GEOEXPLORER MASW

Version 1.3.0

USER MANUAL

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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.

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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 MASW 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.

The calculation function of the FV and FK dispersion spectra available in GEOEXPLORER MASW uses portions of the Seismic Unix software suite, downloadable from the website:
https://wiki.seismic-unix.org/doku.php
The license text is present in the seismicunix subfolder of the GEOEXPLORER MASW installation folder.

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Table of contents

1 Introduction

The **MASW** module was developed with the aim of providing a tool for analyzing the dispersion of surface waves and modeling the seismic-stratigraphic profile.

2 GEOEXPLORER MASW

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

Illustration 2-1

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

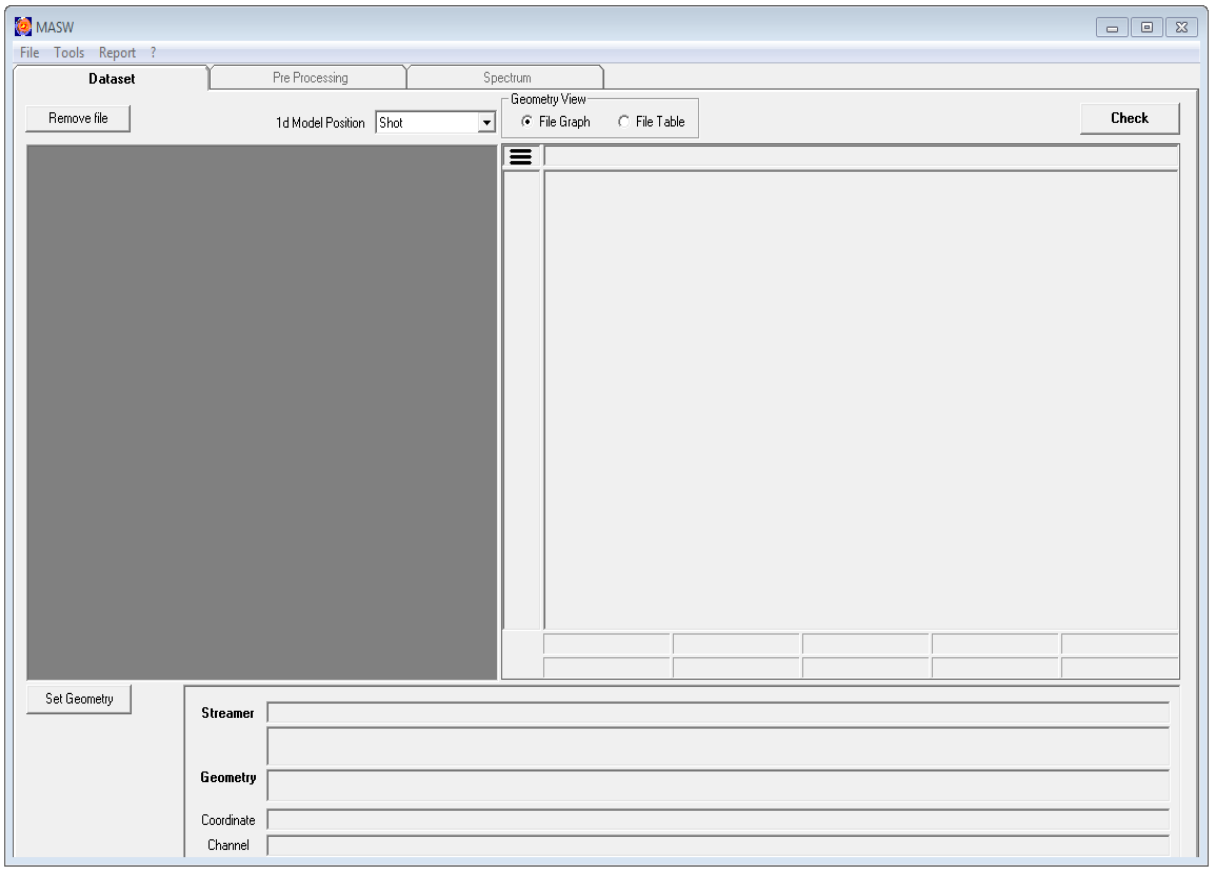


Illustration 2-2

The main page of the software is the Dataset tab where it is possible to load the raw datasets of the acquisitions or the conditioned files for processing from different sources.

2.1 Menu bar

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

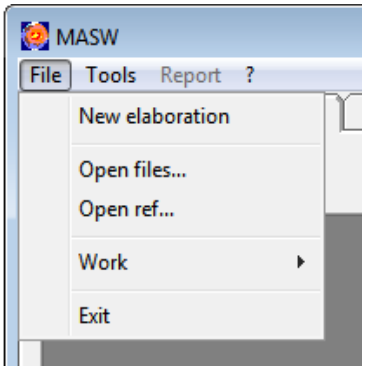


Illustration 2.1-1

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

   Note: t is possible to load SEG 2 files. (see chapter 2.2.1 Dataset page 13). 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.

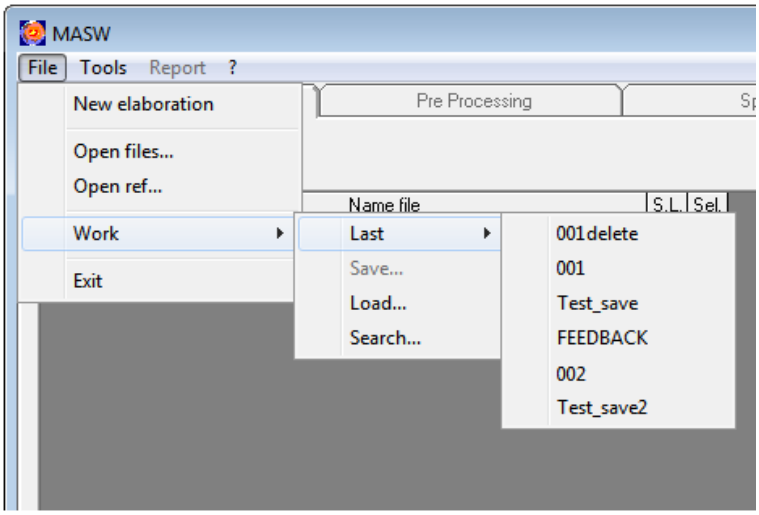


Illustration 2.1-2

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

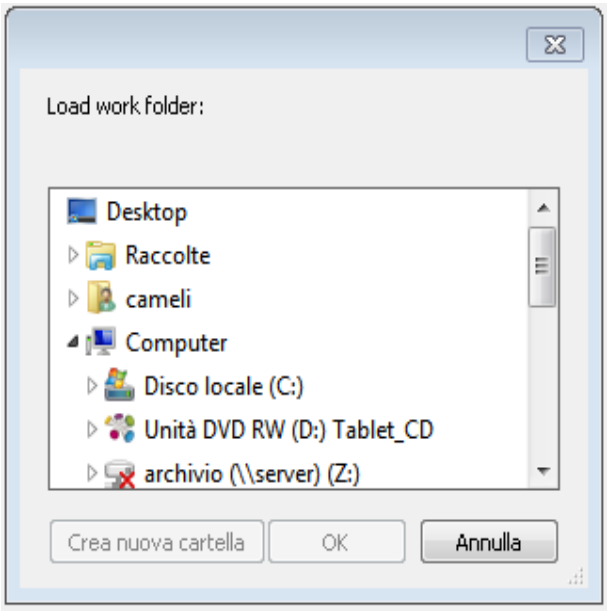


Illustration 2.1-3

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.

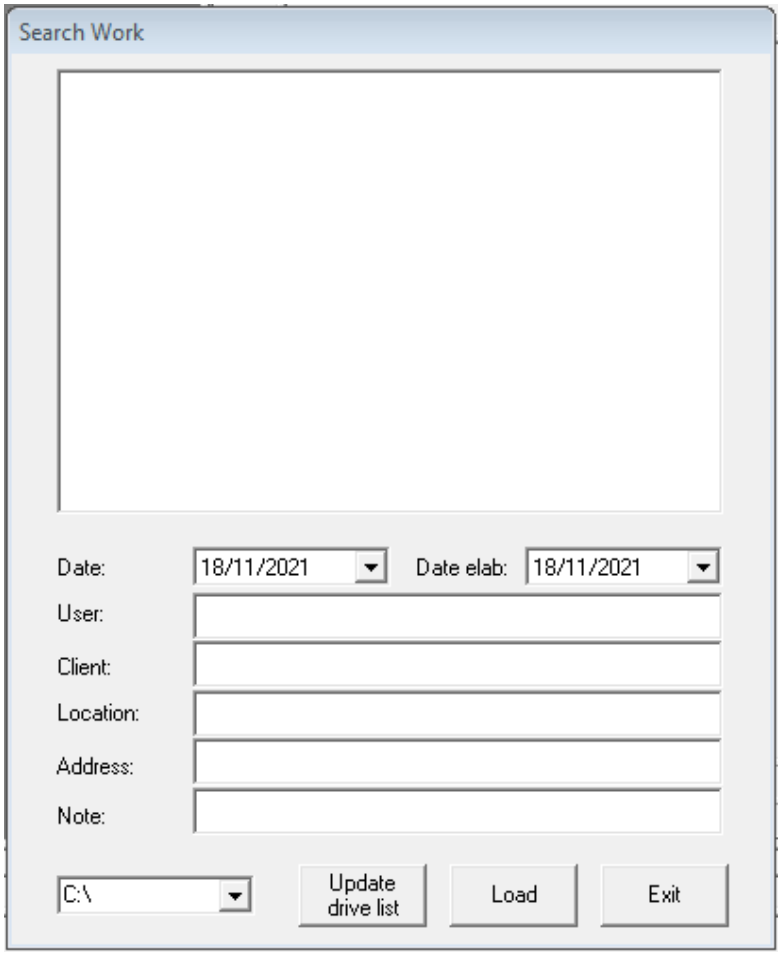


Illustration 2.1-4

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.

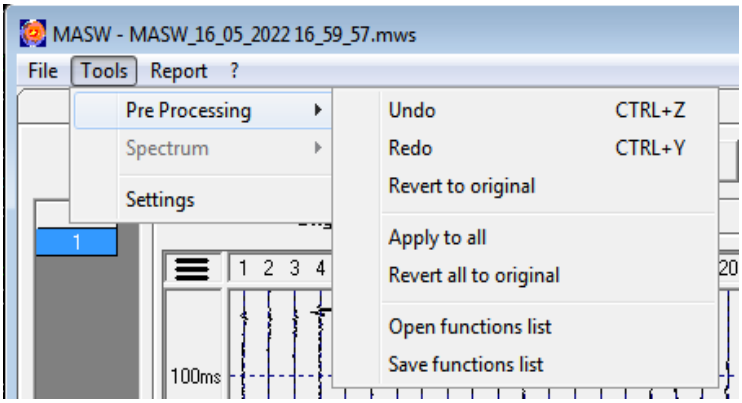


Illustration 2.1-5

   - **IV.** *Apply to all:* Apply the function list of the selected file to all other files.

