GEOEXPLORER REFRACT

Version 2.0.2

USER MANUAL

(09/2022)

SARA electronic instruments s.r.l.
Via Mercuri 4 – 06129
PERUGIA – ITALY
Phone +39 075 5051014
Fax + 39 075 5006315
Email: info@sara.pg.it
URL: www.sara.pg.it

Warning! Some software features may be different compared to this manual but the basics remain the same.
If you are in trouble understanding the software's operations feel free to ask for help to our engineers.

this page has been intentionally left blank

This software is produced for professional and research purposes. The use of the software for the purpose of recording geophysical data and / or assessment of risks and mechanical characteristics of soils is reserved for qualified and specialized personnel such as doctors of engineering, architecture, physics and geology, having also followed specialization courses in geophysics and structural calculation. All certifications regarding this material are the responsibility of the end user.

The software is provided in its most updated version, without any express or implied warranties. The developer of GEOEXPLORER REFRACT is not responsible for any loss, injury or damage of any kind in the event that the software is used in situations of vital importance and without the necessary technical expertise essential for the validation of the data obtained and does not accept responsibility in the case of inappropriate use of the product.

this page has been intentionally left blank

Table of contents

1 Introduction 6
2 GEOEXPLORER REFRACT 6
2.1 Menu bar 7
2.2 Tabs 13
2.2.1 Dataset 14
2.2.2 Pre Processing 20
2.2.3 Picking 23
2.3 Intercept 27
2.4 GRM 30
2.4.1 Selection 30
2.4.2 Analysis 33
2.4.3 GRM Section 34
3 Introduction to data acquisition 36
3.1 Noise-Test 36
3.2 Geometry and acquisition parameters 37
3.3 Seismic sources 39
3.4 Sensor 39
4 Data processing 40
4.1 Geometry assignment 40
4.2 Filters 40
4.3 I.A.G.C. (Istantaneous Automatic Gain Control) 42
4.4 Detrending 44
4.5 Intercepts 45
4.6 GRM 46
4.7 Bibliography 47

1 Introduction

The **Refract** module has been developed with the aim of providing a tool for stratigraphic analysis by refraction, in order to extract the seismic-stratigraphic profile of an acquisition with the relative speeds.

2 GEOEXPLORER REFRACT

To use the module is mandatory to plug the **USB license** dongle to the Pc.

Please note: it is recommended to run the software as administrator.

Illustration 2-1

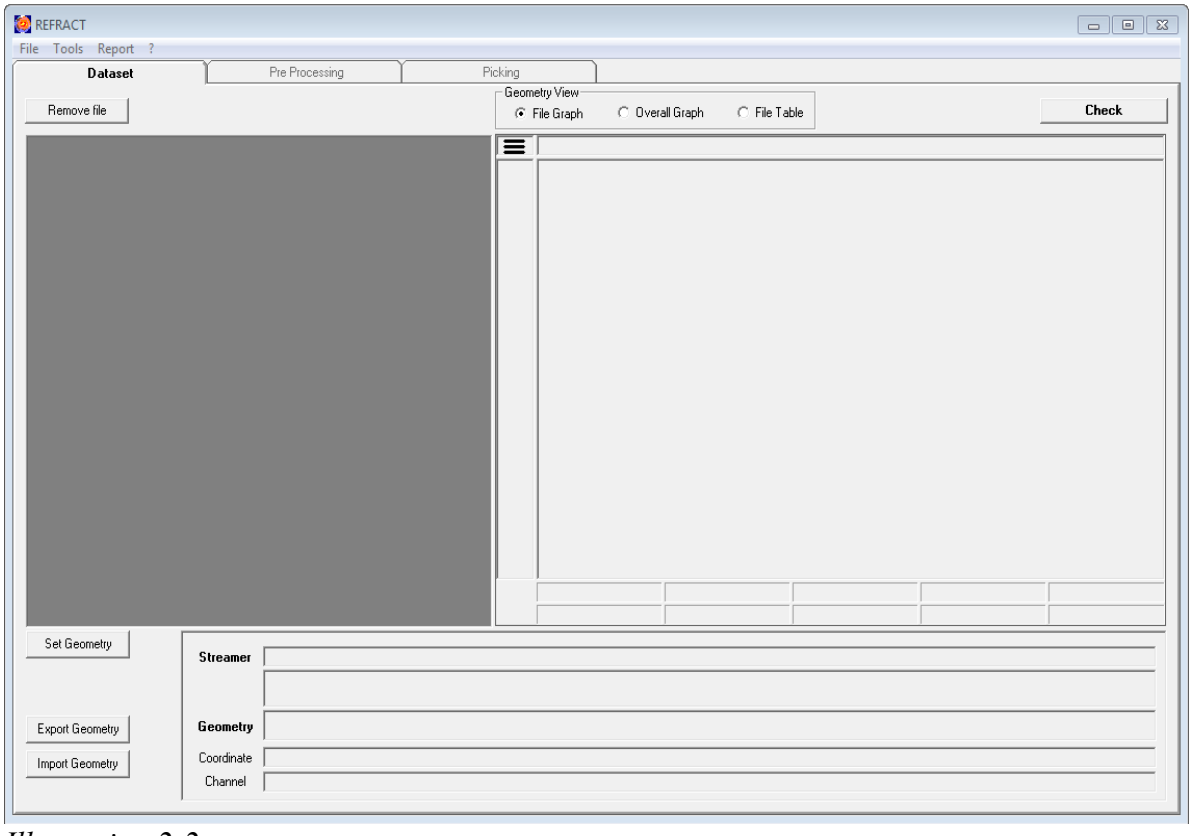


Illustration 2-2

The main page of the software is the *Dataset* tab where is possible to load in different ways the dataset recorded in the field or directly the seismograms ready for the picking.

2.1 *Menu bar*

From the File menu is possible to load the data in different ways:

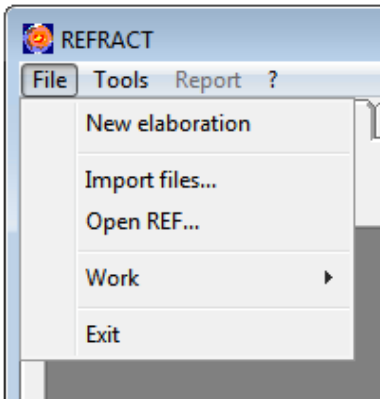


Illustration 2.1-1

1. *New elaboration:* Resets the program and makes it available for new processing.
2. *Import files:* This option allows to load data massively, even if the dataset has been recorded with a third part seismographer.

   Please note: it is possible to load SEG 2 files. (See chapter 2.2.1 Dataset page 14). The software will automatically convert the data in .drm.
3. *Open REF:* It is possible to load the .ref acquisition file generated by the **Surface** module of the **GEOEXPLORER DoReMi**. (please see the **GEOEXPLORER DoReMi** manual)

   Please note: it is recommended to always make a backup copy of the files.
4. *Work:* This menu allows to save, search, load works and to see the works history.

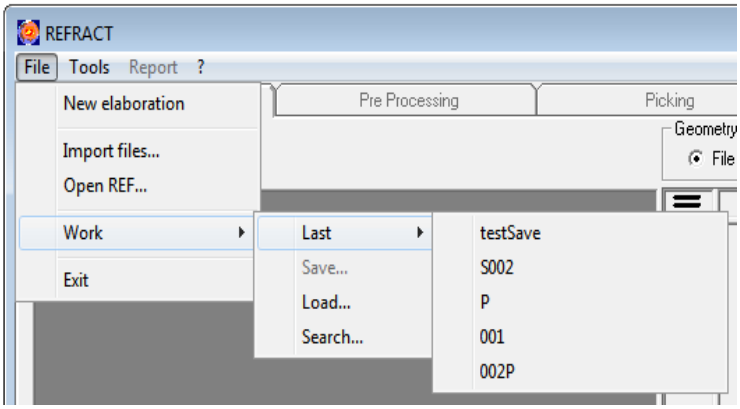


Illustration 2.1-2

The *Load work* option allows to select a previously saved folder. This folder contains a previously processed dataset

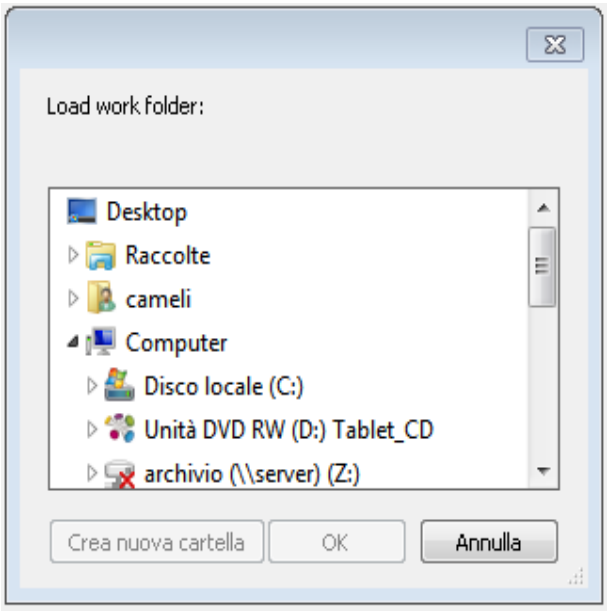


Illustration 2.1-3

The *Search work* window allows to look for a work in the device and in the time interval selected.

If the dates selected are both the current day the search will be done on the whole device without restriction.

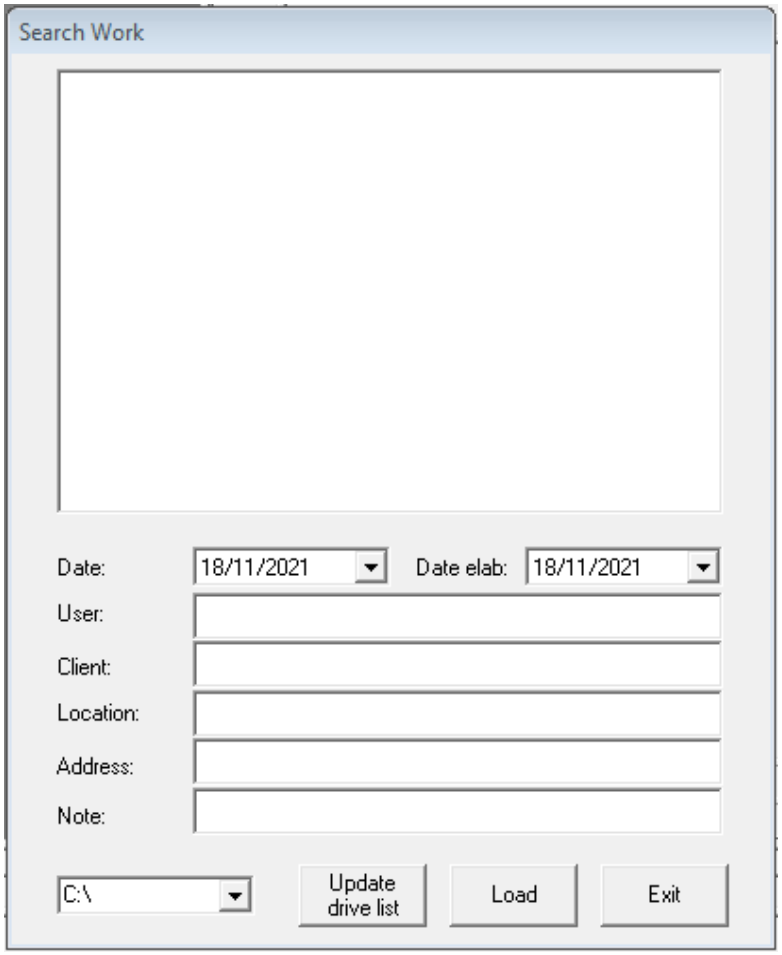


Illustration 2.1-4

This software generate a temporary copy of the uploaded files on which it works. Proceeding with saving the *work*, the program generates a folder with the selected name in the desired position. The folder contains the original files, the support files and the processing information, thus creating an image relating to the status of the processing process at the time of saving.

> *Please note: in addition to making a backup copy of the original files, it is advisable to proceed with periodic backups in different folders, in order to preserve the various processing steps. The software also provides the overwriting function in the same save folder, but we* ***DO NOT RECOMMEND*** *this procedure*
>
> *Please note: Manually modifying the contents of the save folders can lead to anomalous behavior of the software and/or to the loss of processed information.* ***WE STRONGLY NOT RECOMMEND*** *modifying save folders.*

The *Tools* menu allows to:

1. *Pre Processing:* Contains a series of useful tools that can be used in the pre processing view: (Illustration 2.1-5)
   - **I.** *Undo:* Undoes the last function applied at the selected file.
   - **II.** *Redo:* Executes the previously undone function again.
   - **III.** *Revert to original*: Restores the file to the state it was in before Pre processing.

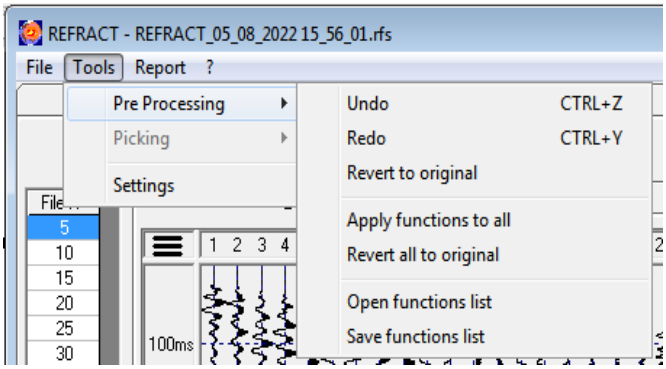


Illustration 2.1-5

   - **IV.** *Apply to all:* Apply the function list of the selected file to all other files. *Warning: any other functions applied to the other files will be lost.*
   - **V.** *Revert all to original:* Restores all files to the state they were in before preprocessing..
   - **VI.** *Open:* Allows to open a .fun file from the disk, and applies the functions contained in it to the selected file.
   - **VII.** *Save*: Saves a .fun file to disk, containing the list of functions applied to the selected file, with the relative parameters.

*Please note: The function history remains stored for each channel. If the **Revert to original** or **Undo** functions are used, the history of the undone functions remains stored until the file is changed. In this case, only the functions applied remain in the history.*

*Note: in the case of the **Revert all to original** function, only the displayed file will keep the canceled functions in the log. By changing the seismogram, the latter will also be reset.*

2. *Picking*: It contains some functions that can be used on the picking screen Illustration 2.1-6
   - **I.** *Reset all picking*: it resets the picking carried out on all the files of the dataset to zero. This operation cannot be undone.
   - **II.** *Reset all intercepts*: it eliminates the intercepts picked up on all the files of the dataset. This operation cannot be undone.

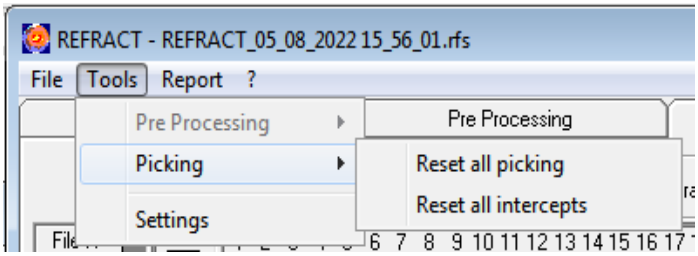


Illustration 2.1-6

3. *Settings*: A window opens in which it is possible to set some processing settings on the intercept method, in particular with regard to the graphical representation of the results.(Illustration 2.1-7)

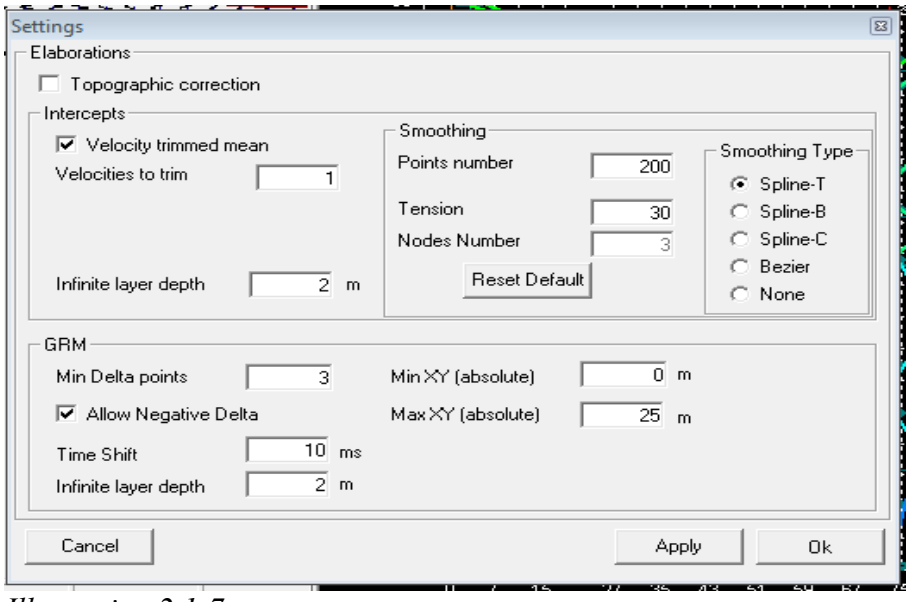


Illustration 2.1-7

I. *Topographic correction* enables the vertical correction in both the stratigraphy of the intercepts and of GRM, if it is enabled the stratigraphy will reflect the altimetric profile of the spreading, according to what are the z geometries of the geophones.

