Basement Step Model construction and forward modeling, with Rayfract® 3.25 and Golden Software Surfer® 11

We show how to define the recording geometry by importing dummy shots into a Rayfract® profile database, without first break picks. Next we create a basement step model grid with Surfer. Then we generate synthetic shots with our Eikonal Solver, by forward modeling wave propagation through this model grid. Finally we invert these synthetic traveltime data with our *2D Smooth inversion* and *1.5D layer-based Wavefront refraction* methods.

We use the model described by M.S. Mendes and T. Teixidó in 2008, in their Fig. 1. Instead of only 5 shots into 48 receivers we model 9 shots, with shot spacing of 6 (six) receiver *station spacings*. Mendes et al. run only 5 WET iterations for their Fig. 2, not the default 20 iterations shown in our Fig. 5.

Create a new Rayfract® profile database, import dummy shots

Download archive STEP.ZIP containing file ONESHOT.ASC from our web site.

Now create a new profile database named STEP, as described in our manual available at http://rayfract.com/help/manual.pdf . Specify *station spacing* of 2m, in *Header|Profile*. Copy above file ONESHOT.ASC into directory \RAY32\STEP\INPUT. ONESHOT.ASC specifies 49 channels, with first breaks set to -1. You may edit such a dummy .ASC shot with any text editor e.g. Windows WordPad.

Now import file ONESHOT.ASC repeatedly, once for each shot position which we want to model, as in above manual.pdf . Specify *Import data type* ASCII column format. Leave *Default spread type* at default setting 10: 360 channels. Specify *Shot pos. [station no.]* 0, 6, 12, 18, 24, 30, 36, 42, 48. Specify *Shot Number* 1 to 9 for these shots, during import. Leave *Layout start* at 0.0 .Once done with import, set topography elevation "z" to 0.0 in *Header|Station* for one station. Hit ENTER and confirm prompt, to extrapolate elevation 0.0 to all stations.

Build model grid file with Surfer 11

Start up Surfer 11. Select *File|New* and choose *Plot Document*, then click OK. Now select *Grid|Function...* and specify the parameters for generation of our overburden grid as in Fig. 1 :

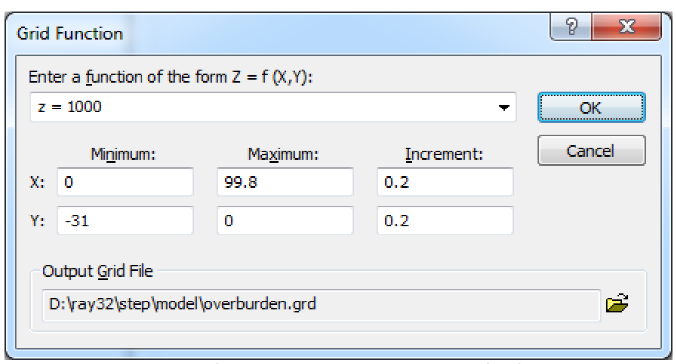

Fig. 1 : Generate overburden grid in Surfer

Click on OK to generate our constant-velocity overburden grid file. Select *Grid|Function...* again and set the "function" text field to "z = 3000". Specify \RAY32\STEP\MODEL\BASEMENT.GRD for *Output Grid File*. Click on OK to generate the constant-velocity basement grid file.

Next we edit a *blanking file,* with any text editor. Select *Start|Run...,* enter the program name NOTEPAD.EXE and hit RETURN. Then enter content as in Fig. 2 :

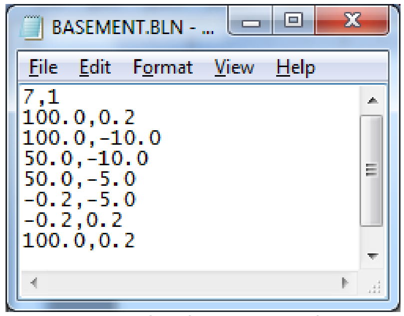

Fig. 2 : Edit blanking file, for blanking of basement grid

Be sure to hit ENTER at end of last line 100.0, 0.20, to force an end-of-line character in the disk file. Select *File|Save As...* . Set *Save as type* to *All Files*. Set *File name* to BASEMENT.BLN. Click on *Save button*. This file is a *Golden Software Blanking File*; see your Surfer 11 manual Appendix C. Our blanking file describes the "step" 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.