     Please note: 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 pre processing.
   - **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.*

*Please 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. Spectrum: Illustration 2.1-6

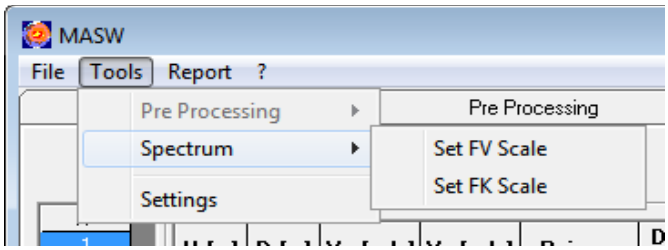


Illustration 2.1-6

I. *Set FV Scale:* Opens a popup that allows to set the scales of the F-V spectrum (Illustration 2.2-25).

II. *Set FK Scale*: Opens a popup that allows to set the scales of the F-K spectrum (Illustration 2.2-26).

3. *Settings:* A window opens in which it is possible to set the following options Illustration 2.1-7

1. *Min channels number:* Identifies the minimum number of channels that a file must have to be processed by the MASW

Illustration 2.1-7

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)

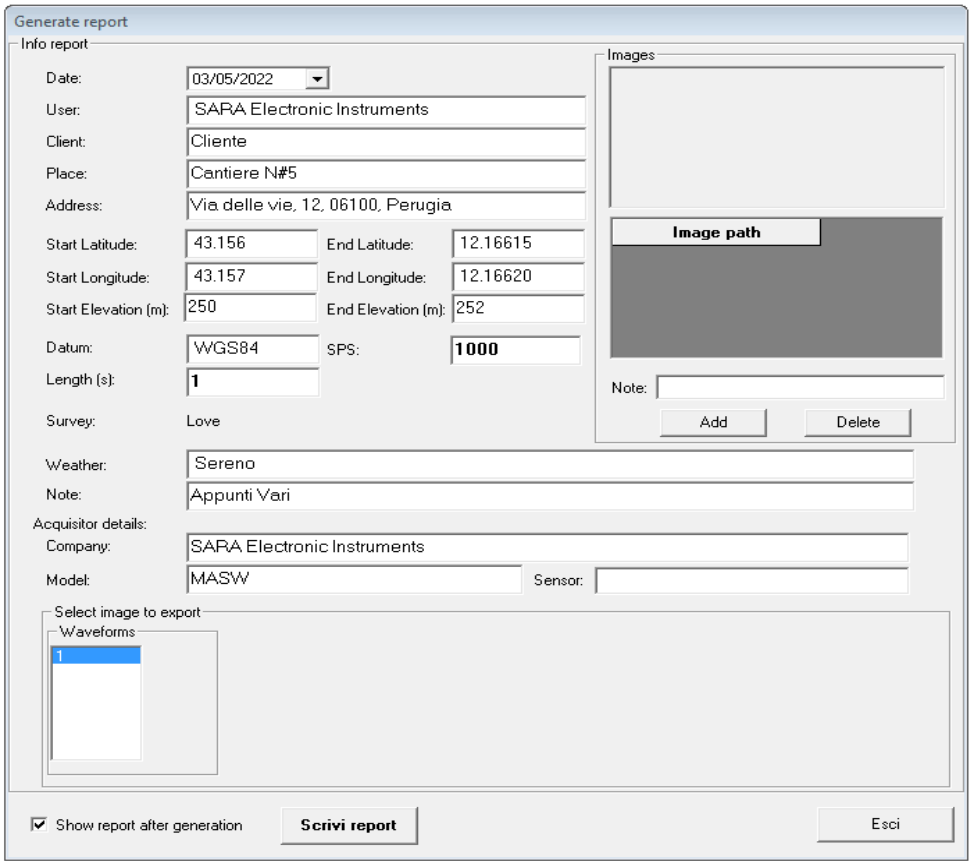


Illustration 2.1-8

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 Spectrum*

   In this tab it is possible to perform the direct processing of the stratigraphy, filling in the stratigraphic model.

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.

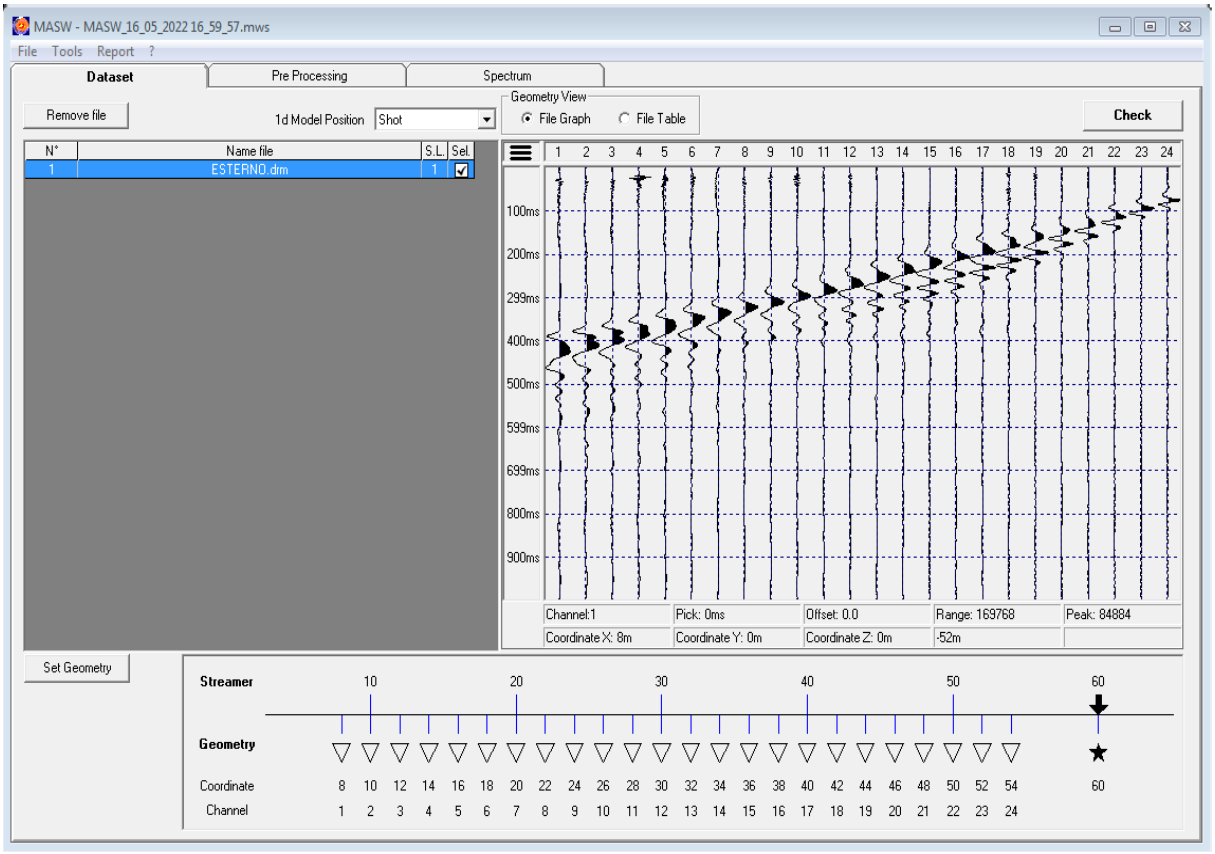


Illustration 2.2-1

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.

By right-clicking on a file a popup menu will appear *(Illustration 2.2-2)* through which it is possible open the geometry setting screen using the *Set Geometry* option.

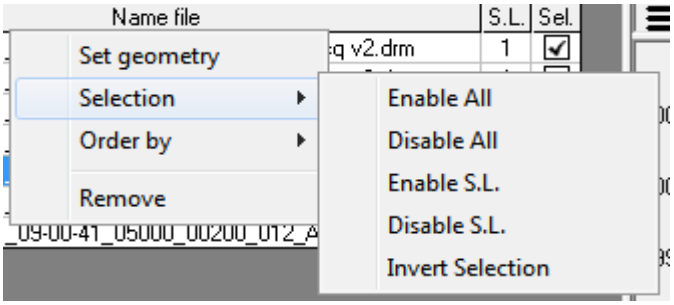


Illustration 2.2-2

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 2.2-2*

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

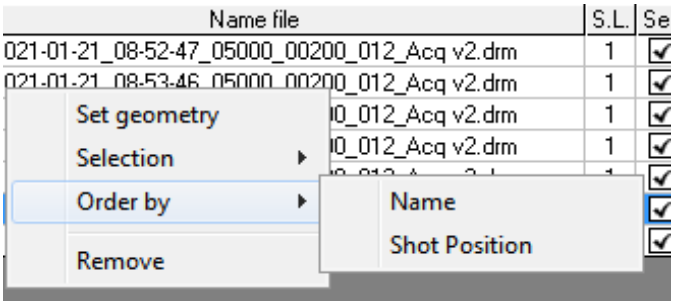


Illustration 2.2-3

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.

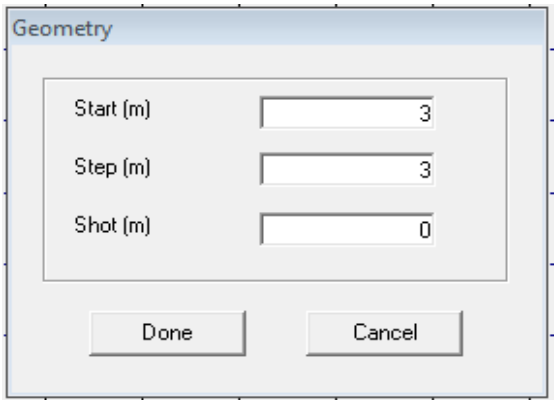


Illustration 2.2-4

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. *Auto offset:* Automatically sets the channel offset.
6. *Set offset:* It allows the user to manually set the channel offset.
7. *Invert:* Reverse the channel.
8. *Time shift + of waveform:* Translates the signal by 1 ms, adding samples at the beginning of the recording.
9. *Time shift – of waveform:* Translates the signal by 1 ms, removing the first recording samples.
10. *Custom Time shift:* Opens a small popup where the shift value can be set. Positive or negative values, will indicate the direction of translation.

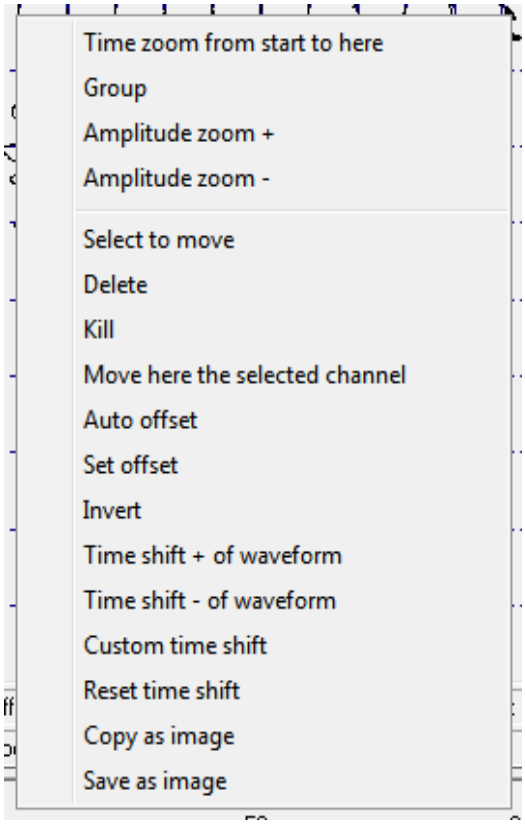


Illustration 2.2-5

11. *Reset time shift:* Undo changes made via the channel shifting options.
12. *Copy as image:* It allows to copy the image of the seismogram to the clipboard.
13. *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. (Illustrazione 2.2-6)

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.

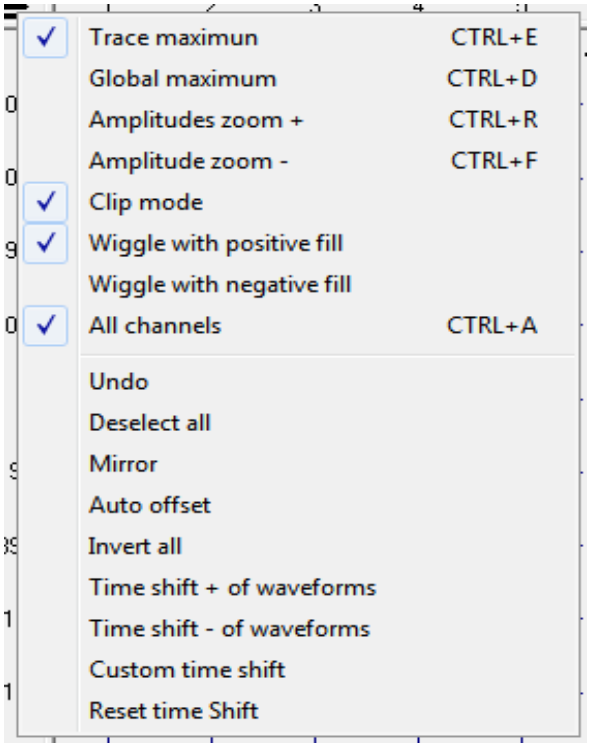


Illustrazione 2.2-6

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

1. *Undo:* Undoes the last operation performed on the seismogram.
2. *Delselect 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.

Through the combo box *1d Model position* it is possible to define which will be the position of the calculated stratigraphic model with respect to the geometry of the files, it is possible to choose between:

1. *Shot*: the model is positioned at the height of the shot.

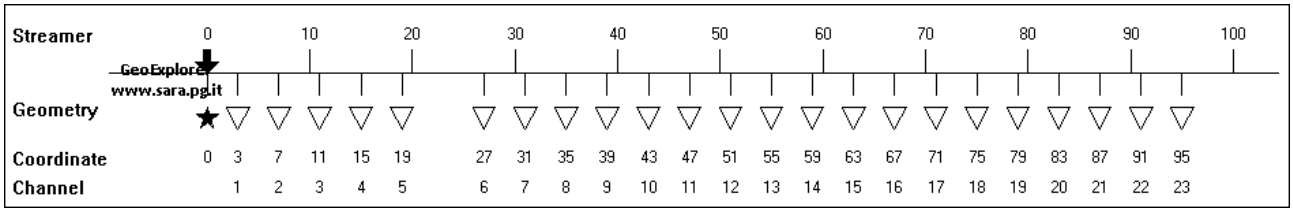


Illustration 2.2-7

2. *Half layng*: the model is positioned in the middle of the line.