II. *Intercepts*:

a) *Velocity trimmed mean:* If enabled, excludes extreme values, (smaller and larger) from the calculation of average speeds. The number of values to be excluded is reported in *Velocities to trim* which indicates the number of speeds to exclude between the minimum and maximum values. For example, if the value is 1, the smallest and largest speed will be suppressed.

b) *Infinite layer depth* defines the arbitrary depth of the semi-infinite layer to be represented in the stratigraphy

c) The *Smoothing* section provides a series of tools to manage the design of the interfaces between the layers through various spline functions. If None is selected, the interface will be designed simply by joining the points calculated by the intercept method.

III. *GRM*:

a) *Min delta Points* allows the user to select the minimum number of points that must be generated from a pair of files to be valid and usable for GRM processing.

b) *Allow Negative Delta*, if selected, it enables the use of negative deltas in the generation of pairs.

c) *Time Shift*: defines the time shift to be applied to the TV and Tg lines in the GRM graphs.

d) *Infinite layer depth* it is equivalent to that of intercepts.

e) *Min XY/ Max XY* indicate the minimum / maximum value in meters of the distance between two geophones.

The *Report* menu, allows to set all the work specific information for printing the pdf, as well as the photos the elaborations. (Illustration 2.1-8)

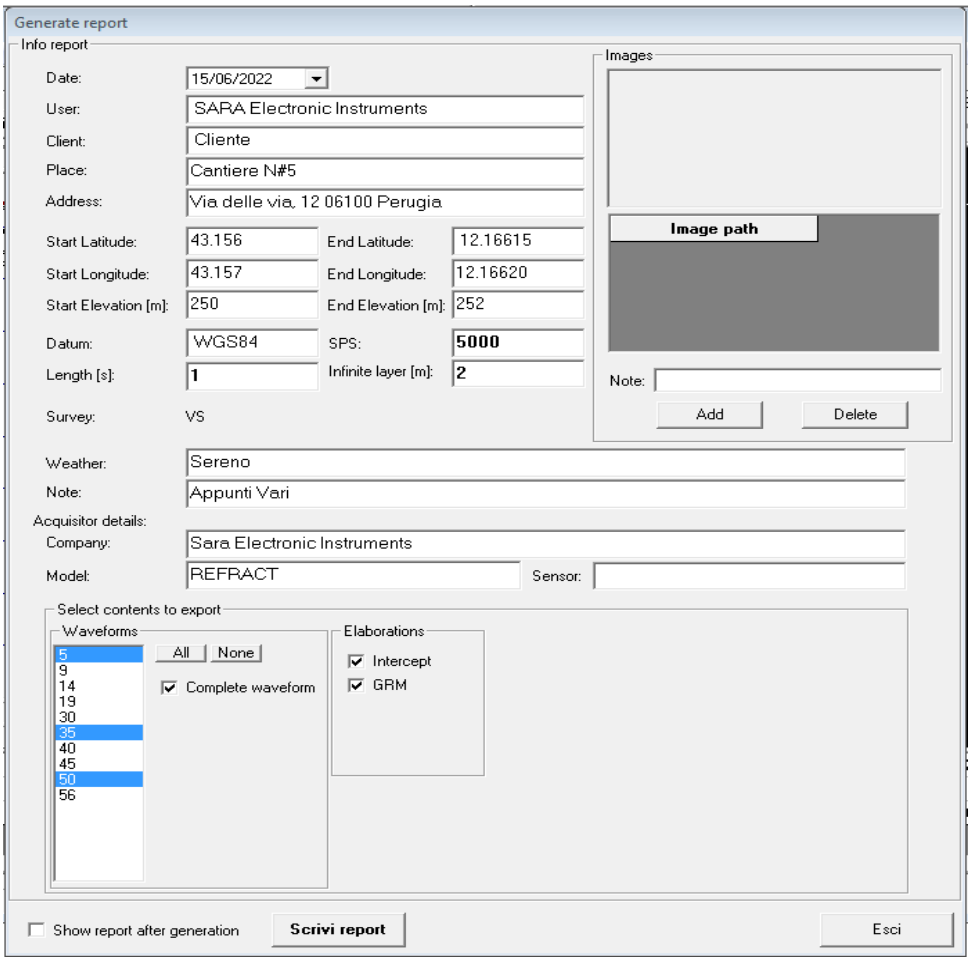


Illustration 2.1-8

The *?* menu gives the software information like version and contacts. (Illustration 2.1-9)

Illustration 2.1-9

2.2 *Tabs*

The software is structured in tabs which will guide the user through the whole the elaboration process:

1. *2.2.1 Dataset*

   In this tab is possible to load a dataset and set the geometry

2. *2.2.2 Pre Processing*

   In this tab it is possible to perform various functions on the signals in order to highlight the desired characteristics

3. *2.2.3 Picking*

   In this tab it is possible to perform the picking of the first arrivals and intercepts. From here it will be possible to start stratigraphic processing using the intercept and the GRM methods.

2.2.1 *Dataset*

Once loaded a dataset, the table within this tab will populate with the various shots. By selecting a file it will be possible to see a preview of the content in the seismogram on the right. A preview of the geometry can be seen in the graph below.

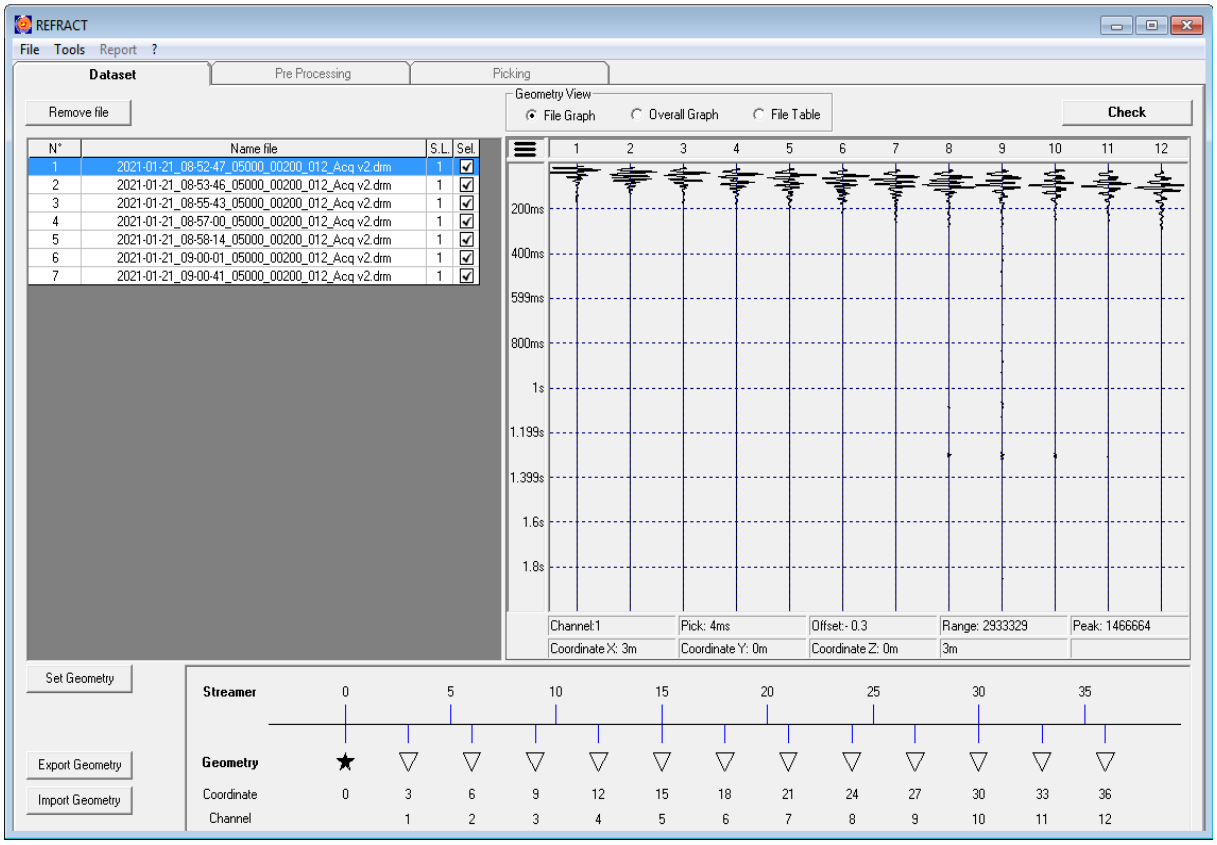


Illustration 2.2-1

Double clicking on S.L. the user can set the spread value. This value allows, if necessary, to keep the various geophone spreads divided, which will then be saved in separate .ref files. For each new .ref file loaded this value will be increased.

Using the checkbox in the Sel column, it is possible to enable or disable the file. Only enabled files will be used for subsequent processing.

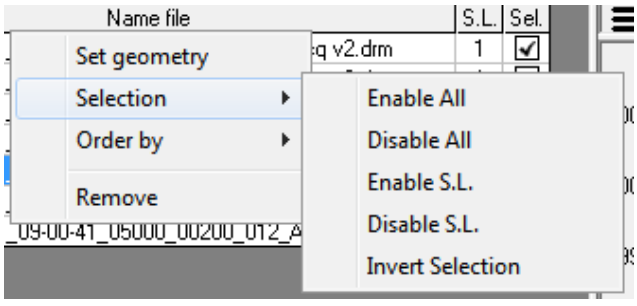


Illustration 2.2-2

By right-clicking on a file a popup menu will appear (*Illustration 2.4-4)* through which it is possible open the geometry setting screen using the *Set Geometry* option.

There is the possibility to massively modify the selection of files through the *Selection* menu,

in particular it is possible to enable / disable all files (*Enable All / Disable All*), enable / disable the spreading (*Enable S.L / Disable S.L.*) and invert the selection (*Invert Selection*) *Illustration 2.4-4*

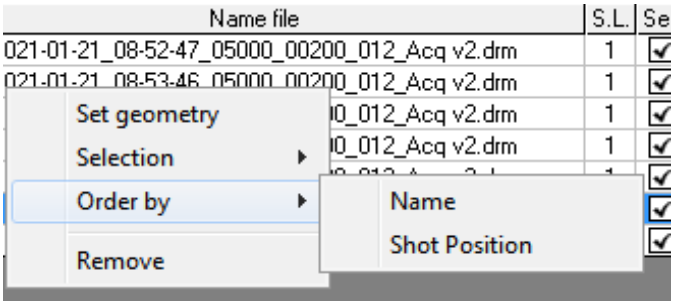


Illustrazione 2.2-3

It is also possible to sort the dataset by file name or burst position *(Illustrazione 2.2-3)* and remove the file using the *Remove* menu.

Set geometry Illustration 2.2-4 allows to manage the horizontal geometry of an acquisition file quickly by being able to modify the geometry of the geophones, indicating the position of the first geophone and the spacing between them, and the position of the shot.

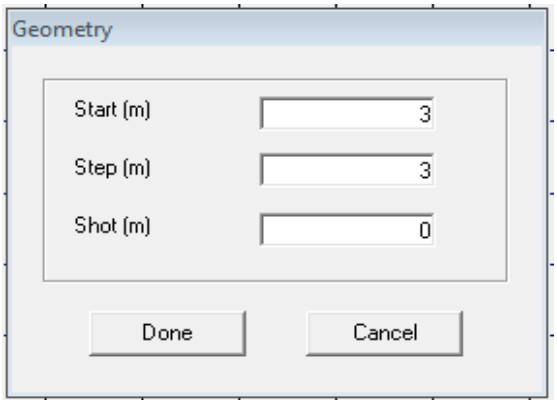


Illustration 2.2-4

The context menu Illustration 2.2-5, accessible with a right click of the mouse on the seismogram, has some additional functions inside it, in addition to the display functions.

1. *Select to move: S*elect a channel to move. The channel in question will be highlighted in a different color.
2. *Delete:* Delete the channel from the seismogram.
3. *Kill: S*ets the channel amplitudes to zero.
4. *Move here the selected channel:* Moves the previously selected channel to the current position.
5. *Kill above here:* Sets the channel widths to zero for all time values above the clicked point.
6. *Auto offset:* Automatically sets the channel offset.
7. *Set offset:* It allows the user to manually set the channel offset.
8. *Invert:* Reverse the channel.
9. *Time shift + of waveform:* Translates the signal by 1 ms, adding samples at the beginning of the recording.
10. *Time shift – of waveform:* Translates the signal by 1 ms, removing the first recording samples.
11. *Custom Time shift:* Opens a small popup where the shift value can be set. Positive or negative values, will indicate the direction of translation.

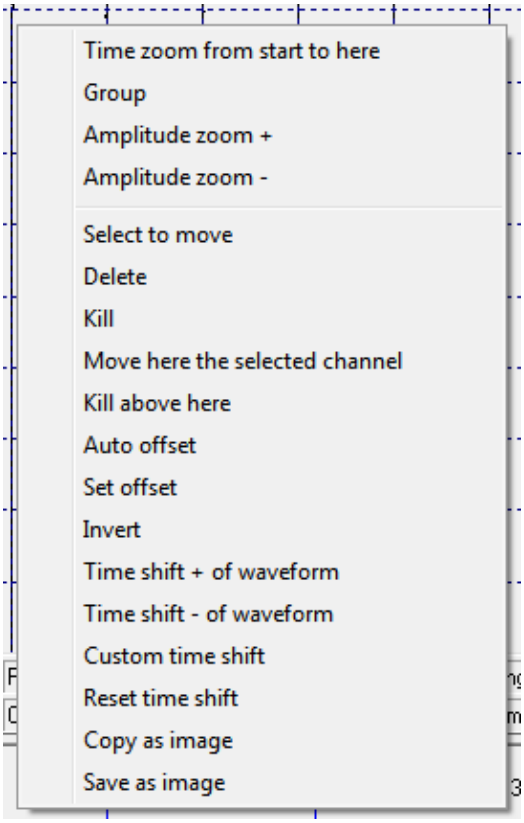


Illustration 2.2-5

12. *Reset time shift:* Undo changes made via the channel shifting options.
13. *Copy as image:* It allows to copy the image of the seismogram to the clipboard.
14. *Save as image:* It allows to save the seismogram image on file.

These functions can be used separately for each channel.

In the generic menu of the seismogram there are other functions that allows the user to better manage the processing.

Some of them are the same as those for the single channel and perform the same function, the difference is that in this case they no longer act on the single channel, but on all the channels of the seismogram. (Illustration 2.2-6)

In the main menu Illustration 2.2-6, in addition to the display functions, there are the tools:

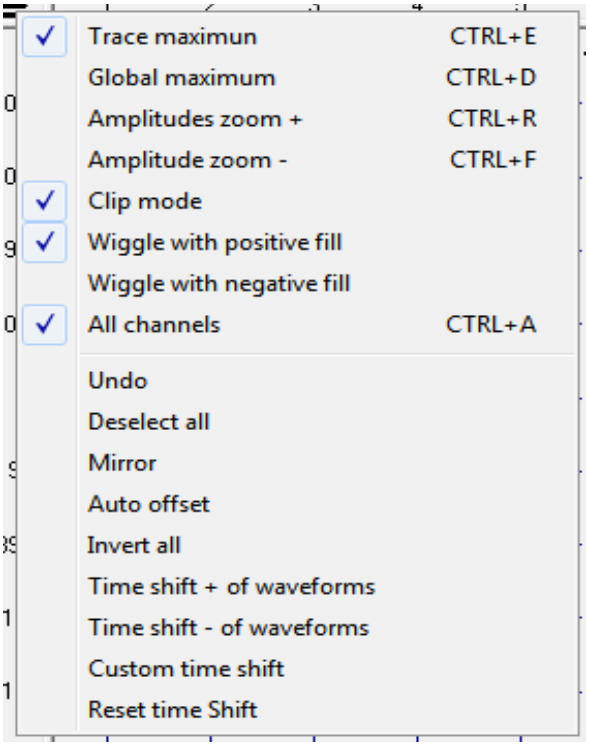


Illustration 2.2-6

1. *Undo:* Undoes the last operation performed on the seismogram.
2. *Deselect all:* Deselect any channels have been selected.
3. *Mirror:* It mirrors the seismogram by reversing the order in which the channels appear.
4. *Auto offset:* Automatically sets the offset of each channel.
5. *Invert all:* Reverses the signal polarity of each channel.
6. *Time shift + of waveform:* Translates the signal of each channel by 1 ms, adding samples at the beginning of the recording.
7. *Time shift – of waveform:* Translates the signal of each channel by 1 ms, removing the first recording samples.
8. *Custom time shift:* Opens a small popup where the shift value of each channel can be set. Positive or negative values, will indicate the direction of translation.
9. *Reset time shift:* Undo changes made via the channel shifting options.

