GEOEXPLORER MARW

Version 1.0.2

USER MANUAL

(06 / 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.*

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WARNING!

This software has been created for professional purposes. It must be used on a computer system and with a suitable electrical devices, used by qualified personnel in compliance with the ECC electronic safety and electromagnetic compatibility laws. All the certificates regarding those materials are responsibility of the end user. The software is provided "as is" without any express or implied warranty. The developer of the GEOEXPLORER MARW is not responsible of any loss of data, accident or damage of any kind and accepts no liability in case where the product has been used inappropriately or not as intended.

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1 Introduction

The MARW (Multi-channel Analysis of Reflected Waves) module has been developed with the main aim of improving the quality of the data recorded, with the possibility to perform a quality check directly on the field. The module gives the possibility to the operator to make a fast acquisition and use different tools from filters and velocity spectrum to deconvolution and static correction to compute and create a 1D converted model.

2 MARW

To open the module you must to have plugged the USB license.

Illustration 1

Please note: the file .ref is created when one seismogram is recorded or added on the Reflection window.

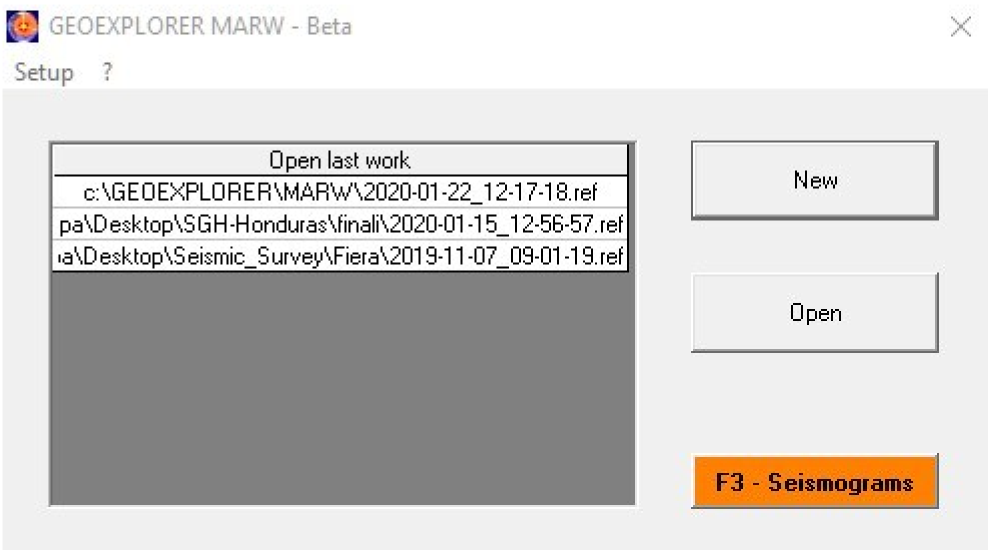

Illustration 2

The main window is composed with the *Open last work* list where is possible to see the last *ref* file opened, the *New* button that allows to select the folder where the data are stored, the *Open* button the allows to open a .ref file and the *F3 seismograms* button that has the same function it has in the GEOEXPLORER DoReMi.

2.1 New

After selecting the folder with the *New* button, the software will open the *Reflection* window, an empty summary window for the acquisition.

Illustration 3

With the *Add file* button it is possible to load all the acquisition files and fill the acquisition list; selecting a file from the list the software will show the acquisition geometry.

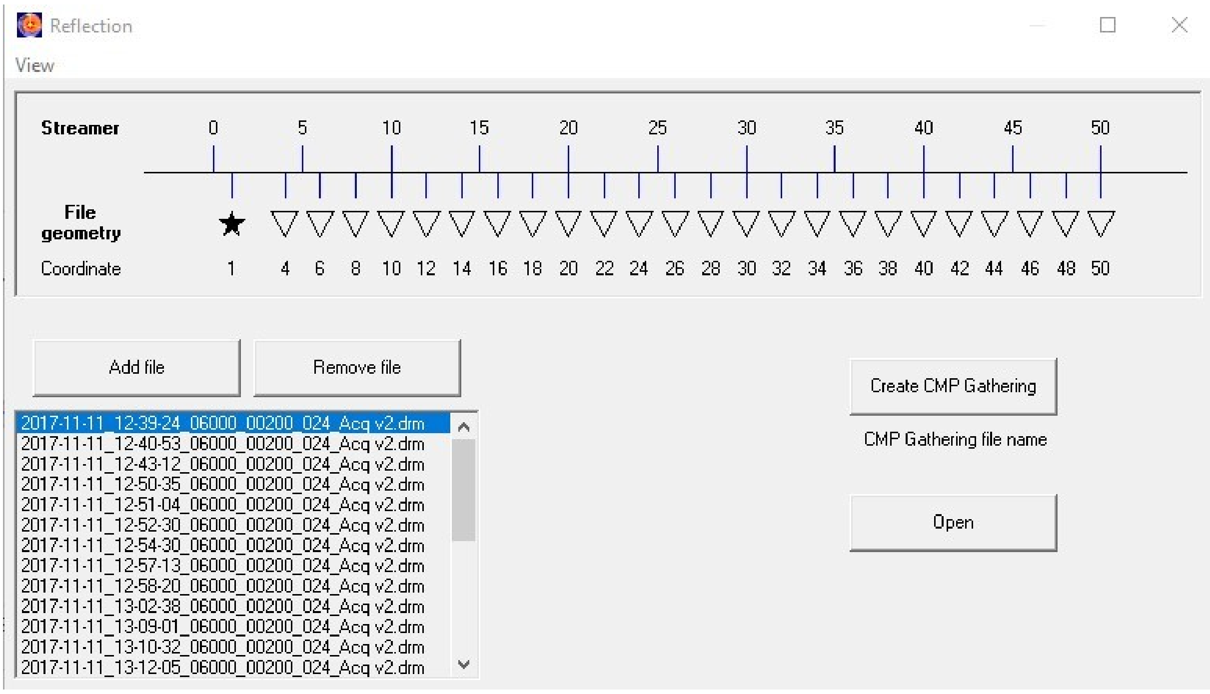

Illustration 4

With the *Remove file* button is possible to delete one file from the list.

With the *Create CMP Gathering* button it is possible to gather the seismograms to generate the various CMP for the selection.

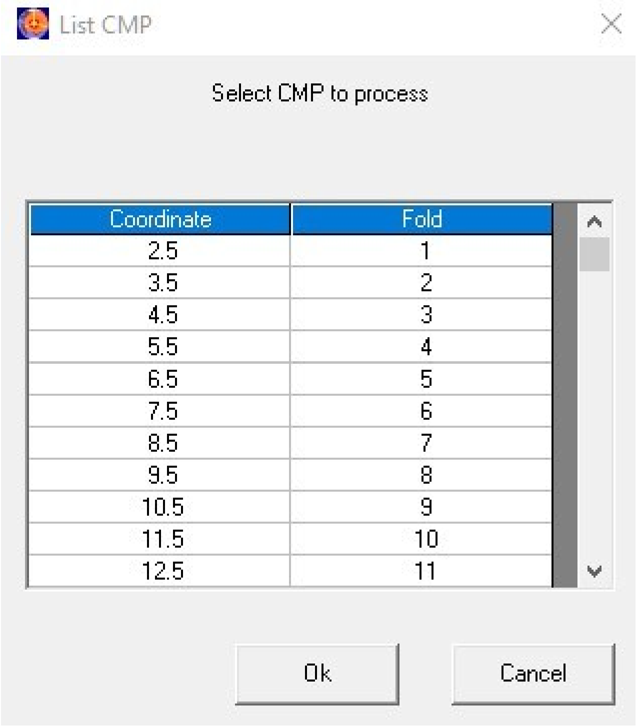

Illustration 5

After selecting the CMP from the list, the *Open* button allows to create the CMP and on the *Reflection window* it is possible to see above the *Open* button the name of the CMP selected.

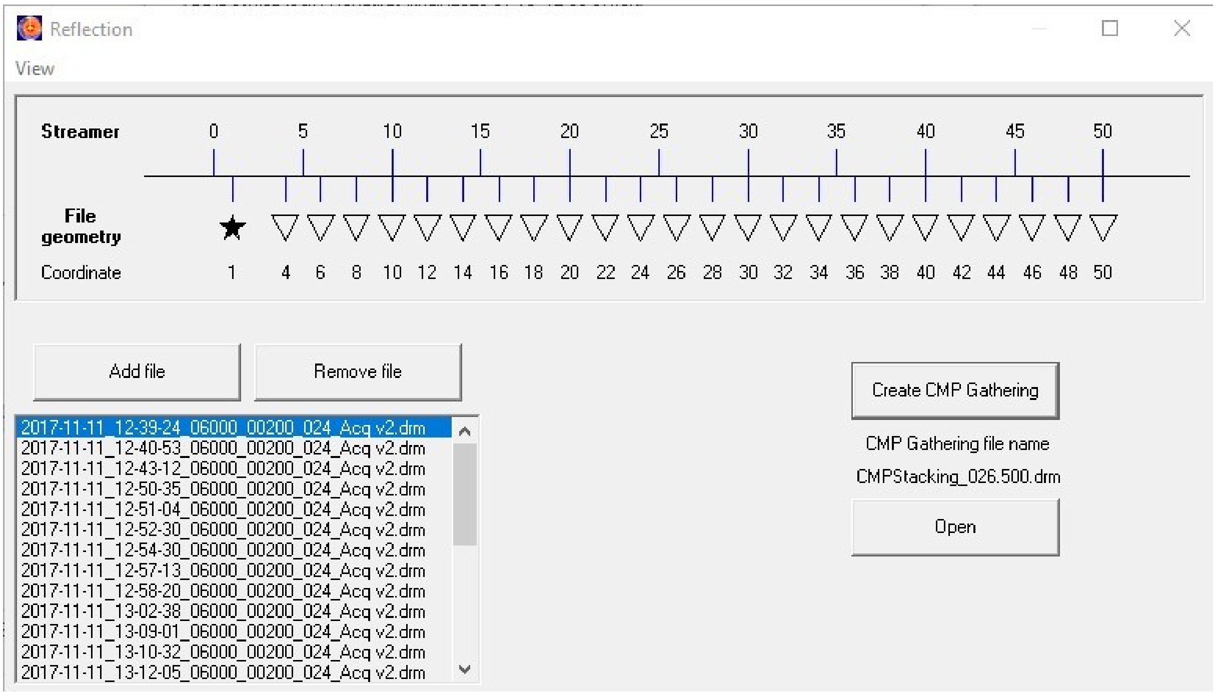

Illustration 6

To open this file on the elaboration window use the *Open* button.

2.2 Waveform display window

With this window is possible to process the data.

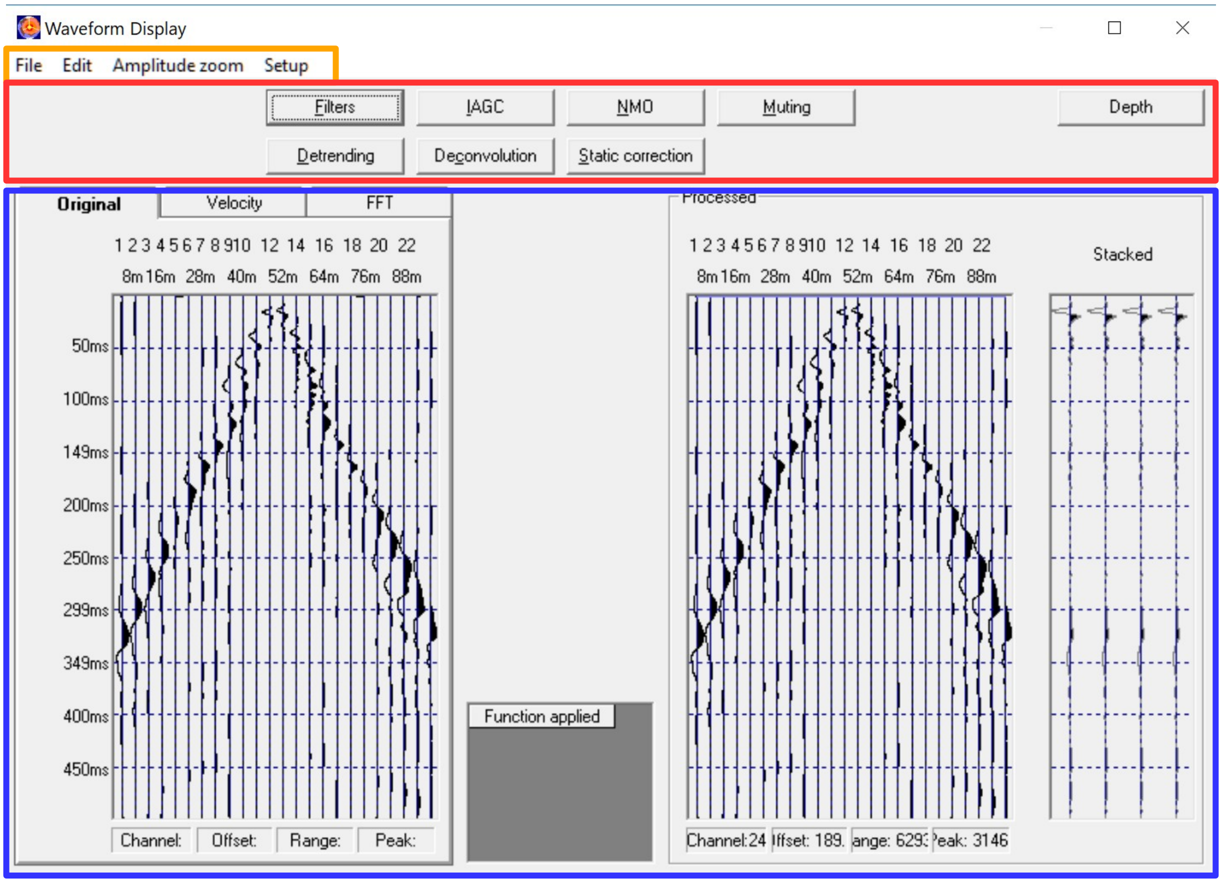

Illustration 7

Menu bar (orange box) contains the main menu of the software.

