Thrust Fault Modeling and Imaging with Surfer 8 and Rayfract 2.51

A new Rayfract™ profile database is created, and dummy shots are imported into it. Then a gridded model file is generated with Golden Software Surfer™ version 8. Synthetic shots are generated by forward modeling seismic wave propagation through the model with Rayfract. Then these shots are imported into the profile database, and interpreted with “Smooth inversion” and “Automatic Delta-t-V and WET inversion”.

Creation of a new Rayfract profile database, import of dummy shots

Download files ASCII.ASC and DELTATV.PAR from our web site :

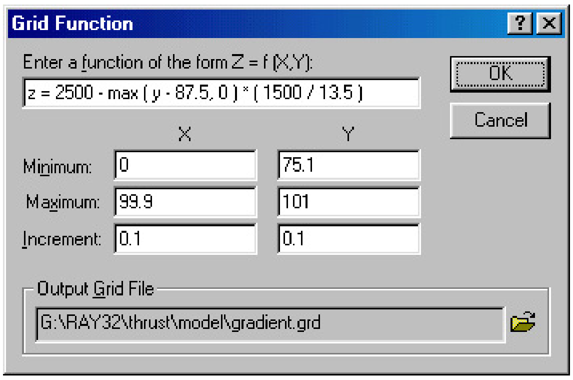
http://rayfract.com/tutorials/thrust.zip .

Now create a new Rayfract profile database named THRUST, as described in our manual as available at http://rayfract.com/help/manual.pdf . Specify a station spacing of 2 meters, in Header|Profile. Then copy above file ASCII.ASC into directory \RAY32\THRUST\INPUT. Copy DELTATV.PAR into a new subdirectory \RAY32\THRUST\MODEL and rename it to THRUST.PAR.

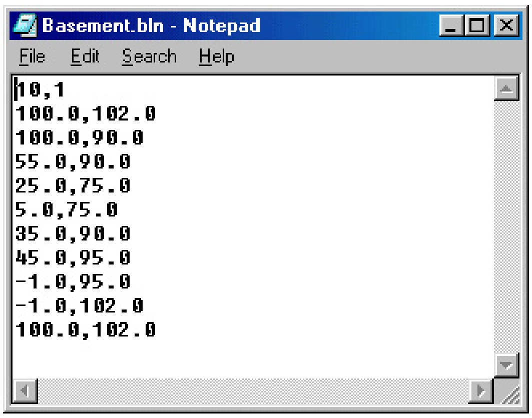
Now import file ASCII.ASC into above profile database, as described in our manual. Specify import data type ASCII column format, and use the receiver spread type 02: 48 channels. Check option “Batch import”, so you don’t need to confirm layout start and shot position etc. for each individual dummy shot. Once done, set the topography elevation “z” to 100.0 in Header|Station for one station. Hit ESC to extrapolate 100.0 to all stations.

Model grid file generation with Surfer 8

Start up Surfer 8. Now select Grid|Function... and specify the grid generation parameters as follows :



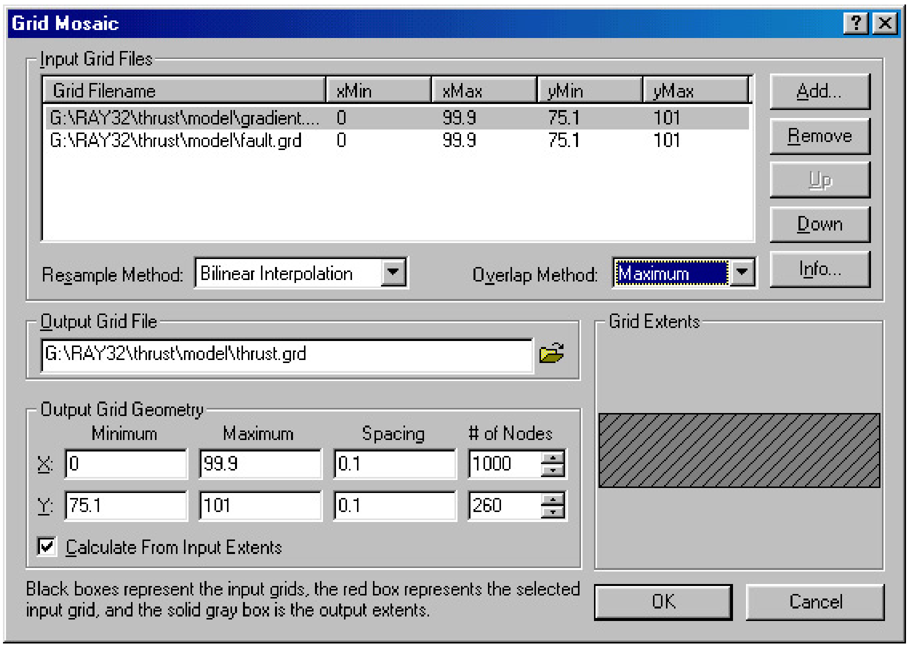
Click on OK to generate our 1D overburden velocity gradient grid file. Select Grid|Function... again and set the “function” text field to “z = 4000”. Specify \RAY32\THRUST\MODEL\BASEMENT.GRD as output file. Click on OK to generate the constant velocity basement grid file. Now select Start|Run..., enter the program name NOTEPAD.EXE and hit RETURN. Then enter the following content :



