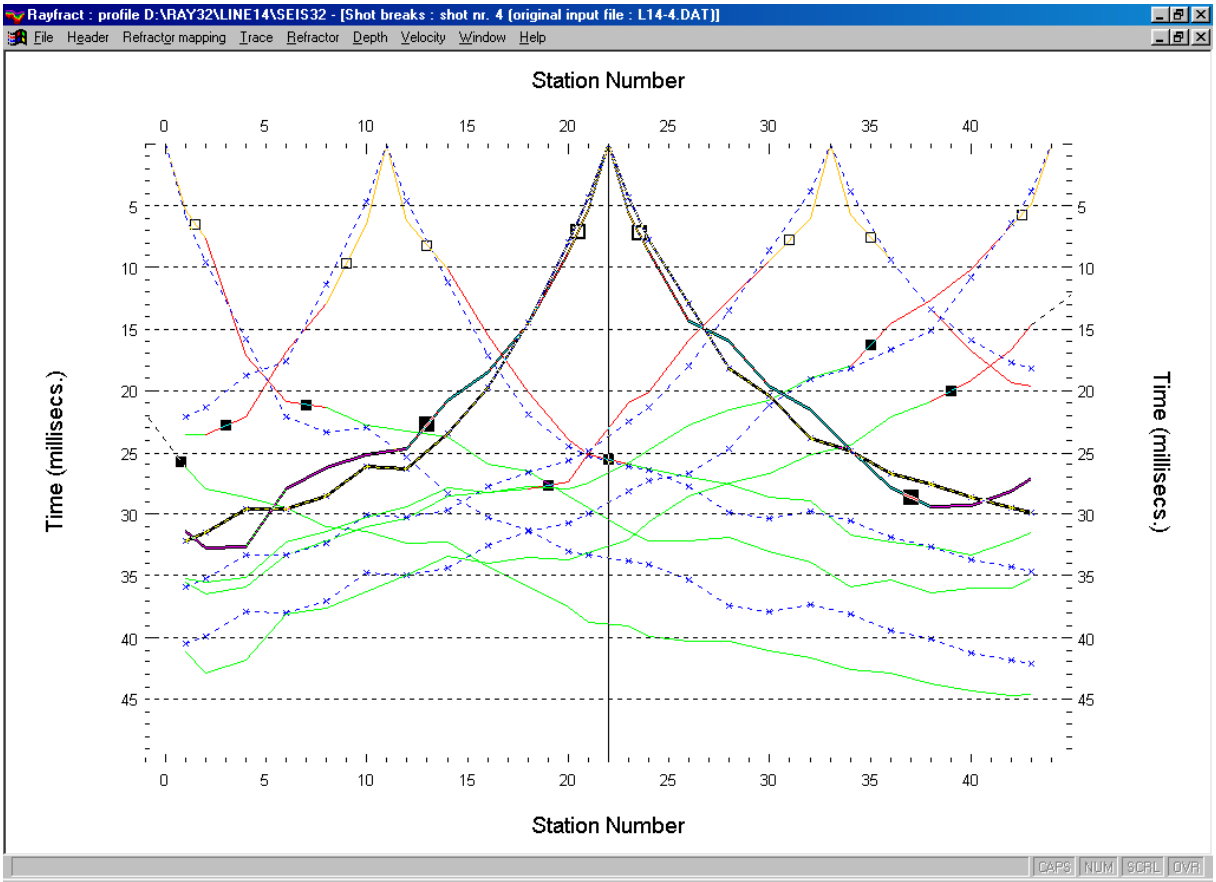
If you still need contours, open a new „Plot Document“ via File|New. Then generate a separate contour map for the same DELTATV.GRD file, via Map|Contour Map. Double click on the resulting map, and select tab *Levels*. Now click on column header *Level* and set *Interval* to 500 (metres/sec.). Confirm with OK. Now click on column header *Line* and on the horizontal *Color* bar. Select the *40% black* square in the second row. Confirm with OK, and adjust tabs *Limits* and *Scale* as above. Then select View|Fit to Window, and save the resulting contour plot with File|SaveAs... and filename \RAY32\LINE14\CONTOUR.SRF.

Then combine the two maps by pasting them both into a new Surfer „Plot Document“. For each of the two existing plot document windows : click on the content (image map or contour map, respectively) and select Edit|Select All, followed by Edit|Copy. Then paste into the new plot document via Edit|Paste, and insert with a left button mouse click in the center of the document window. Then select both maps with Edit|Select All. Now overlay the two maps via Map|Overlay Maps. Then interactively adjust the scale and the limits of the resulting map, as described above.

You will then obtain an initial tomogram as shown on the next page.