Process tools (red box) contains all the tools to use for the elaboration.

Seismograms (blue box) contains the tabs for the original seismogram, the spectrum velocity and the FFT of every channel, the processed seismogram on the right and the stack of the processed. Between the two seismograms will appear the menu of the selected tool and the history of the process.

Please note: the three tabs (Original, Velocity and FFT) are completely independent from the tool you are using. For example is possible to visualize the FFT while you are using the muting or the IAGC. For every operation you apply the software will compute the new visualized tab.

Please note: the amplitude and time zoom of the two seismograms (Original and Processed) are not independent; if you apply a zoom on the Processed this zoom is automatically applied on the Original seismogram or vice-versa.

2.2.1 *Process tools*

There are different tools that will allow you to process the data to highlight the reflections.

2.2.1.1 Filters

The MARW software allows you to apply different kind of filters to the seismogram. Regarding the filters see the relative chapter on the GEOEXPLORER DoReMi user manual.

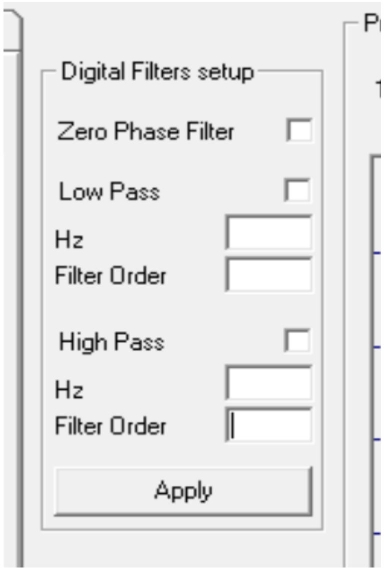

Illustration 8

2.2.1.2 FFT

The *FFT* tab will show the frequency range of every channel allowing you to decide what could be the best filter to use.

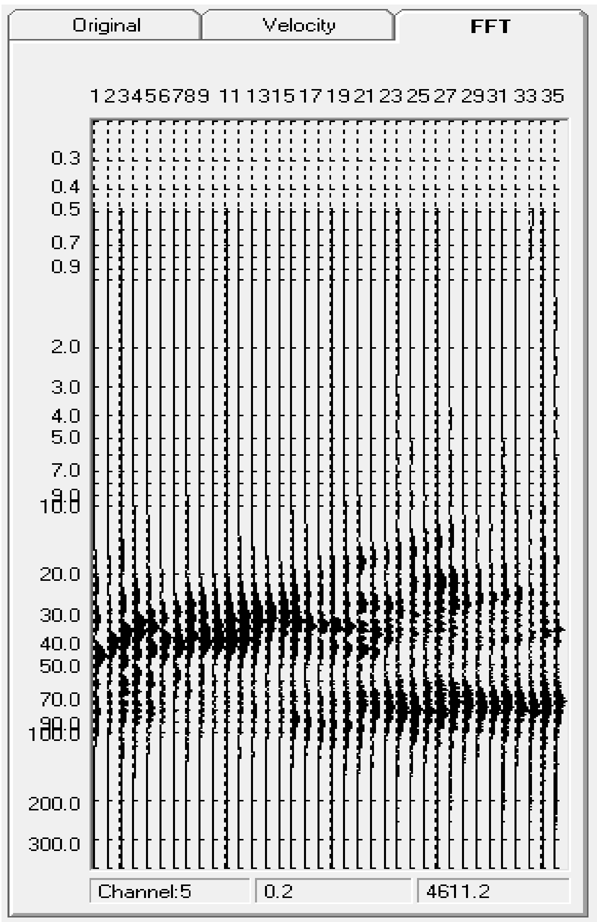

Illustration 9

2.2.1.3 IAGC

The Instantaneous Automatic Gain Control is a tool that allows you to restore the effect of geometry spreading.

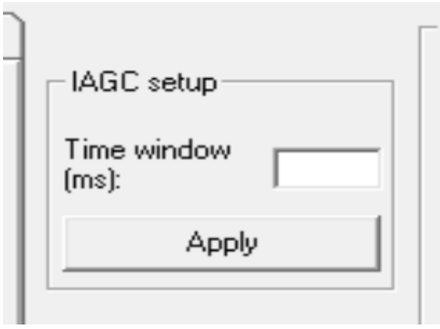

Illustration 10

2.2.1.4 Velocity spectrum

This function will show the velocity spectrum of your data. It is possible to set the spectrum parameter on the menu *Setup* (see chapter 2.2.2.4 Setup menu page 21).

Below on the left is possible to see one of the possible result of the velocity spectrum. The colored bar over the spectrum allows you to highlight the high value of coherence. Clicking on it, the color arrangement of the value will have a different lowest level and a black line will appear on the colored bar.

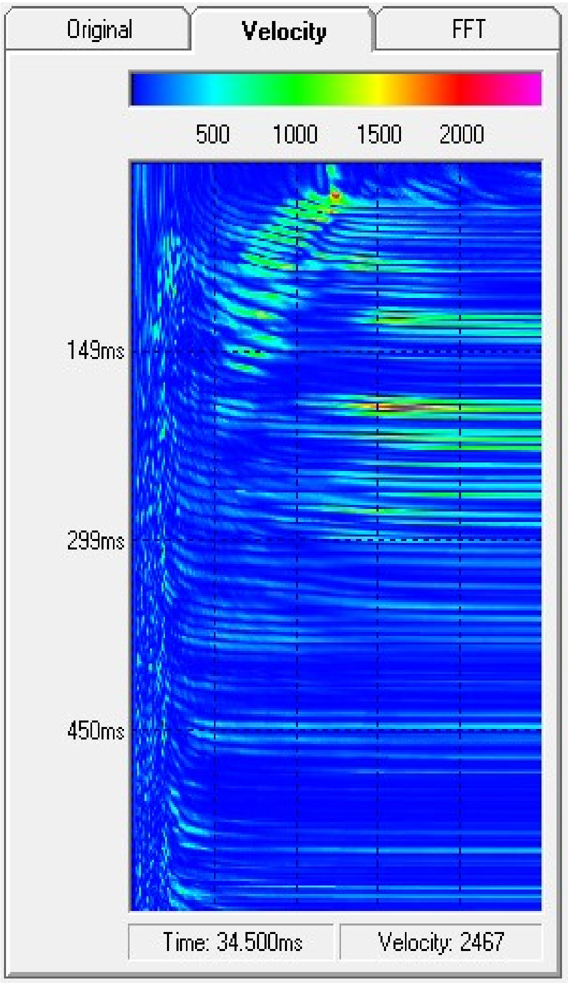

Illustration 11

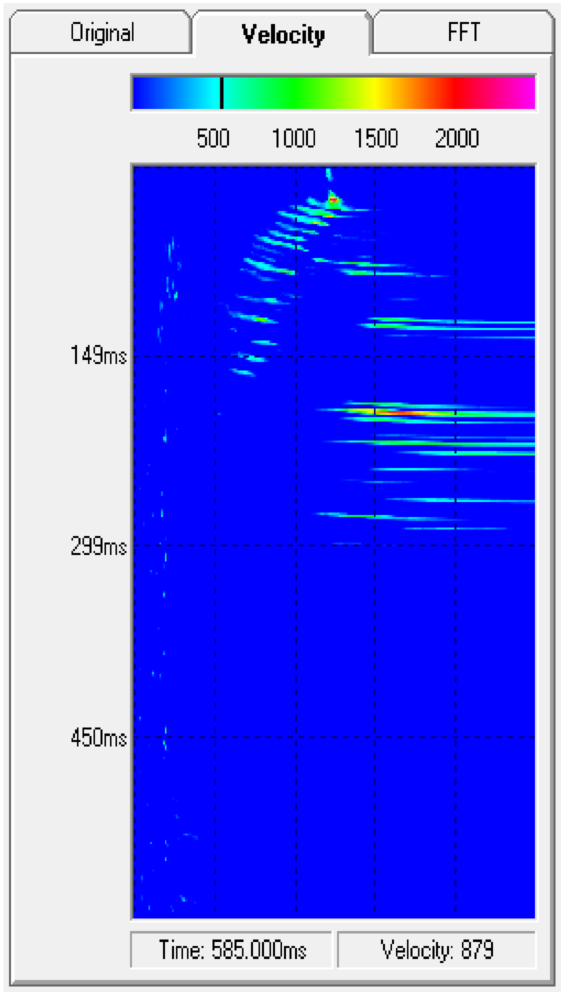

Illustration 12

Moving the mouse over the *Spectrum velocity* the software will plot the reflection on the seismograms (light blue points). By the right click the pick menu will appear; clicking on *Pick* the software will save the T0 and velocity of the point selected and changing the reflection on the seismogram in to a red line. The MARW software will calculate even the first multiple reflection of the selected reflection, drawing it as a lighter red line.