The seismogram windows use the same display functions of the **GEOEXPLORER DoReMi** program, therefore we refer to the **GEOEXPLORER DoReMi** manual for their explanation.

Regarding the geometries, 3 different views are available:

1. **File Graph:** displays a 1d representation of the geometry of the selected file. Illustration 2.2-7

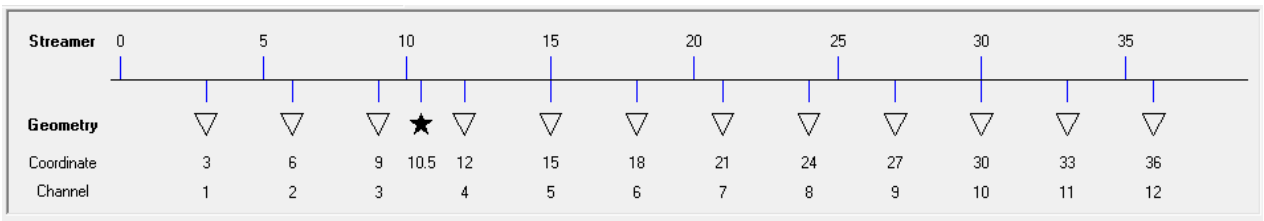


Illustration 2.2-7

2. **Overall Graph:** displays a 1d representation of the overall geometry. Illustration 2.2-8

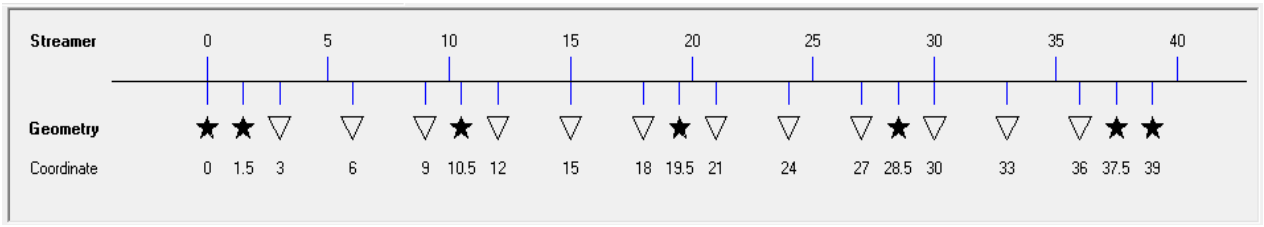
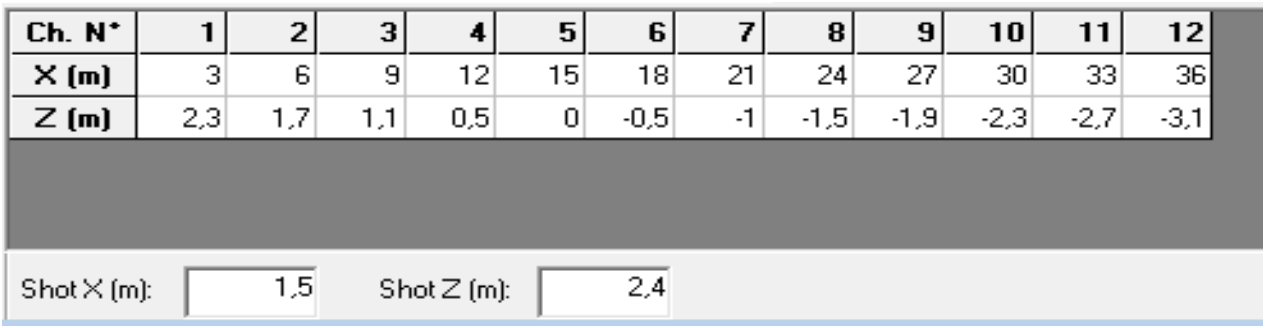


Illustration 2.2-8

3. **File Table:** displays the geometry of the selected file in tabular form. From this view it is possible to modify the values of the X and Z positions of the geophones, by double clicking on the corresponding cell. it is also possible to change the coordinates of the shot using the appropriate text fields. Illustration 2.2-9



Ch. N°	1	2	3	4	5	6	7	8	9	10	11	12
X (m)	3	6	9	12	15	18	21	24	27	30	33	36
Z (m)	2,3	1,7	1,1	0,5	0	-0,5	-1	-1,5	-1,9	-2,3	-2,7	-3,1

Shot X (m): 1,5 Shot Z (m): 2,4

Illustration 2.2-9

There are 3 buttons:

1. *Set Geometry:* Opens the geometry setup pop-upIllustration 2.2-4
2. *Export Geometry:* Exports geometry in csv format
3. *Import Geometry:* Imports geometry in csv format

Note: importing the geometry only modifies the depths (z) taking the Xs as a reference. For each pair X, Z reported in the csv file, all geophones at position X will be searched in each file and their Z dimension will be updated.

Once completed the dataset configuration, click on *Check* button. By clicking on it, checks will be carried out on the dataset and, if successful, the next tab will be displayed.

If there are more shot enabled with the same properties the software will automatically stack the seismograms.

2.2.2 *Pre Processing*

In this tab it is possible, using appropriate tools, to process the dataset in order to highlight the features useful for identifying the first arrivals.

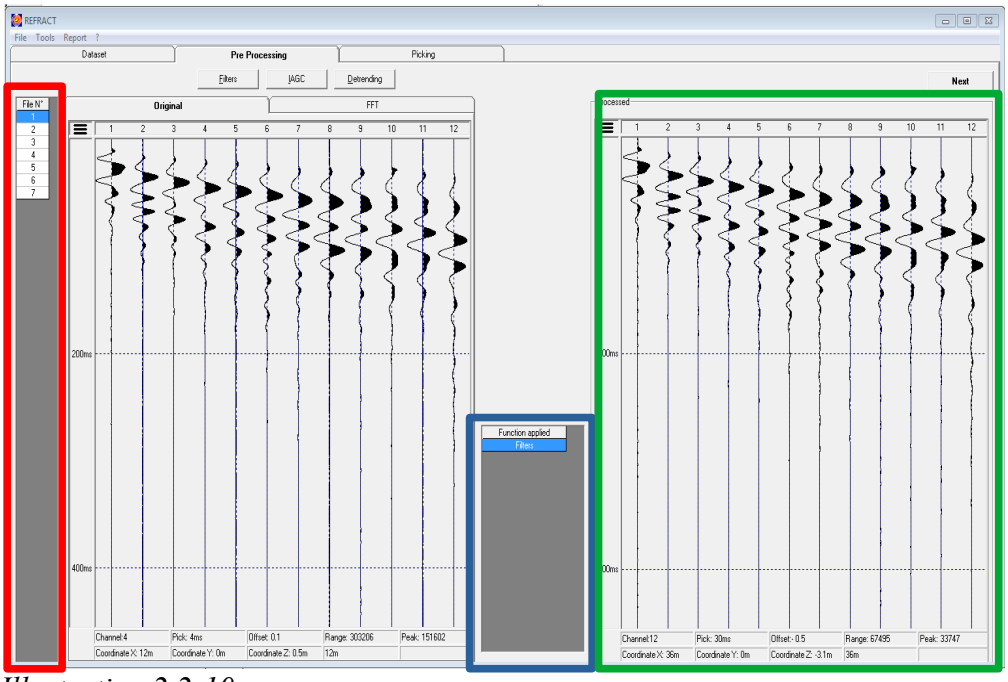


Illustration 2.2-10

The window (Illustration 2.2-10) is arranged as follows, from left to right, there is the table through which it is possible to select the file to work on (red box), the original seismogram, alternating with the FFT display (Illustration 2.2-18), the list of functions applied in the lower center (blue box), and the processed seismogram (green box), that is the one resulting from the application of the various picking functions.

The context menus on both seismograms contain the classic display settings, as well as the ability to copy the image to the clipboard and save it to file, also available on the FFT graph.

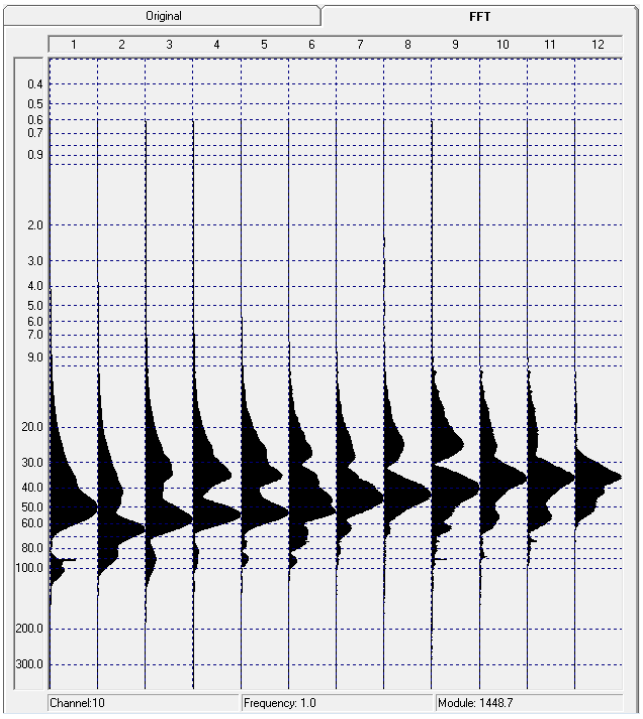


Illustration 2.2-11

Three tools are made available to the user to process the data:

1. *Filters:* There are 2 different filters available, Zero Phase and Non Zero Phase, with Low Pass and High Pass modality. Each of them can be activated through the relative checkbox. Furthermore, for the Low Pass and High Pass filters, it is possible to set frequency and order. By combining both filters it is possible to generate a passband. More info ar the chapter 4.2 Filters pag. 40. (Illustration 2.2-12)

   Illustration 2.2-13 shows both the original data (left) and the filtered one (right).

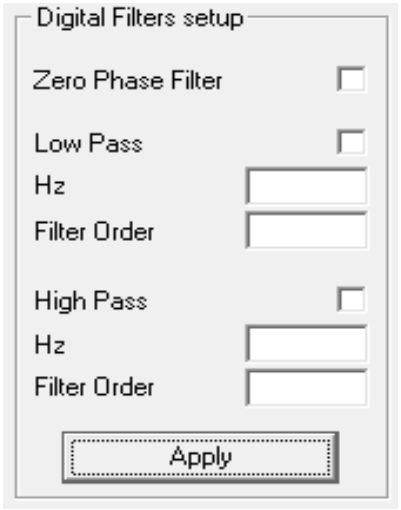


Illustration 2.2-12

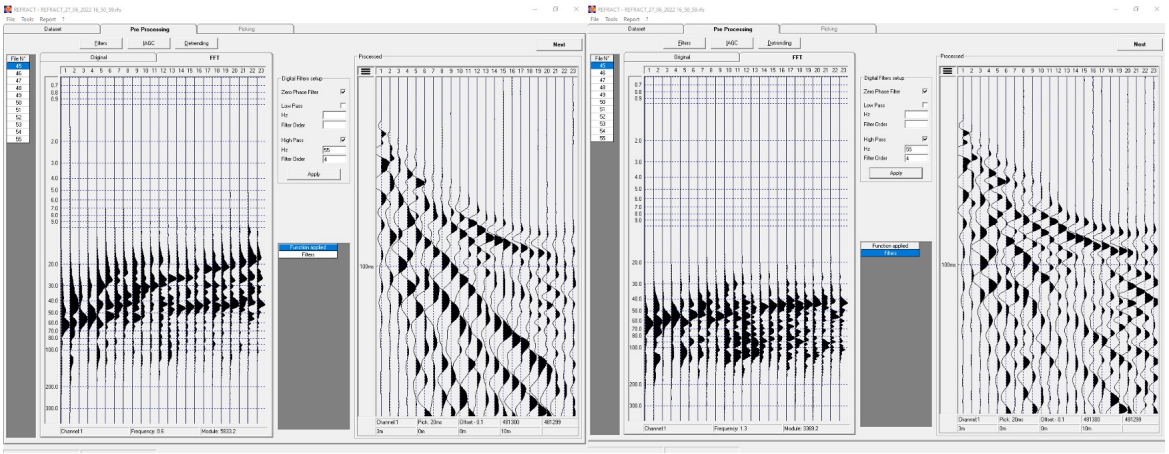


Illustration 2.2-13

2. *IAGC:* the time window can be set in milliseconds before applying the function. Illustration 2.2-14 For the definition refer to chapter 4.3 I.A.G.C. (Instantaneous Automatic Gain Control) pag. 42.

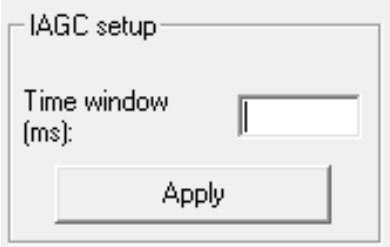


Illustration 2.2-14

Illustration 2.2-15 shows an example of IAGC application.

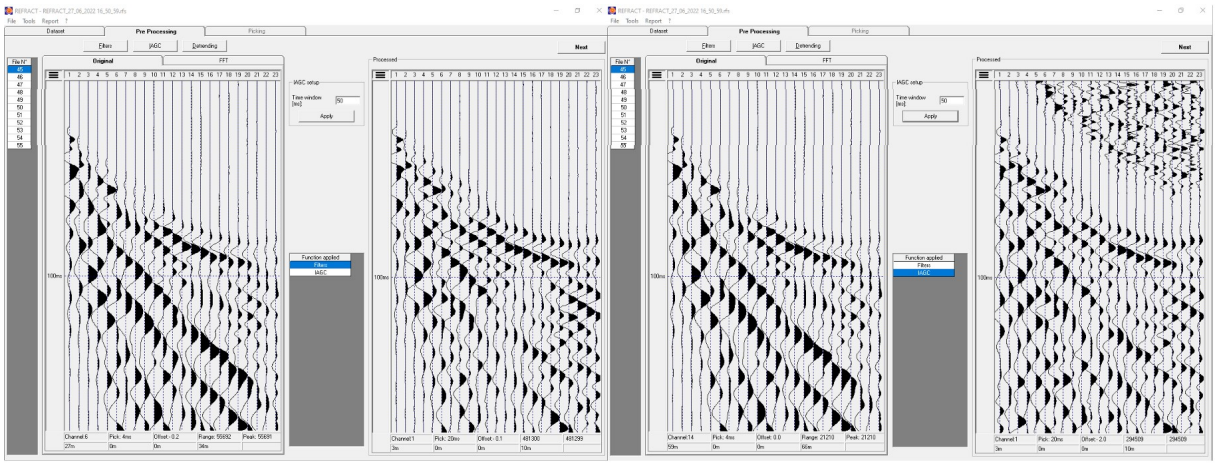


Illustration 2.2-15

3. *Detrending:* This tool allows the user to eliminate the trends present within the data. It can be chosen the degree of the polynomial that will be calculated. Illustration 2.2-16

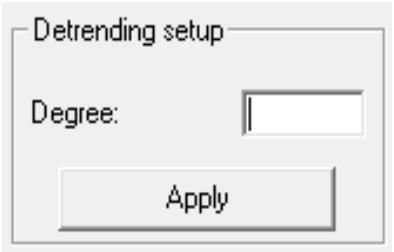


Illustration 2.2-16

The *Tools → Pre Processing,* menu contains useful features for interacting with this section of the program. Please refer to section 2.1 Menu bar.

Once the dataset is ready just click on the *Next* button which will enable the *Picking* tab.

2.2.3 *Picking*

In this tab is possible to perform the first break picking on the various seismograms. On the basis of the picking carried out, it is possible to pick the intercepts.

The pickings of the current file are shown in red. If the *Show all picks* checkbox is enabled, the lines representing the picking carried out on the other files are represented on the seismogram. Other files can be selected from the table on the left. he colors serve only to distinguish them from each other.