Once you have gridded the Delta-t-V output with Surfer as described above, you may want to forward model traveltimes by raytracing through the model and compare modelled times with first break traveltimes as measured and picked. Select Depth|Forward model traveltimes and specify the DELTATV.GRD file as generated above. Once the raytracing finishes after a few seconds, Refractors|Shot breaks to obtain a display similar to the one shown below. Blue traveltime curves and crosses show the synthesized traveltimes, while outlined yellow/red/green curves represent the first breaks as measured, picked and assigned to refractors ealier (not described in this tutorial; see online help chapter „Mapping traces to refractors“. But this mapping is NOT required for processig as described below) :



Note that Delta-t-V output does not show a sudden increase of velociy with depth in the „transition zone" between „overburden" and „basement" i.e. at a depth of about 15 meters. Synthetic traveltime curves still show a systematic and relatively abrupt increase in apparent velocity, for first break traveltimes of about 25 milliseconds and later. This increase corresponds to the abrupt / discontinuous increase in velocity / apparent velocity jump as observable on measured times and traveltime curves. Of course the Delta-t-V method does smear over vertical velocity discontinuities to some degree, when linearizing CMP vs. Offset sorted and stacked traveltime curves on a piecewise basis. This linearization is required in order to be able to estimate „instantaneous" velocities. But according to the relatively good match between measured times and synthetic times (as obtained by raytracing through Delta-t-V output as gridded and optionally smoothed with Surfer), this „vertical smearing" does not invalidate the Delta-t-V output to a large degree.

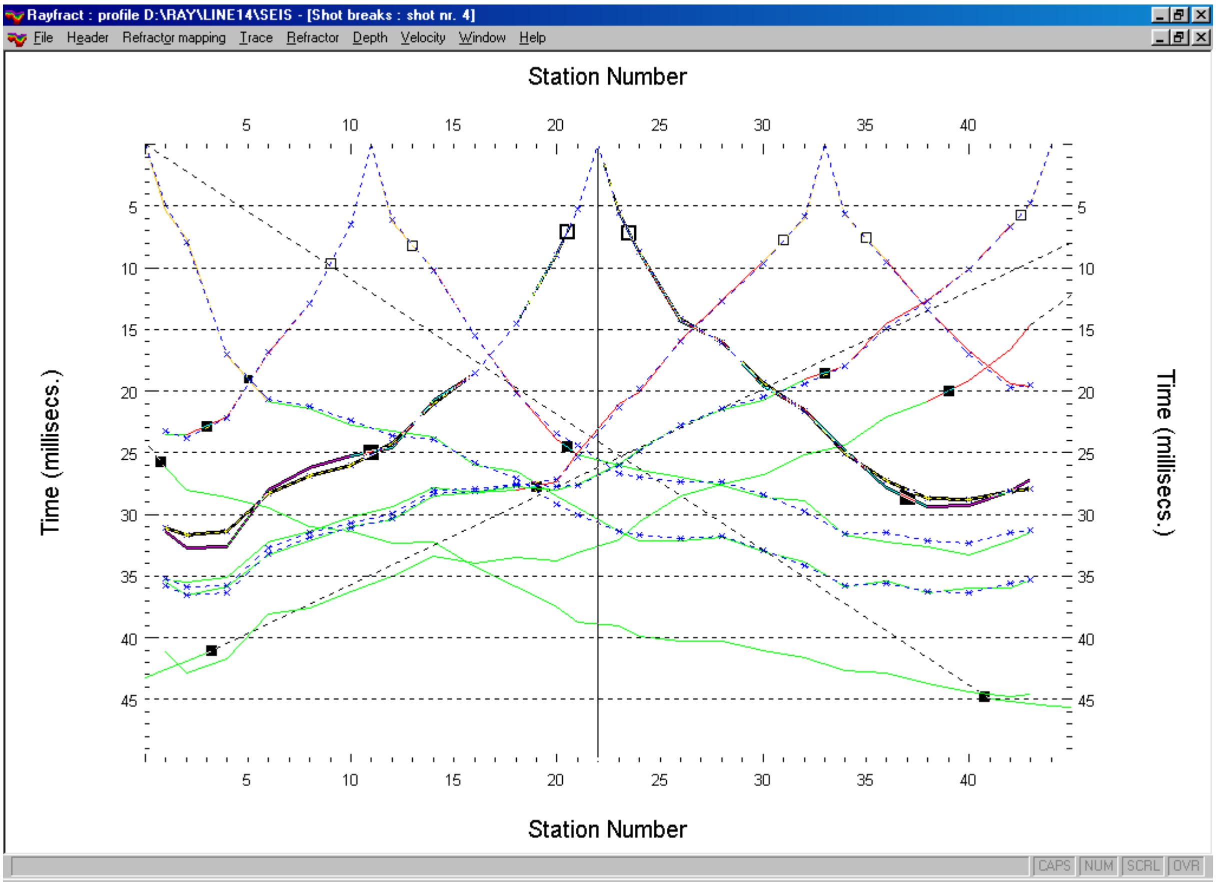
Possible explanations for a gradual increase of accoustic i.e. seismic wave propagation velocity with depth are :

- systematically increasing overburden pressure on the rock, with increasing depth and as exercised by the geological sequences lying above it.
- the topmost regions of most geological units / strata may have been directly exposed to the atmosphere at some time in the geological past and may have undergone significant weathering (exfoliation, frost wedging etc.) and fracturing as a consequence.