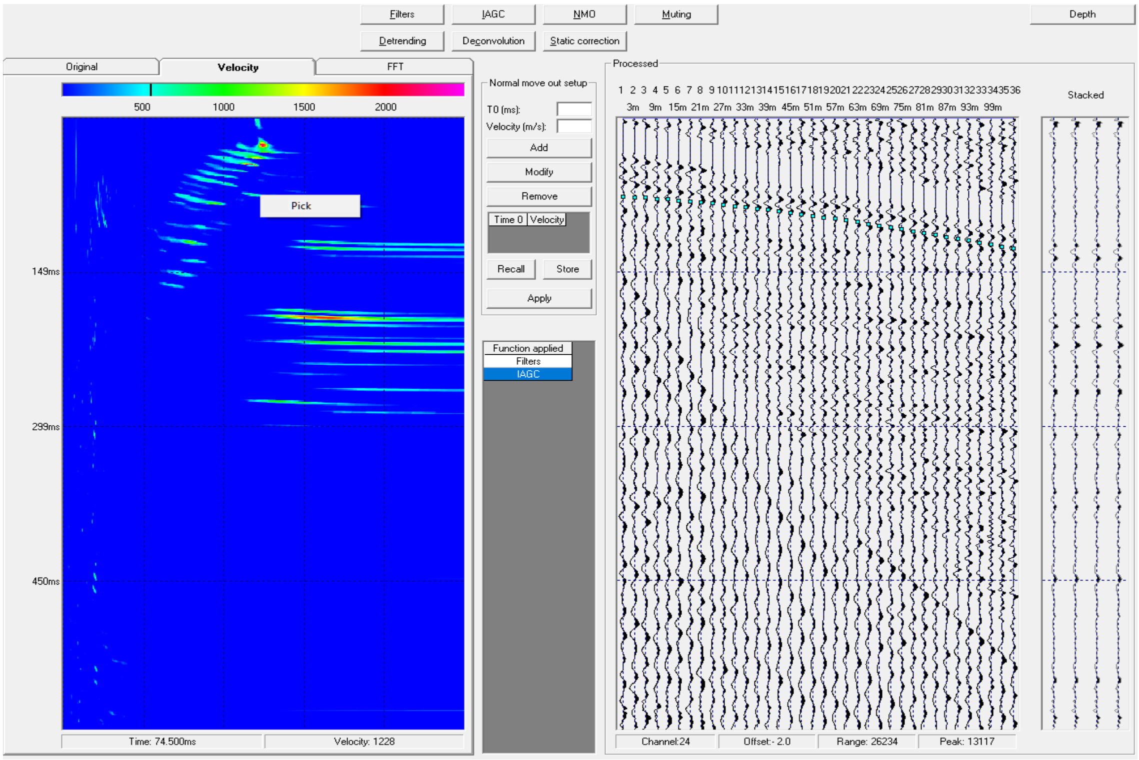

Illustration 13

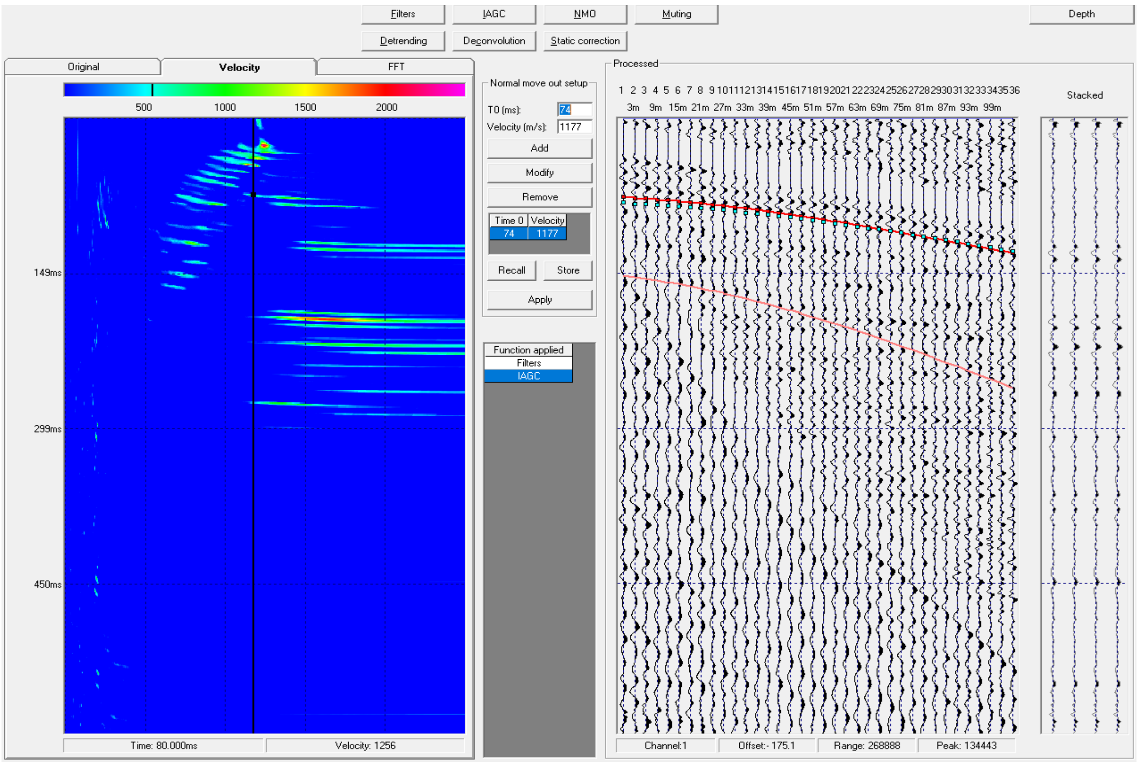

Illustration 14

On the spectrum velocity will be calculated the velocity profile; the dashed black line represents the interval velocity calculated by mean the Dix Formula, while the dark solid line represents the stack reflection velocity.

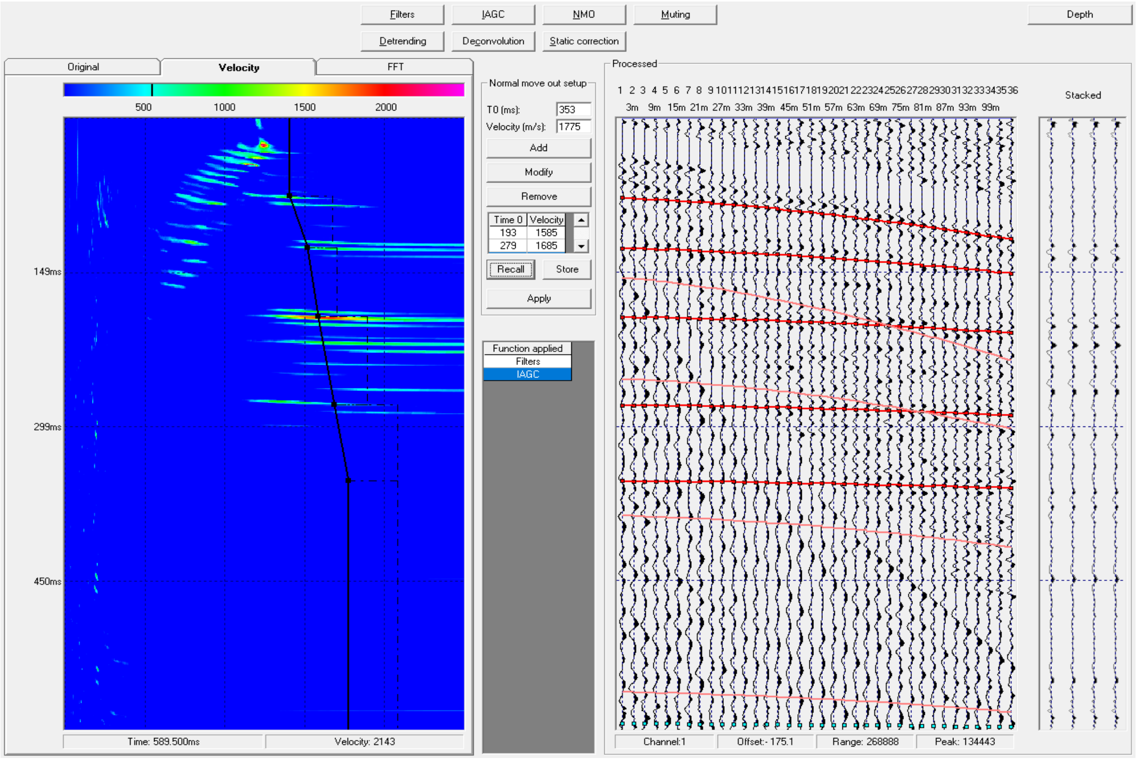

Illustration 15

While you are picking it is possible to hide the first multiple of every picked reflection. On the *Amplitude zoom* menu the voice *Hide/Show first multiples* allows you to choose if visualize the multiples.

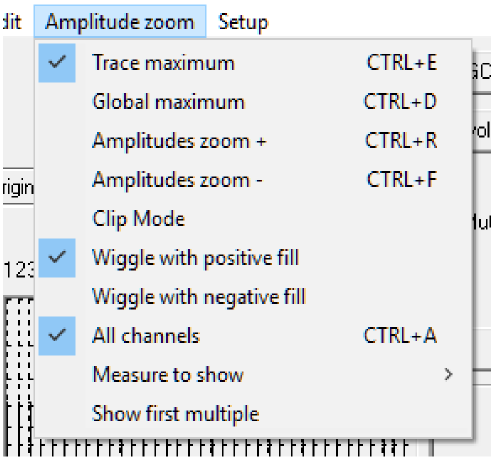

Illustration 16

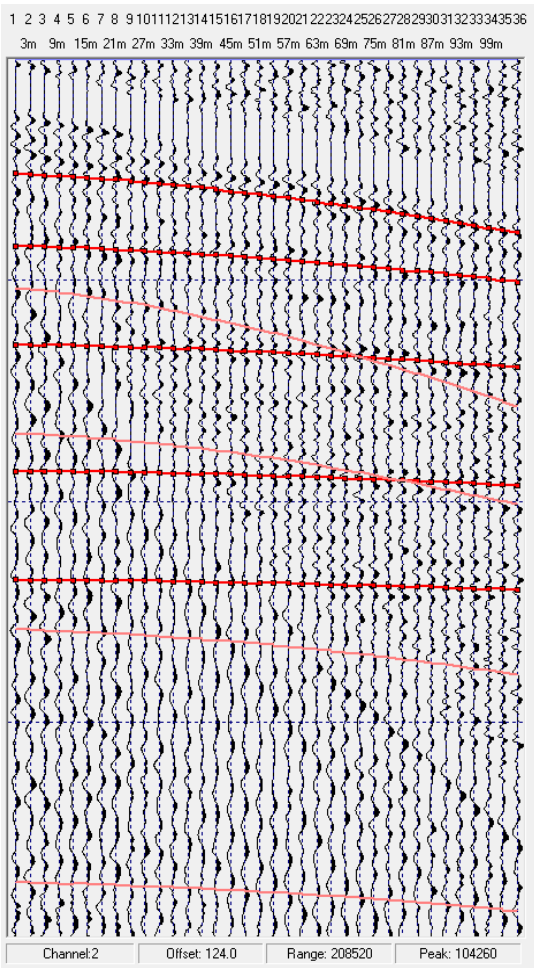

Illustration 17

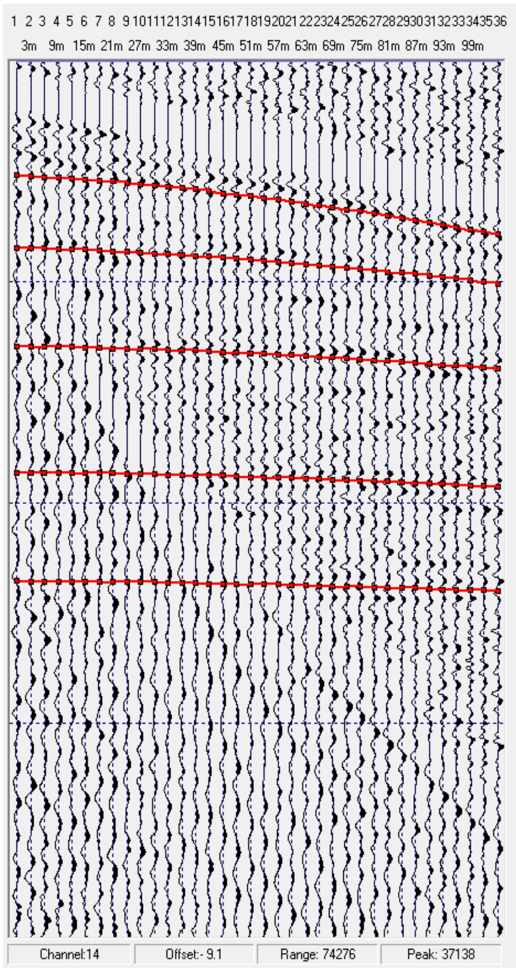

Illustration 18

2.2.1.5 NMO (Normal Move Out)

With this tool you will check the picking you have done on the *Velocity Spectrum*, and apply the Normal Move Out to the seismogram.

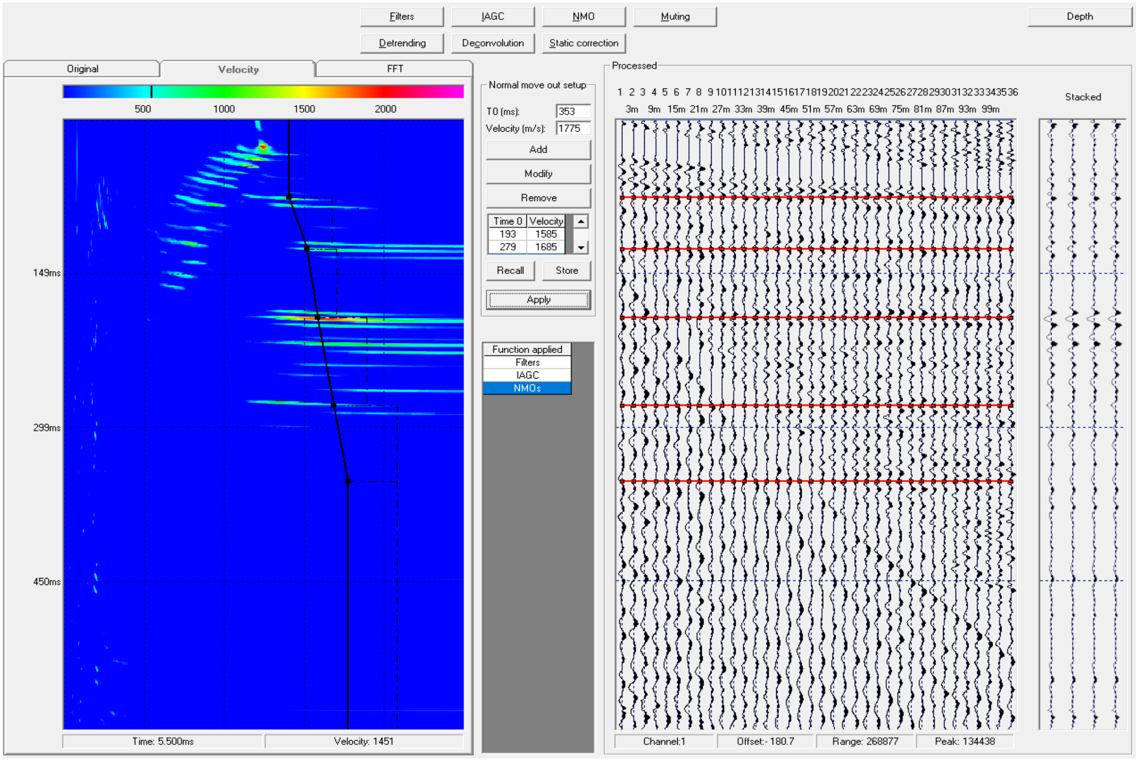

Illustration 19

Between the two windows (*Velocity Spectra* and *Processed*) will appear the *Normal move out setup.* On this menu is possible to set manually a T0 and a velocity of one reflection, edit the selected reflection on the list, save reflections and recall them and apply the NMO.