Go back into Surfer, select *Grid|Blank...* and then the BASEMENT.GRD file as generated above. Then select our BASEMENT.BLN file. Specify \RAY32\STEP\MODEL\FAULT.GRD as output file name and click on *Save button* to generate our "basement with monocline" grid file.

Now we add our constant-velocity overburden to the step model. Select *Grid|Mosaic...* and then above OVERBURDEN.GRD file. Click on *Add... button* 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 STEP.GRD. Our *Grid Mosaic dialog* should now look as follows :

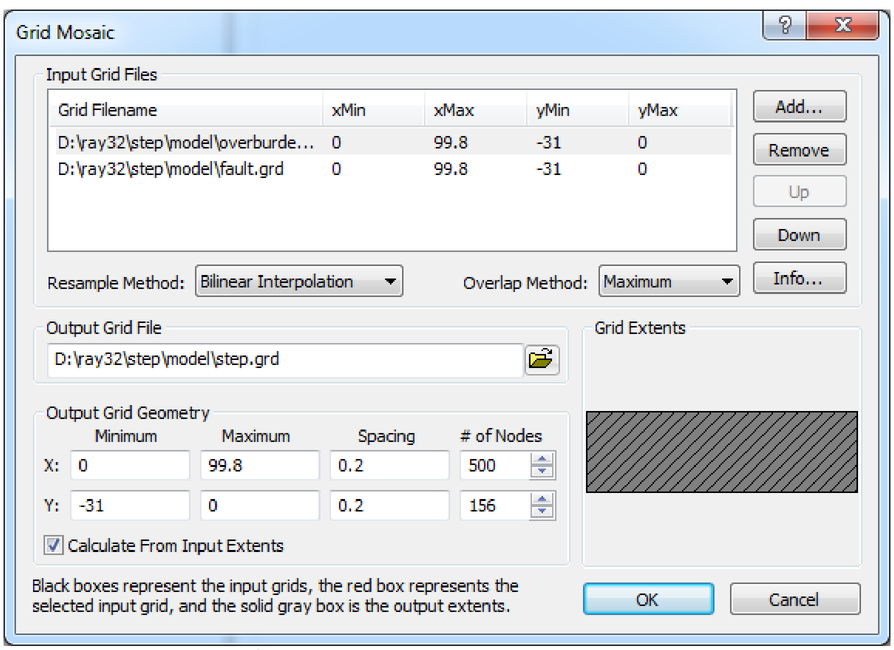

Fig. 3 : Combine overburden with blanked basement grid

Click on *OK button* to generate the final step model. Select *Map|New|Image Map...* and our STEP.GRD file. Click the resulting plot with left mouse key. Select *View|Manangers|Object Manager*. Left-click *Image-step.grd*. Click on *Colors bar* in *Property Manager|General tab*, and load *Color scale* BlueRed1. Check *Interpolate pixels* and *Show color scale*. Left-click *Map icon* in *Object Manager*. Click *Scale tab* in *Property Manager*, uncheck *Proportional XY*, set *X Scale|Length* to 6.0 in and *Y Scale|Length* to 4.0 in to obtain Fig. 4 :