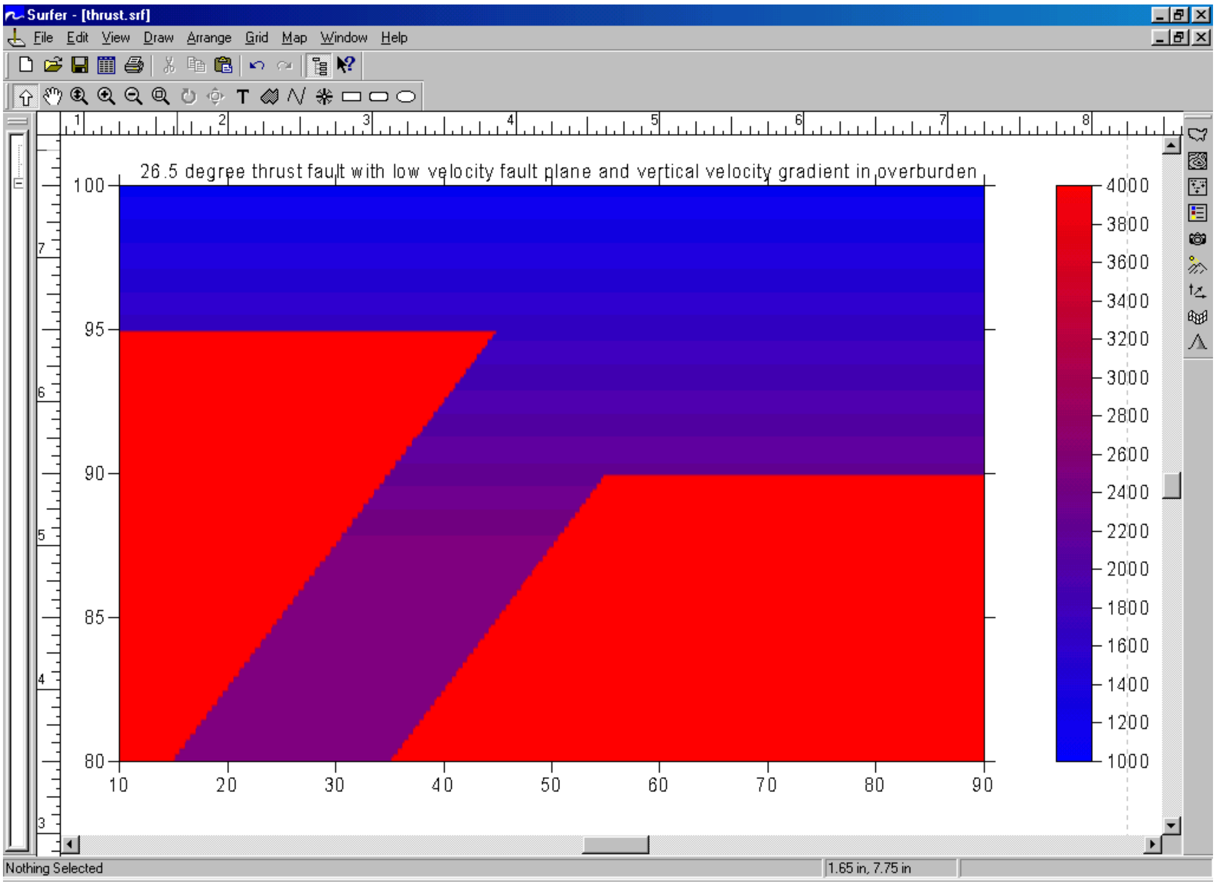
Select File|Save As... and specify \RAY32\THRUST\MODEL\BASEMENT.BLN. This file is a Golden Software Blanking File; see your Surfer 8 manual Appendix C. Our blanking file describes the "overburden + fault plane low velocity zone" polygon which we want to cut out of above basement grid file. The lower side of the polygon is the "top of basement" topography i.e. relief. Basically we model the thrust fault as a "Basement step" plus low velocity fault plane dipping to the left with a gradient of 0.5 i.e. angle of 26.5 degrees.