T0: set the time at zero-offset.

Velocity: reflection velocity; that will change the hyperbole shape.

Add button: will add a reflection with the T0 and Velocity you have set.

Modify button: will edit the selected reflection on the list with the parameters you have set up.

Remove button: remove the selected reflection on the list.

Store button: store the actual velocity model.

Recall button: recall the stored velocity model.

Please note: the functions Recall and Store can save one list of picked reflection, and this picking is saved on the main folder of the DoReMi. That means if you run another survey, the last stored NMO picking can be recalled until another NMO picking is stored.

Illustration 20

2.2.1.6 Muting

This tool allows you to delete all the data above the purple line. In general is used to delete the data before the first break and/or overstretched signals after the NMO. To create this line you must to hold the shift button and click over the processed seismograms to pick the anchorage point of the muting line.

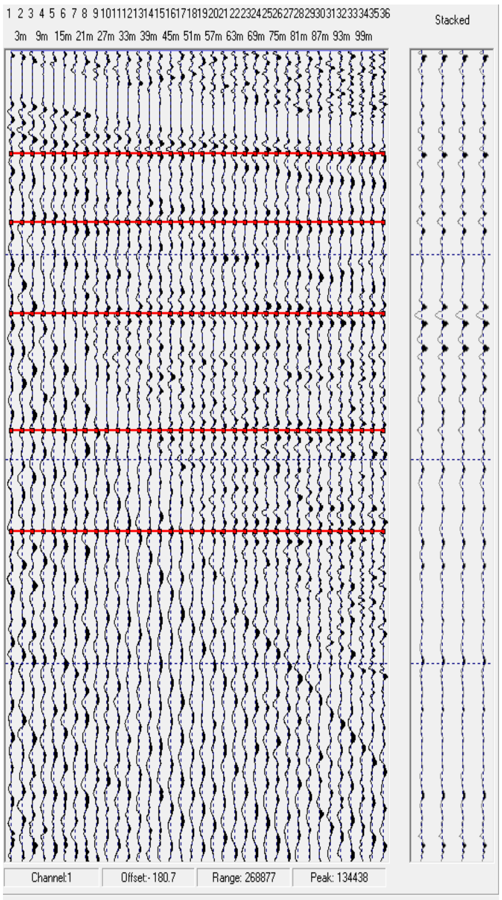

Illustration 21

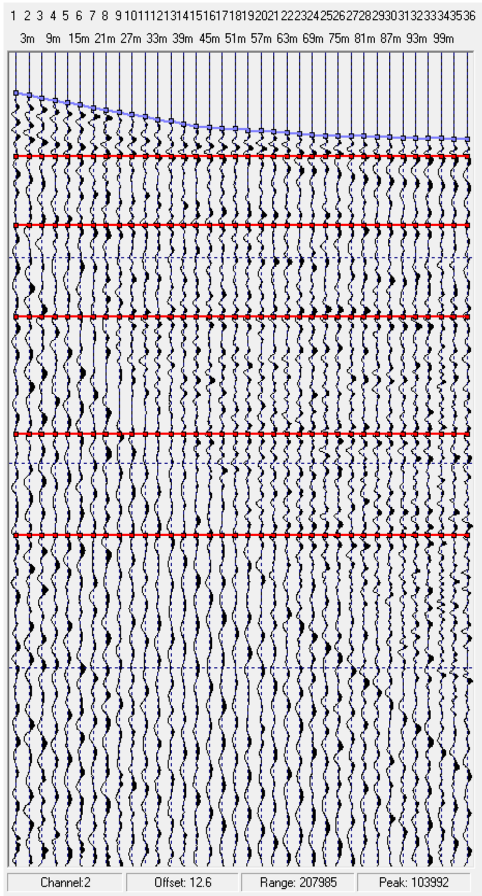

Illustration 22

2.2.1.7 Detrending

This tool allows you to delete a trend. The Degree allow you to choose what polynomials to calculate.

Illustration 23

2.2.1.8 Deconvolution

The deconvolution allows you to remove the wavelet from the recorded data, showing the reflectivity. The software MARW allows you to use the *predictive deconvolution* and *spiking deconvolution.*

Noise (%): gives the possibility to add white noise to the seismogram.

Window length (ms): allows you to choose the length of the data used to calculate the Wiener filter.

Filter length (ms): allows you to choose the Wiener filter length.

Lag: this value is only pickable on the stack of the auto-correlations (red box).

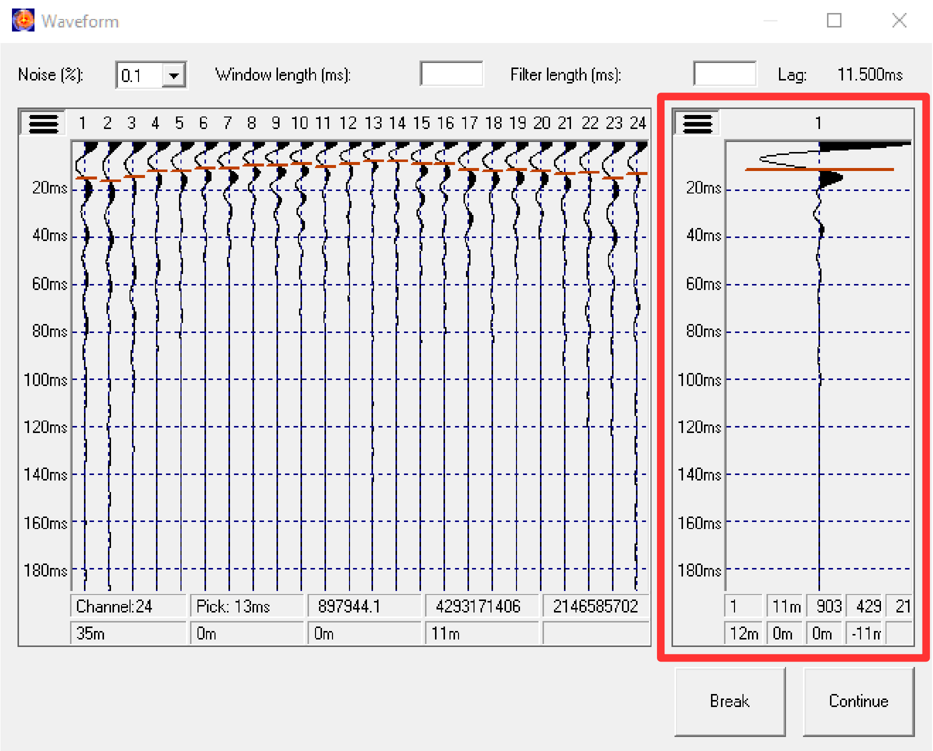

Illustration 24

To select the value of the *Lag* you must to open the picking menu by right click on the stacked waveform. To select the predictive deconvolution use *Pick select*; with this option the value is exactly the value in ms of your click on the waveform. Using *Pick for spiking* the value chosen will be 0 ms.

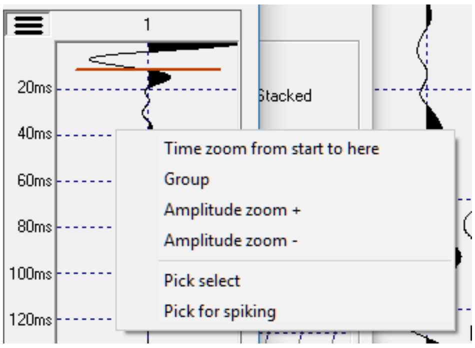

Illustration 25

2.2.1.9 Static correction

This tool allows you to determinate the near surface velocity model of the weathered layer, and applying the correction to align every channel as the acquisition was done on the reference layer.

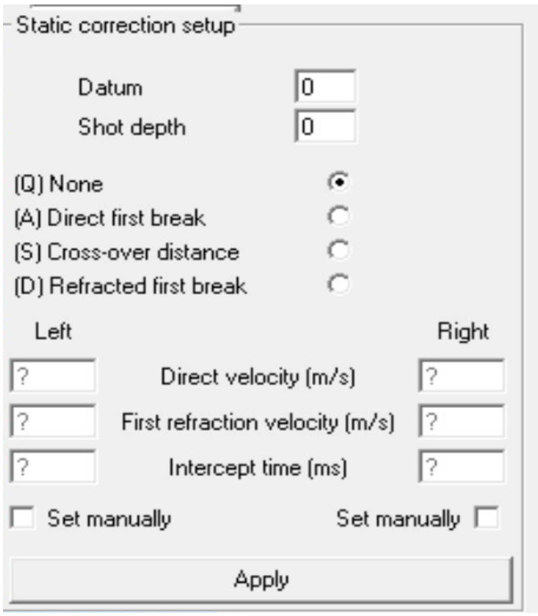

Illustration 26

This tool need different data:

Datum: is the elevation of your reference level.

Shot depth: is the depth of your shot from the surface.

- *(Q) None*
- *(A) Direct first break*
- *(S) Cross-over distance*
- *(D) Refracted first break*

Those option buttons allow you to pick on the seismogram the direct wave and the first refraction.

- *Direct velocity*
- *First refraction Velocity*
- *Intercept time*

On those fields it is possible to see the information of your picking on the seismogram.

Please note: if it is enabled the option Set manually, the picking options will not be enabled. With this option enabled is possible to write manually the velocities and the intercept time. Enabling and disabling this option the picked values will be deleted.

To pick the first break of the direct waves (pink segment) you have to hold SHIFT + left click on the point of the first arrive of the direct on the seismogram. The software will move the focus from *(Q) None* to *(A) Direct first break* and a second SHIFT + click will anchor the first break segment. The segment is editable until the third SHIFT + click is done. Whit that click the cross-over distance is anchored. From this point the software will show the refraction segment (violet segment). You have to click holding SHIFT on the seismogram to anchor the segment and allow the software to calculate the velocities of the direct waves and refracted waves.

Please note: for every SHIFT + left click the software will move down on the option button menu, from (A) to (D).

If you have to change the position of the 3 point clicked (first direct arrive, cross-over distance and last refraction arrive) holding the combination of button SHIFT+A or S or D will unlock the position of the points and it is allowed to change their position by using SHIFT+left click.