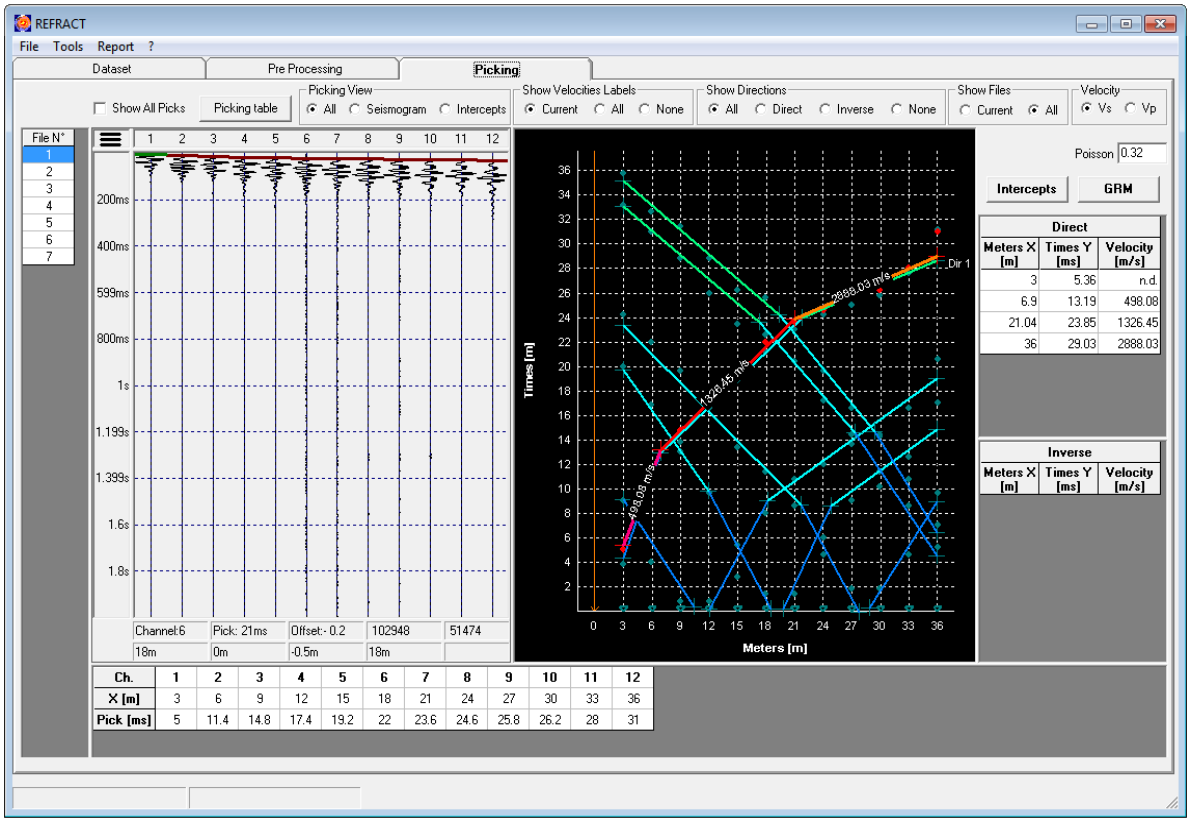


Illustration 2.2-17

With the ticks within *Picking View*, the user can choose whether to show both the seismogram and the intercept graph or only one of the two. If it is chosen to show only one, it will occupy the entire area originally occupied by the two graphs.

With the ticks inside *Show velocities labels* it is possible to choose whether to show the labels with the speed on the intercepts; The choice is between Current File, All and None. In *Show directions* it is possible to choose whether to show only the direct intercepts or the inverse ones or both. By means of the ticks in *Show Files* it is possible to choose whether to display only the intercepts of the current file (in red tones) or also those of the other files (in blue tones).

In *Velocity* it is possible to define the type of wave being analyzed, depending on whether the acquisition was made in P waves or in S waves. Through the *Poisson* TextBox it is possible to manually set the poisson value for the acquisition, which it will then be used for some calculations.

The seismogram (Illustration 2.2-17) has the same display functions present within **GEOEXPLORER DoReMi**.

To perform the picking hold the *SHIFT* key and click with the left mouse button on the point of the first arrival. Holding the left mouse button and the *SHIFT* key, it is possible to pick the other channels by dragging the cursor along the seismogram.

It is possible to browse the seismogram using the keyboard. By *Left* and *Right arrows* the channels will be selected. (the currently selected channel is highlighted by a different line color). *Up* and *Down* arrows move the picking op or down 1 sample at a time. *Pag Up* and *Pag Down* keys move the picking op or down 1 millisecond at a time. *Home* and *End* keys move the picking at the beginning or at the end of the window.

The context menu, accessible with a right click of the mouse on the seismogram, has some functions inside it, in addition to the display functions.(Illustration 2.2-18)

In addition to the Pick function that allows the user to pick on the channel, the seismogram can be saved, or copied to the clipboard as an image

In the generic menu of the seismogram there are only the standard display functions.

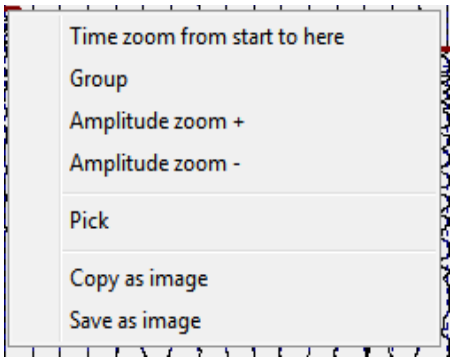


Illustration 2.2-18

On the right pane it is possible to perform the intercepts picking (Illustration 2.2-17). To start picking just double click anywhere on the graph, by continuing to click on the graph in one direction or the other, new segments of the intercept will be generated. Moving to the right the user will get the picking of the direct, to the left that of the inverse. Only two picking segments are allowed on the same file, the direct and the inverse one. The program will make all necessary checks. By clicking outside the spreading, or by clicking with the right mouse button, it is possible to interrupt the picking of the intercepts.

Picking can only be carried out within the seismic line, between the first and last geophone. The program will autonomously move the picking extremes that fall outside the line, keeping the speed consistent.

The table in the lower part of the window (Illustration 2.2-19) shows the picking of the various channels of the selected file, also showing their horizontal geometry. It is possible to manually edit the picking value, by double clicking on the desired cell.

The picked values will be shown in the tables on the right (Illustration 2.2-20), the direct above and the inverse below. By double clicking on the distance or time cells it is possible to edit the values. After the manual modification the speed values will be recalculated and the drawing will be updated.

Ch.	1	2	3	4	5	6	7	8	9	10	11	12
X [m]	3	6	9	12	15	18	21	24	27	30	33	36
Pick [ms]	5	11.4	14.8	17.4	19.2	22	23.6	24.6	25.8	26.2	28	31

Illustration 2.2-19

By right-clicking on any of the tables containing relevant data, a popup appears, through which the table can be exported as a csv, or as an image, to file or to the clipboard. (Illustration 4.5-2)

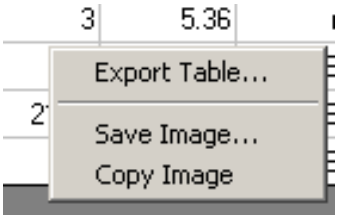


Illustration 2.2-21

Direct		
Meters X [m]	Times Y [ms]	Velocity [m/s]
12.01	0.17	n.d.
18.16	9.06	691.79
36	19.05	1785.79

Inverse		
Meters X [m]	Times Y [ms]	Velocity [m/s]
10.47	0.35	n.d.
3	9.11	852.74

Illustration 2.2-20

By right clicking on the vertical scale of the intercept graph, a contextual menu will be shown with the following options (Illustration 2.2-22)

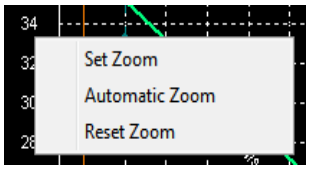


Illustration 2.2-22

- *Set Zoom*: sets the zoom taking as a reference for the maximum value the value which have been clicked.
- *Automatic Zoom*: Sets the zoom automatically based on the displayed intercepts.
- *Reset Zoom*: set the zoom to the default value.

Right clicking on a vertex of the intercept line will show a context menu with the following options (Illustration 2.2-23)

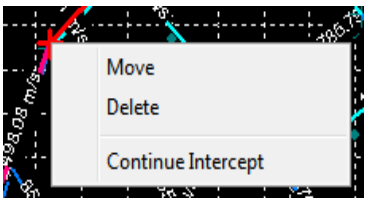


Illustration 2.2-23

- *Move*: It allows the user to reposition the vertex on the graph by clicking on another point on the graph.
- *Delete*: Removes the selected point.
- *Continue Intercept*: It allows the picking of intercepts to be resumed from the last point positioned.

Right clicking along the intercept line will show a context menu with the following options (Illustration 2.3-6)

- *Set Layer*: Opens a pop-up that allows you to set the layer value of the first intercept segment (Illustration 2.2-25) .
- *Add Point*: Allows the user to position a new point, breaking the segment that was clicked.
- *Continue Intercept*: It allows picking to be resumed from the last point entered.
- *Delete Intercept*: Deletes the selected intercept.

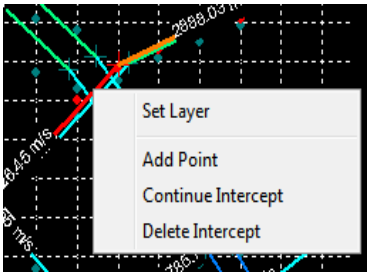


Illustration 2.2-24

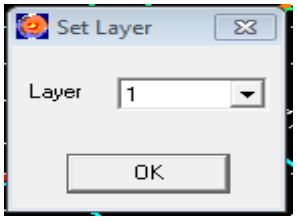


Illustration 2.2-25

It is also possible to manually edit the intercepts picking values (meters and times) double clicking on the relative cell in the *Direct* or *Inverse* tables which are placed on the right of the window.

Clicking on the P*icking table* button a table is shown showing all the picking carried out, on each burst. The table ca be exported by right clicking on it (Illustration 2.2-26)

Complete picking table

Shot/ Geophones	S1	S2	S3	S4	S5	S6	S7
3 m	5 ms	3,8 ms	9 ms	20 ms	24,2 ms	33,2 ms	35,8 ms
6 m	11,4 ms	10,8 ms	4 ms	16,8 ms	22 ms	31 ms	32,6 ms
9 m	14,8 ms	13,8 ms	0,8 ms	13 ms	19,6 ms	28,8 ms	31,4 ms
12 m	17,4 ms	16,8 ms	0,8 ms	9,6 ms	16,6 ms	26 ms	28,8 ms
15 m	19,2 ms	18,8 ms	2,8 ms	5,4 ms	13,4 ms	23,4 ms	26,2 ms
18 m	22 ms	21,2 ms	8 ms	1,4 ms	11,4 ms	22,6 ms	25,6 ms
21 m	23,6 ms	23 ms	10,8 ms	1,4 ms	8,6 ms	20,4 ms	23 ms
24 m	24,6 ms	24,2 ms	12 ms	6 ms	4,6 ms	17,2 ms	19,6 ms
27 m	25,8 ms	25 ms	13,6 ms	9 ms	1,8 ms	14,4 ms	16,6 ms
30 m	26,2 ms	25,8 ms	14,4 ms	10,2 ms	1,8 ms	11,4 ms	14,2 ms
33 m	28 ms	27,6 ms	16,6 ms	12,6 ms	4,6 ms	8,6 ms	10,8 ms
36 m	31 ms	31,2 ms	20,6 ms	17 ms	9,6 ms	5,2 ms	7 ms

Illustration 2.2-26

By clicking on the *Intercepts* button, a new form will be opened, in which it is possible to view the result of data processing using the intercept method.

By clicking on the *GRM* button, a new form is opened, in which it is possible to prepare the data for the calculation of the stratigraphy using the GRM method.

2.3 *Intercept*

This form displays the stratigraphy calculated using the intercept method. (Illustration 2.3-1) In the table on the left it is possible to choose the file whose stratigraphy is wanted to be displayed.

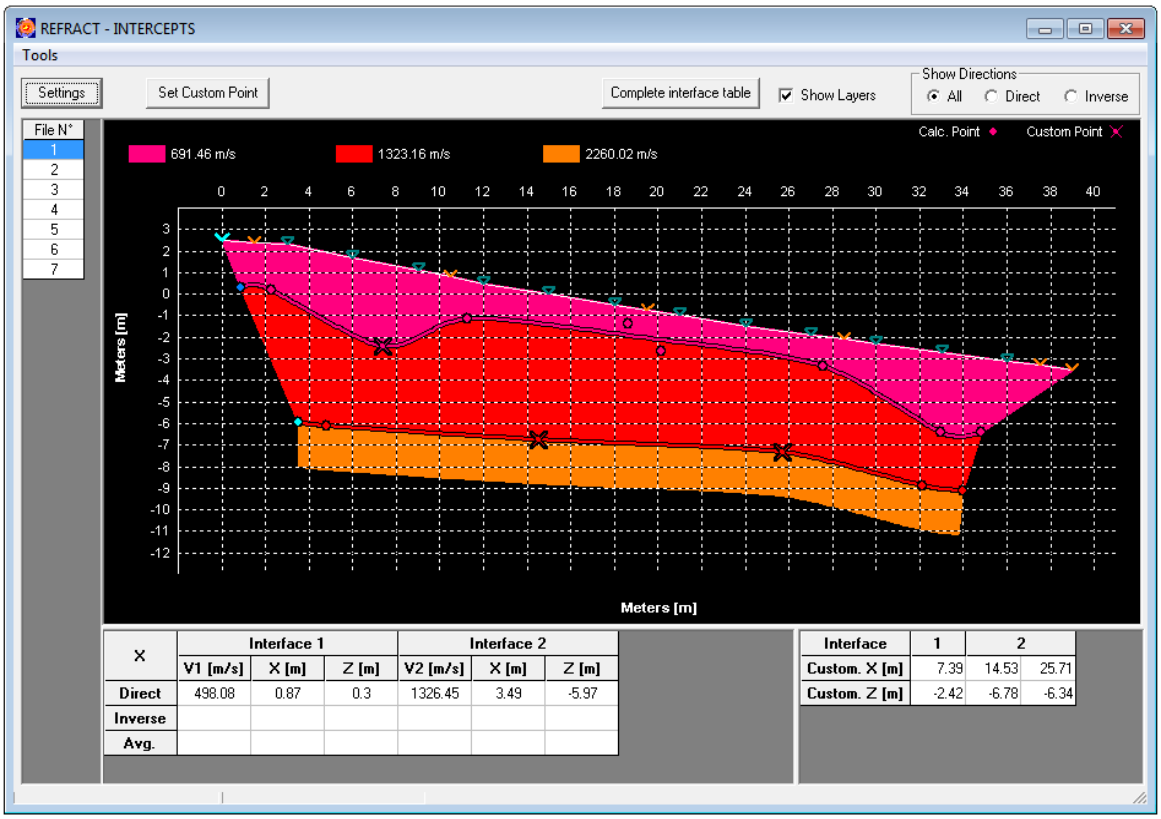


Illustration 2.3-1

It is possible to enable or disable the display of the layers through the *Show Layers* flag. If *Show Layers* is disabled, only the points calculated using the intercept method will be displayed in the graph. (Illustration 2.3-5)

Using the *Show directions* options it is possible to choose whether to display the complete stratigraphy, or the one resulting only from direct or inverse intercepts.

The table at the bottom left for each interface shows the values of the intercepts used for the calculation of the stratigraphy.

By clicking on the *Set custom point* button, a pop-up will be shown through which it is possible to manually set known points by defining their distance, depth and interface. (Illustration 2.3-2)

The coordinates of the custom points will be shown in the table at the bottom right. The custom points are also drawn differently on the stratigraphy graph in order to make them easily distinguishable. (Illustration 2.3-1)

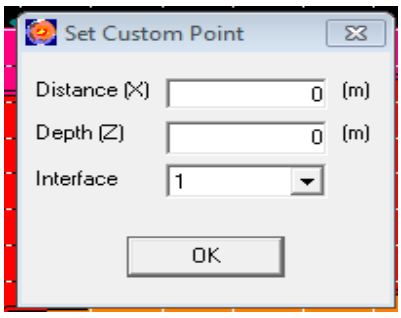


Illustration 2.3-2

It is also possible to insert a custom point by right-clicking on the desired interface line, and select the *Set custom point* option from the drop-down menu. In this case it will be possible to insert the point directly on the graph by clicking on the desired point. (Illustration 2.3-3)

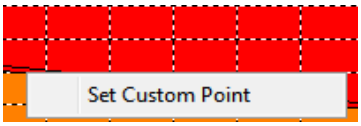


Illustration 2.3-3

By right clicking on a custom point, a contextual menu is shown from which the user can choose whether to delete the point, or modify it. (Illustration 2.3-4) If the user choose to edit the point, the same pop-up used for the insertion will be shown (Illustration 2.3-2).