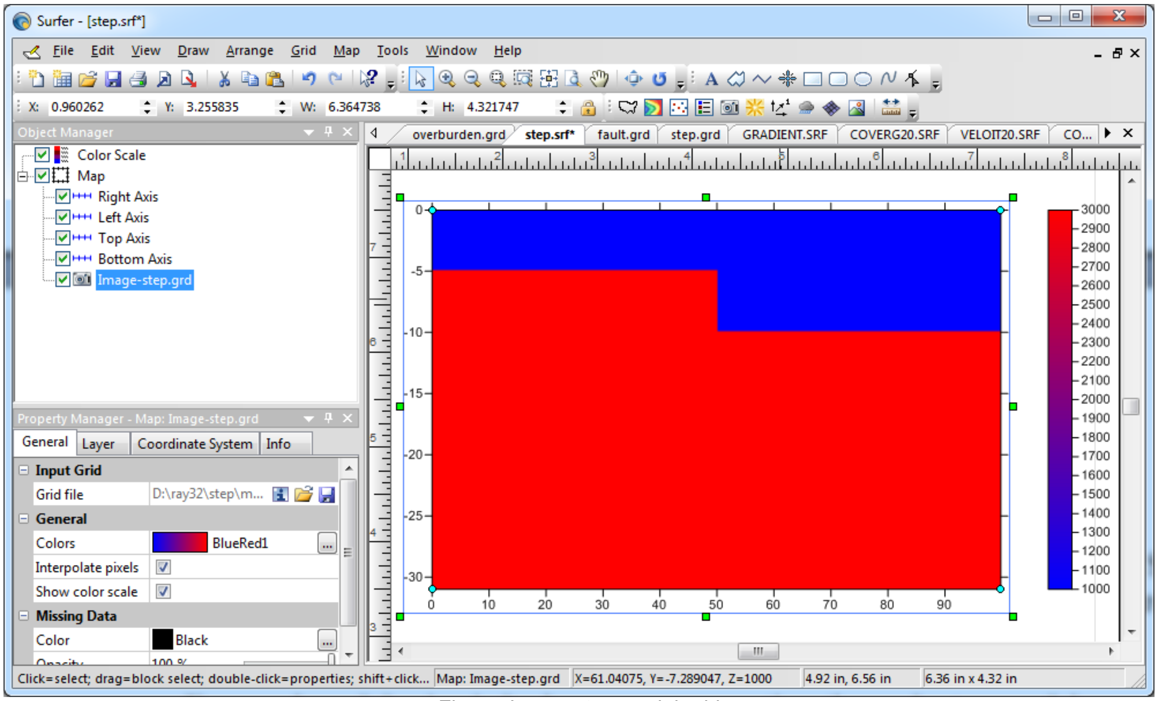

Fig. 4 : Image step model grid

You may need to repeat above grid generation steps with Golden Software Surfer once or twice, and shut down/restart Surfer in between. Otherwise Surfer may not update/read old versions of disk files.

Forward model seismic body wave propagation through step model

Open profile database \RAY32\STEP as created above, with Rayfract® *File|Open Profile…* Select *Model|Model synthetic shots…* and \RAY32\STEP\MODEL\STEP.GRD . Select *File|Export header data|Export First Breaks as ASCII…* . Save to file STEP.ASC. Select *Refractor|Shot breaks*. Now press ALT+P, set *Maximum time [msecs.]* to 50 and hit ENTER, to obtain Fig. 5 :

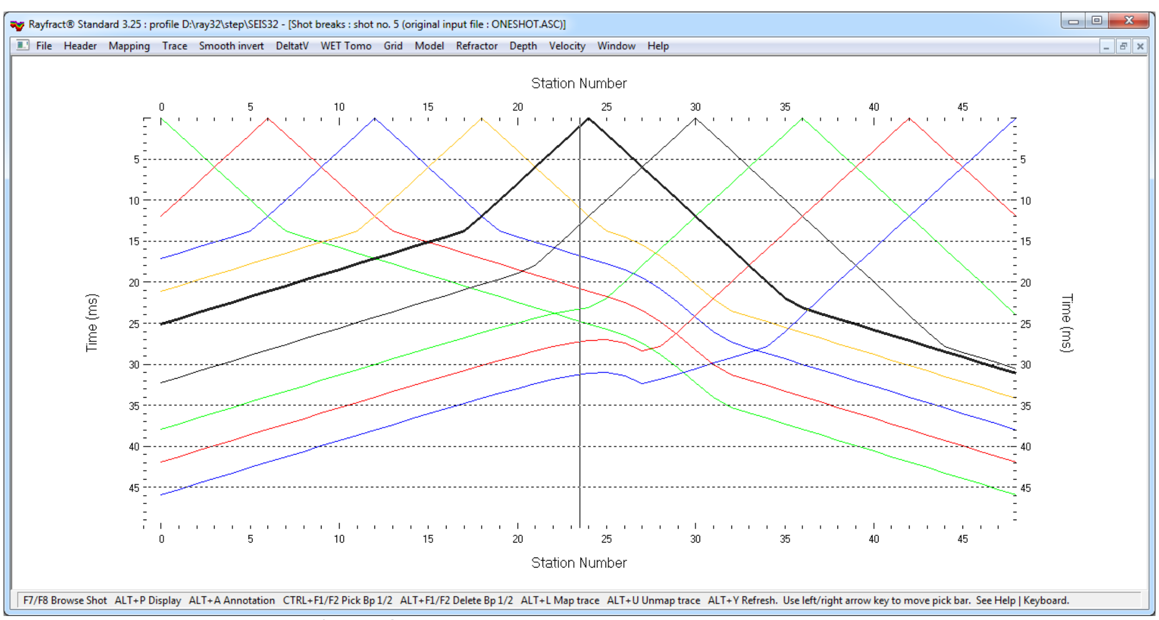

Fig. 5 : *Refractor|Shot breaks display*, showing shot-sorted traveltime curves

Next we show Smooth inversion of these synthetic traveltime data as shown in Fig. 5 :