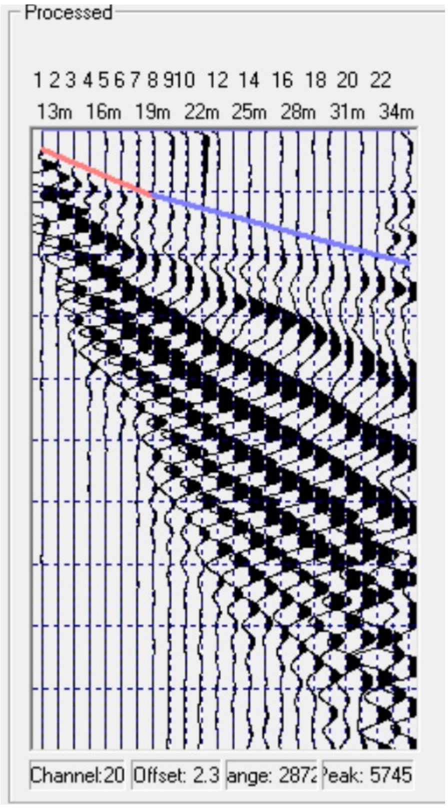

Illustration 27

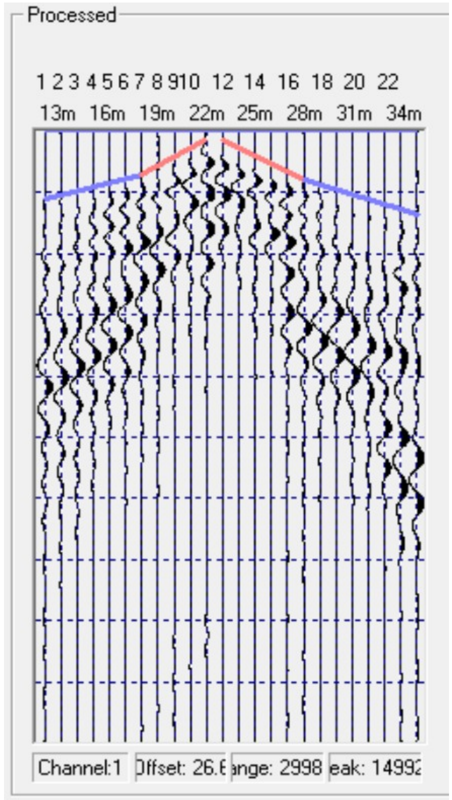

Illustration 28

If the shot is located inside the seismogram, the software allows you to have a double selection of the velocities, one for the left side and one for the right side.

The velocities you have picked and the intercept time are not editable until you do not check the *Set manually* option. Enabling this option will remove the segment on the seismograms allowing you to write the desired velocity and intercept time.

Please note: this tool is enabled even if you do not have set the elevation of every geophone. The default elevation setting is 0 for every geophone and for the source location.

Please note: in general it is useful to set a datum with an elevation at least with the same value of the higher elevation of the survey.

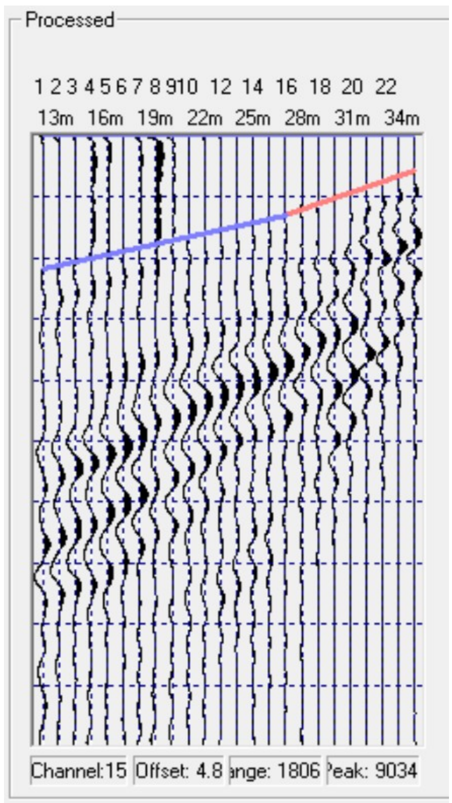

Illustration 29

2.2.2 Menu bar

On the menu bar there are different menu:

- *File*
- *Edit*
- *Amplitude zoom*
- *Setup*

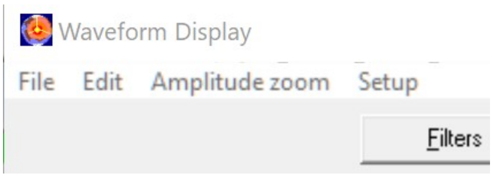

Illustration 30

2.2.2.1 File menu

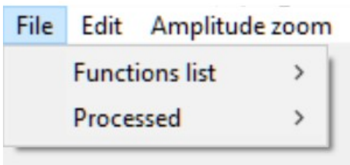

Illustration 31

In this menu it is possible to save, load and create a file that will contain all the information of the process done at that point. The file have the extension .fun

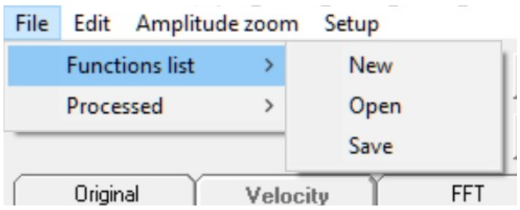

Illustration 32

It is possible to save the processed seismogram.

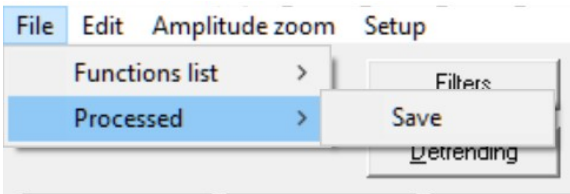

Illustration 33

2.2.2.2 Edit menu

In this menu are present all the tools that allow you to undo or redo the last tool applied or to reload the original seismogram.

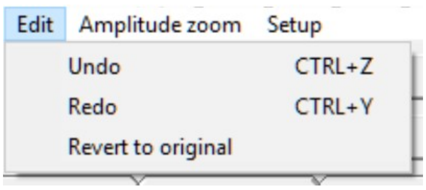

Illustration 34

2.2.2.3 Amplitude zoom menu

This menu contains all the functions explained on the GEOEXPLORER DoReMi user manual.

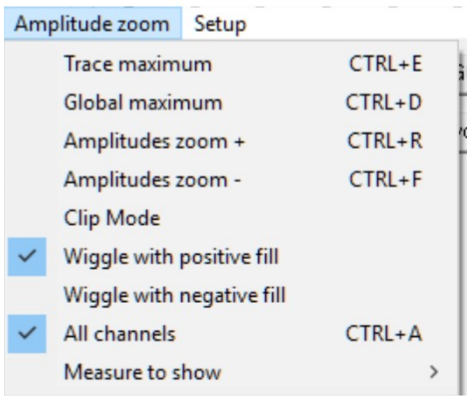

Illustration 35

2.2.2.4 Setup menu

This menu allows you to change the velocity spectrum parameters of the slant-stack computation.

Clicking on *Velocity spectrum* the window *Setup of velocity spectra* will appear.

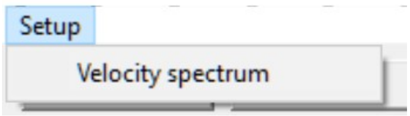

Illustration 36

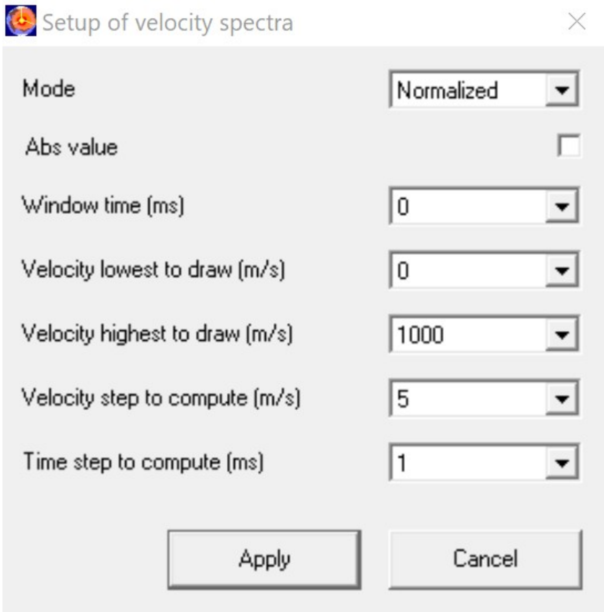

Illustration 37

It will be possible to modify how the software calculates the spectrum using those voices:

- *Mode*: *Simply* or *Normalized*: this option allows you to decide if use a normalized criteria to compute the spectrum or not.
- *Abs value*: this option allows you to use the absolute value while computing the spectrum.
- *Window time (ms)*: this option allows you to decide how big is the time window of the seismogram value summation.
- *Lowest velocity to draw (m/s)*: this option allows you to choose what is the lowest velocity to compute.
- *Highest velocity to draw (m/s)*: this option allows you to choose what is the highest velocity to compute.
- *Velocity step to compute (m/s)*: this option allows you to decide what is the velocity step increment for the computation.
- *Time step to compute (ms)*: this option allows you to decide what is the time step increment for the computation.

2.3 Depth conversion

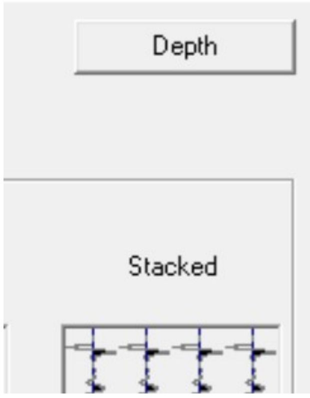

Illustration 38

This function will calculate the depth of your picked reflector converting the seismogram from the time domain to depth domain with the NMO velocity model.

Please note: for surveys that have small maximum offset, the NMO velocity and the depth conversion velocity have a small difference; increasing the survey size will make this difference increase and the difference between the true depth and the converted depth with the NMO velocity model will increase.

After the conversion the software will open a new window named *Depth window.*

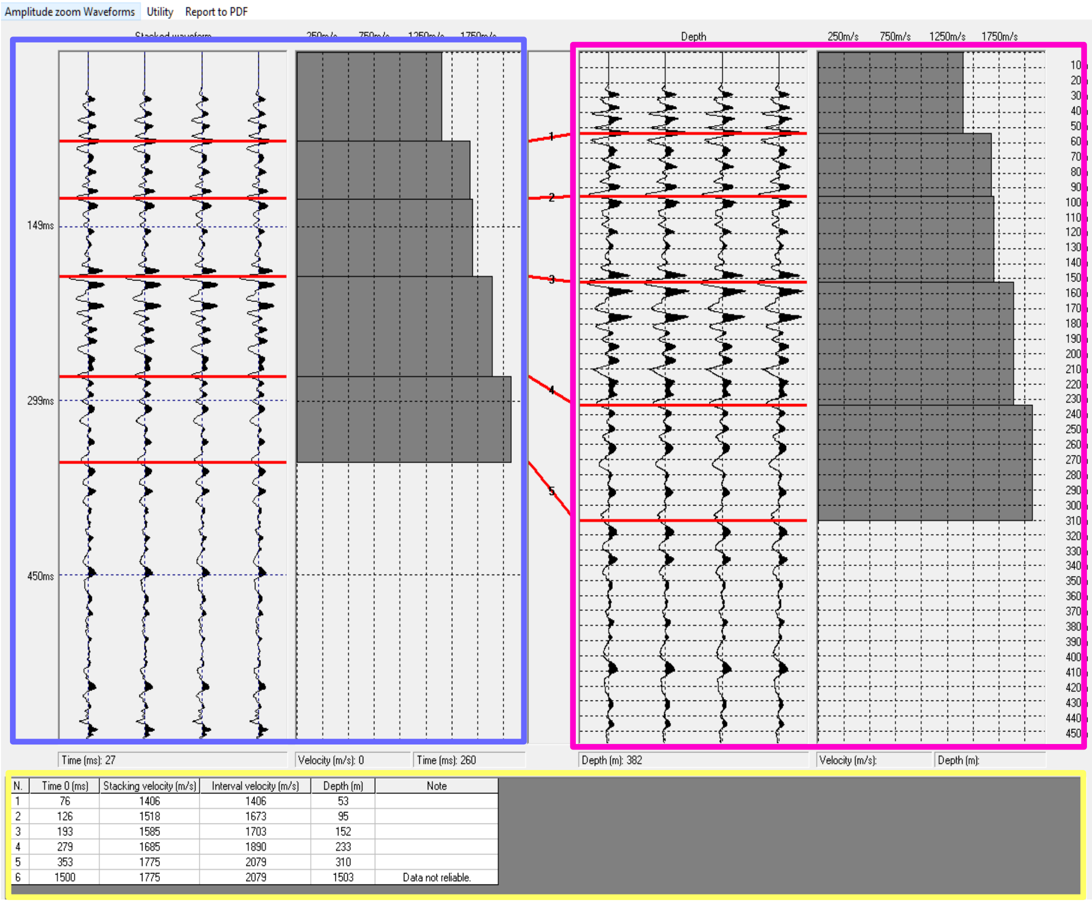

Illustration 39

This window contains the stacked waveform in time and the related interval velocity 1D section (blue box). On the right is possible to see the stacked waveform and the interval velocity 1D section depth converted (violet box). Every red bar line is the picking you have done on the previous step; between the two representations the bar lines with the numbers are related with the table of the reflection (yellow box). In this table of content is possible to see the value of T_0, Stack velocity, Interval velocity and Depth value of every reflection. It is possible even to write some note on the Note field.