Illustration 2.3-4

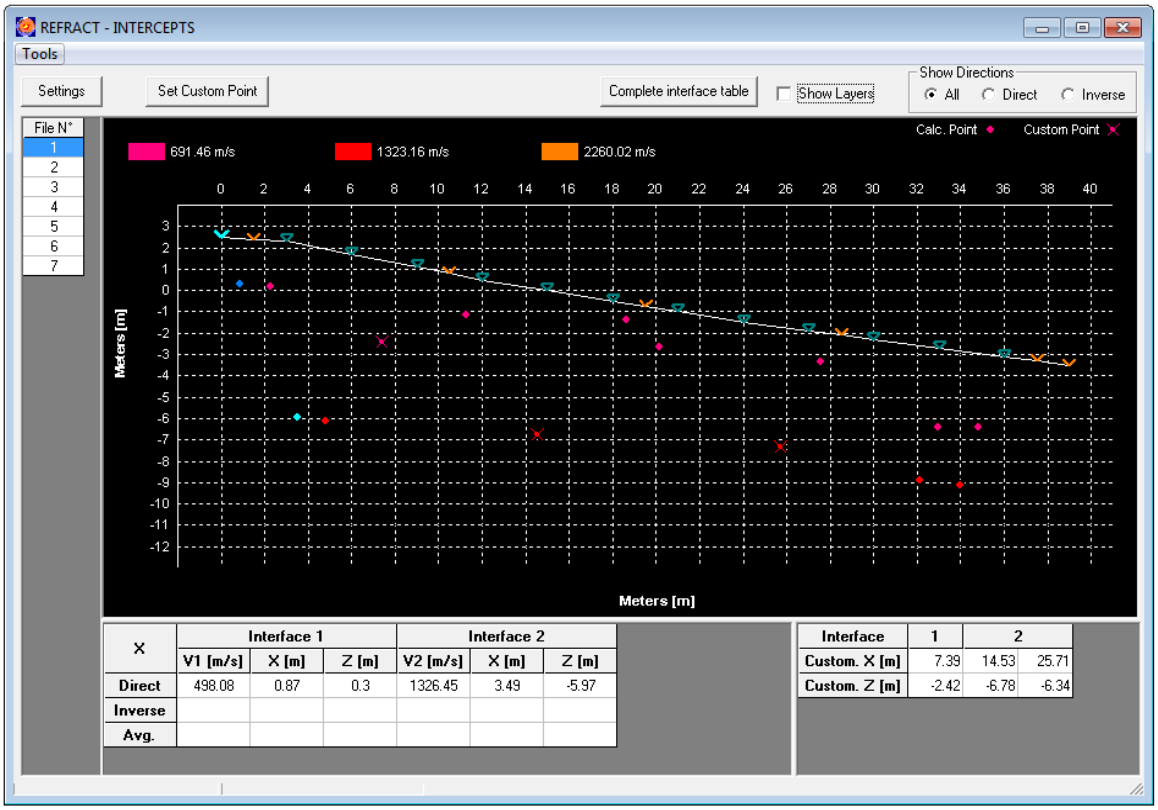


Illustration 2.3-5

By right clicking on the graph, a context menu will appear (Illustration 2.3-6), through which the graph can be copied to the clipboard or saved as a file. Furthermore, through the Export 1d Stratigraphy option it is possible to export the 1d stratigraphy of a selected point. To save the stratigraphy, just click on the desired point, for this purpose an orange vertical line will appear (Illustration 2.3-7), which will help the user in selecting the point from which to extract the stratigraphy. To stop the operation, right-click on the graph with the mouse.

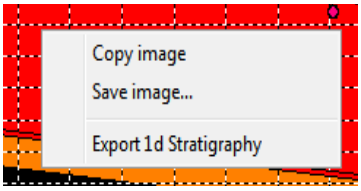


Illustration 2.3-6

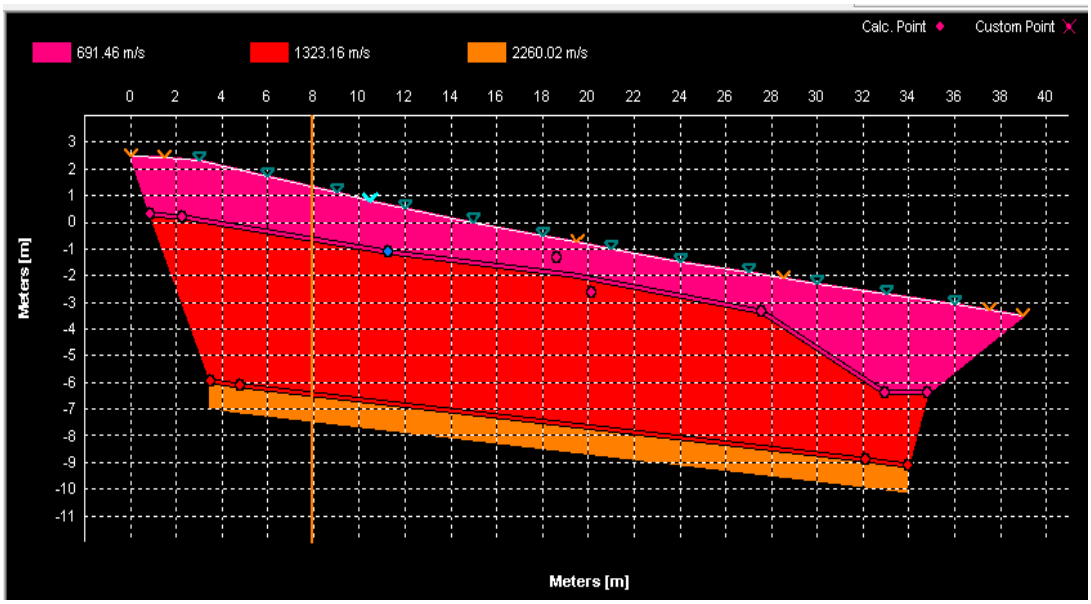
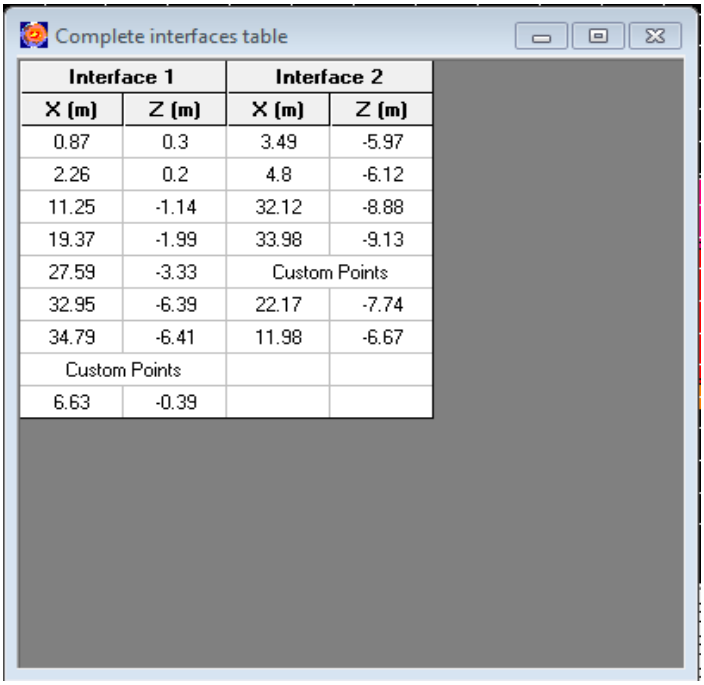


Illustration 2.3-7

Clicking the *Complete interface table* button shows a table showing all the calculated points, and the custom points grouped by interface. The table can be exported by right clicking on it (Illustration 2.3-8).



Interface 1		Interface 2	
X (m)	Z (m)	X (m)	Z (m)
0.87	0.3	3.49	-5.97
2.26	0.2	4.8	-6.12
11.25	-1.14	32.12	-8.88
19.37	-1.99	33.98	-9.13
27.59	-3.33	Custom Points	
32.95	-6.39	22.17	-7.74
34.79	-6.41	11.98	-6.67
Custom Points			
6.63	-0.39		

Illustration 2.3-8

2.4 *GRM*

The GRM analysis preparation window consists of two tabs, *Selection* and *Analysis.*

2.4.1 *Selection*

The Selection tab (*Illustration 2.4-1*) allows the user to select the data to be used for processing. In particular, for each refractor, it is possible to compare the available data and select which pairs of files to use.

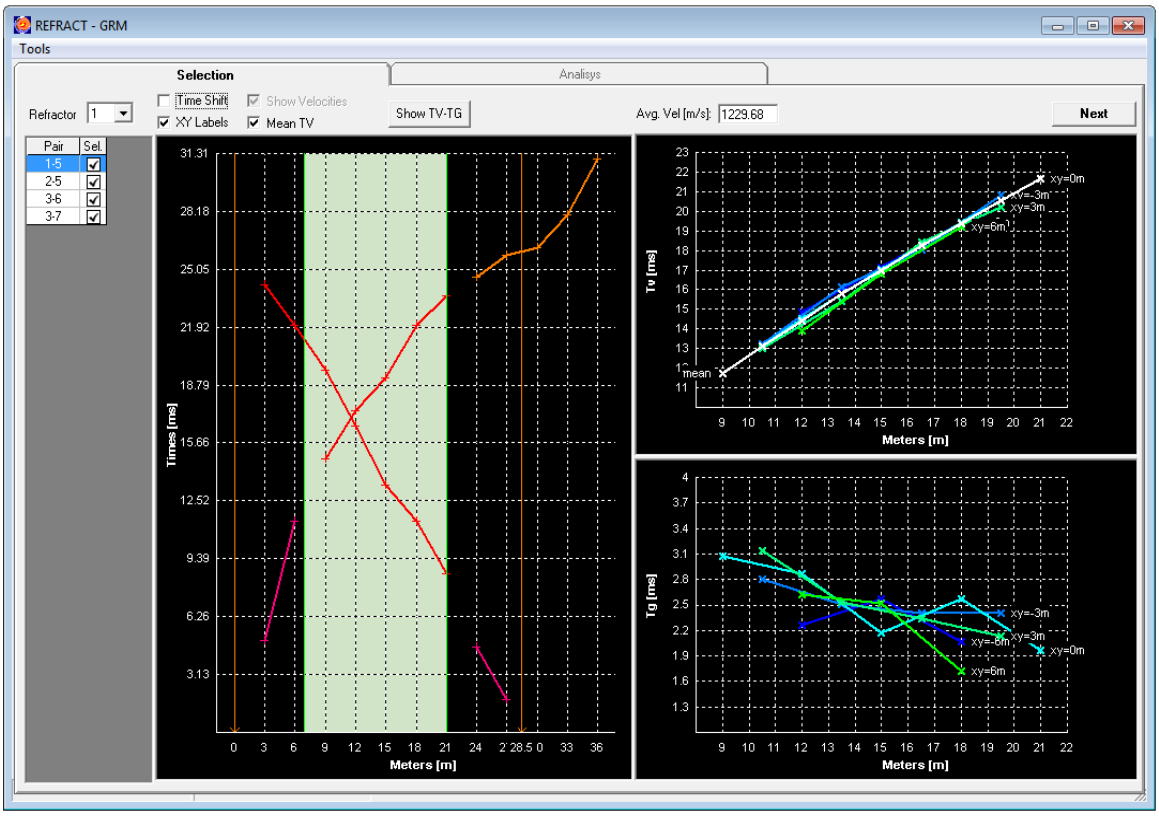


Illustration 2.4-1

Using the combo box at the top left it is possible to select the refractor that is wanted to work on. The table on the left shows the list of the pairs generated by the software. By clicking on a row of the table it is possible to view the graphs of the overlaps (on the left), of the TV and of the Tg, for the selected pair. By clicking on the checkbox next to the file name it is possible to select / deselect the pair. By right clicking on the pairs table, a contextual menu will be shown through which it is possible to enable / disable all the pairs.

The pairs are generated by comparing the files two by two, looking for overlaps between the direct picking of one and the reverse picking of the other. The software verifies that the number of geophones included in the intercept overlap is greater than the *Min Delta Points* value set in the program settings. (Chapter 2.1)

In the graph on the left the overlaps of the intercepts are graphically represented, highlighted

with a vertical green band.

The graphs on the right (*Illustration 2.4-1*) show the trends of the Tv (above) and Tg (below) curves. For each pair, N different colored curves are shown, each for a different XY value. The XY value represents the distance between the geophones used to calculate the Tv and Tg values.

It is possible, through the 4 checkboxes at the top left, to change the display as needed.

- ***Time Shift***: enables / disables the time shift, which can be set in the program settings, which translates the various curves vertically in order to be able to distinguish them more easily. There is no vertical scale in this view. (*Illustration 2.4-2*)
- ***Show Velocities:*** enables / disables the display of the speeds calculated by the interpolation of the TV points.
- ***XY Labels***: shows / hides the XY labels.
- ***Mean TV***: shows / hides the mediated line of TVs.

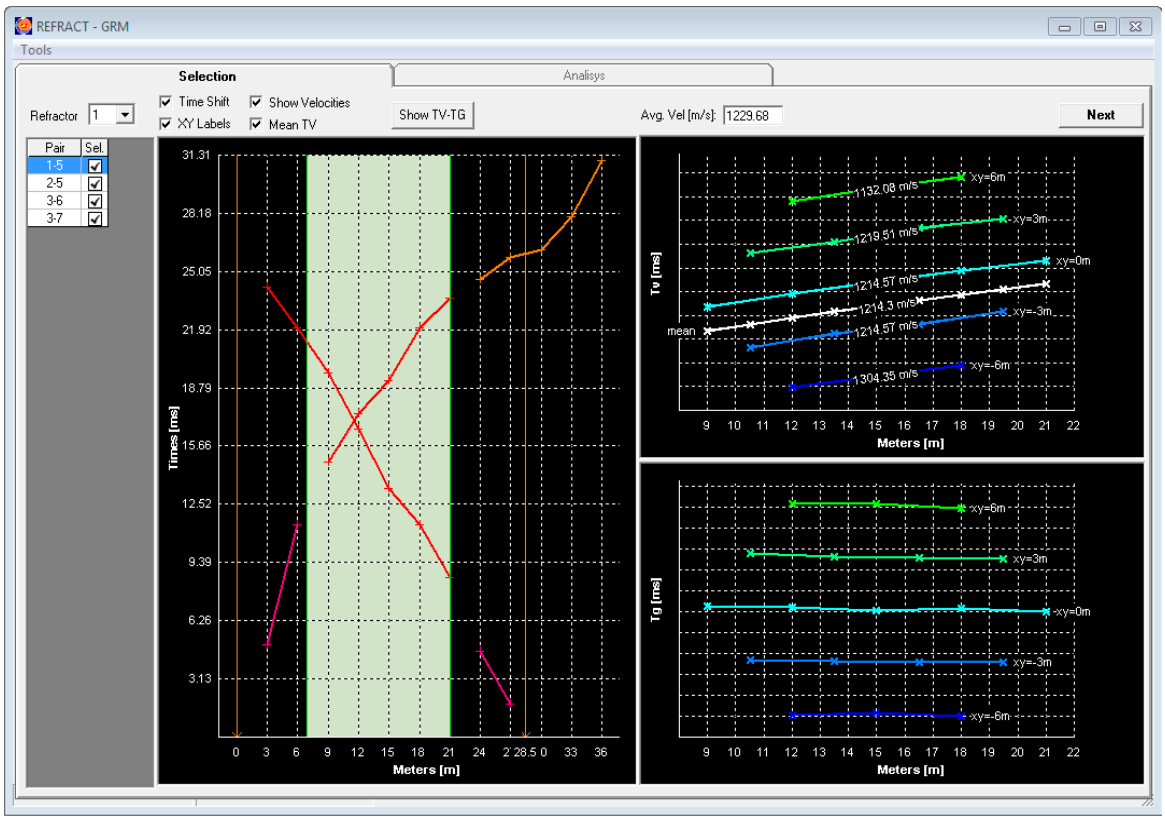


Illustration 2.4-2

The *Avg.Vel* text box shows the average speed of all TVs calculated on all selected files and on all XYs, in order to have a general indication of the speed of the selected refractor.

By clicking on the *Show TV-TG* button, a popup will be displayed showing the TV and TG graphs in tabular form. (*Illustration 2.4-3*)

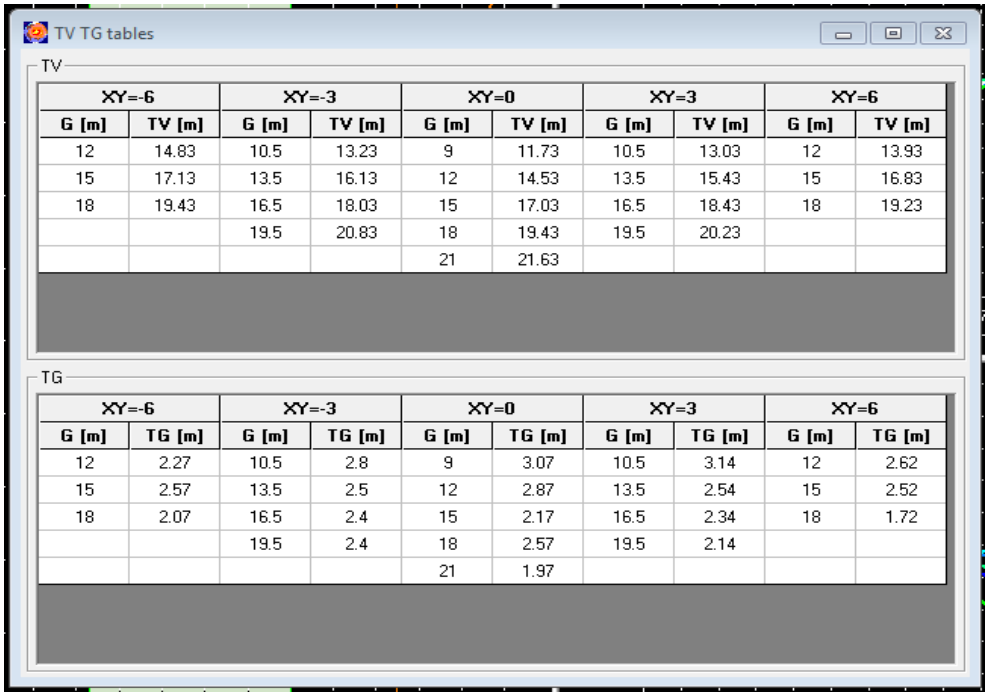


Illustration 2.4-3

Once the desired pairs have been selected for each refractor, it is possible to continue using the *Next* button which will enable the *Analysis* tab.