- select *Smooth invert|WET with 1D-gradient initial model*
- confirm prompts to obtain 1D starting model as in Fig. 6
- confirm prompts to obtain 2D WET tomogram after 20 iterations as in Fig. 7
- select *WET Tomo|Interactive WET tomography…*
- set *Number of WET tomography iterations* to 100
- uncheck *or RMS error does not improve for n =*
- click *button Edit grid file generation*. Set *Store each nth iteration only : n =* to 20
- click buttons *Accept parameters* and *Start tomography processing* for Fig. 8 and 9

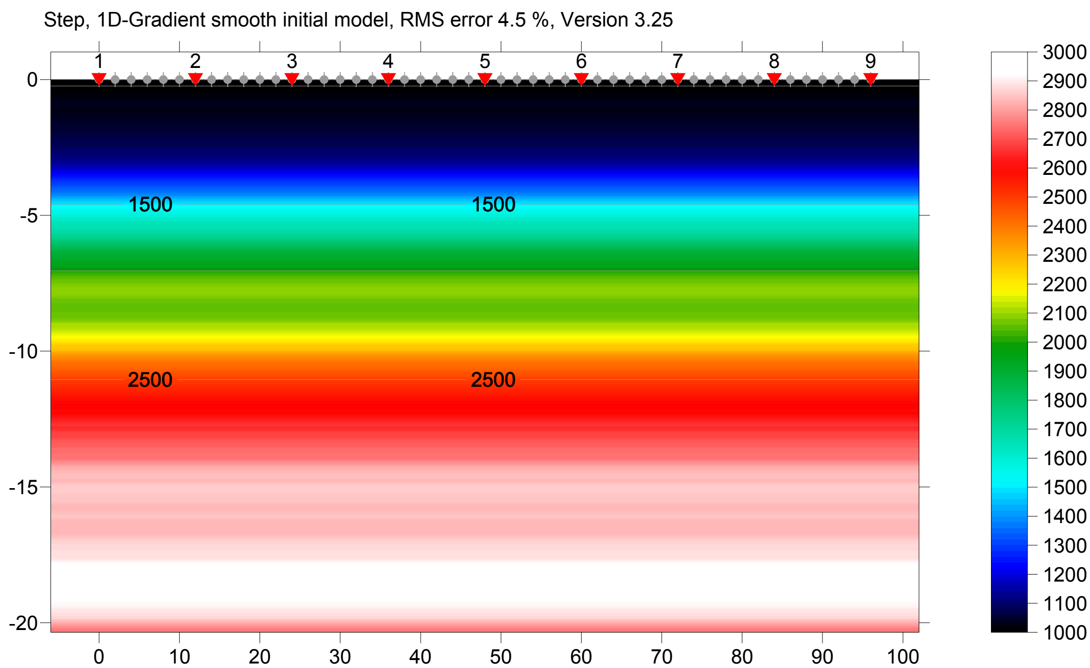

Fig. 6 : 1D-gradient starting model, obtained with *Smooth invert|WET with 1D-gradient initial model* and default settings