Please note: the last layer, on the Note field, has this note: DATA NOT RELIABLE. That because on the NMO picking is not possible to pick the last sample; for this reason the software applies a velocity based on the last picking, to the end of the seismogram.

N.	Time 0 (ms)	Stacking velocity (m/s)	Interval velocity (m/s)	Depth (m)	Note
1	76	1406	1406	53	
2	126	1518	1673	95	
3	193	1585	1703	152	
4	279	1685	1890	233	
5	353	1775	2079	310	
6	1500	1775	2079	1503	Data not reliable.

Illustration 40

On the menu bar there are some visualization tools that are already explained on the GEOEXPLORER DoReMi user manual.

2.3.1.1 Report

The *Utility* tool allows you to copy the table of contents.

The *Report* tool will open the *Report window* where is possible to set all the parameters of System, place information and survey info for the report.

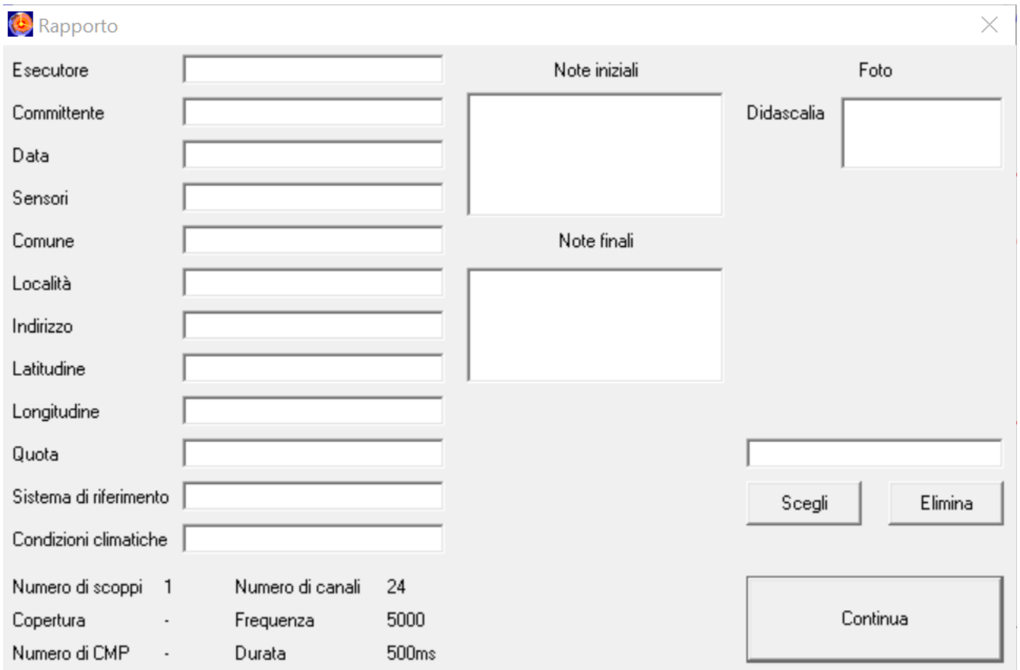

Illustration 41

Those are the fields that is possible to set:

System information.

- *Sensors*: in this field is possible to write what kind of sensors you have used for the survey.
- *N° of channels*: is computed automatically by the software and shows the number of channel of this data set.

Place information.

- *City*: is possible to set the city of the survey.
- *Place / Location*: is possible to set the place / location of the survey.
- *Address*: is possible to set the address of the survey.
- *Latitude*: is possible to set the latitude of the survey.
- *Longitude*: is possible to set the longitude of the survey.
- *Elevation*: is possible to set the mean elevation of the survey.
- *Coordinate system*: is possible to set the coordinate system of the survey.
- *Weather condition*: is possible to set the weather condition of the survey.
- *Note*: is possible to write any other information.

Survey information.

- *Customer*: is possible to set the customer of the survey.
- *Contractor*: is possible to set the contractor of the survey.
- *Sampling per second*: is possible to set the SPS of the survey.
- *Recording length*: is possible to set the recording length of the survey.
- *Geophones spacing*: is possible to set the distance between geophones of the survey.
- *N° of shots*: is computed automatically by the software and shows the number of shots used on the CMP.
- *Folding*: is computed automatically by the software and shows the folding of the CMP.
- *Date*: is computed automatically by the software and shows the date of the survey.
- *Photo*: with this tool is possible to select a photo of the survey.

Pressing on the *Continue* button the software will open the *Save window*, where you can choose the file name of the report and where to save it as a *.pdf* file.

3 Field introduction

The multichannel analysis of reflected waves for a 1D model was created for a fast and accurate subsoil analysis, like litology, seismic waves velocity information, modules evaluation, especially where the classical techniques (MASW, ReMi, ESAC, HVSR) cannot give solid information for the intrinsic limitation of the technique.

For many years the this technique was used and developed on specific fields (*oil & gas*) giving a wide range of experiences and bibliographic documentation, where an experienced user can find information that allows to reach a high details of the subsoil with a lower cost and less time in comparison with the past.

In the last few years the seismograph evolution, sensor enhancement, the development of new acquisition technique and analysis have given an important improvement of signal to noise ratio; for that reason the survey resolution and the efficacy of the interpretation and modelization for microzonification, water search, for void identification and bedrock localization is certificated by many publications.

It is important to underline that: for the seismic reflection technique is mandatory to know the signal theory, the physics laws and all the survey acquisition rules to improve the data quality and to avoid mistakes during the survey. The data processing is not a linear process, is important that the user has to know every tool that he will use. For that is important to increase the knowledge and participate to specific courses.

Considering the theory of all the tools is very wide, this document tries to give simply indication to obtain a good processing of the seismic data even using simplified tools.

The data processing is a non-linear and a non standardized process where different tools are used (filters, amplitude restoring, noise reduction, etc.) and a very wide bibliography for every tools for a very deep analysis of the data is possible to read, in general the main data process tools used to obtain a good quality of the data are not many.

This quick start has the main aim to give the minimum knowledge of the acquisition process ad the basic knowledge of the tools used and implemented on the software MARW.

4 Data acquisition

For the seismic reflection, like for the other geophysical techniques, is mandatory to record the data with a very good quality; that means a very easy data processing. Although the high data quality is not always possible because it is function of the environmental condition (topography, seismic line length, etc.) or geological condition (inclined stratification, diffraction, etc.), is important to choose the right geophones, type of energization, seismic line geometry and seismic parameters for the acquisition (SPS, and recording length) to use. For those reasons and for other, before the acquisition is important to perform the *noise test,* this will help to choose those parameters.

4.1 Noise-Test

The *noise-test* has different technique to evaluate those parameters; it is possible to see the other techniques consulting the bibliography. One of the most fast and efficient method is described below. It consist on use 24 geophones with an inter-distance of 1 m or 0.5 m and to locate on one seismic line end the shot at 1 m or 0.5 m. Then using the *walkaway* technique move the shot far away moving it for the seismic line length and repeat this process a second time.

Illustration 42

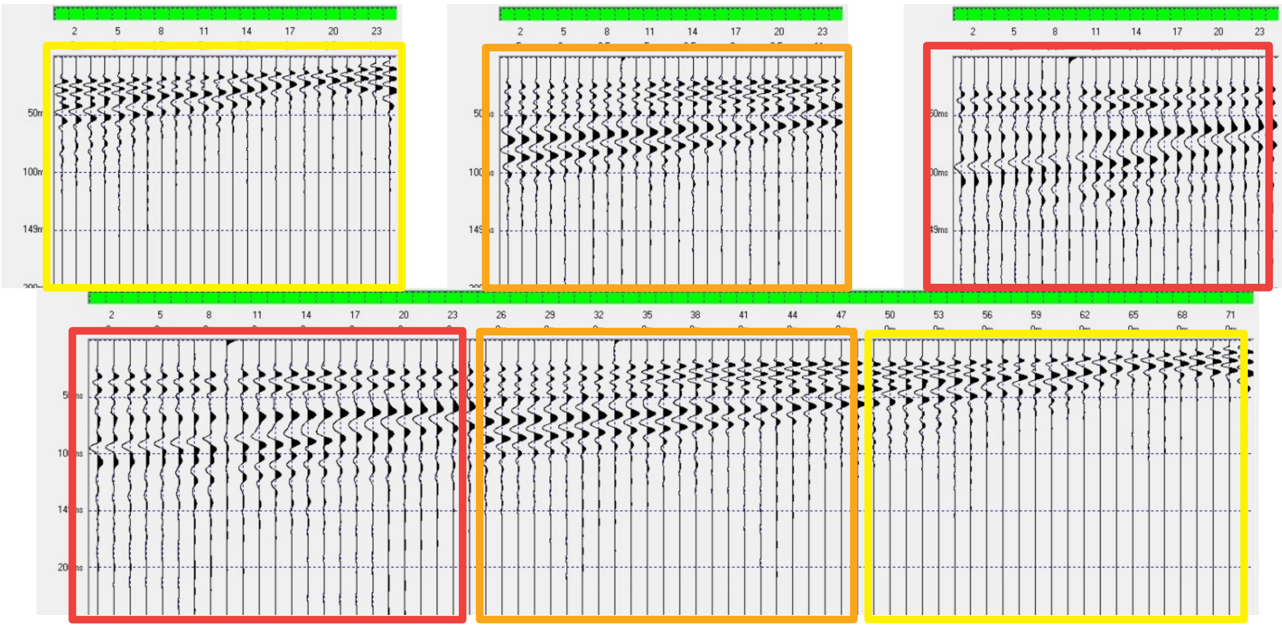

Illustration 43

With all the data recorded is possible to create one seismogram with all the shots where is possible to perform a fast noise analysis and to look for reflections. This operation must to be done with every kind of body waves used (P and SH) and every kind of seismic source used (sledgehammer, dropped mass, explosive, vibroseis, etc.). To decide the geometry and data acquisition parameters is important to consider the main aim of the survey and the result of the noise test.

4.2 Geometry and acquisition parameters

The first important step to consider is a standard geometry for an acquisition does not exist, and is always useful to perform the *noise test,* it is possible anyway to follow some simple rules to obtain a good quality of the collected data.

The first and most important rule is the number and inter-distance between geophones. Every good acquisition must to have a minimum number of geophones, this value has to be minimum 24; that means an easier analysis and seismic reflection recognition, allowing to discriminate between the reflection a coherent and incoherent noise. A higher number of geophones allow a lower geophones inter-distance and that reduce the spacial aliasing reaching a higher definition. Is not necessary to have a very large number of geophones, as it will be shown in this document it is possible to reach a very high quality with 36 or 48 geophones.

The second most important rules is the definition of the maximum *offset,* the distance between the shot location and the last geophones. It is important to keep the ration between the desired deep and the maximum offset between 1:1 and 1:2 to remain in the *near vertical reflection* field. Keeping this ration between those two value will help to record the reflections with a good quality allowing a good velocity analysis and to have an effective deconvolution.

The last important rule is over the sampling for second and the length recording. In general a good sampling rate is between 1000 Hz and 3000 Hz, only in the case you are focusing on a depth of 5-10m you will need a higher sampling. Use this sampling will reduce the time you need for all the acquisition process.

This value of sampling is easy to understand if you consider the soil filter you signal as a low pass filter and it is hard to obtain a value higher then 300 Hz with the different usable source. To draw the signal without *aliasing* it is recommended to sample at the double of the maximum signal frequency (Nyquist frequency 600 Hz) a sampling per second of 1000 Hz is sufficient. Is important for minimize the *aliasing* and to use properly the filter and other tool sampling at 3000 Hz.

For the recording length it is important to do some calculation to estimate the optimal length; considering a mean velocity of the body waves used (P or SH) and the targeted depth. Is important to consider the waves will do this depth two times.

For example, using the S waves and considering a mean velocity of 150 m/s, estimated with the *noise test,* with a depth of 100 m, the record length must to be:

2 x 100 m / 150 m/s = 1.33 sec

Using the P waves, with a mean velocity estimated with the *noise test* for a target deep 100 m, the seismograms length must to be:

2 x 100 m / 1500 m/s = 0.133 sec.

After the definition of those parameters is possible to move to the second step of the acquisition.

The *dataset* to process for the 1D seismostratigraphy is defined as *CMP gather* (Common Mid Point). That means all the traces on the seismogram will illuminate the same point and they have the same mid point.