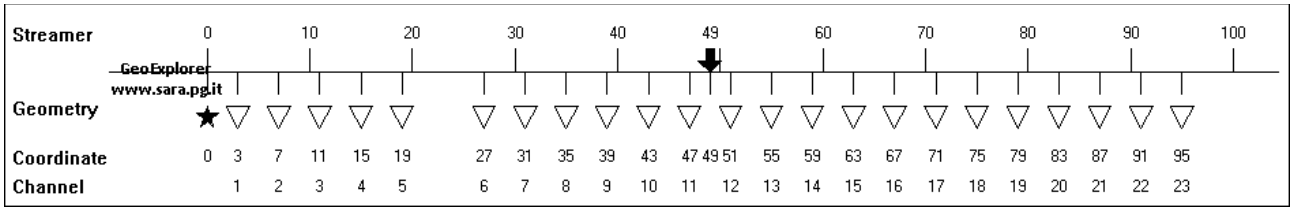


Illustration 2.2-8

3. *Half offset max*: the model is positioned halfway between the shot and the geophone furthest to it.

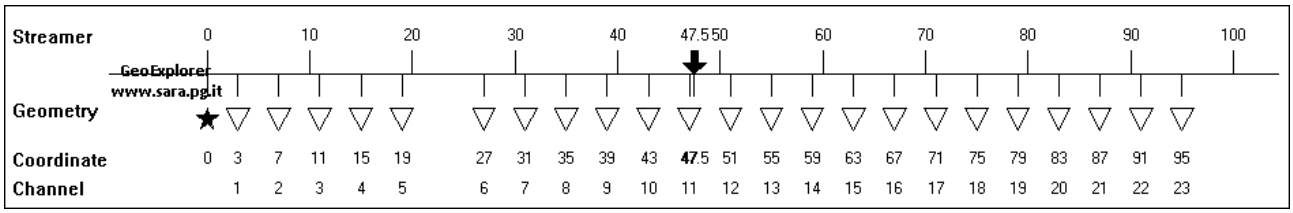


Illustration 2.2-9

Regarding the geometries, 2 different views are available:

1. **File Graph:** displays a 1d representation of the geometry of the selected file. Illustration 2.2-10

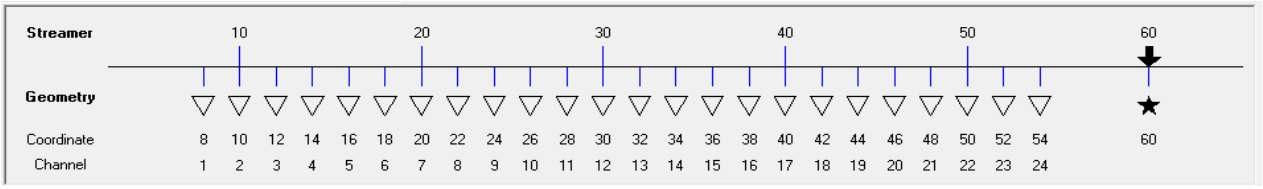


Illustration 2.2-10

2. **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 2.2-11

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 2.2-11

The *Set Geometry* button opens the geometry setup popup (Illustration 2.2-4).

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 characteristics useful for improving the spectra and eliminating noise from the seismogram.

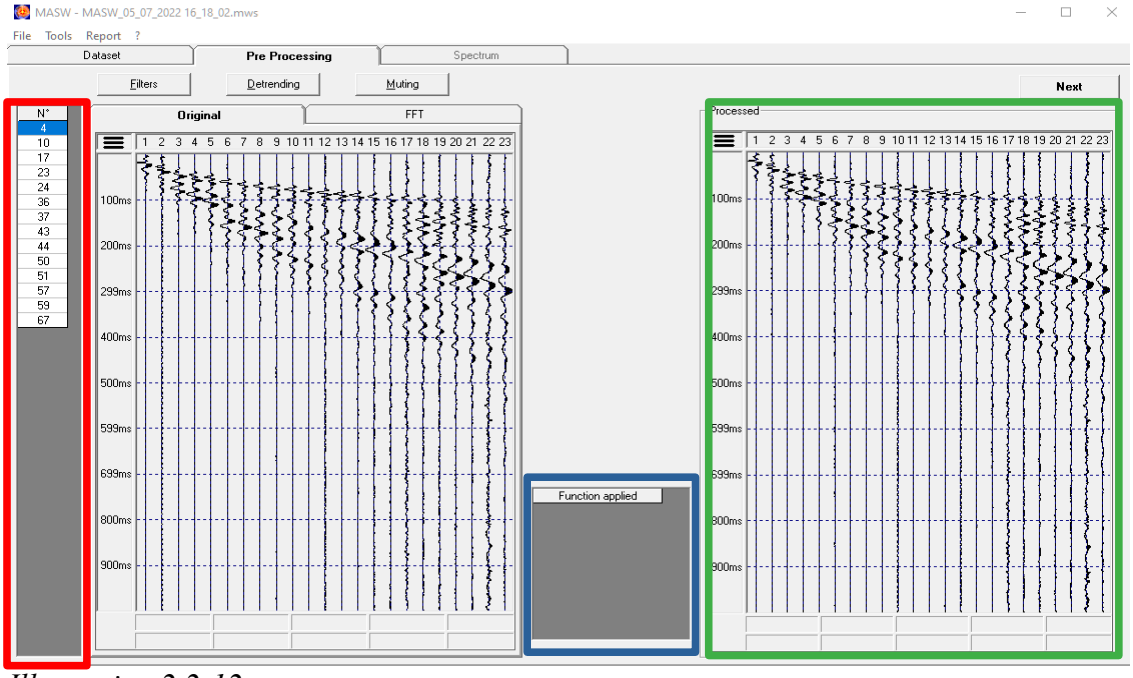


Illustration 2.2-12

The window (Illustration 2.2-12) 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 2.2-13), 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.

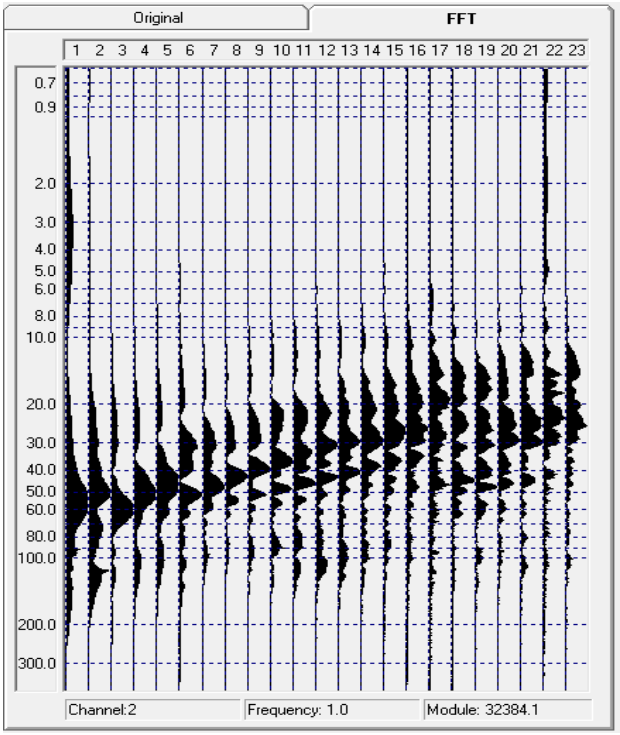


Illustration 2.2-13

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 pass band. For more information please read chapter 4.2 Filters pag. 31 (Illustration 2.2-14).

   The image below shows an example of cleaning the seismogram with a pass band filter between 10 and 100Hz. (Illustration 2.2-15)

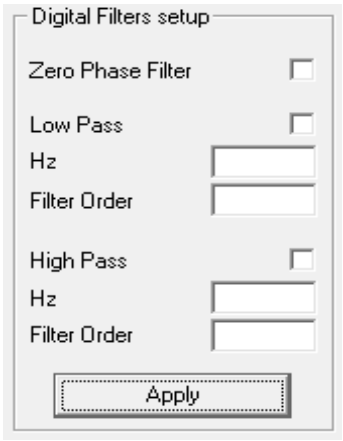


Illustration 2.2-14

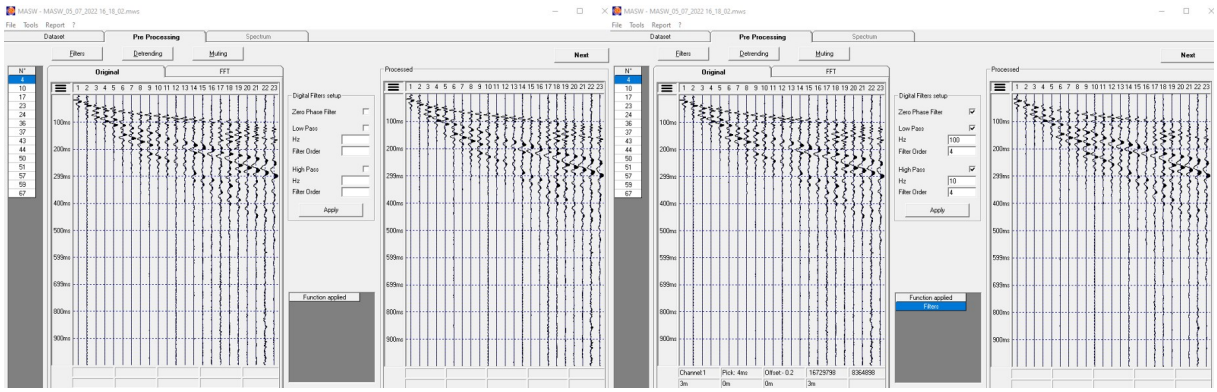


Illustration 2.2-15

2. *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).

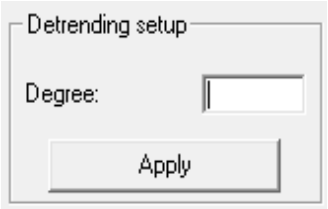


Illustration 2.2-16

3. Muting: This tool allows to eliminate all the amplitude values of the signal that remains above or below the violet line that will be drawn on the graph on the right when the tool is activated. To create the muting line just hold down SHIFT while clicking with the left mouse on the seismogram, generating the anchor points.(Illustration 2.2-20).

In the three illustrations below we can see the steps for muting above the first arrivals and below the last surface wave train.

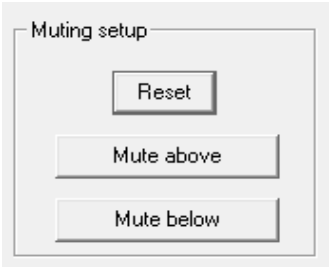


Illustration 2.2-17

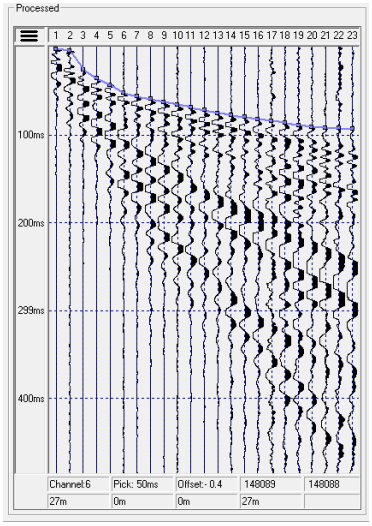


Illustration 2.2-20

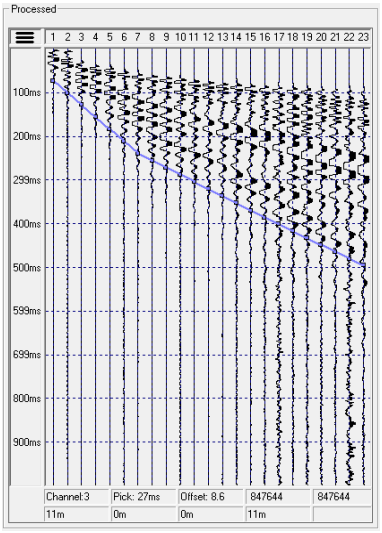


Illustration 2.2-19

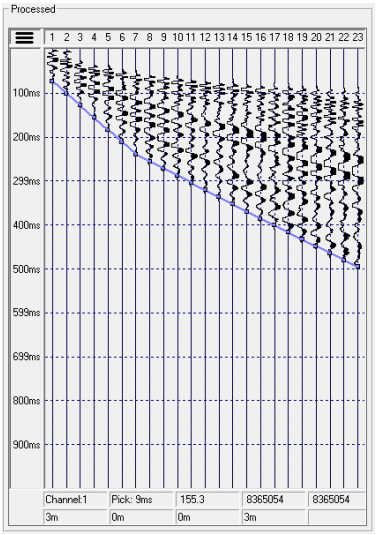


Illustration 2.2-18

The *Tools → Preprocessing*, 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 *Spectrum* tab.