NB: if at least one pair has not been selected for each refractor, the following error will be shown: Illustration 3.1-1

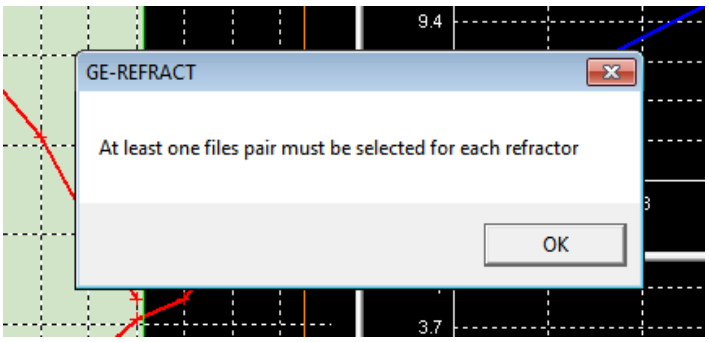


Illustration 2.4-4

2.4.2 *Analysis*

The *Analysis* tab is similar to the previous one, albeit with some substantial differences (*Illustration 2.4-5*). Passing from Selection to Analysis, all the pairs selected for each refractor are combined together, in order to obtain a single Tv graph and a single Tg graph.

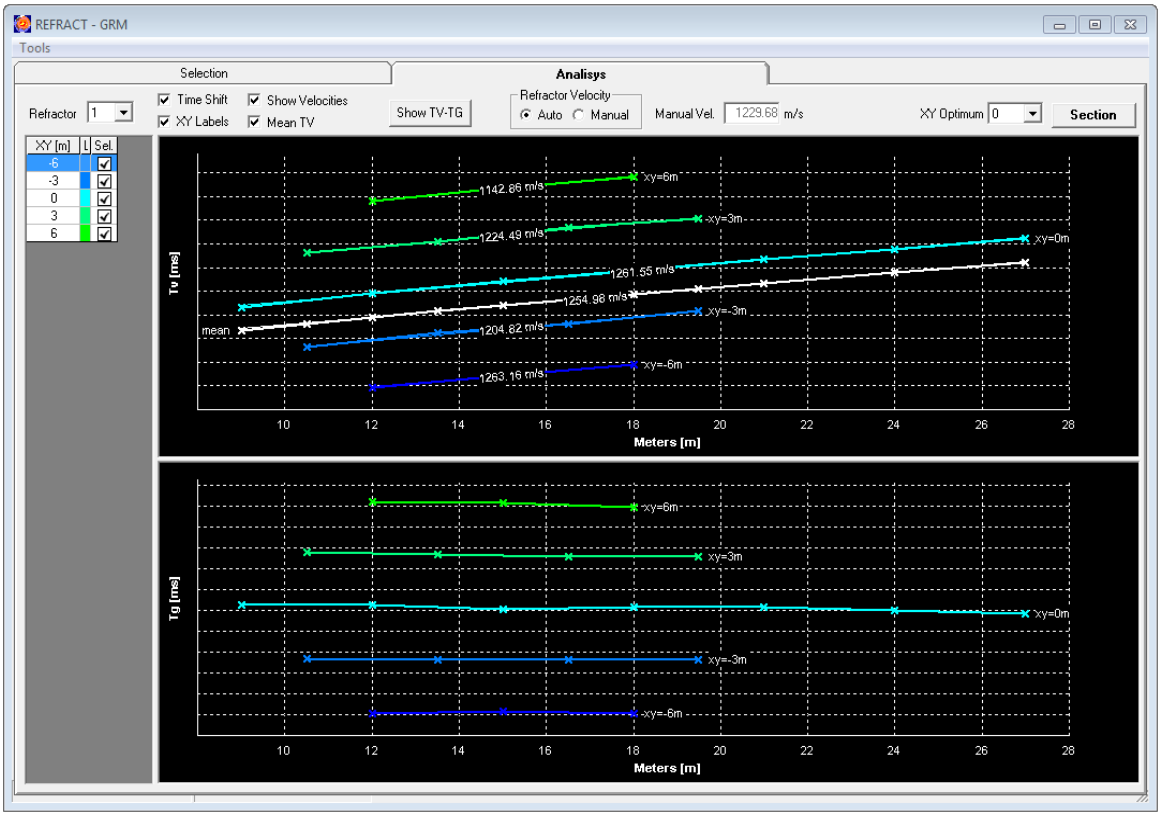


Illustration 2.4-5

The behavior of the combobox for the selection of the refractor and of the display checkboxes remains the same.

Using the table on the left, it is possible to choose whether to enable or disable the display in the graph of TV and TG calculated on a specific XY value.

By clicking on the *Show TV-TG* button, a popup will be displayed showing the TV and TG graphs in tabular form as already shown for the *Selection* tab. (*Illustration 2.4-6*)

Using the *Refractor Velocity* control, it can be chosen ***Auto*** to use the automatically calculated speed, or ***Manual***, to manually select a speed value using the text box to its right.

If the ***Manual Velocity*** option is enabled, it is possible to place a line on the graph that represents the set speed. By right-clicking on the TV graph and selecting the *Move manual velocity* drop-down menu option (*Illustration 2.4-6*), or by double clicking anywhere on the TV graph, the modification of the position of the manual speed line will be enabled, which can be positioned by left clicking on the mouse.

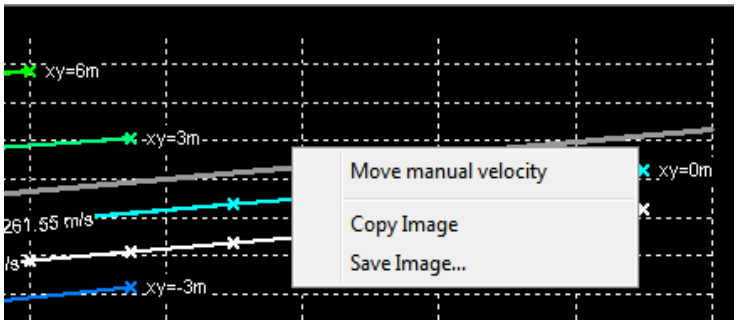


Illustration 2.4-6

Using the combobox at the top right, it is possible to select the XY *Optimum*, that is the XY it is wanted to use for the stratigraphy calculation. By default the value 0 is selected.

The choice of the XY must be made separately for each refractor.

By clicking on the *Section* button, the stratigraphy calculated using the GRM method will be shown in a new window.

2.4.3 GRM Section

The GRM stratigraphy is similar to that of the intercepts. (*Illustration 2.4-7*)

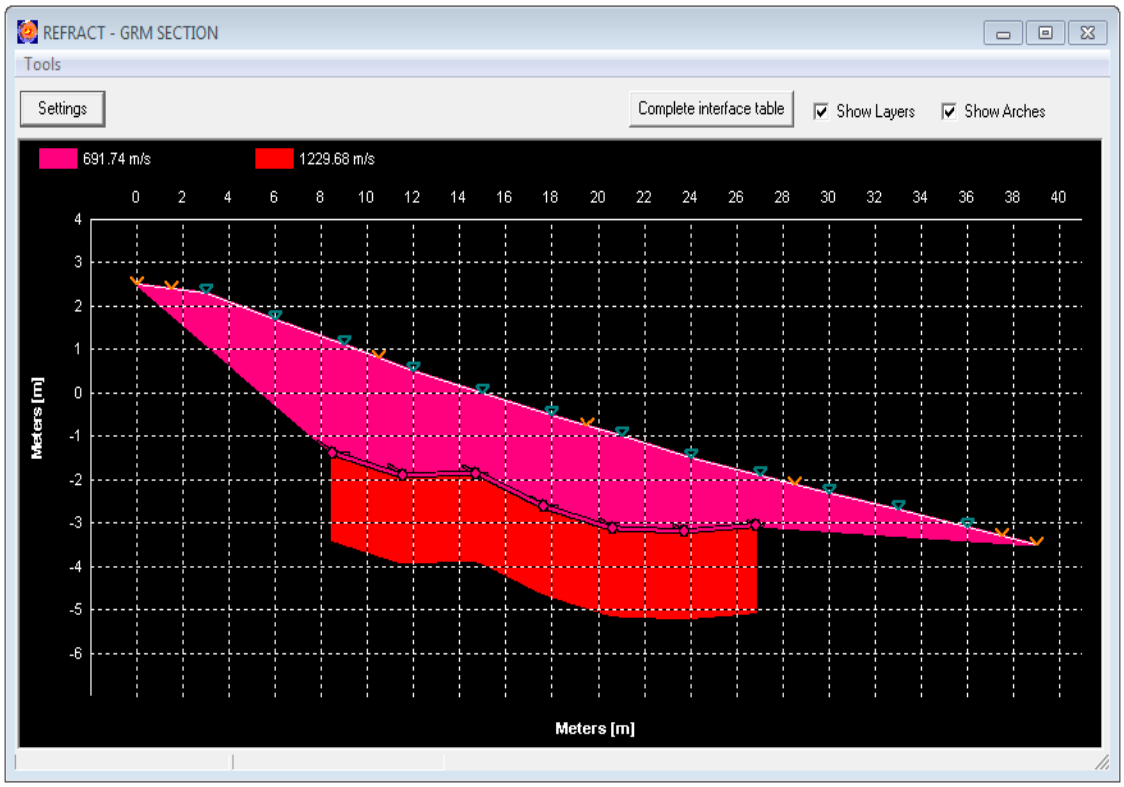


Illustration 2.4-7

Through the *Settings* button it is possible to quickly open the program settings, while, through the *Complete interface table* button it is possible to view the table with the depth points

calculated for each refractor. (*Illustration 2.4-8*)

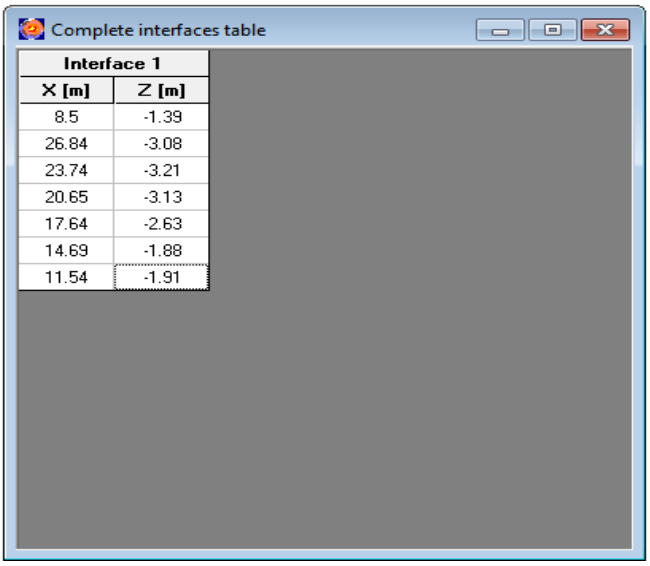


Illustration 2.4-8

Show Layers enable / disable the display of the fill and interface line of the layers.

Show Arches enables / disables the display of the arcs of the circles passing through the calculated points.

> *Note: Due to the differences between horizontal scale and vertical scale, the circles have an elliptical shape in the graph, but they are, theoretically, circles.*

By right clicking on the graph, a contextual menu appears (*Illustration 2.4-9*), from which it is possible, as for the intercepts, to copy the image, save it as a file, and extract the 1d stratigraphy in the selected point. As regards the latter option, refer to the explanation in Chapter *2.3* .

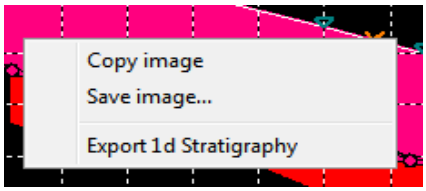


Illustration 2.4-9

3 Introduction to data acquisition

In refraction seismics, as well as in other geophysical techniques, it is very important to obtain high quality data from the field acquisitions to be subjected to the subsequent processing phase. Although this is not always possible due to the conditions of the site (small spaces, non-flat topographical surface, anthropogenic noise) or of the subsoil (very inclined contrasts, localized diffractors, surface aquifer, etc.), it is nevertheless necessary to know how to make the right choice on the type of sensors, type of source and length and sampling frequency to be used. For these and other reasons, prior to the actual investigation phase, it is essential to perform a noise-test useful to define the best parameters, geometries and sensors to be used for correct acquisition.

3.1 *Noise-Test*

The noise test, to which reference is made to the reference bibliography for a more complete discussion of the topic, can be performed with various methodologies. However, the fastest and most effective system consists in positioning the sensors (at least 12) with a very close spacing (about 1-2.0 m) and placing the source outside the spreading at a distance of half the intergeophonic distance (walkaway noise-test procedure). Once the first set of traces has been acquired, subsequent seismograms are acquired by moving the source gradually by a distance equal to the length of the string.

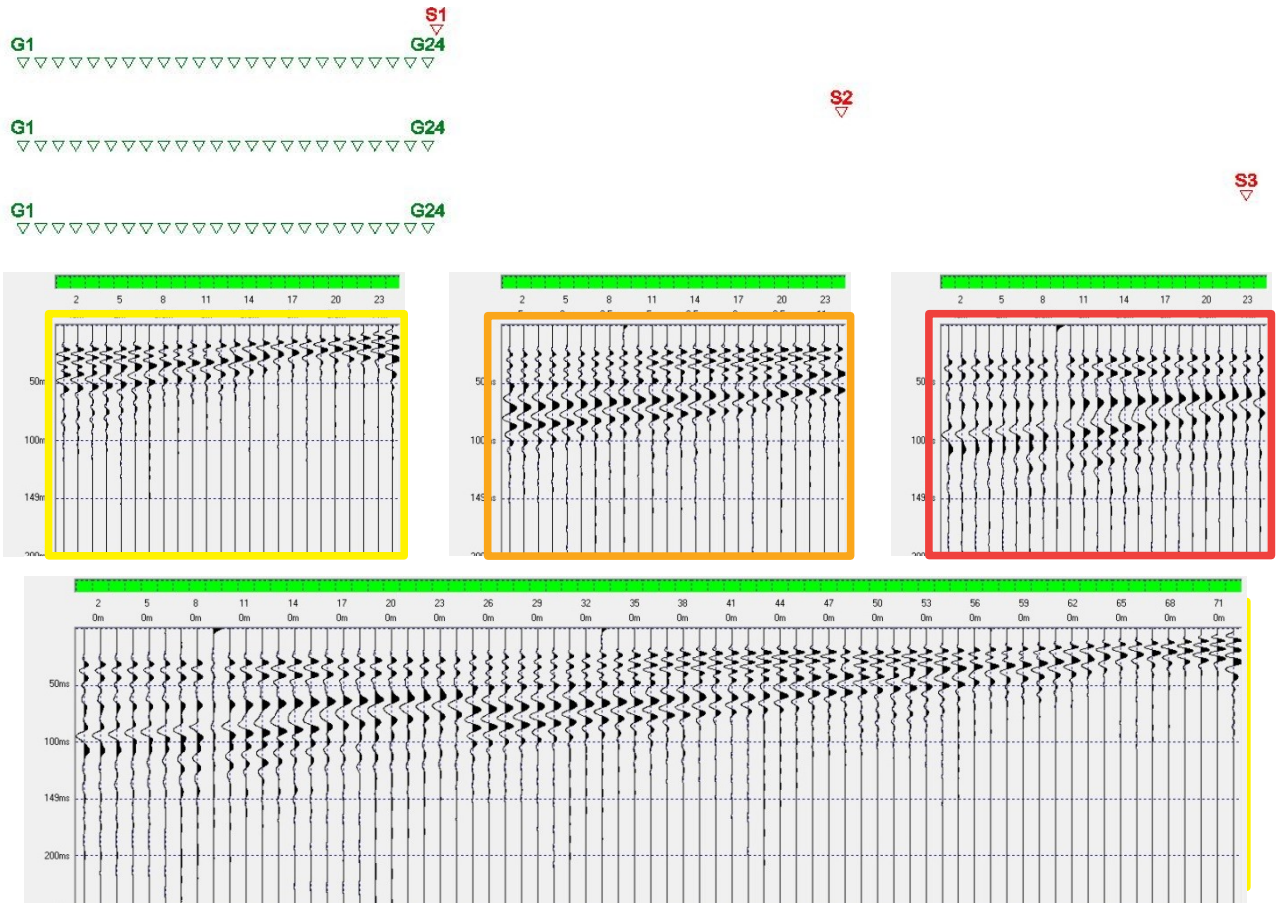


Illustration 3.1-1

The traces thus obtained can then be assembled in sequence to form a single seismogram on which to perform a rapid analysis of the noise and verify the presence of any problems. This operation must necessarily be repeated for the various types of sensors (P and SH) and for the types of sources available (hammer, mallet, seismic rifle, explosive, etc.). Finally, based on the purpose of the seismic research and the results of the noise-test, it is possible to define the correct geometry and survey parameters.

3.2 *Geometry and acquisition parameters*

Given that a standard geometry for refraction acquisitions does not exist, and that it is always advisable to prepare a noise test before each acquisition, it is however possible to follow a few basic rules to obtain excellent quality data.