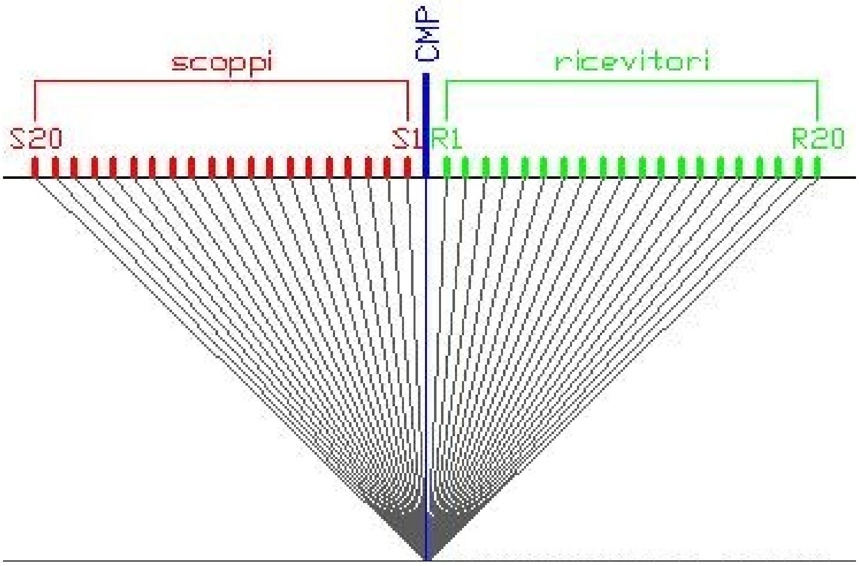

Illustration 44

Is possible to obtain this result in three different ways:

1. Positioning the geophones with a regular distance on the field and shooting on an external shots location with a mirror arrangement of shot location and geophones from a central mid point. Recording the seismograms for every shots, with a previous set of the geometry, the software will select every single channel of every shot to gather the desired CMP;
2. Another method is to activate only the symmetric channel of the shot from the CMP considered for the acquisition after setting the geometry. Then it will be possible to create manually the CMP.
3. The last method is to use one channel. The process is identical to the method 2, but it need to move the channel on the symmetric location of the shots. This seems to be most versatile, allowing to record as many shots are needed with a small system. Once chosen the geometry of the acquisition it is necessary to repeat the acquisition as many times needed. It important to consider that, the quality of the data (the S/N ratio) is proportional to the square root of the trace number S/R=√(n° traces). This means that recording a lot of shots does not means a quality improvement.

The three methods are shown on the picture below

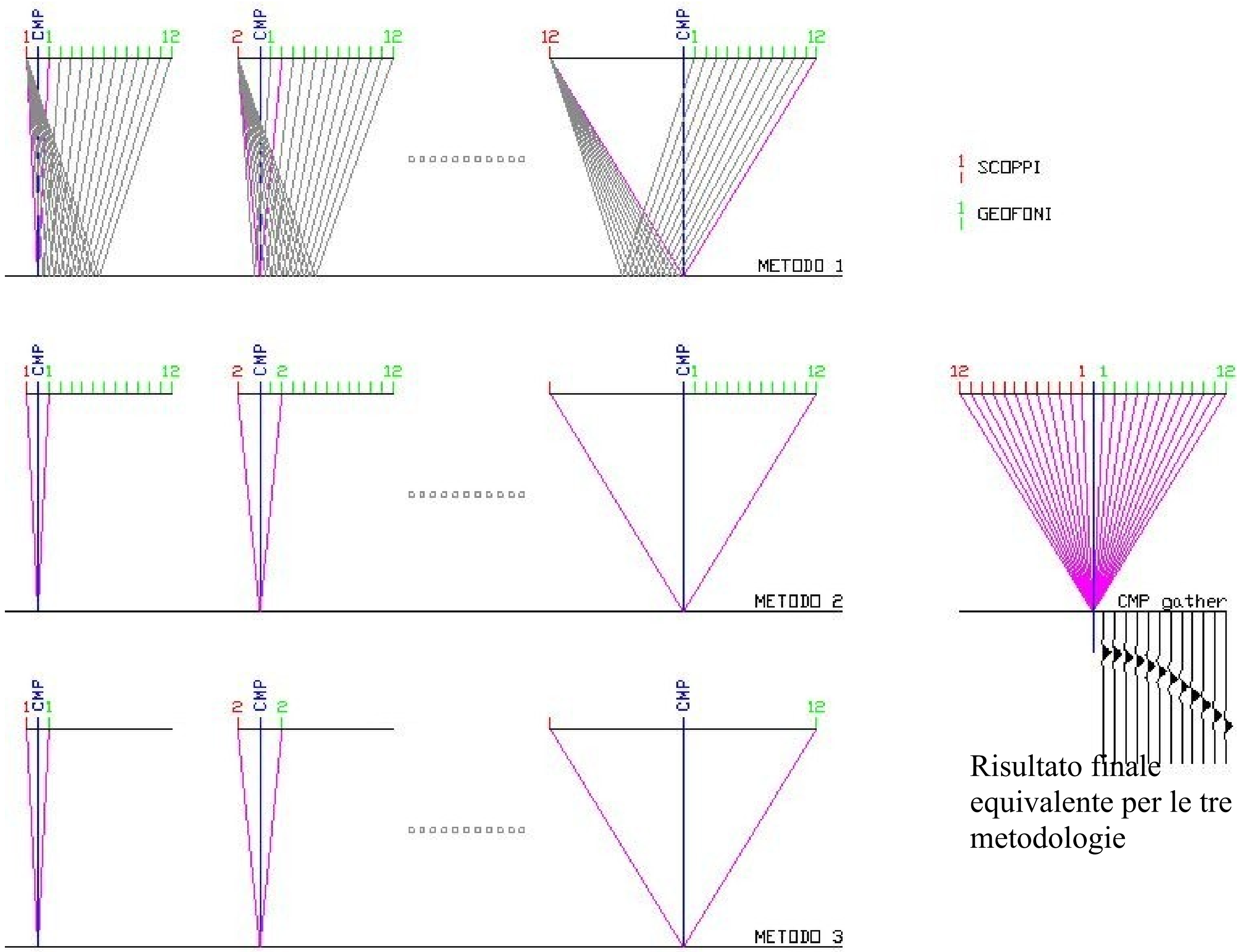

Illustration 45

Once chosen the methodology and recorded the dataset, it is possible to mirror all the acquisitions and records on a second dataset with the aim of doubling the traces number to have a higher quality result.

If the dataset will be recorded with the 16bit DoReMi version is recommended to set the GAIN with a value higher than the standard and avoiding the clipping of the data. Please refer with GEOEXPLORER DoReMi manual for more details. This setting will help with the signal/noise ratio and will prevent the data deterioration during the processing.

4.3 Simplified acquisition technique

With a generic geology setting (horizontal layering and no lateral variation), the acquisition techniques explained in the previous chapter are mandatory to obtain the information of the 1D model that are on the vertical, with a little deviance, of the CMP.

If the reflectors are not horizontal, the ray path of reflections will be smeared on a surface instead of a point. This smearing is *up-dip* and the effect of this deviation changes the shape of the reflection hyperbola with a less curvature caused by the increase of apparent velocity: $V\cos(\alpha)$, with α inclination angle of the reflector.

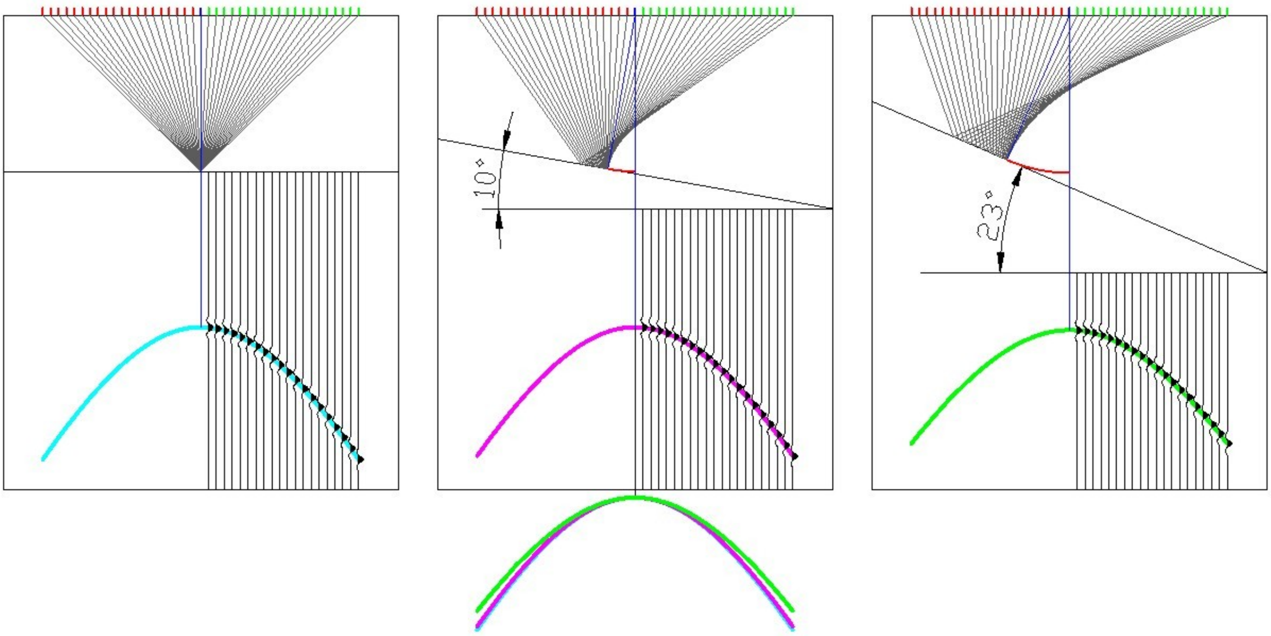

Illustration 46

With an angle of 10-15° the variation is neglectable as shown on the picture above with the purple hyperbola. If the angle is bigger the variation of the apparent velocity form the real velocity is not anymore neglectable and it is mandatory to correct this variation with the *Dip Move Out* (this topic will not be treated) that will remove the smearing effect derived from the inclination.

If the geologic setting is complex, like non flat reflection surface, is mandatory to perform a 2D acquisition to create a 2D section.

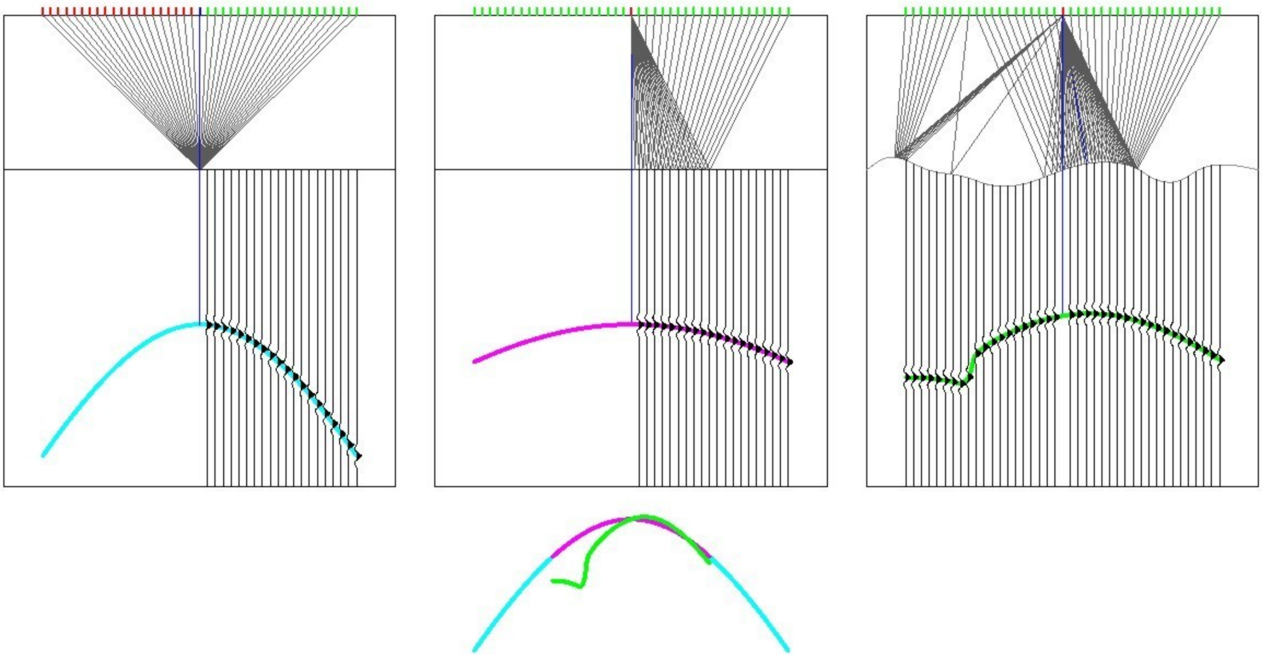

Illustration 47

Although the acquisition process is explained above, is possible to use a simplified method, if the geologic setting is simple.