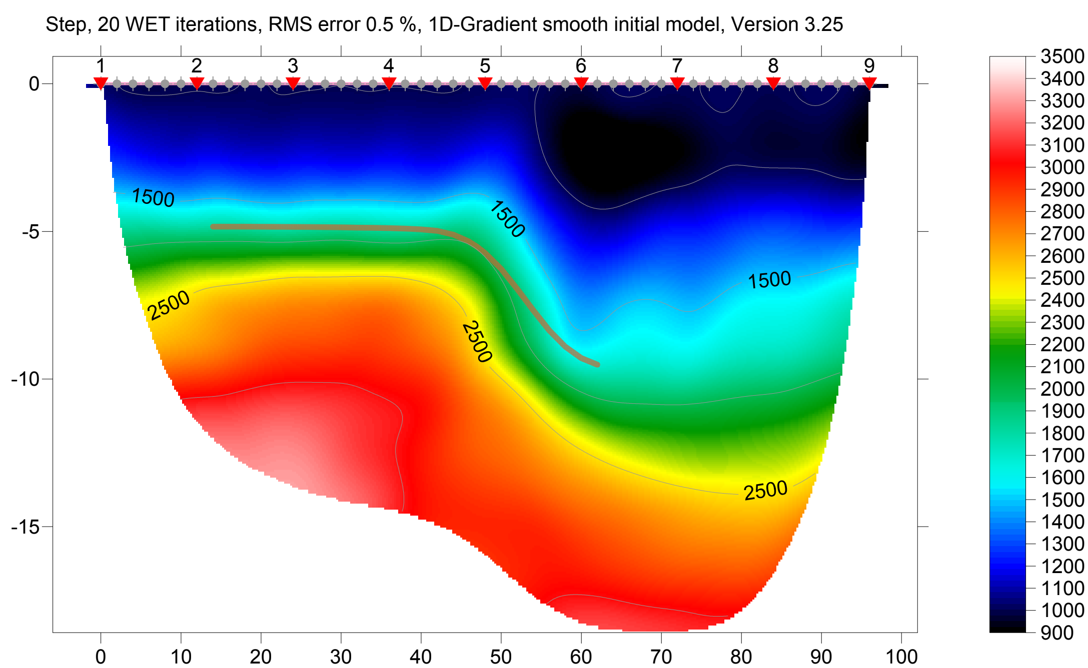

Fig. 7 : Smooth inversion, 20 WET iterations, default settings. . Basement refractor obtained with Wavefront refraction method is plotted as brown line. See jenny13 tutorial for instructions.

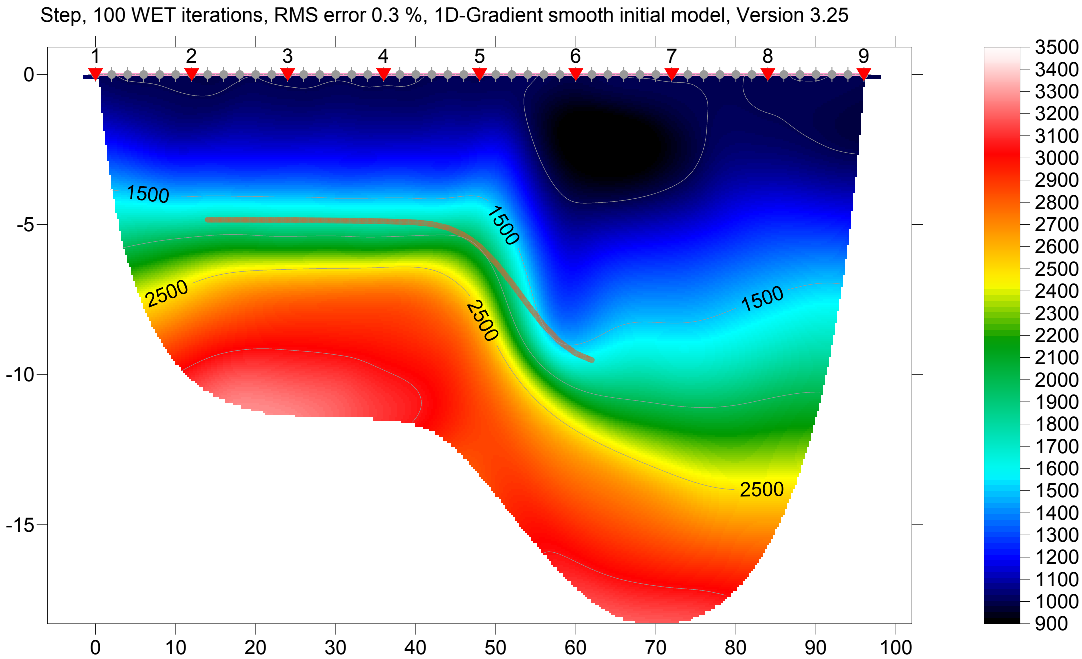

Fig. 8 : Smooth inversion, 100 WET iterations. Basement refractor obtained with Wavefront method plotted as brown line.