Given the limitations in the depth of investigation that refraction has, we refer to the reference bibliography for further information, the acquisition process requires that the spacing between the geophones and the number of geophones to be used are well defined, in relation to the predetermined target in terms of depth to reach. Long stretches lead to investigated depths equal to 1/3 - 1/4 of the maximum offset used in the acquisition.

The number of shots performed allows for a robust definition of the morphological trend of the refractors having more information available for the various processing techniques. Also in this case there is no minimum value of shots for the intercepts, while at least a pair of reciprocal shots is needed for the GRM.

An indicative process for a correct acquisition is to perform a sufficient number of shots that can be used for the techniques managed by GE REFRACT, so that there is sufficient coverage both in terms of reciprocal pairs and in terms of maximum offset. The illustrations show some examples of acquisitions made.

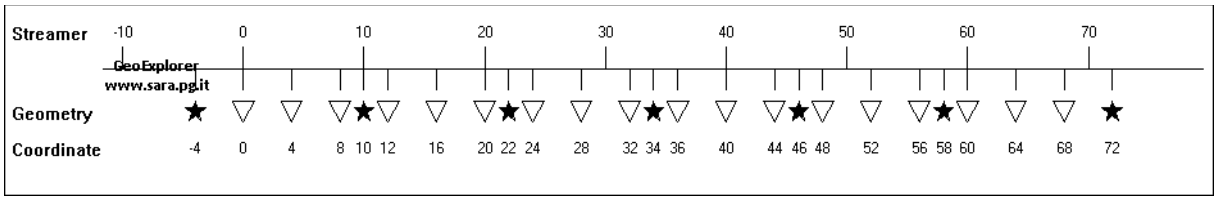


Illustration 3.2-1

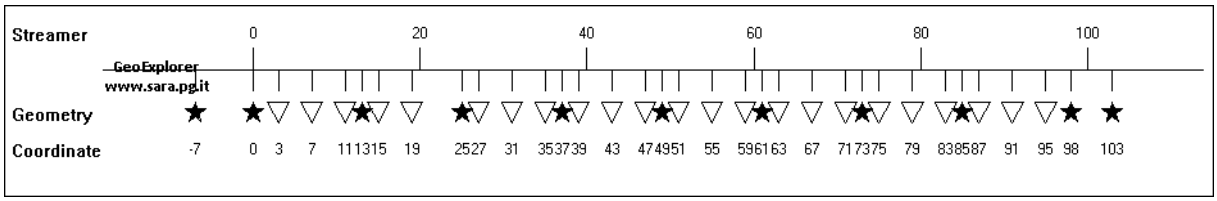


Illustration 3.2-2

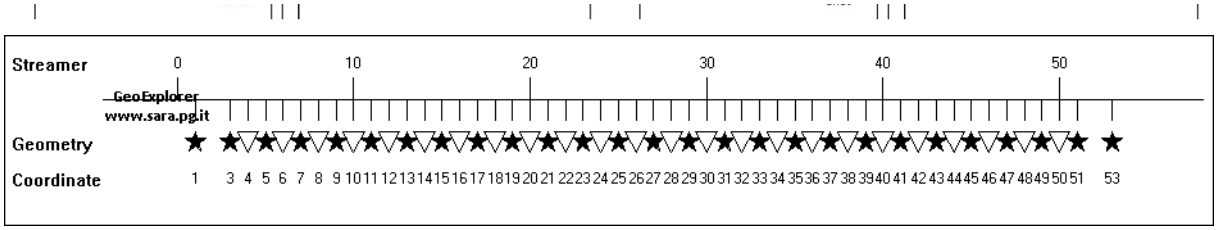
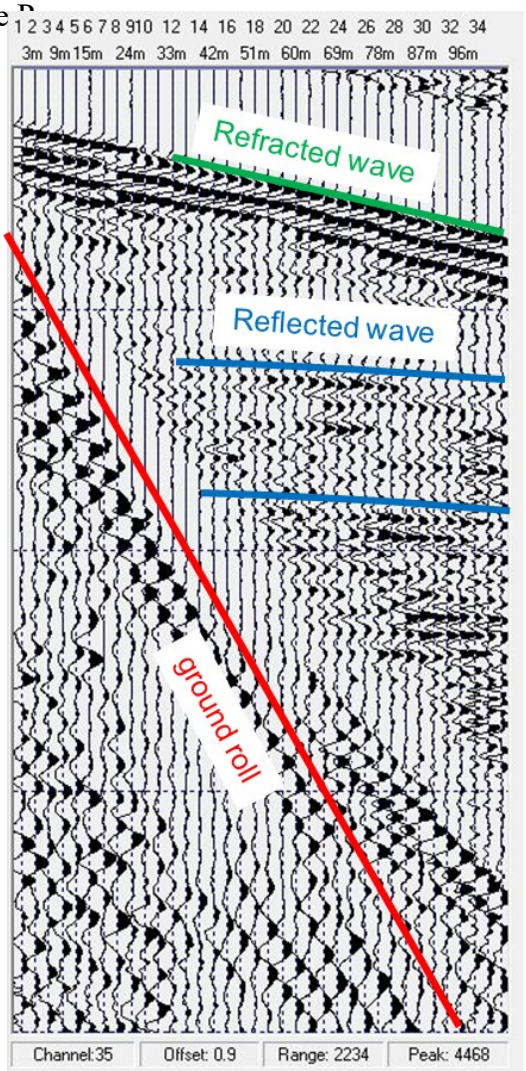


Illustration 3.2-3

According to the acquisition contexts and the geometries used, the recording length must be evaluated. In fast P wave contexts a shorter duration is required but a higher sampling since the picking is performed on the sample. In general we recommend a sampling of 5000Hz and a duration of 0.5s. With Sh waves, given their lower speed, the duration must be increased and sampling can be decreased. The noise test must always be performed in order to evaluate the correct configuration of the acquisition parameters.

With a view to mixed acquisition, therefore also performed for MASW and / or MARW, the recording length must be increased so that the development of the surface wave and possible reflections can be recorded. Please refer to the **GEOEXPLORER MARW** and **GEOEXPLORER MASW** manual for further details.

Onde P



Onde S

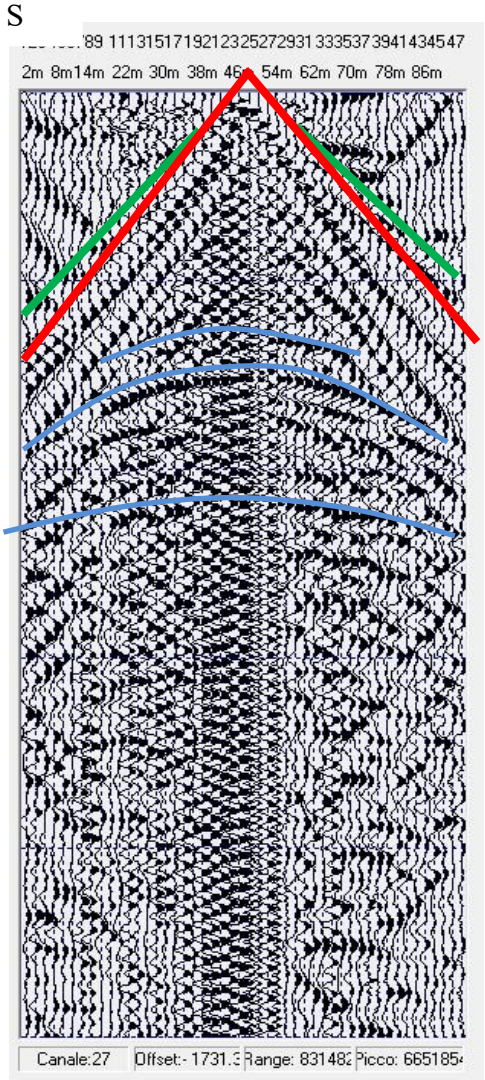


Illustration 3.2-6

It is possible, through the Walkaway virtualization technique, to double the number of geophones of the paving by joining two bursts with a common burst and adjacent ones. Refer to the GE DoReMi manual for more details.

3.3 *Seismic sources*

The seismic sources to be used during the test must have adequate energy capacity, in relation to the maximum offset that is expected to be used in the test. They must also produce elastic waves with a wide range in frequency and have low noise.

	sorgenti di superficie	sorgenti in foro
onde P	esplosivo, mazza, massa cadente, ecc.	esplosivo cannone ad aria, sparker, martello, ecc.
onde SH	martello su tavola, cannone per SH, vibratore orizzontale, ecc.	martello ad azione orizzontale vibratore
onde SV	mazza massa cadente	esplosivo, cannone ad aria, sparker, martello, vibratore, ecc.

Illustration 3.3-1

3.4 *Sensor*

As previously indicated, refractive seismic works on the first arrivals of the generated body waves. The higher the definition of the first arrival can be, the lower the picking uncertainty will be.

The use of high-frequency sensors involves the elimination of the low-frequency component which impede a good picking of the first arrivals. We therefore recommend sensors that can have high frequencies (> 20Hz).

This does not mean that the classic sensor for MASW can be used for a mixed acquisition where geometries and acquisition parameters are set for a joint processing of the techniques. The data will then be conditioned to highlight the first arrivals.

4 Data processing

The refraction seismic technique is based on the interpretation of the first arrivals of volume waves. It is a technique that therefore requires data of excellent quality where it is possible to perform the picking in a unique way without having to interpret the first arrival. The software allows the user to apply some tools in order to improve the signal-to-noise ratio and facilitate the picking phase.

In addition to this, it is necessary to know the geometry of the entire acquisition, in order to be able to analyze and interpret the arrival times in order to define the portion of geophones that was affected by the arrival of direct or refracted waves.

4.1 *Geometry assignment*

Compiling the geometric information relating to the shots position and receivers is the first step to be performed in a reflection seismic interpretation.

This information should already be present within the *header line* of the tracks before the execution of some important functions such as speed analysis or the removal of elevation statics.

The program allows to manage this information even in the processing phase allowing the geometric definition of the array, of the shots and the possibility of exporting the overall geometry for the definition of the topographic variation (see chap. 2.2.1 Dataset page 14).

It is a good idea, before attempting to process the data, to enter the "properties" section of the seismogram, within the **GEOEXPLORER DoReMi** software, and correctly set the geometry of the seismic spreading if not already entered in the acquisition phase.

4.2 *Filters*

Frequency filters can be classified as band-pass, band-cut, low-pass (high-cut) and high-pass (low-cut) depending on whether they discriminate above or below a certain frequency limit. , inside or outside a given frequency band.

All types of filters are applied to each individual track and are based on the same principle: reconstruct a zero-phase wave with an amplitude spectrum that matches one of the four specified filters. This allows for the construction of three main types of filters: single band pass, time varying filter and space and time varying filter. In the commonly performed processing, the single filter applied to all the tracks is used for their entire time length. In theory, the goal of band-pass filtering is to pass a certain frequency band and suppress the remainder by defining the limits and the width of the filter that will operate on the spectrum of the traces, namely:

$$A(f)=\begin{cases} 1, f_l < f < f_h \\ 0, elsewhere \end{cases}$$

where f_l and f_h represent the threshold frequencies.

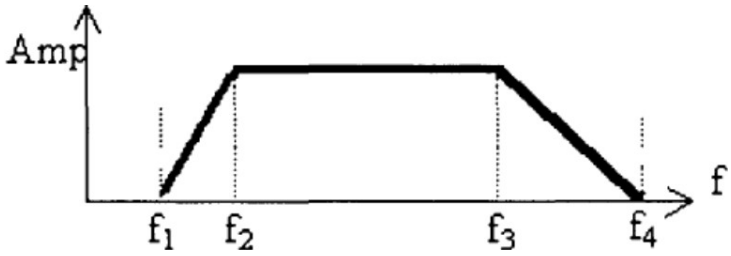


Illustration 4.2-1

To smooth the results and prevent unwanted artifacts from forming, the filter needs a ramp-shaped function for both the low and high frequency parts.

In practice, it is possible to manually enter the values of the four corners of the filter (f_1, f_2, f_3 and f_4) or enter the threshold values (f_2 and f_3) and the slope value (filter order) for the ramps. The lower the order of the filter, the lower the slope of the ramp and the lower the possibility of disturbing the filtered seismogram.

To avoid having an incorrectly processed seismogram in *output*, it is always better to stay on orders of I °, II ° (simulates the natural filtering of a geophone) or III ° degree of the ramps, but it will be the duty of the operator to carry out test tests and choose the best combination based on the results. As for the bandwidth to be used for filtering, it is always better to first check the spectrum of the individual traces to view the real frequency range of the signal.

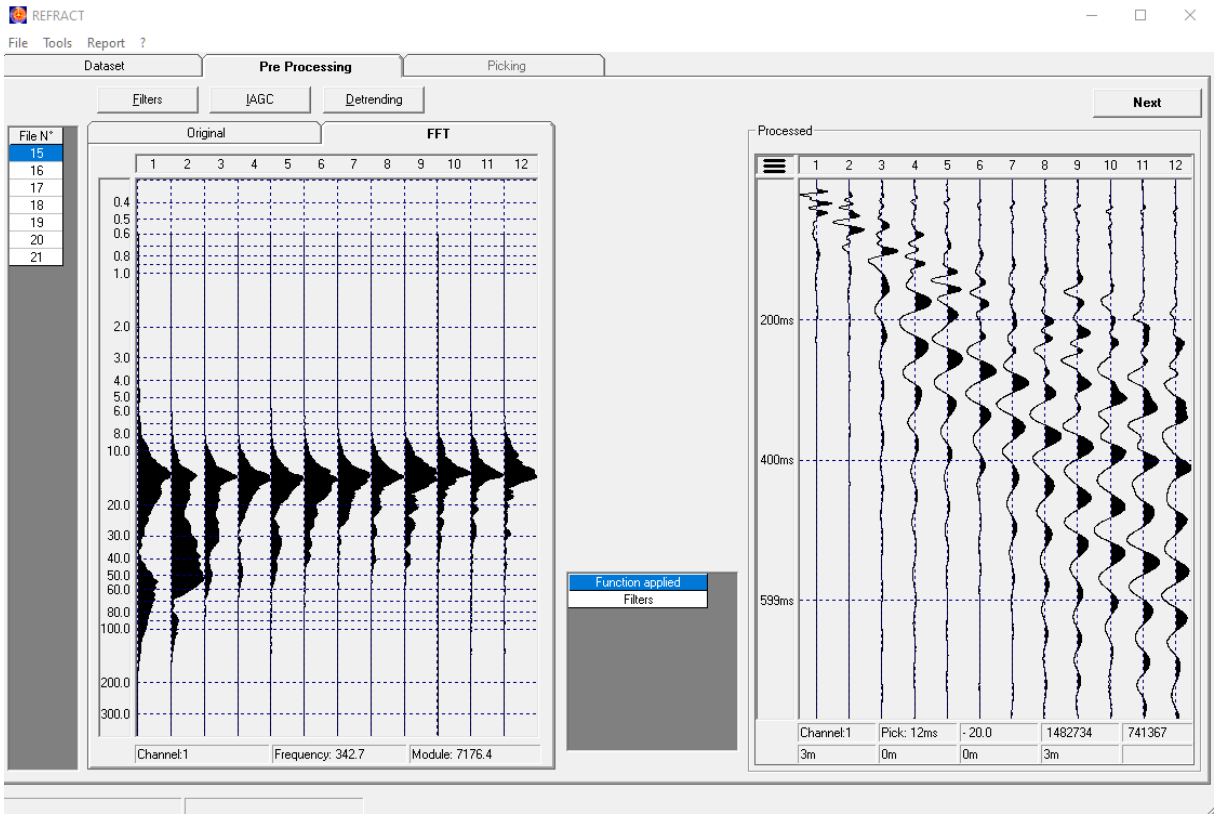


Illustration 4.2-2

Once ensured that this is present between frequency X and frequency Y it is completely useless to go beyond these limits as, outside of them, there is practically no data. Furthermore, the more the filter threshold values are distant from each other (therefore too close to the

extreme values X and Y above) the less the effect produced by the filtering will be while, on the contrary, the more these values are close to each other, the greater the effect will be. elimination of the signal as only a few frequencies will be able to pass and the signal will be mono-frequency.

It is possible to see how careful filter selection can improve and facilitate the picking of early arrivals.