Go back into Surfer, select Grid|Blank... and then the BASEMENT.GRD file as generated above. Then select our BASEMENT.BLN file. Specify \RAY32\THRUST\MODEL\FAULT.GRD as output file name and click on Save to generate our "faulted basement without overburden" grid file.

Now generate our thrust fault model grid file. Select Grid|Mosaic... and then above GRADIENT.GRD file. Click on Add... and select above FAULT.GRD file. Set "Overlap method" to Maximum. Click on the folder icon to the right of field "Output Grid File" and enter file name THRUST.GRD. Our "Grid Mosaic" dialog should now look as follows :



Click on OK to generate the thrust fault model grid file. Select Map|Image Map... and our THRUST.GRD file. Double click the resulting plot with your left mouse key. Adapt Limits and Scale tabs and obtain the following output :



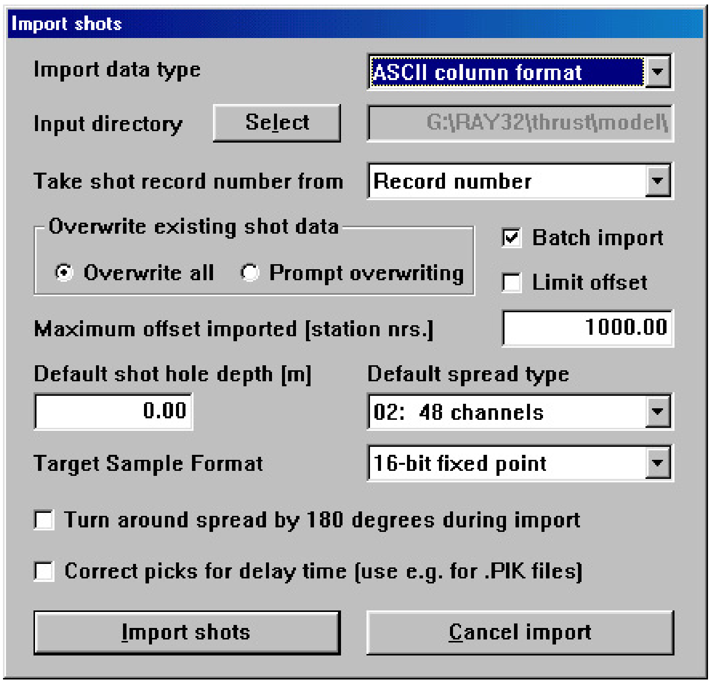
In the next step we will generate synthetic traveltimes for our dummy shots and above thrust fault model.

Forward modeling of seismic wave propagation and subsequent inversion with Rayfract

We need to run Delta-t-V at least once before we can forward model traveltimes for this profile. Select Delta-t-V|Interactive Delta-t-V. Hit ENTER to start the inversion of the dummy shots. The resulting DELTATV.PAR file will be equivalent to the one as downloaded above.

Now select WET Tomography|Forward model traveltimes... and our THRUST.GRD file as located in \RAY32\THRUST\MODEL. Confirm the "Traveltime fit" prompt. Select File|Export header data|Export Modeled First Breaks as ASCII... . Enter the file name \RAY32\THRUST\MODEL\THRUST.ASC. Click on Save to generate the THRUST.ASC file with our synthetic traveltimes, for above dummy shots.