2.2.3 Spectrum

In this window it is possible to view the FV and FK spectra of the various files. It is also possible, by populating the left table with the expected stratigraphy, to generate the *Rayleigh* or *Love* modes that will be drawn on the graph. (Illustration 2.2-21)

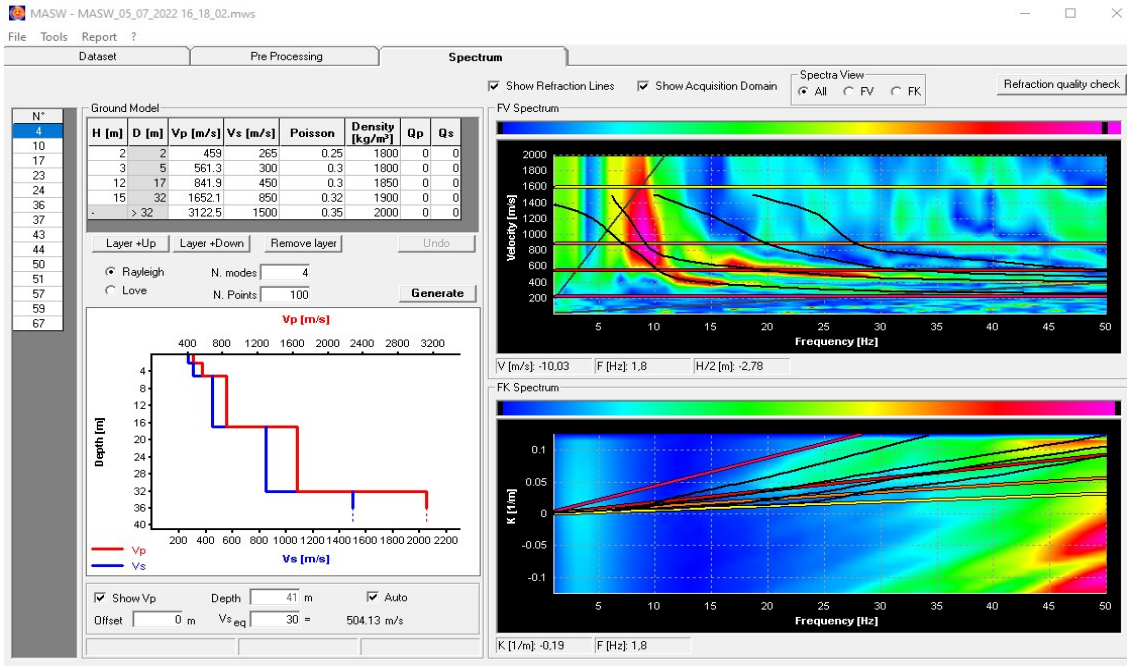


Illustration 2.2-21

On the left of the screen we find the file table through which it is possible to choose which file to work on.

In the *Ground Model* box the stratigraphy table can be found at the top. New layers can be added using the *Layer + Up* and *Layer + Down* buttons, which add a new layer above and below the selected layer respectively. *Remove Layer* deletes the selected layer. The *Undo* button allows to undo the last change made on the stratigraphy.

The values of *Vp, Vs* and *Poisson* are linked together, by modifying the Vp, the Vs will be recalculated on the basis of the Poisson value and vice versa. By changing the Poisson value, the Vp will be recalculated.

By right clicking on the table it will be possible to export the stratigraphy in a format compatible with HVSR. (Illustration 2.2-22)

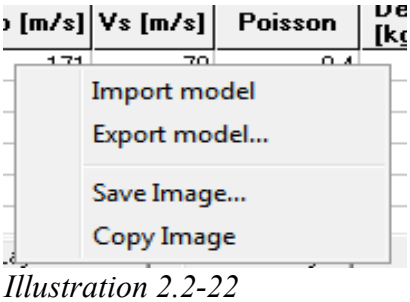


Illustration 2.2-22

Just below the stratigraphy table it is possible to select the parameters for the generation of the modes, it is possible to choose the type of wave, *Rayleigh* or *Love*, the number of modes to be calculated (*N. Modes*), and the number of points to be calculated (*N. Points*).

The software automatically starts the calculation of the modes when the type of source is changed, in all other cases it is necessary to act manually using the *Generate* button.

Below is the graph representing the stratigraphic model, under which there are some display options, as well as the controls for the generation of the equivalent Vs (Illustration 3.1-1).

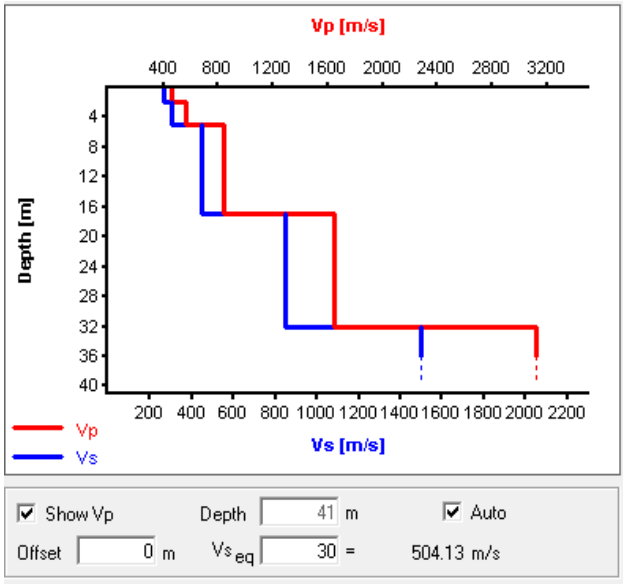


Illustration 2.2-23

Show Vp allows to enable/disable the visualization of the Vp on the stratigraphic model graph. *Depth* defines the maximum depth to be displayed, while by selecting the *Auto* checkbox, the *Depth* value is automatically calculated by the software.

Using the *Offset* and *Vs eq* check boxes it is possible to set the calculation of the Vs equivalent. The offset indicates from which altitude the calculation of Vs begins, while in the Vs eq field it is indicated after how many meters starting from the offset to calculate your Vs.

The graphs of the Fv and Fk spectra are displayed on the right of the screen.

Through the options in *Spectra view* it is possible to select whether to display both graphs or only one of the two, while the *Show Refraction Lines* option, if enabled, allows the user to show the speed lines calculated through the *Refraction quality check* on the graph. The *Show acquisition domain* option allows you to show the lines that delimit the field of existence of the acquisition, beyond which it is possible to find aliasing phenomena. By right-clicking on each of the graphics in the view, the image can be copied to the clipboard or saved to a file.

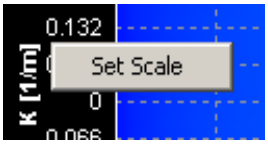


Illustration 2.2-24

By right clicking on the graph scales, a popup (Illustration 2.2-24) appears that allows you to open the scale settings, where the user can set the maximum and minimum limits of the values in the axes. (Illustration 2.2-25,Illustration 2.2-26).

Furthermore, as regards the PV graph, it is possible to set the *Number of phase velocities*.

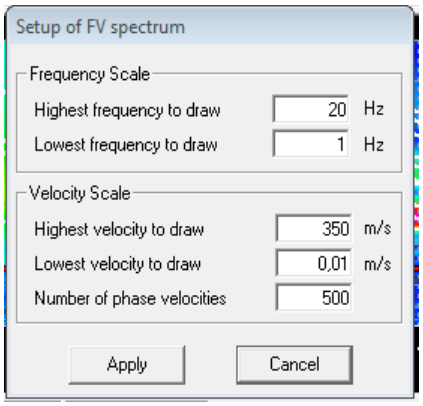


Illustration 2.2-25

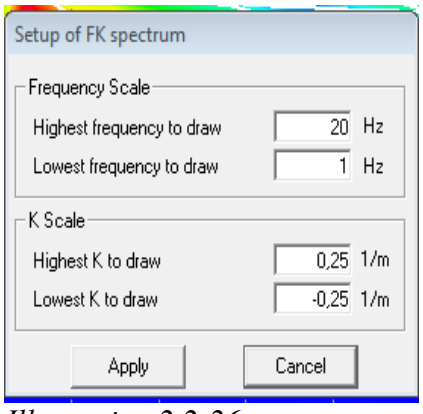


Illustration 2.2-26

2.2.4 Refraction quality check

In this window, similar to the GE-REFRACT picking window, it is possible to pick the first arrivals and intercepts on the file selected in the *Spectrum* tab. This tool allows to perform a quality check of the data through the speeds obtained from the picking of the intercepts.

It is first of all necessary to perform the picking of the first arrivals on the seismogram, and then, on the basis of the picking carried out, it is possible to pick the intercepts on the graph.

For further information regarding picking and display mechanics, refer to the ***GEOEXPLORER – REFRACT*** *manual.*

Unlike the REFRACT module, here it is not necessary to pick the direct and inverse ones, but the picking of a single intercept on the graph will suffice.

The picked values will be displayed on the table at the top right, on which it is possible to manually modify the times and positions, by double clicking on the desired box.

The graph at the bottom right will instead show the stratigraphic column resulting from the picking of the intercepts. (Illustration 2.2-27)

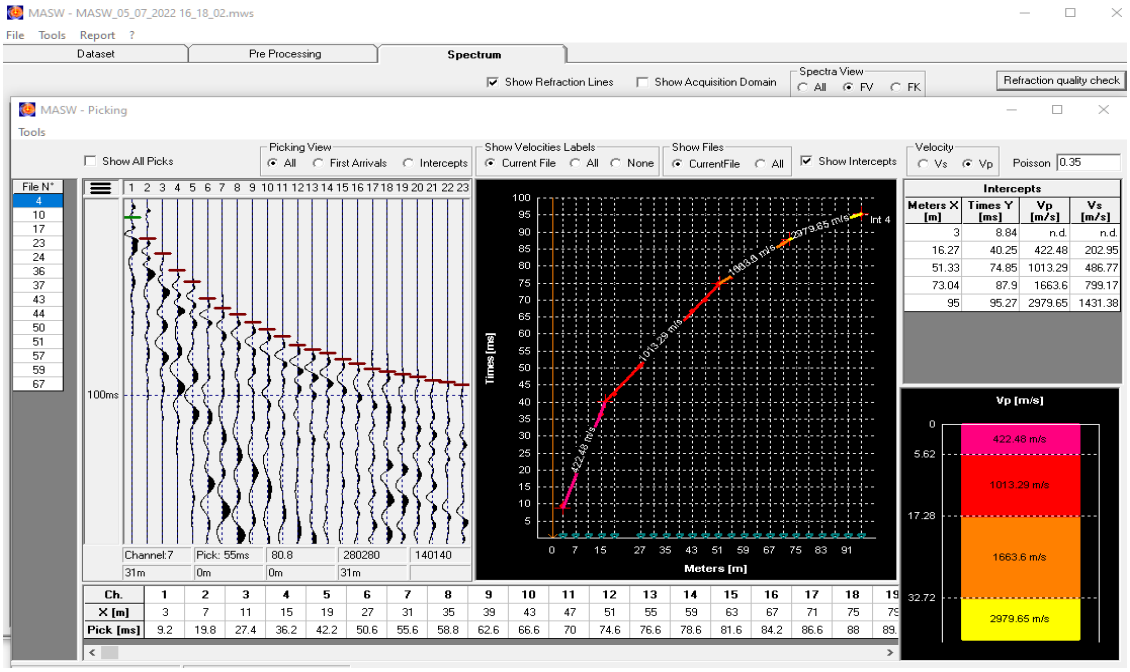


Illustration 2.2-27

The seismogram has the same display functions present within **GEOEXPLORER DoReMi**.

To be able to perform the picking just hold down the SHIFT key and click with the left mouse button in the point relative to the first arrival. Keeping the click and the pressure of the SHIFT key, it is possible to carry out the picking on the other channels by dragging the mouse 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 2.2-28)

In addiction to the *Pick* tool that allows to perform the picking on the channels, is possible to save the seismogram as an image, or copy the image on the clipboard.

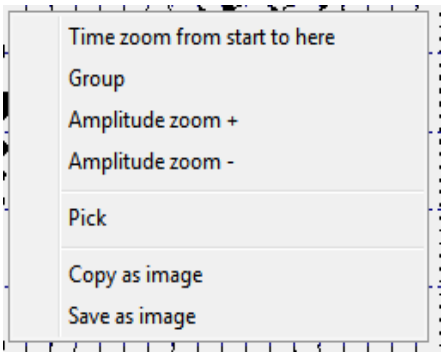


Illustration 2.2-28

The *Tools menu* (Illustration 2.2-29) offers the following options:

- *Reset all picking*: It resets to zero the picking carried out on all the files of the dataset. This operation cannot be undone.
- *Reset all intercepts*: It eliminates the intercepts picked up on all the files of the dataset. This operation cannot be undone.

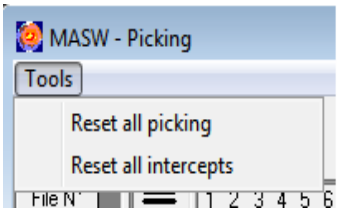


Illustration 2.2-29

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

The table in the lower part of the window 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.

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 one picking line is allowed on the same file. 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 picked values will be shown in the table on the right. 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.

By right clicking on the vertical scale of the intercept graph, a contextual menu will be shown with the following options (Illustration 2.2-30)

- *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.