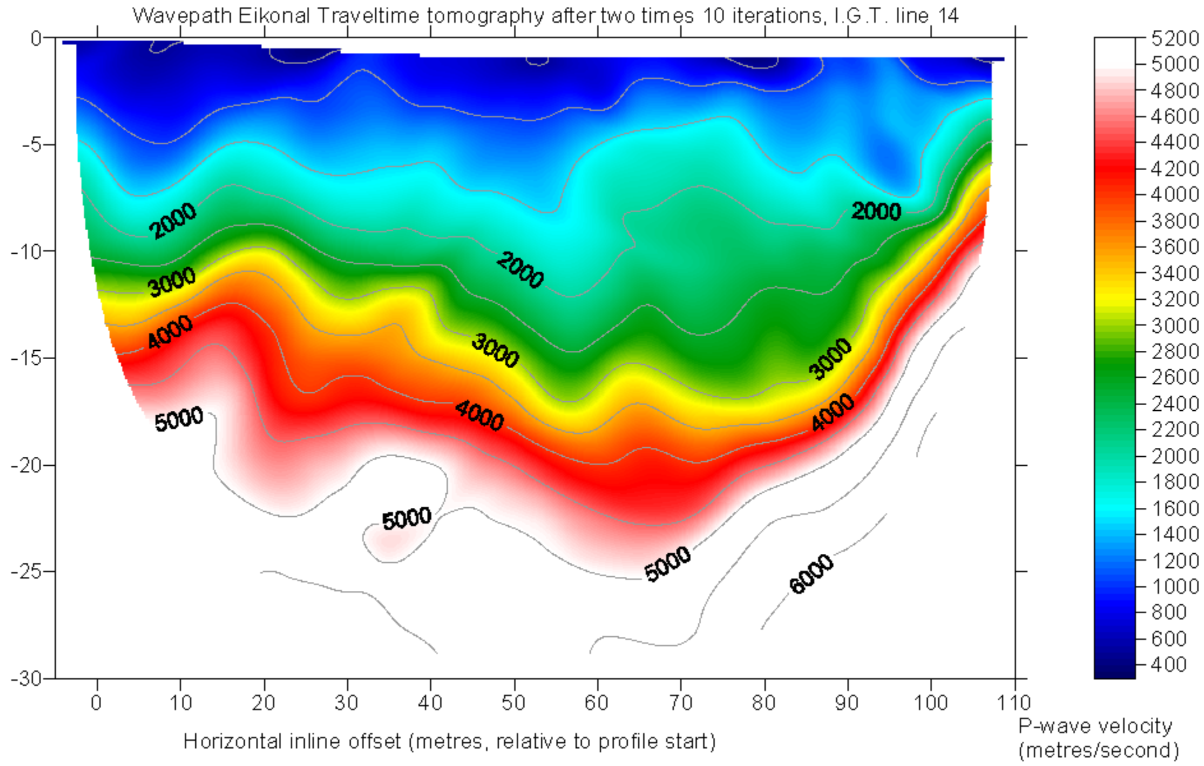
Refining Delta-t-V velocity model with WET tomographic traveltime inversion

Now select Depth|Tomography processing of traveltimes ... . Then click on button *Select* and specify the DELTATV.GRD file as generated above. Leave all other processing parameters at their default values. Now click on button *Start tomography processing*.

Once the tomography processing has terminated after 10 iterations and about five minutes of processing time (on Pentium III processor at 500 MHz), you will want to refine the output obtained from this first run. To do so, reselect Depth|Tomography processing of traveltimes ... . Now specify the VELOIT10.GRD as obtained from the previous tomography run. Also, change parameter *Central Ricker wavelet frequency* to 100 Hz. This has about the same effect as reducing the wavepath width by 50 percent. Now click on button *Edit velocity smoothing* and activate option *Minimal smoothing after each tomography iteration*. Click on *Accept parameters*. Then start the second tomography processing run by clicking on button *Start tomography processing*. Once the processing terminates, select Refractors|Shot breaks to display picked and synthesized traveltimes together as shown below (Note the improvement of the match compared to the earlier display as obtained by raytracing through the Delta-t-V output) :



Now image the output of the final tomography iteration as stored in file VELOIT10.GRD, via Surfer Map|Image Map as above :