Now import the newly generated synthetic shots for our thrust fault model, into the same Rayfract™ profile database, as described in our manual. Select File|Import Data... and set "Input directory" to \RAY32\THRUST\MODEL. Your "Import shots" dialog will look as shown below :

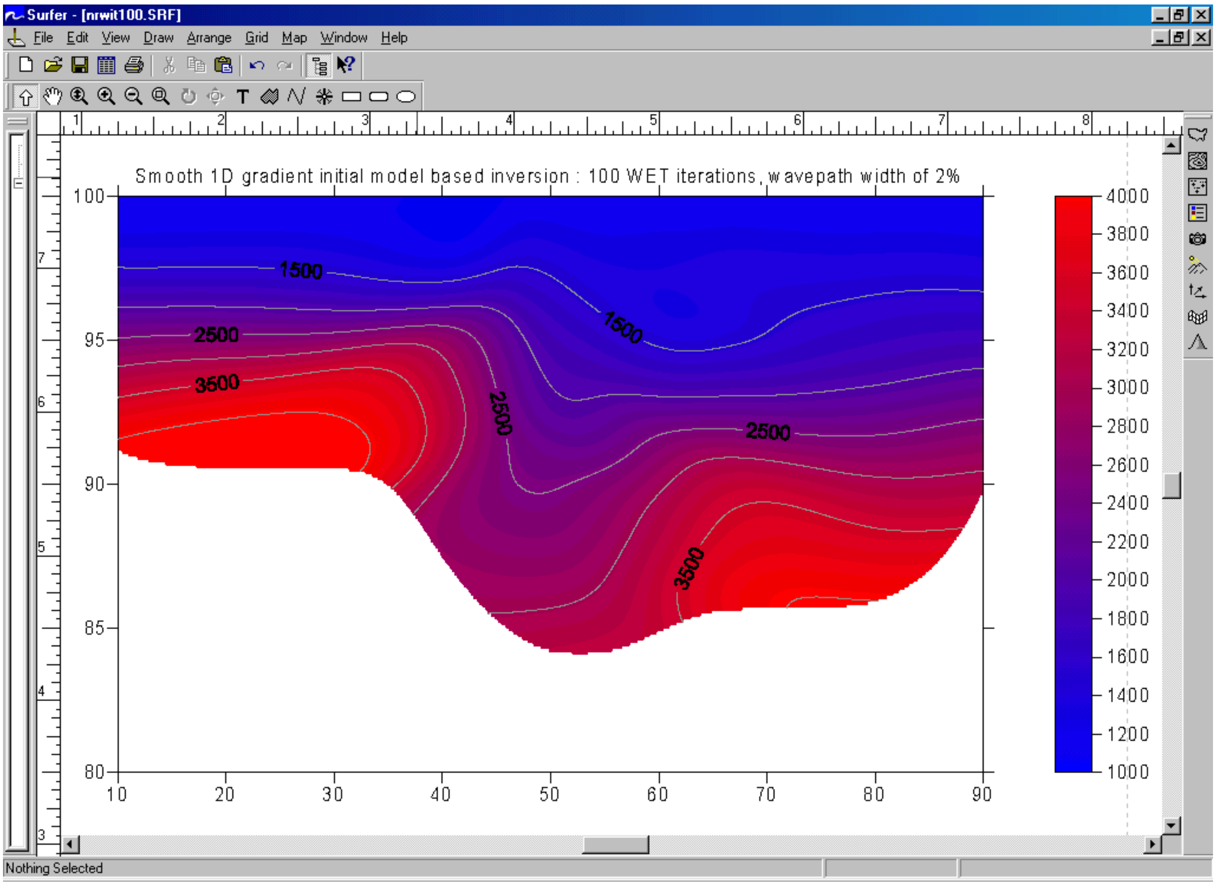


To verify that our profile database is consistent with our thrust fault model, select WET Tomography|Forward model traveltimes... and THRUST.GRD again. The prompt should state a zero misfit. Select Refractor|Shot breaks. The modeled dashed blue traveltime curves should completely cover the data as generated and imported above.