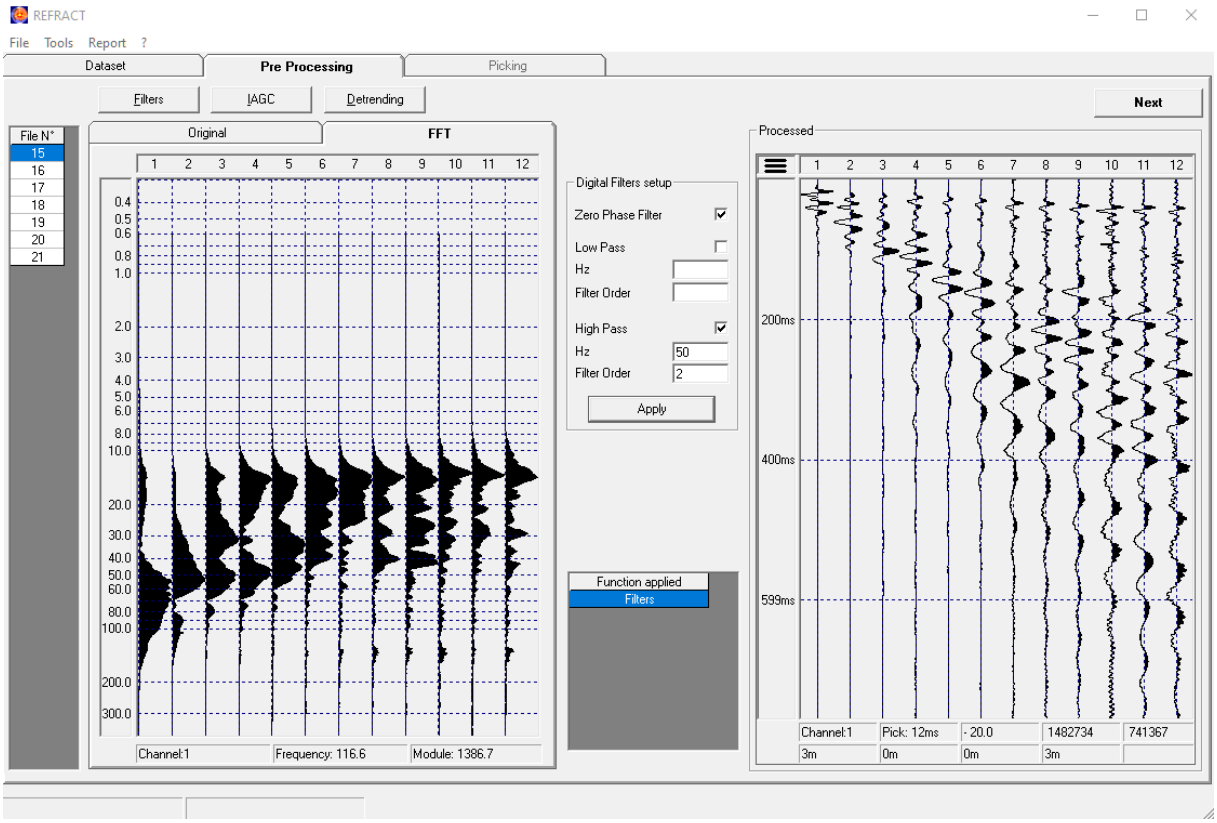


Illustration 4.2-3

For further information, refer to the manual of the **GEOEXPLORER DoReMi.**

4.3 *I.A.G.C. (Instantaneous Automatic Gain Control)*

The intensity of the signal observed on the acquired seismic traces decreases with increasing time. The reasons for this are different:

1. In expanding from the source point, the signal loses energy; this phenomenon is known as spherical divergence. The same amount of energy is distributed over an increasingly larger surface.
2. At the discontinuities the signal is partly reflected and partly transmitted. Depending on the angle of incidence, part of this energy is converted into S waves, refracted waves etc.
3. In its path the energy is dispersed (scattering); the subsoil is not homogeneous and when the seismic waves encounter variations, the wave front is distorted and deflected in all possible directions.

Typically, a gain function is applied to compensate for this energy loss. This type of correction

varies according to the context and the seismic data acquired, consequently several combinations must be tested. Operationally, to apply the automatic gain function (IAGC) a time window is chosen, which ideally overlaps the initial part of the seismic trace, within which the algorithm selects all the numerical data present and calculates the root mean square value. This normalized value is multiplied by the first sample of the seismic trace.

Subsequently, the time window is shifted down by a sample and the same operations are performed. The result obtained is multiplied by the second sample. This proceeds following the same pattern until the time window reaches the end of the seismic trace.

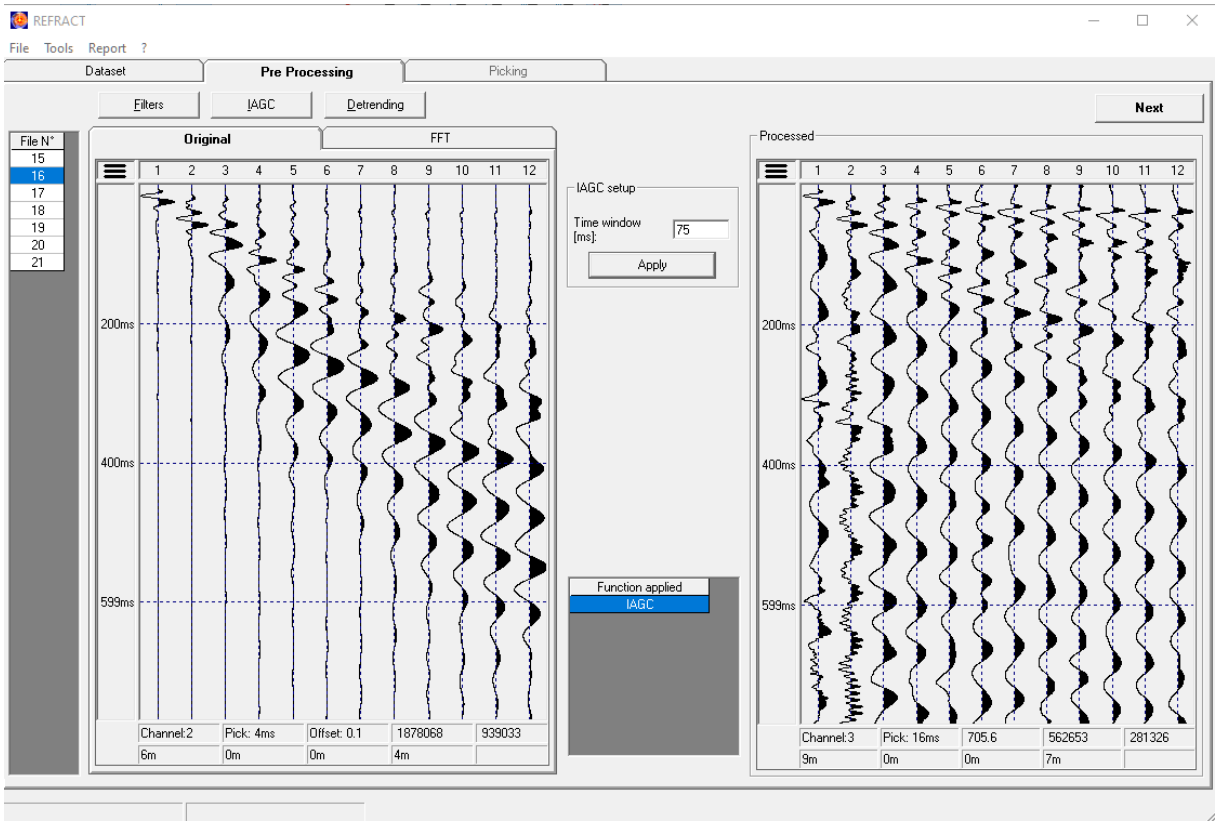


Illustrazione 4.3-1

For further information, refer to the manual of the **GEOEXPLORER MARW.**

4.4 *Detrending*

This function has the objective of eliminating trends present in the signal. By selecting the degree of the polynominal, the present trend can be eliminated. Below is an example of the detrending of an outbreak.

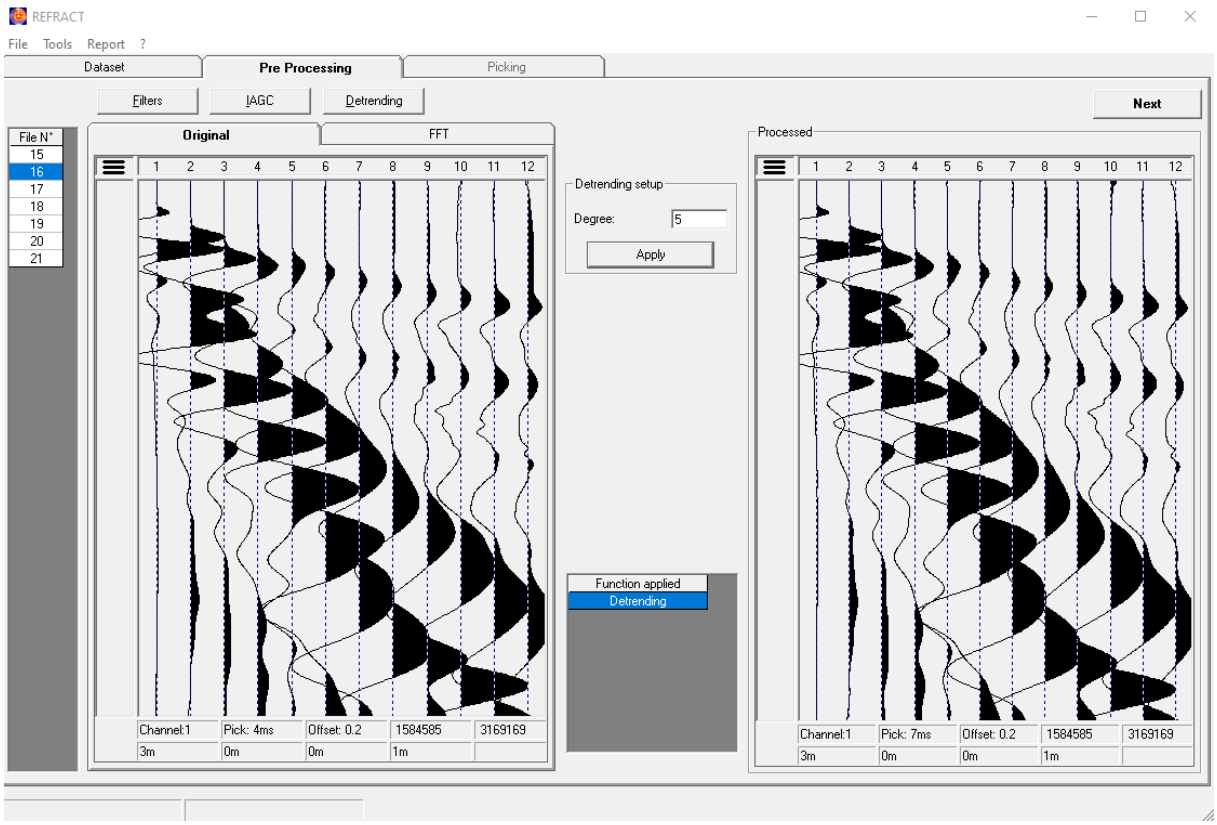


Illustration 4.4-1

This function can therefore improve the signal to noise ratio of the first arrivals to make interpretation easier.

4.5 *Intercepts*

The intercept technique is a very fast processing technique and in certain geological contexts very reliable. The basic principle of this technique is the assumption that each shot is considered performed on a homogeneous laterally and parallel plane seismostratigraphy.

This allows to calculate the depths and the location within the spread of the critical refraction points and to have an evaluation of the refractor speeds.

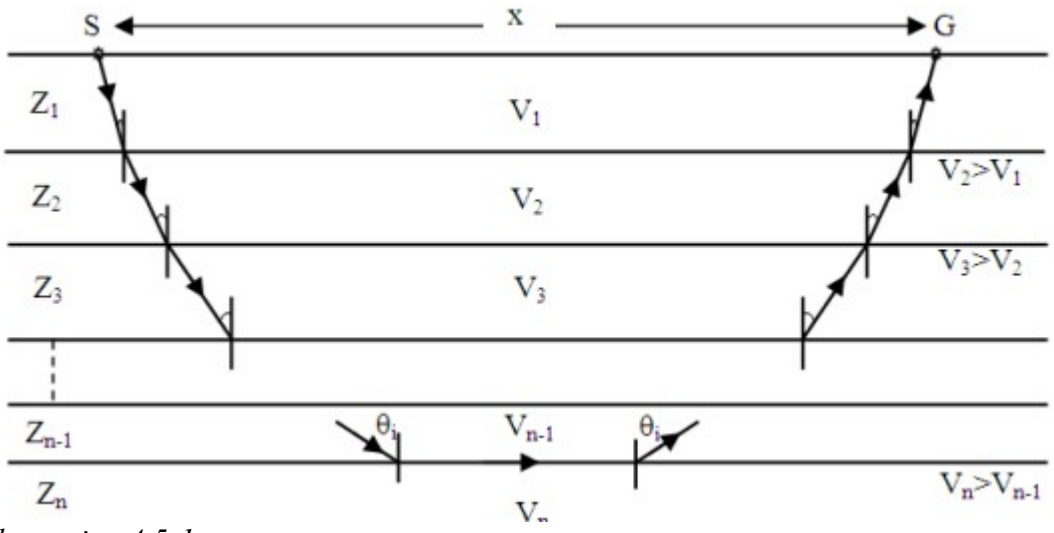


Illustration 4.5-1

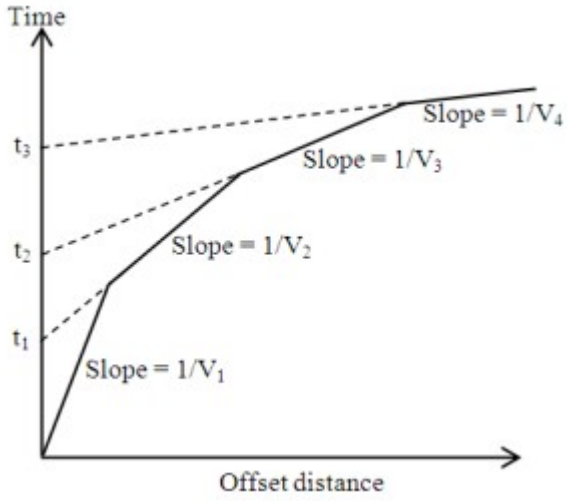


Illustration 4.5-2

$$T_{SG} = \frac{X}{V_N} + \sum_{i=1}^{n-1} \left(\frac{2 Z_n \cos(\Theta_i)}{V_i} \right)$$

$$Z_i = \frac{t_i V_i V_{i+1}}{[2(V_{i+1}^2 + V_i^2)^{1/2}]}$$

4.6 *GRM*

The *Generic Reciprocal Method* technique was developed by Palmer in 1986. This technique allows you to identify and describe the morphological trend of a wavy refractor of any depth starting from the direct and inverse travel times.

The arrival times of two geophones, located at a variable distance XY, are used for the analysis of the refractor speed and for the calculations of the time-depth function.

The depth conversion factor does not depend on the slope for angles less than 20 °, so the depth calculations in the case of a wavy refractor are particularly useful even when the overlying layers show velocity gradients.

The technique therefore identifies geometric places, rather than actual depth points, and the surface of the refractor is assimilated to the envelope of such places.

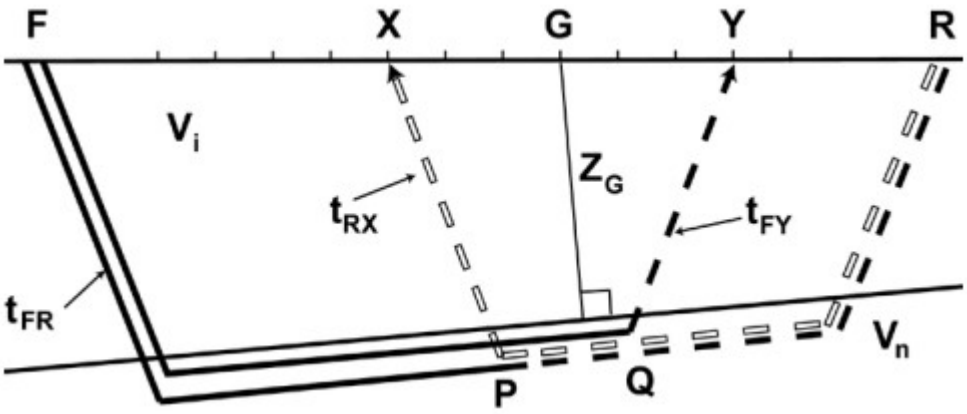


Illustration 4.6-1

$$T_V = \frac{(T_{FY} - T_{RX} + T_{FR})}{2}$$

$$T_G = \frac{(T_{FY} + T_{RX} - (T_{FR} ¿ \frac{+XY}{V_n'}))}{2}$$

If an XY equal to 0 is used, the time-depth function is similar to the positive term of the "Plus-Minus" method (Hagedoorn, 1959).

4.7 *Bibliography*

Palmer D. - *The Generalized Reciprocal Method of seismic refraction interpretation* – 1986 – Department of Mineral Resources and Development – Sydney N.S.W. Australia.

Anomohanran O. - *Seismic Refraction Method: A Technique for Determining the Thickness of Stratified Substratum* – 2013 - Department of Physics, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria - American Journal of Applied Sciences 10 (8): 857-862, 2013 ISSN: 1546-9239.

Lillie J. R. - *Whole Earth Geophysics An introduction textbook for geologists and geophysicists* – 1998 - Pearson College Div; 1° edition (12 May 1998) – ISBN: 0-13-490517-2.

Hagedoorn J. G. - *The plus-minus method of interpreting seismic seismic refraction sections* – 1959 – Geophys. Prosp., 7, 158–182.