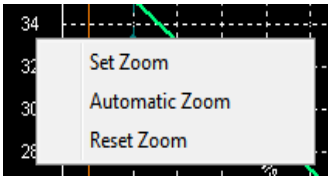


Illustration 2.2-30

Right clicking on a vertex of the intercept line will show a context menu with the following options (Illustration 2.2-31)

- *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.

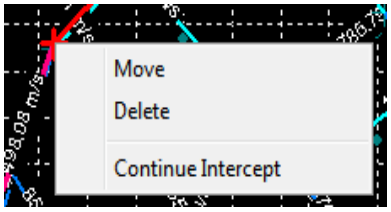


Illustration 2.2-31

Right clicking along the intercept line will show a context menu with the following options: (Illustration 2.2-32)

- *Set Layer*: Opens a pop-up that allows you to set the layer value of the first intercept segment (Illustration 2.2-33).
- *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.

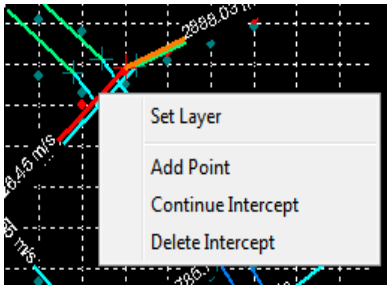


Illustration 2.2-32

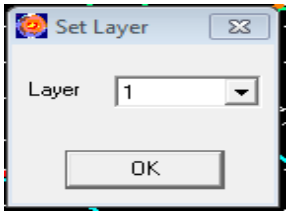


Illustration 2.2-33

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 inter-geophonic 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.

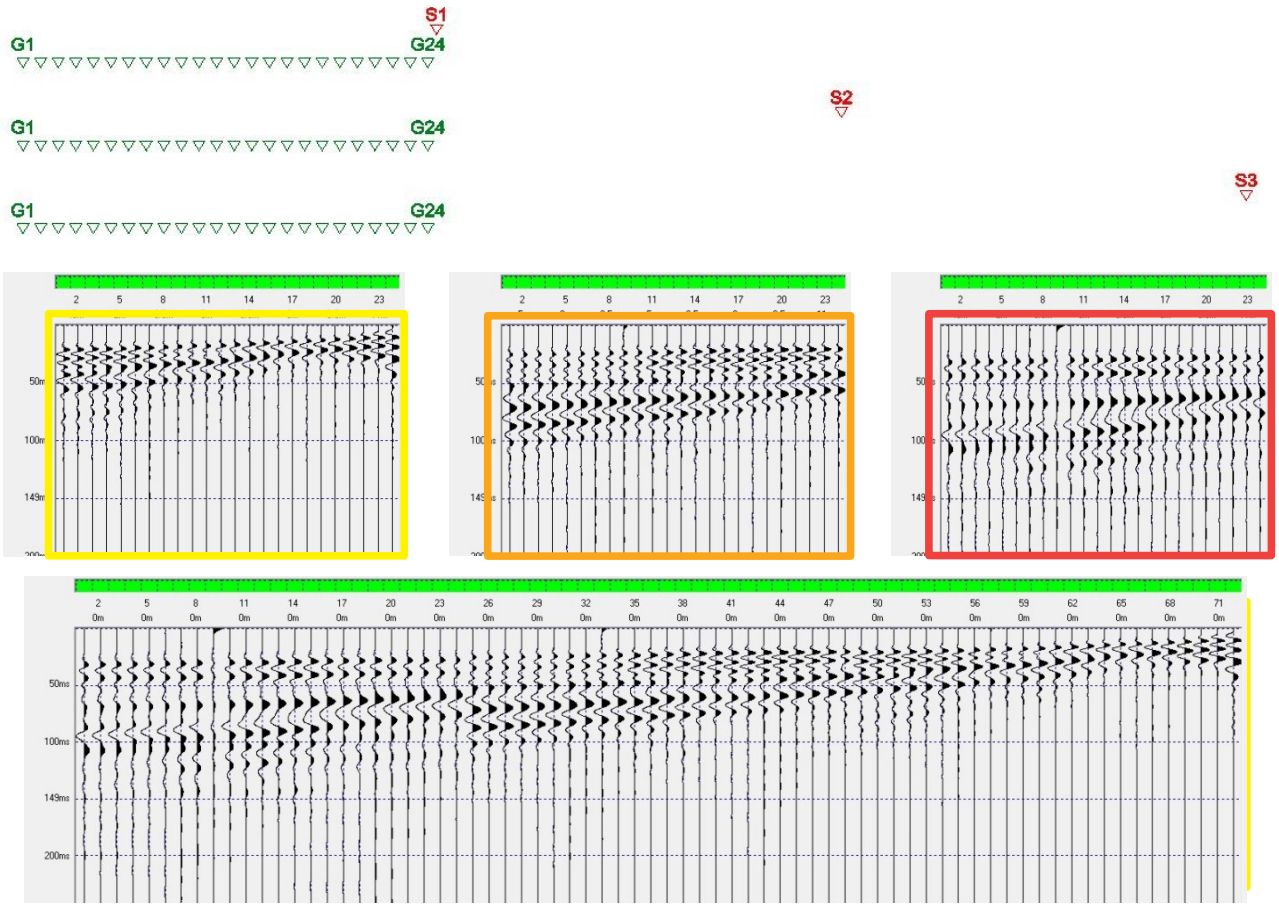


Illustration 3.1-1

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.

The first indication is to avoid that the sensors go into saturation, then arrange the outbreak at least 4m from the nearest geophone in order to avoid saturation and *Near Effect*.

Lateral heterogeneities are a limiting factor for MASWs, so spacing must be managed to minimize this risk. In general, a spacing of 4m may be more than sufficient in normal contexts, but the spatial alias depending on the intergephonic distance and the maximum resolution at low frequency depending on the length of the array and the maximum offset must also be considered. In addition to this, the lowest possible frequency that can be generated by the energy system must be taken into consideration.

The MASW must always be acquired by analyzing the two directions of wave propagation to highlight any lateral heterogeneity, so it is recommended to perform the same acquisition process at one end and the other. We suggest to record the external shot with the interlace technique and to perform at least three internal shor to evaluate the refraction with the MASW.

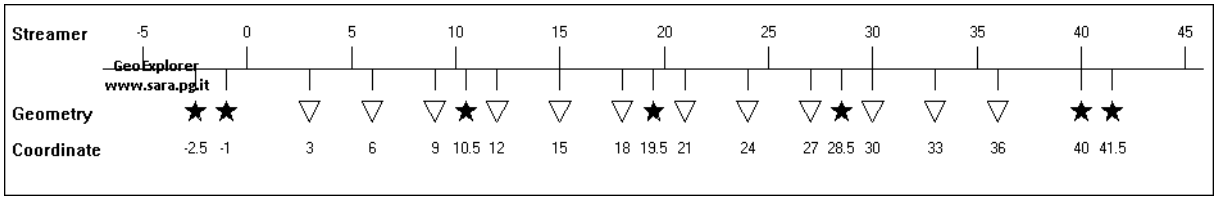


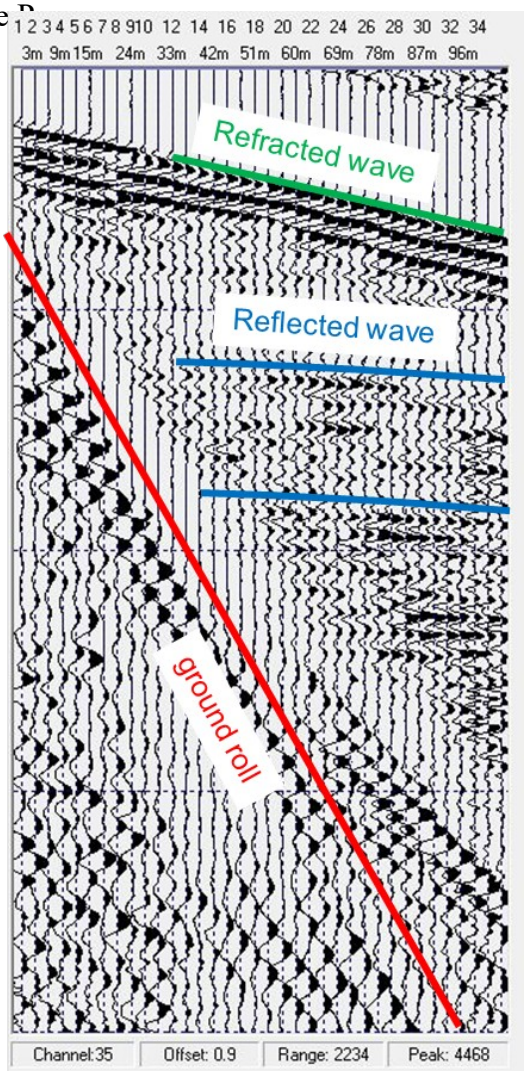
Illustration3.2-1

For the acquisition parameters, the main objective is to record all the surface wave train at the last geophone with a good signal / noise ratio. There is no doubt that depending on the expected speeds and the acquisition geometry, it should be recorded for a sufficient duration. In general, 2s are more than enough, but the noise test allows you to check and modify this parameter.

Knowing that the frequencies are generally between 10 and 50Hz for the *Nyquist* theorem on sampling, a value of 1000Hz or even less is already sufficient, but for the quality check of the data with refraction a high sampling is recommended in order not to incur refraction picking errors, therefore a sampling of at least 3000Hz may be sufficient in soils with not high speeds.

With a view to mixed acquisition with MARW and refraction and / or for a 2D MASW, please refer to the GE MARW and GE REFRACT manuals.

Onde P



Onde S

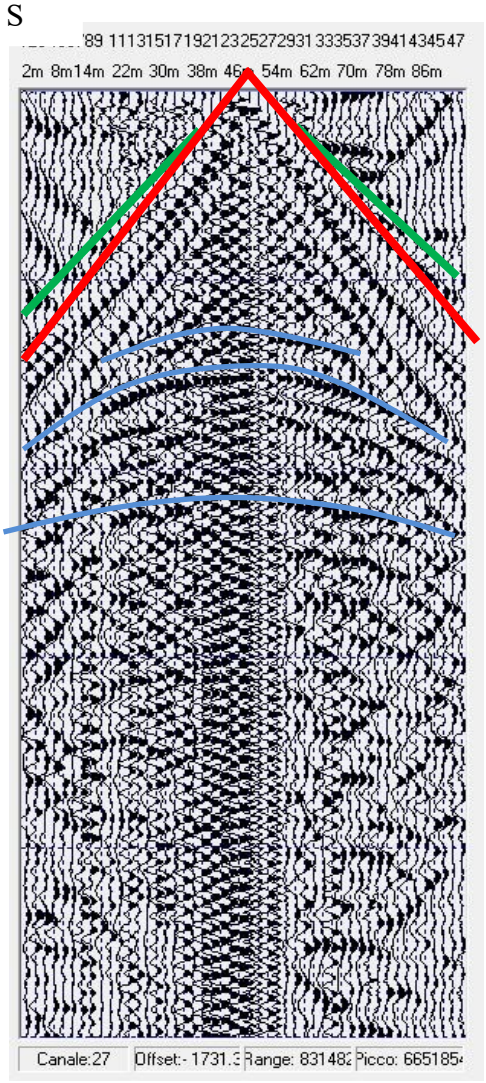


Illustration 3.2-2

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. In the case of MASW, the generating properties for low frequencies must be considered.

	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, the MASW technique is based on the analysis of the dispersion of surface waves. The frequency range of the surface waves depends on the source and the type of soil crossed by the waves.

In general, this signal is concentrated in a range between 10Hz and 50Hz, therefore it must be possible to record the signal with a geophone that does not filter the data in the range of interest. Generally the geophones to be used are geophones from 4.5Hz to 80V / m / s.

This does not mean that it is not possible to analyze soil dispersion even with geophones with higher frequencies, bearing in mind that the low frequency part may not be representative of the real context.

4 Data processing

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 (see chapter. 2.2.1 Dataset pag. 13).

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

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

the traces, namely:

where f_l and f_h represent the threshold frequencies.

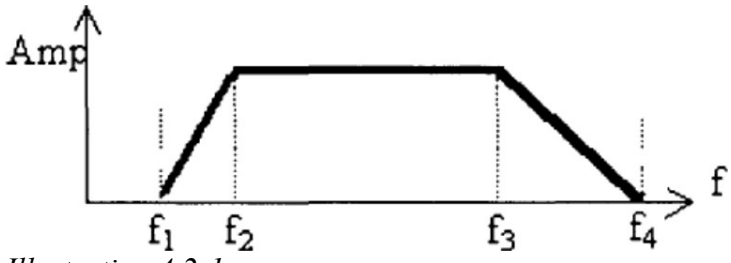


Illustration 4.2-1

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.