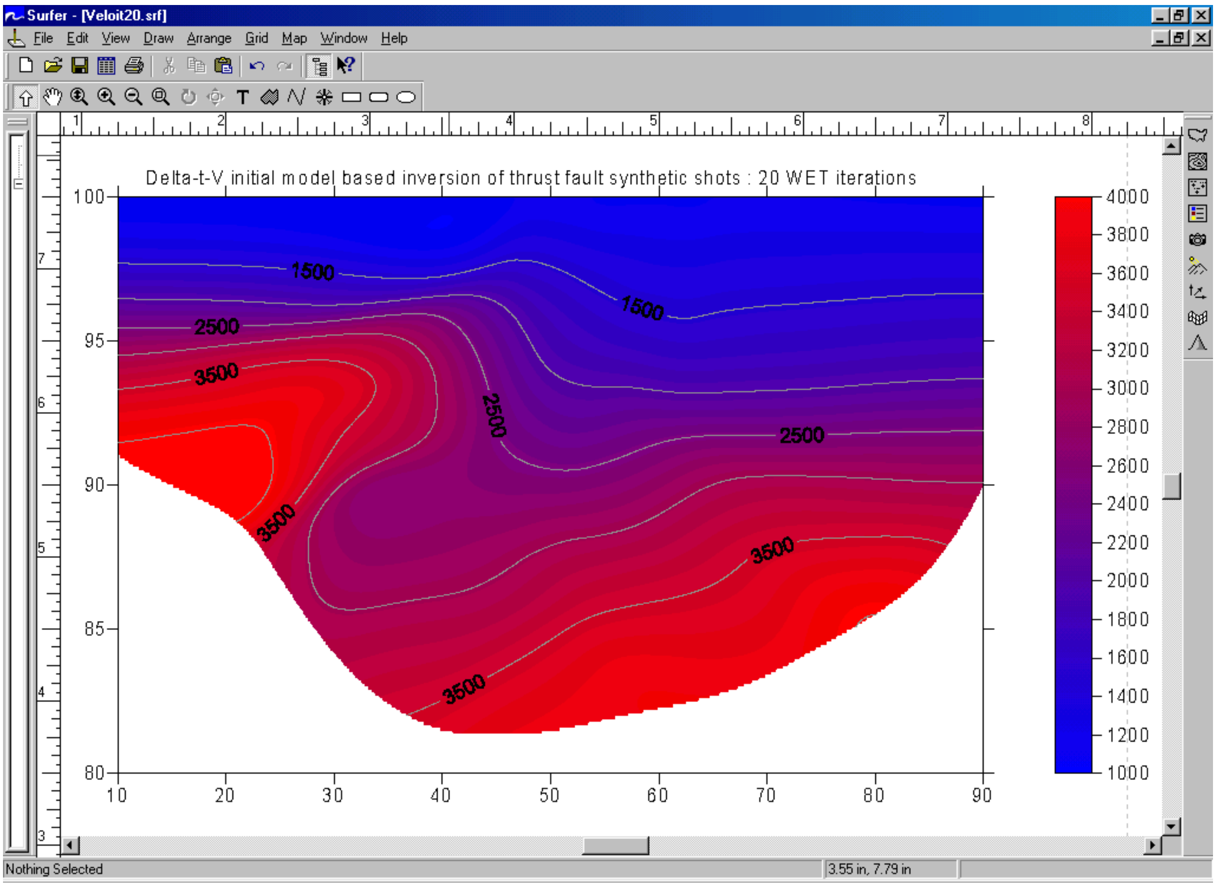
Next we will invert our synthetic shots and show the resulting thrust fault data set interpretations. Please compare these with the original model as constructed and imaged above. Select Smooth inversion|WET with gradient initial model and confirm prompts to obtain our first interpretation, as shown below.

Please note that the WET "Wavepath width" parameter has been decreased from the default value of 3% to 2% and the WET "Iteration count" has been increased to 100 for this first "smooth" interpretation, to increase the resolution. You can edit these parameters in WET Tomography|Interactive WET tomography, once you have obtained the default interpretation as described above. For "Smooth inversion" of a data set with a shot spacing closer than 3 receivers, we recommend to decrease the wavepath width by 33% i.e. one third. Make sure that the "Initial velocity model" selection field as specified on top of the dialog is still set to \RAY32\THRUST\GRADTOMO\GRADIENT.GRD.