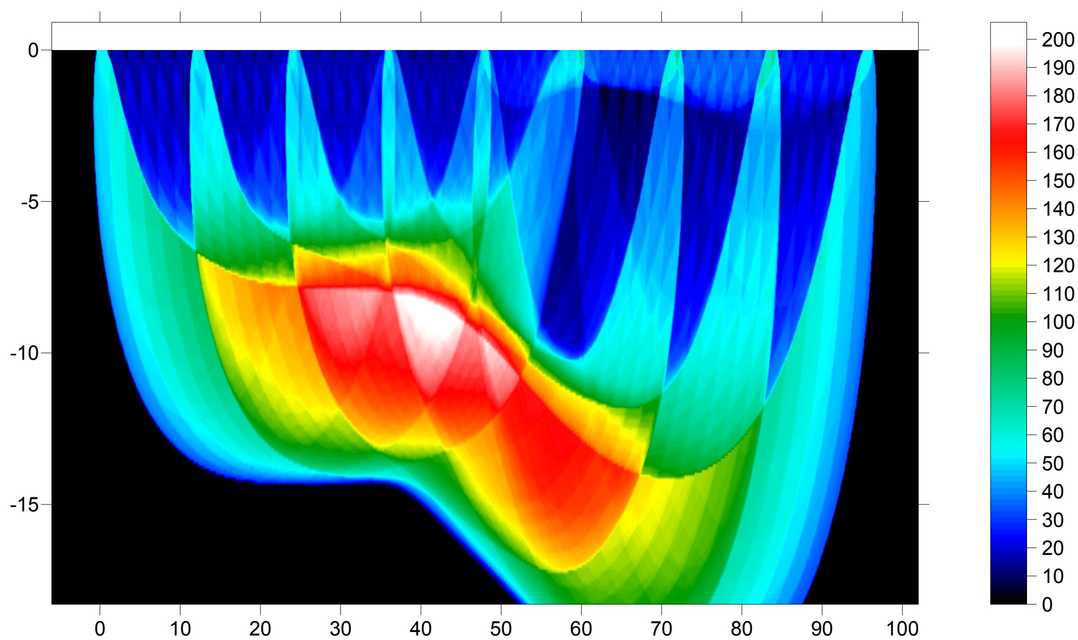

Fig. 9 : WET wavepath coverage plot, obtained with Fig. 8

Obviously Fig. 8 is a better approximation than Fig. 7, of the true step model (Fig. 4) . This shows that increasing the WET iteration count from 20 to 100 makes sense, at least in this case and most of the time.

Obtain a layer-based interpretation with our Wavefront refraction method :

- select branch point no. 1 with CTRL+F1 for traveltime curves in *Refractor|Shot breaks*, Fig. 10
- press ALT+L to map traces to refractors, based on your branchpoint locations
- select *Depth|Wavefront*, press ALT+M, set *Base filter width* to 5, press ENTER for Fig. 11
- select *Velocity|Wavefront*, press ALT+P, set *Maximum velocity* to 5000, press ENTER

Plot the basement refractor shown in Fig. 11 (center) on WET tomograms (Fig. 7, Fig. 8) :

- click on *Window Wavefront Depth Section* (center) in Fig. 11

- select *File|Export header data|Export ASCII model of depth section…*
- click *Save button* to generate file WAVEMODL.CSV with refractor depths and velocities
- check *Grid|Plot refractors on tomogram*
- select *Grid|Select ASCII .CSV layer model for refractor plotting…* and your WAVEMODL.CSV
- select *Grid|Image and contour velocity and coverage grids…*
- select tomogram grid \RAY32\STEP\GRADTOMO\VELOIT100.GRD for Fig. 8