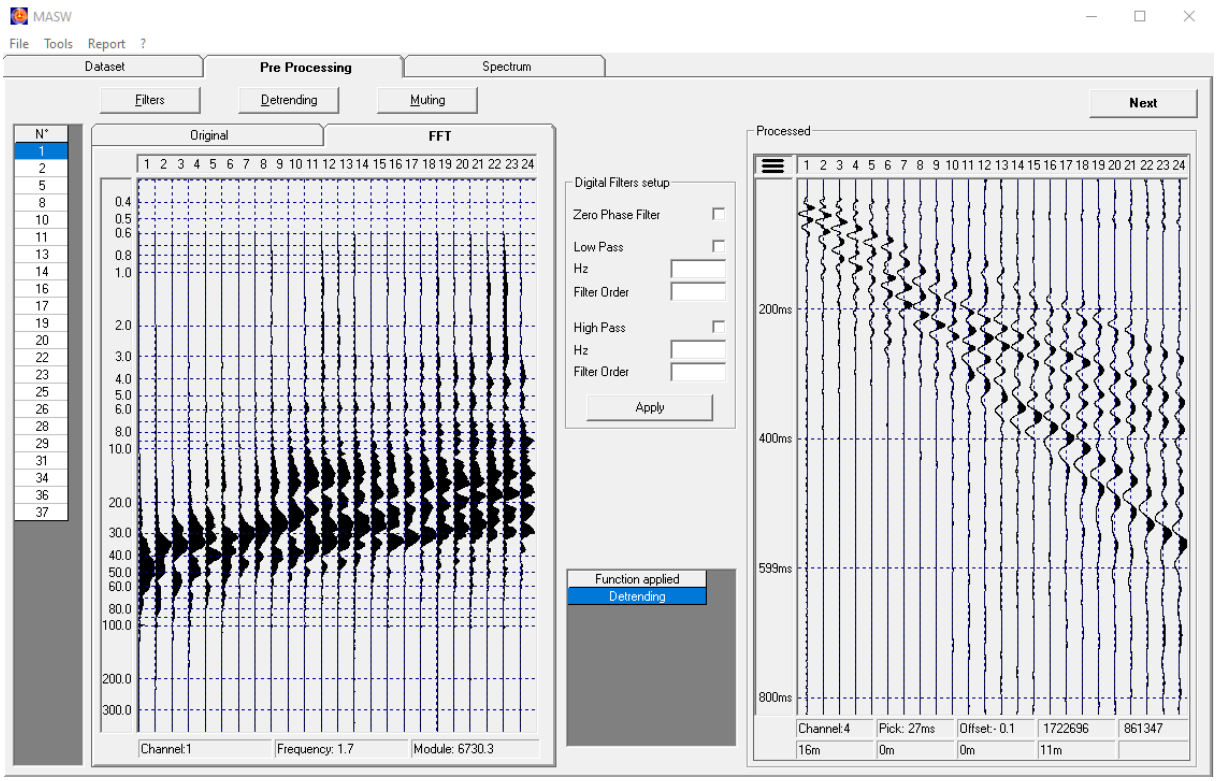


Illustration 4.2-2

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.

The use of filters in the MASW technique is strongly discouraged. In the case of extremely noisy contexts or with the presence of predominant frequencies of electrical - electromagnetic origin, it makes sense to try to eliminate these disturbances.

4.3 Detrending

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

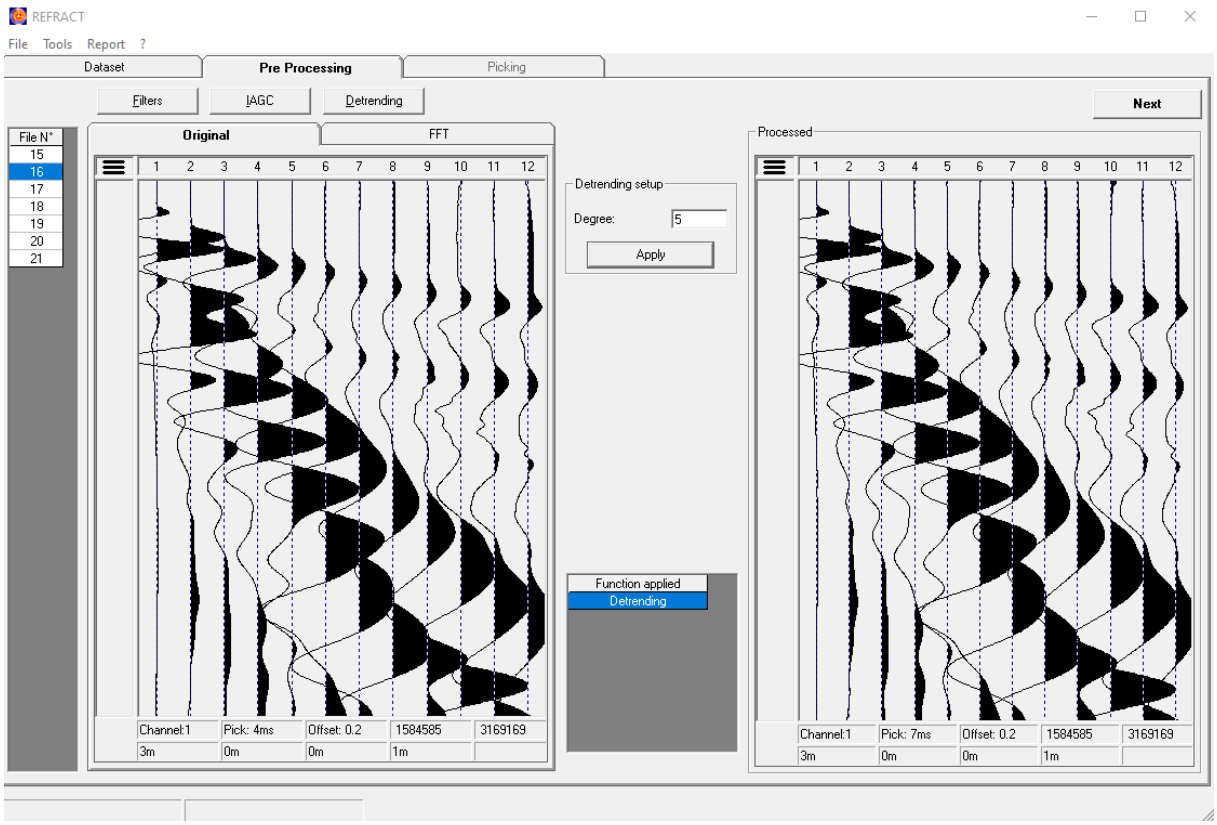


Illustration 4.3-1

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

4.4 Muting

Muting is perhaps the most important function in MASW. It allows to isolate the train of surface waves and therefore to improve the definition of the speed spectrum.

In general, in the case of Rayleigh waves, the signal above the wave train containing the refractions, reflections and environmental noise, and the portion below the wave train containing the environmental noise are eliminated.

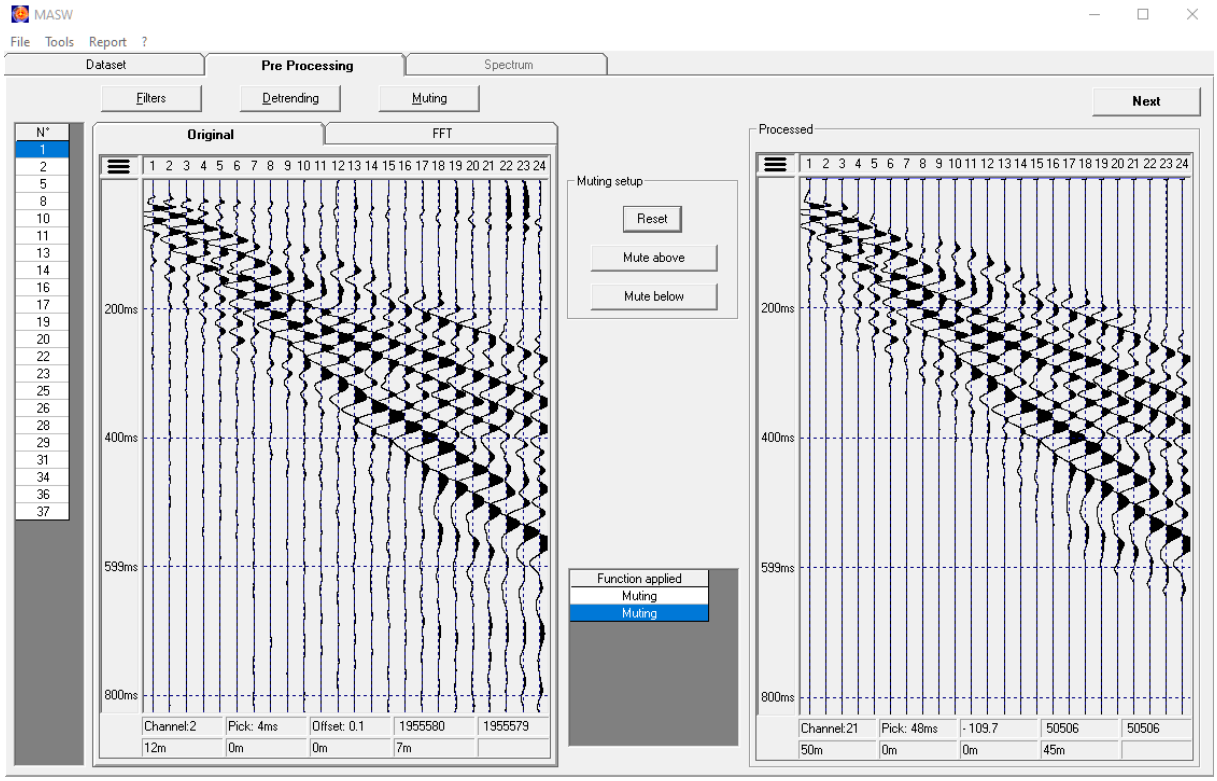


Illustration 4.4-1

In the case of Love waves, the signal of the first arrivals (or just above), containing the environmental noise and the P signal generated by the source, and the signal under the wave train that contains the environmental noise and the reflected signal are eliminated.

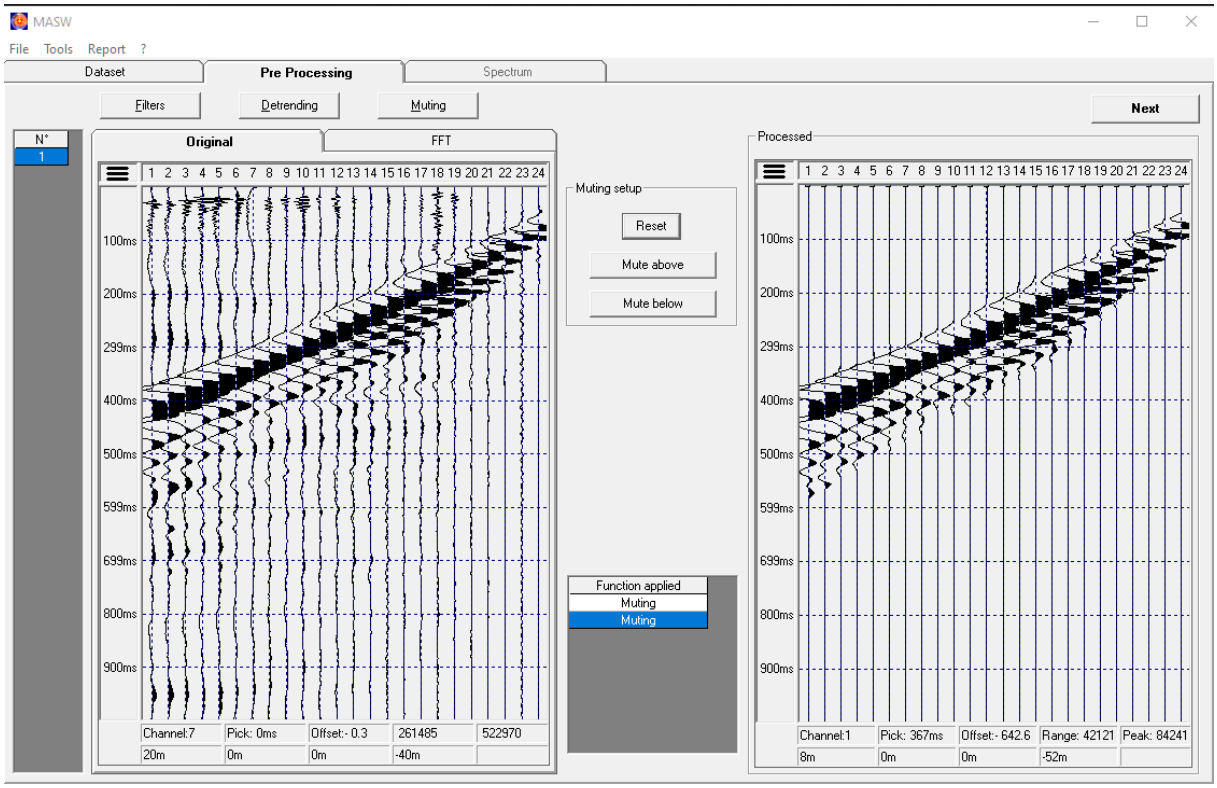
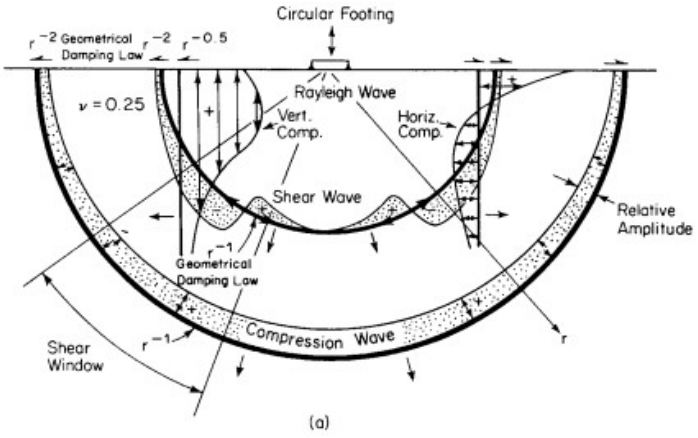


Illustration 4.4-2

4.5 MASW

The MASW method analyzes the dispersion of surface waves to be able to reconstruct a seismostratigraphic profile related to the shear waves.