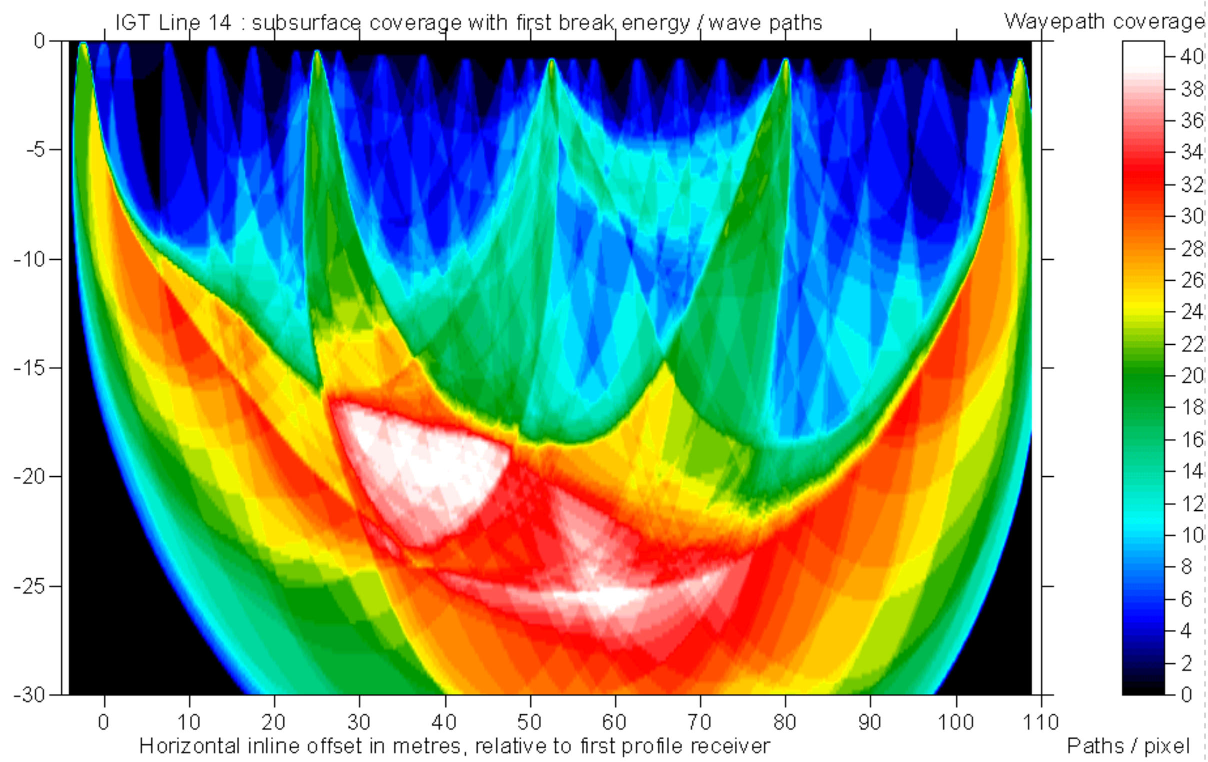


Note how the tomography processing has filtered out irregularities in the model (removal of Delta-t-V processing artefacts) and considerably increased the velocity gradient at a depth of about 15 meters, i.e. at the contact zone between overburden and basement. Also, the systematic updipping of the basement at the right section margin and to a lesser degree at the left section margin, as hinted at by the picked traveltimes, are now modelled correctly.

Note that the imaged vertical „spikes" just below the topography, below horizontal inline offset 89 metres, may be WET processing artefacts. These will be exacerbated if the wavepath width and/or the horizontal smoothing are set to too narrow values. If these parameters have too wide values, the tomogram will be smoothed too much and modelled traveltimes will not fit the „corners" of the picked traveltime curves (caused e.g. by systematic change in seismic velocity, in vertical direction). Note that the higher the number of shots per receiver spread (i.e. traces recorded per profile), the smaller these „oscillations" will be.

You may want to experiment with varying the WET parameters. Since the processing is very fast, this parameter tuning and imaging / review of resulting output can be done in a quasi-interactive kind of way.

To obtain a 2D vertical subsurface section showing the coverage of each 2D pixel with ray paths, just image the file COVERG10.GRD with Surfer 8 Map|Image Map. In the *Image Map Properties* dialog (displayed when double clicking on the map), specify the RAINBOW2.CLR color scale as you did earlier on for the DELTATV.GRD (see above). Limit the data range displayed and scale the plot as described above, to obtain a composite image of all wave paths as shown below (brighter color means higher coverage with first break energy) :



For theoretical background of our WET tomography algorithm, see Wavepath eikonal traveltime inversion (Gerard T. Schuster and Aksel Quintus-Bosz 1993, GEOPHYSICS VOL. 58 NO. 9 September 1993, P. 1314 – 1323).

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