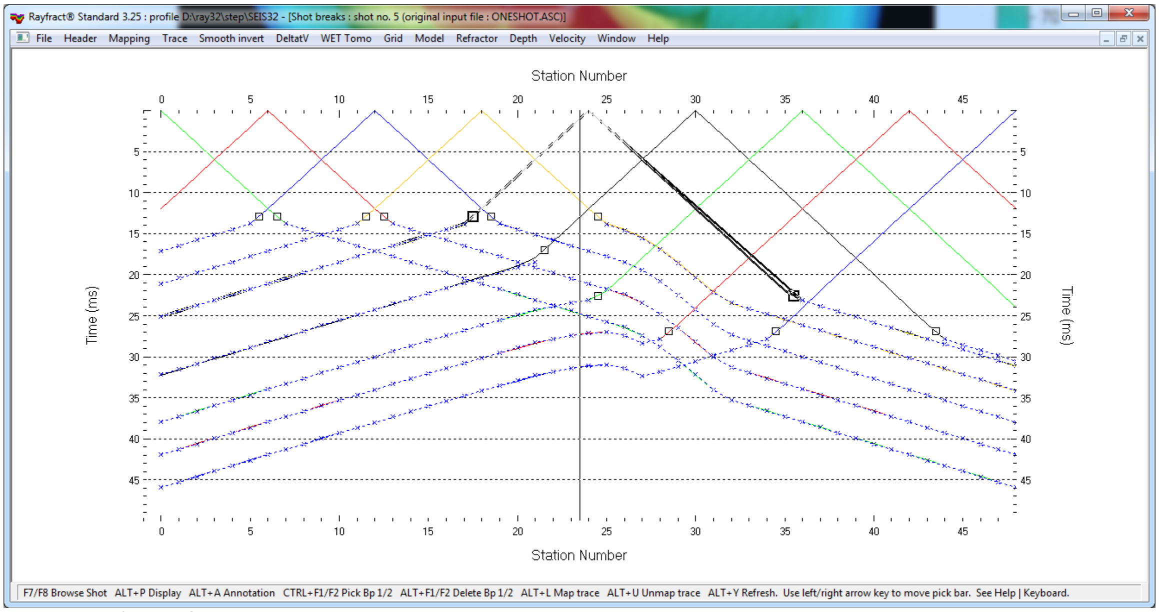

Fig. 10 : *Refractor|Shot breaks* with branch points selected (outlined squares). Dashed blue curves and blue crosses are modeled first breaks for basement refractor, obtained with *Depth|Wavefront*.

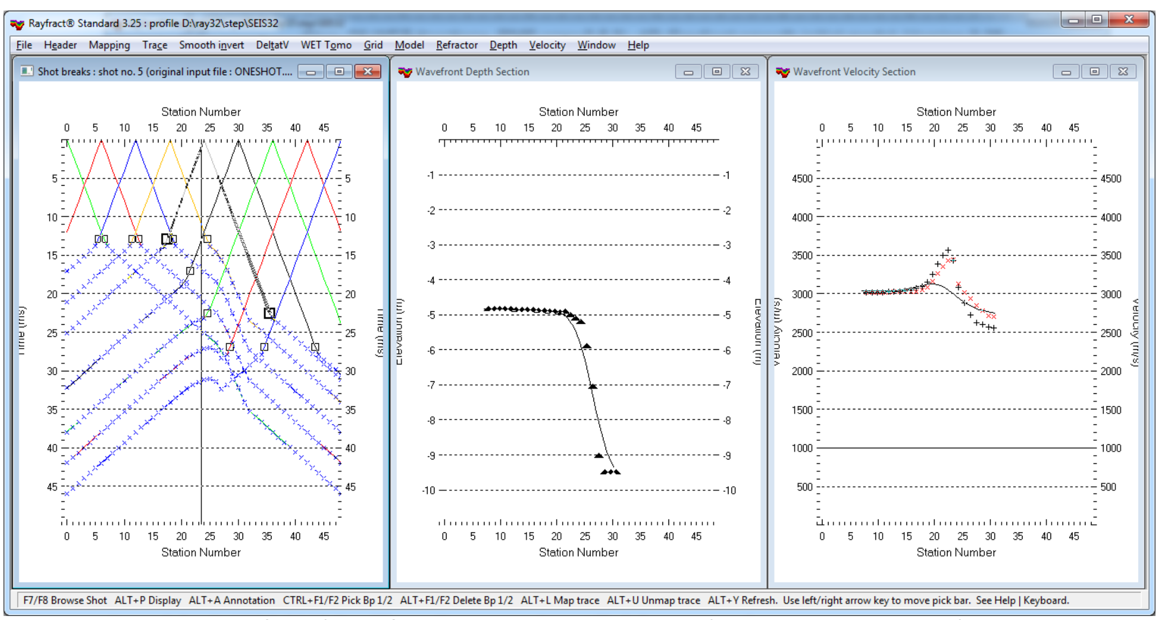

Fig. 11 : left : *Refractor|Shot breaks*, center : *Depth|Wavefront*, right : *Velocity|Wavefront*