During the energization phase, the pulse on the ground generates a series of wave trains, of which the one relating to surface waves represents about 1/3 of the energy content spent.



Wave Type	Per Cent of Total Energy
Rayleigh	67
Shear	26
Compression	7

Illustration 4.5-1

The surface waves are mainly represented by the Rayleigh waves and the Love waves, which are generated respectively by the interaction of the volume waves P and Sv and the surface for the former, and the interaction between the Sh waves, at the contrast of stiffness of the topographical surface.

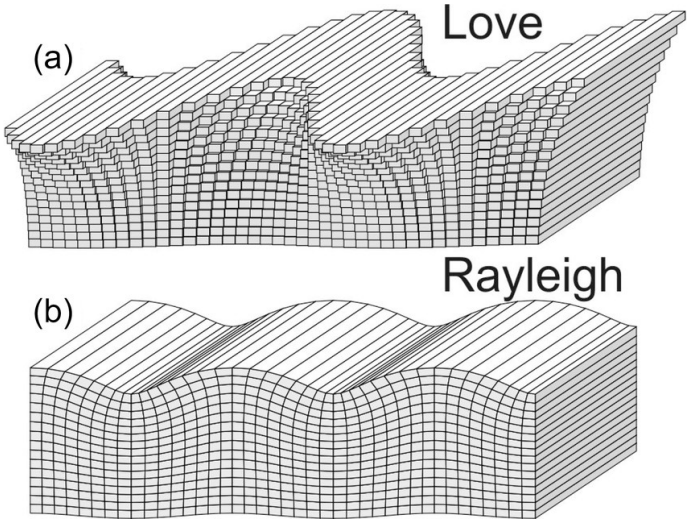


Illustration 4.5-2

The amplitude of these waves decays with the depth and with the distance from the energization point according to the 1 / r law. The depth of investigation is directly proportional to the frequency value, where as the frequency decreases the wave train engages volumes of soil at greater depth.

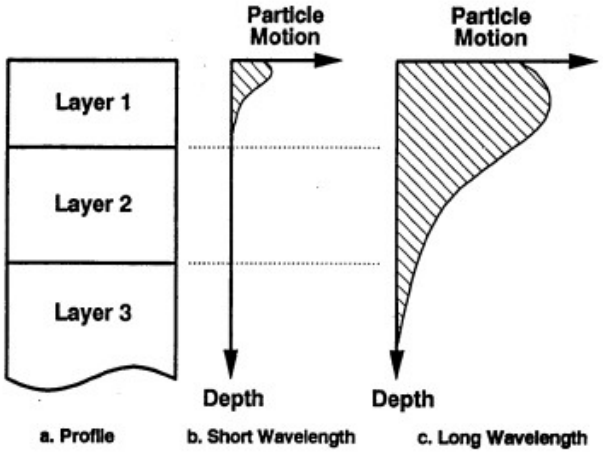


Illustration 4.5-3

In a multilayer system, the energization determines, with regard to the surface waves, a change in the speed of the different wave components, allowing to evaluate the elastic behavior of the soils at increasing depths. The analysis is conducted by examining the dispersion of the wave train due to the speed variation of the frequency components of the wave train.

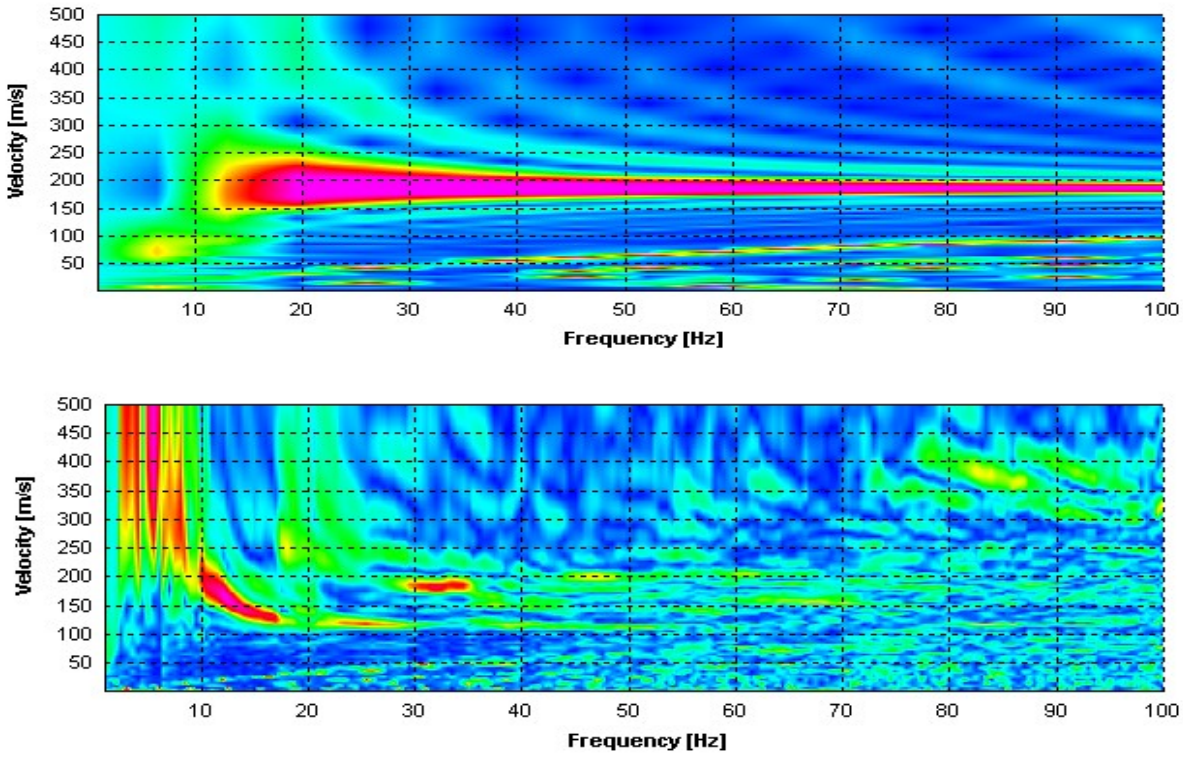


Illustration 4.5-4

In the figure two examples of non-dispersive homogeneous medium (above) and dispersive

stratified medium (below).

The study of the dispersive spectrum makes it possible to identify the modes that characterize the stratigraphy and therefore to generate a 1D model of the same. The final goal of the technique is to calculate the speed profile of the shear waves according to the formula:

$$V_S = \frac{H}{\sum_{strato=1}^{N} \left(\frac{h(strato)}{V_S(strato)}\right)}$$

The resolution of the different frequencies, for the characterization of the subsurface velocity profile, and the ability to acquire information at sufficient depths, depends on the geophonic interval used in the survey and the length of the spread (Park & Xia, 2001).

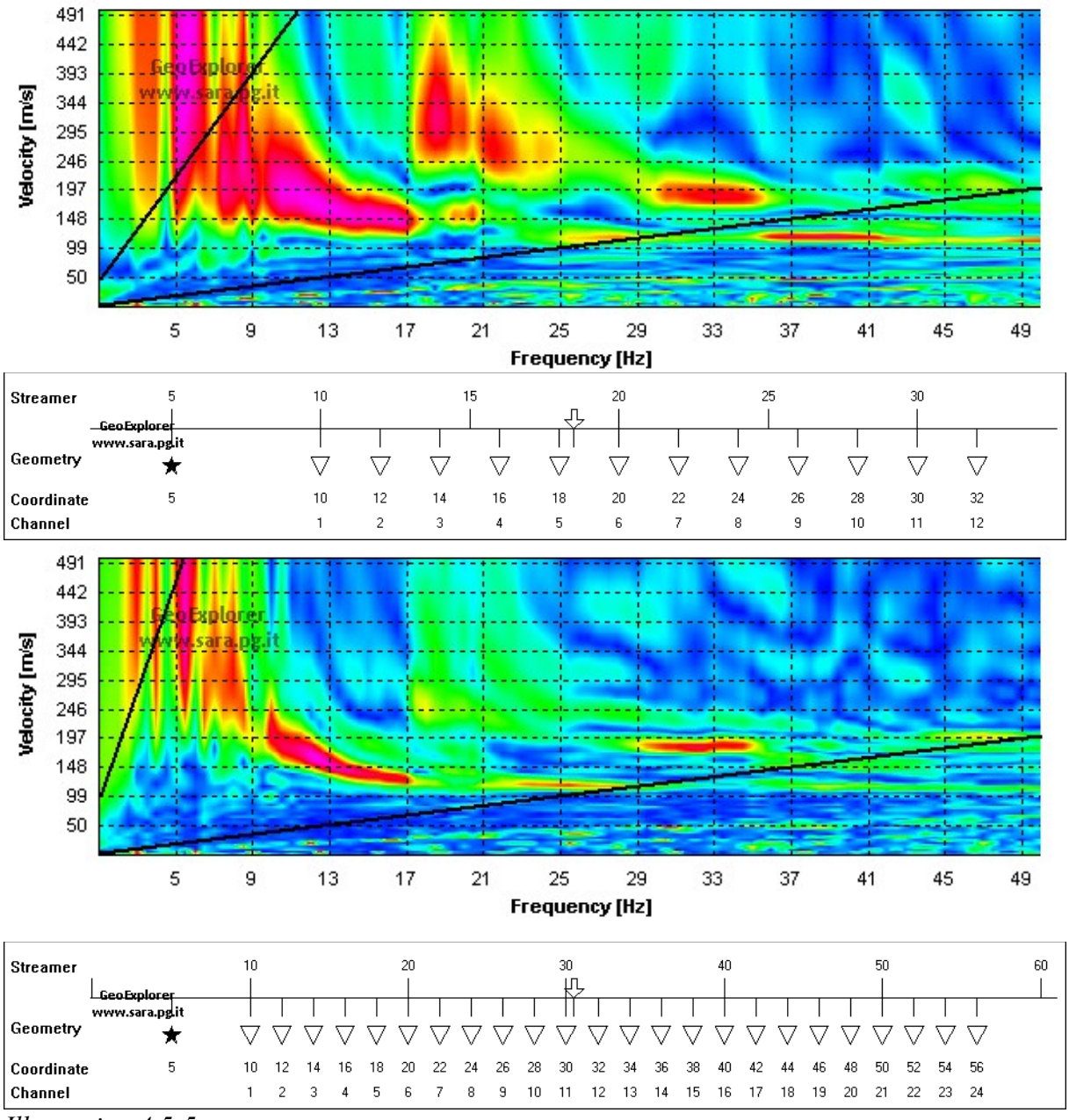


Illustration 4.5-5

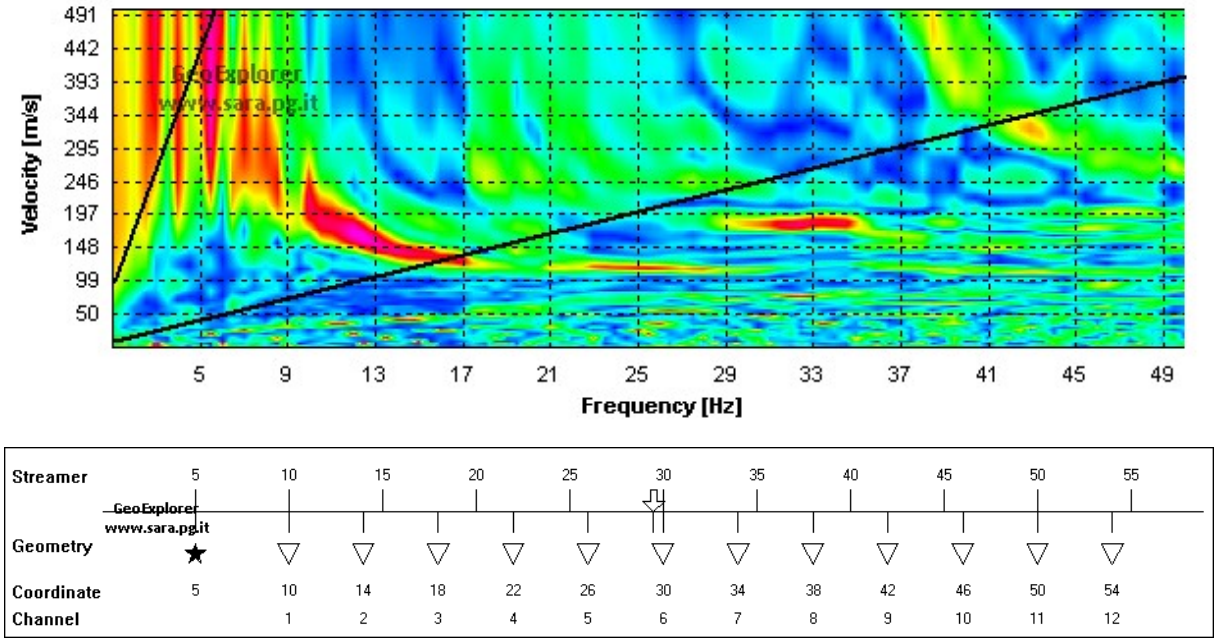


Illustration 4.5-6

In the images above it can be seen how the geometric variations, such as the spill length, and the intergeophonic distance, respectively influence the separation and recognition of modes and the definition of the spatial alias. The image below shows the F-K graph with the effect of the spatial alias.