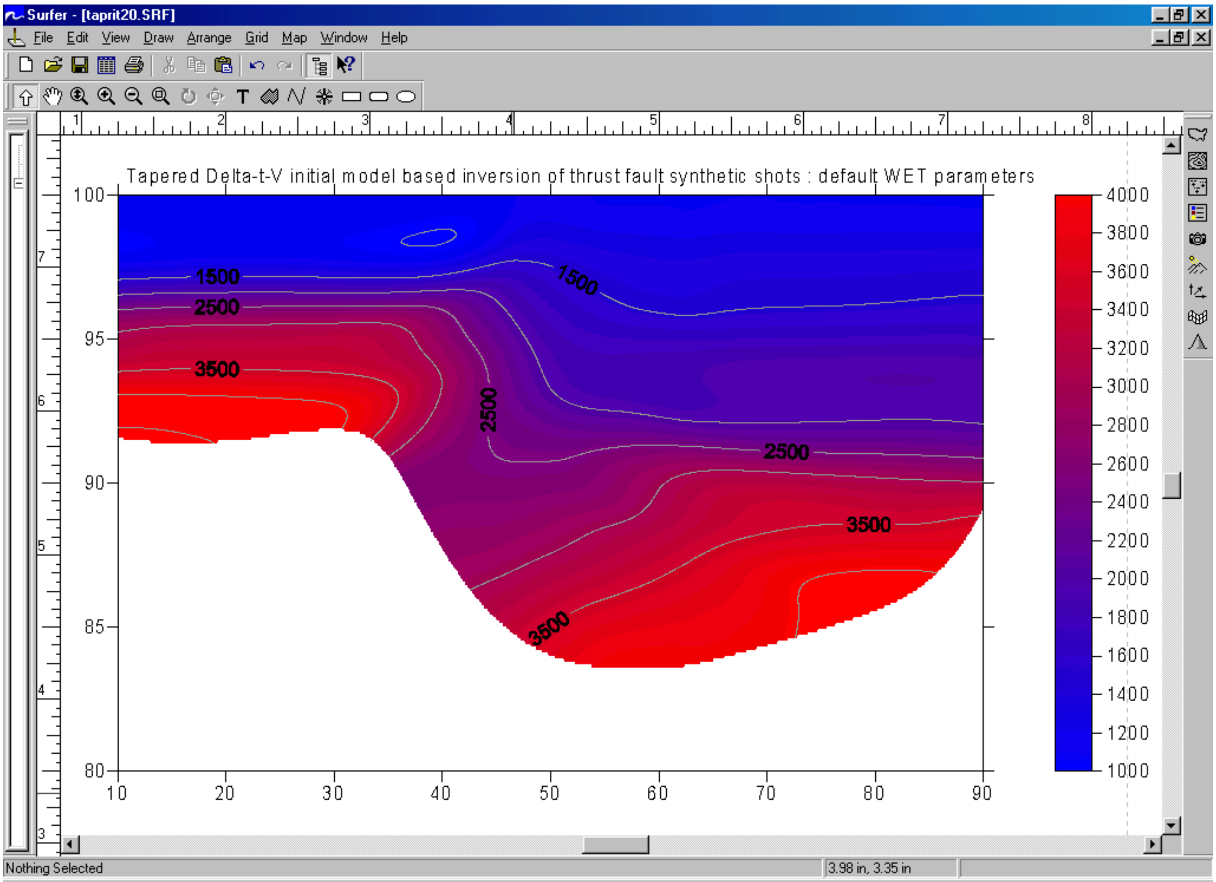
Once you have adjusted the wavepath width to 2% and increased the iteration count to 100, please click on "Start tomography processing " to redo the "Smooth inversion" with these optimized WET parameters. Of course the WET processing now will take five times as long as the default "Smooth inversion" with a WET iteration count of just 20. So you may want to make sure you are doing this on a fast machine.



Now select Delta-t-V|Automatic Delta-t-V and WET inversion and confirm prompts for our next interpretation :



Finally, select Delta-t-V|Delta-t-V Settings|Taper velocity steps at layer interfaces. Then select Delta-t-V|Automatic Delta-t-V and WET inversion again to obtain our third interpretation :



Obviously Delta-t-V option “Taper velocity steps at layer interfaces” helps to further improve the vertical resolution. Please note that enabling this Delta-t-V option may not help in situations of strong lateral velocity variation. Use e.g. the overall traveltime fit as a criterion for judging the quality of interpretations.

Also, in situations of extreme or symmetric refractor curvature (i.e. strong lateral velocity variation) and no vertical velocity variation (except abrupt velocity increase at top of basement), our 1D gradient initial model based “Smooth inversion” works best. Delta-t-V initial model based inversion tends to show artefacts in such situations.

Examples for such “digital” models where our fail-safe “Smooth inversion” works best are a simple digital “basement step” model or a “symmetric V – shaped basement depression” model, with constant velocity overburden and basement. But in our experience such abstract “digital” models are not very realistic.

We still recommend to always initially invert data sets with our “Smooth inversion” method, as shown above. If traveltime curves show at least some degree of continuous vertical velocity variation / velocity inversions, you may then proceed with Delta-t-V initial model based WET inversion. In our experience, vertical velocity gradients and inversions are quite common in most geological field settings.

Intelligent Resources Inc.
P.O. Box 2011
Vancouver B.C. V6B 3P8 / Canada

Phone +1 604 782-9845
Fax +1 604 408-8678
E-mail sales@rayfract.com
Web http://rayfract.com