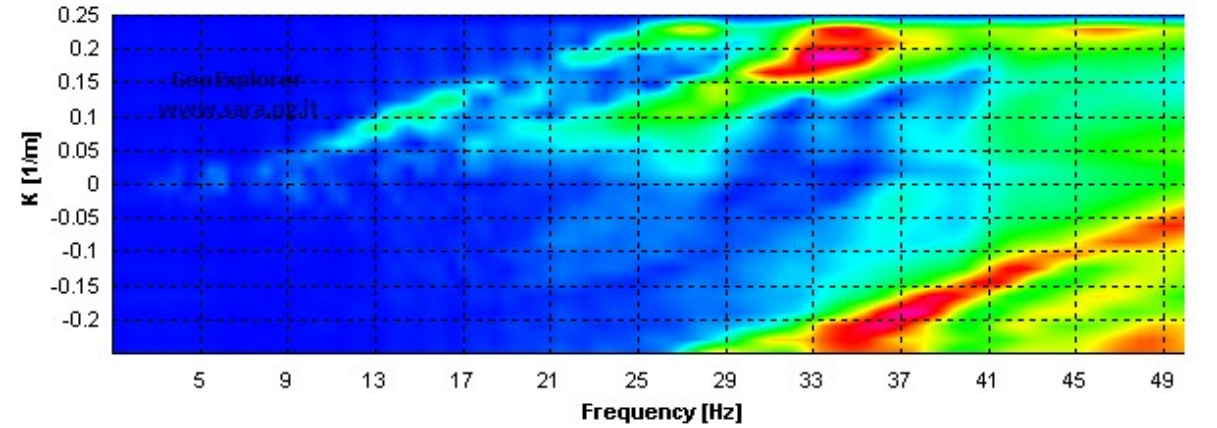


Illustration 4.5-7

It can be seen how at the number K = 0.25 the signal undergoes the alias and can be found in the negative quadrant.

The choice of the acquisition geometry must consider the goal of being able to easily reach the maximum depth, but taking into account the assumptions of the technique such as:

- Lateral homogeneity
- Flat surfaces parallel or with a maximum slope of 15%

There are virtualization techniques that allow you to extend the maximum length of the string and decrease the intergeophonic distance.

The interlacing technique allows you to halve the intergeophonic distance, combining two acquisitions with common spreading but bursts spaced half the intergeophonic distance.

The changes in the spectra can be seen in Illustration 4.5-8 and Illustration 4.5-9

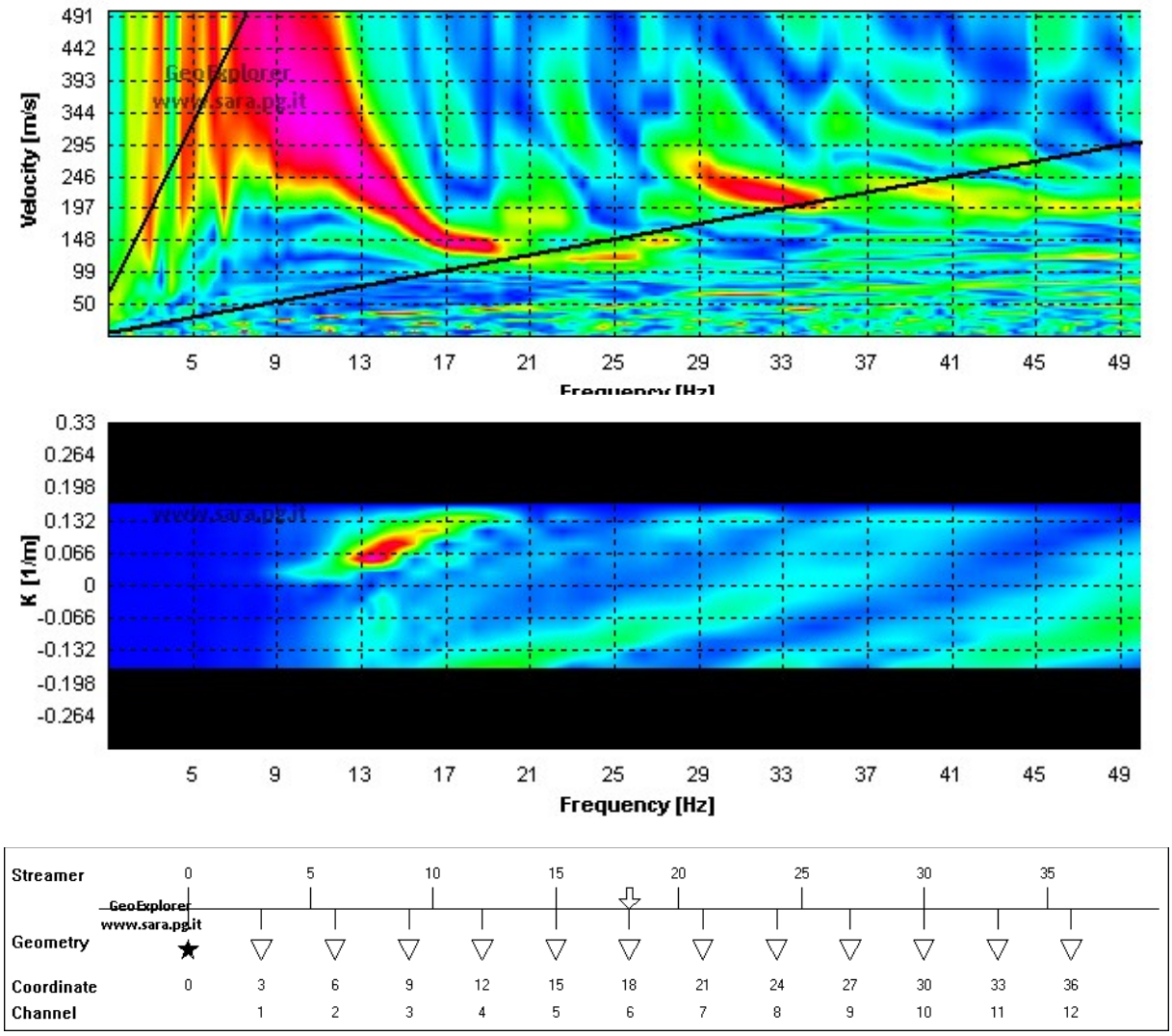
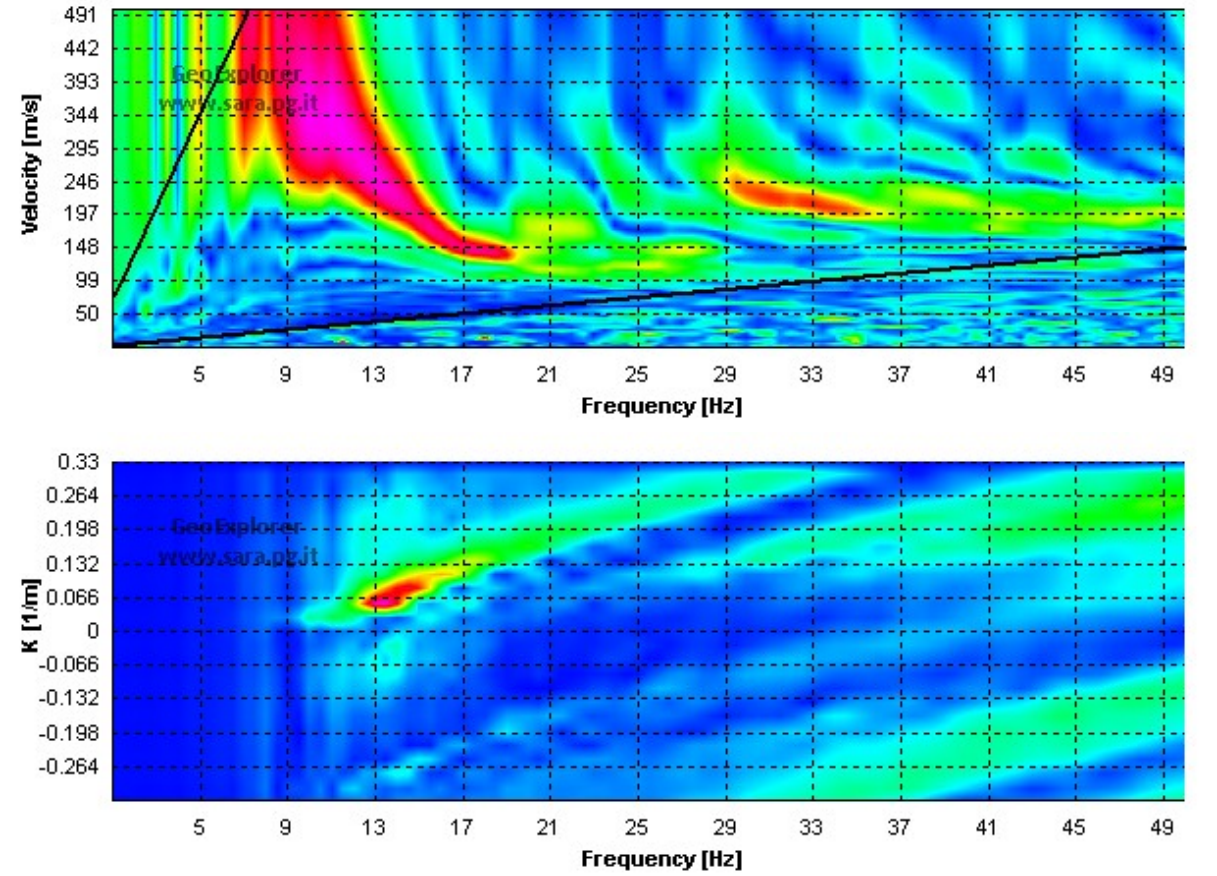


Illustration 4.5-8



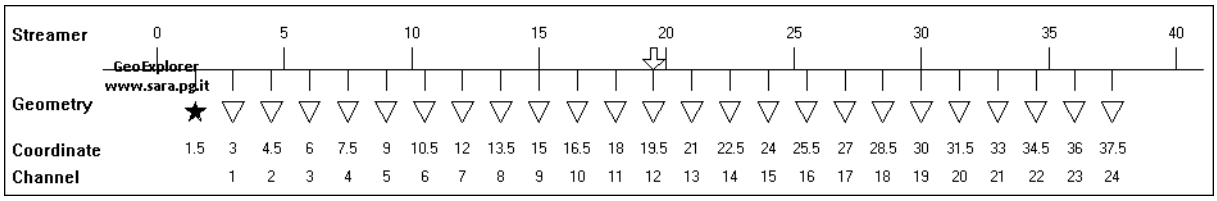


Illustration 4.5-9

The Walkaway technique, on the other hand, allows you to virtualize an acquisition with double the spread. This acquisition is generated by two lines with a common explosion. In Illustration 4.5-5 the changes in the spectrum can be seen.

The use of these techniques, however, involves contraindications that often determine a reduction in resolution and detail of the dispersive spectrum of analysis, but also compensates for the limited penetration capacity of the survey, which rarely exceeds 20-25m, and the impossibility of developing stretches of particular length, being able to engage in the maximum extension of the geophonic direction seismic-stratigraphic situations that are not really uniform or due to logistical limitations.

For more details on how to create these files, refer to the GE DOREMI manual.

4.6 Bibliografia

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