This simplified process does not need a CMP gathering but it needs a *Common Shot Gather* (CSG), a number of shot with the same geometry and shot location.

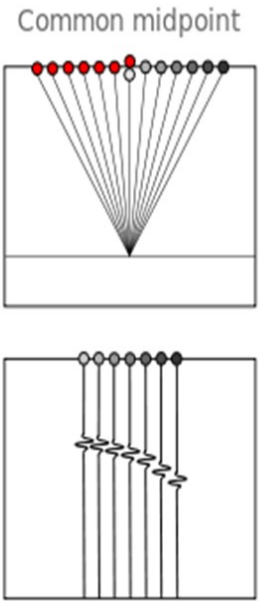

Illustration 48

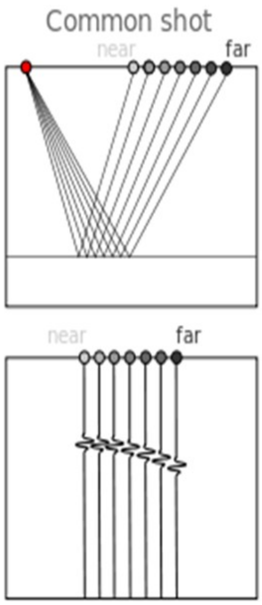

Illustration 49

Changing the geometry of the acquisition, so the traces offset, with some specific condition the CSG and the CMP are comparable, as shown with the light blue hyperbola and the purple hyperbola reflection.

The main difference is the CMP the reflection converges on a single point and the CSG are distribute on a surface. This modifies the position of the 1D vertical model that is not below the CMP but on the center of this surface. Analyzing a CSG is counterproductive if the reflector has an inclination. On this condition the reflection will have a deviance that will allow to use it for the elaboration.

On the right condition the CSG elaboration will give information on the stratigraphy highlighting the major stratigraphy contact and the interval velocity between those surfaces (see the picture below).

P wav

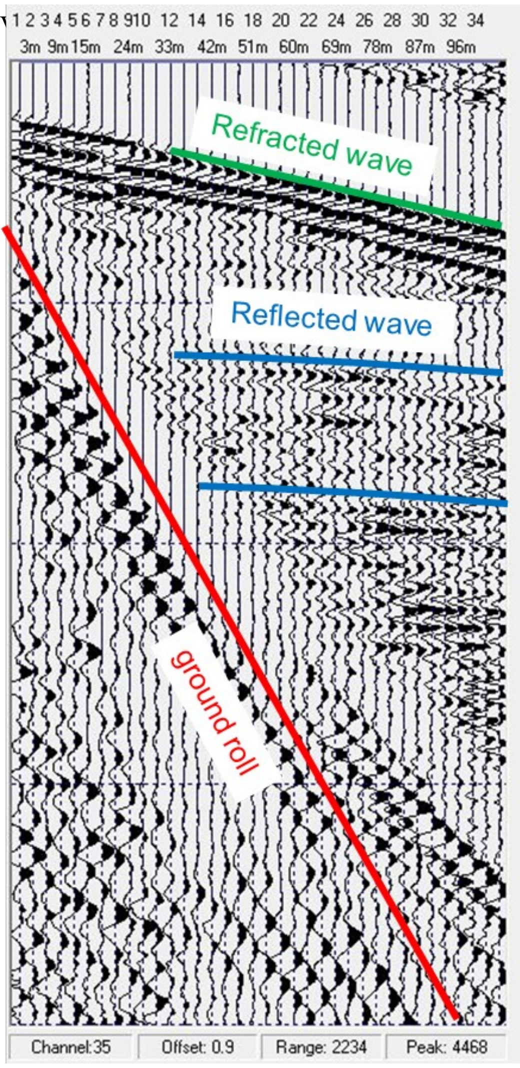

Illustration 50

S wav

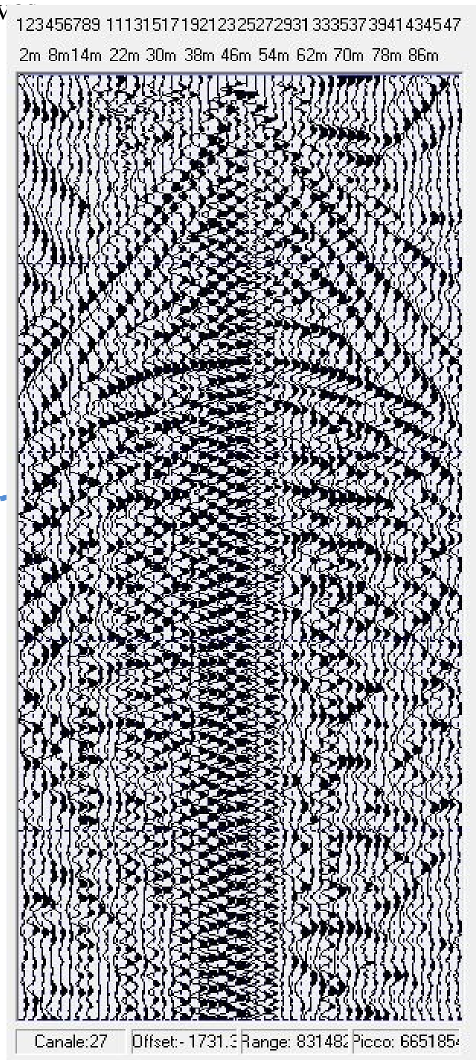

Illustration 51

In the case of the usage of a simplified acquisition is important to consider the number of channels as one of the most important factor to record a high quality dataset. A good number of channels is 24, but using 36 or more channels will give you a very high quality dataset. Same consideration must to be done for the offset that is related to the reachable depth. A small consideration can be done on the shot location for the CSG, it is possible to locate it even inside the geophone line.

5 Data processing

The seismic reflections processing is an imaging technique, it means is based on a subjective interpretation of the represented data. It is necessary, to perform a good elaboration, to have a good knowledge of the seismic interpretation and processing.

The process aim is to identify inside the dataset the significant reflection related with the main geologic domain of the soil.

The data processing must to consistently remove the incoherence noise and coherence noise form the dataset (surface waves, air waves, refraction waves, random noise etc.). to remove those signals sometimes it is need to have a surgical approach (like muting); if not done in a proper way it will give you the possibility to have artifacts in the dataset.

The surface of the soil can have topography variation and/or velocity lateral variation. The correction of these factor need attention because strong lateral variations can give an important distortion on the reflection hyperbola inside the seismogram.

The filters usage need to be done careful because a wrong setting can create disturbs and artifacts.

For a better elaboration of the seismic data, for a better visualization of the reflection, below is explained a generic dataset elaboration with step-by-step elaboration and explanation of the various tools.

This manual is a guide but it is important to understand the process shown here is not standard, so this elaboration it has to be intended as a start for understand how to elaborate the data to achieve a good understanding of every single tool and how to combine them.

5.1 Geometry

The first and very important step for a good elaboration is to set the geometry of the acquisition.

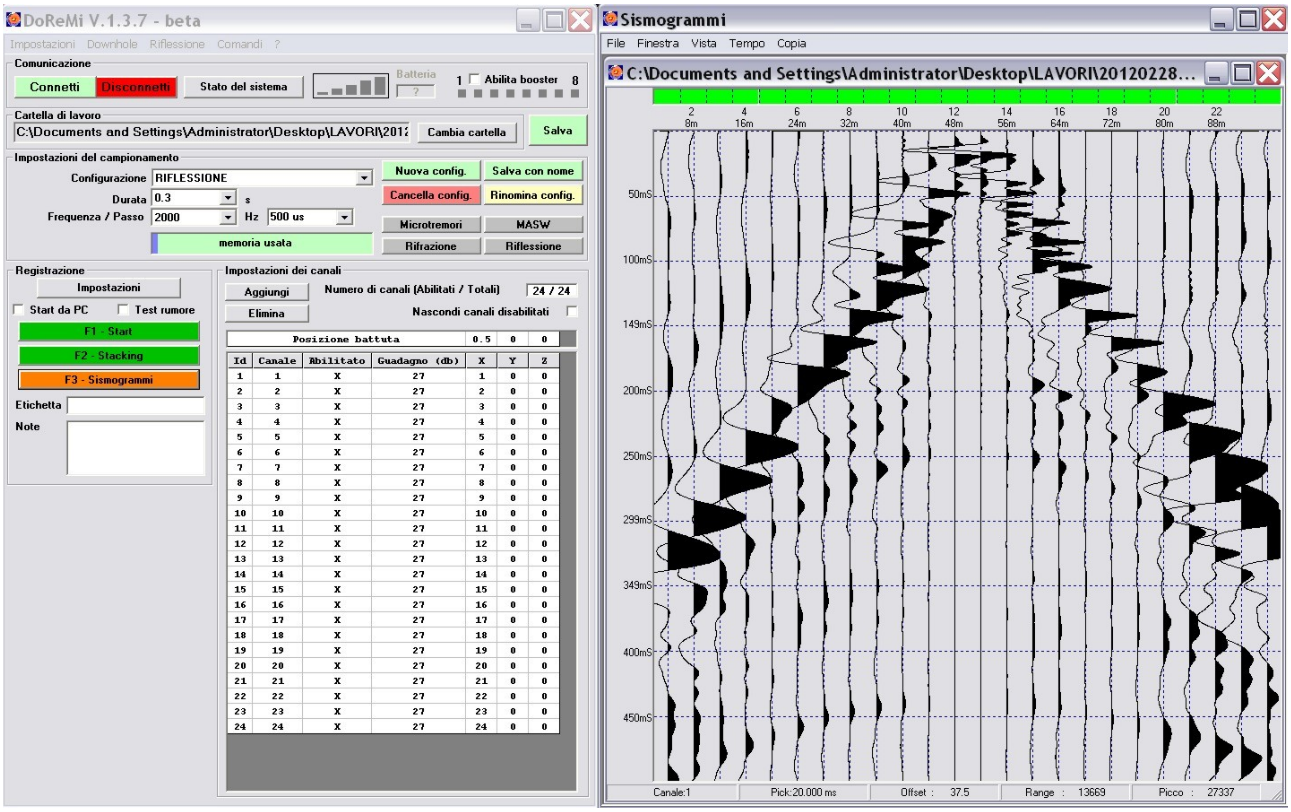

Illustration 52

These information must to be inside the traces *header line* before the processing and are mandatory for some tools like velocity analysis and static correction.

For the acquisition is very important to have a straight seismic line. Without this condition the processing cannot be done. The topography coordinate of every shoot and geophones is mandatory to correct it with the static correction(see chapter 5.2 Static correction Page 36).

It is a good practice, before start the elaboration process, to check those information inside the GEOEXPLORER DoReMi software on the properties of the seismograms.

5.2 Static correction

The static correction for the elevation are used in the processing to correct the elevation; the static correction for refraction are used to compensate the lateral velocity variation of the first layer.

Operationally, those correction need 3 steps:

1. *picking* of first break;
2. computation and application of elevation correction;
3. computation and application of refraction correction.

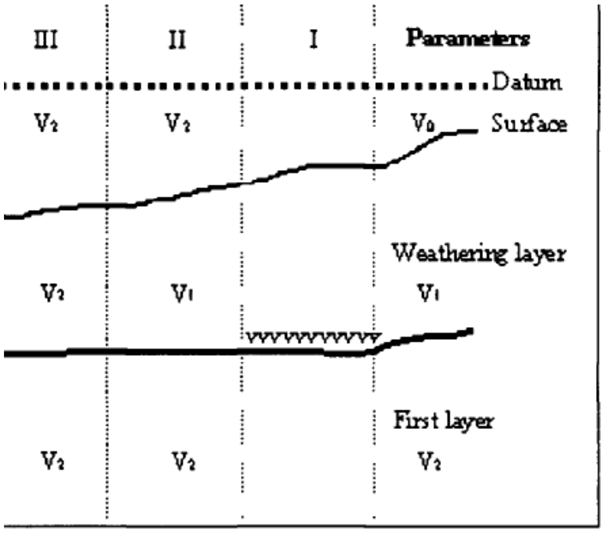

Illustration 53

The *picking* it is done on the time domain of the first break and gives the information of the first layer (weathering layer) (V_1) and the first refractor (V_2).

The aim of the static correction is to define the arrival time of the refraction if the sensor where on the reference surface (*datum*) on a selected elevation, chosen by the user, without the effect of the weathering layer (V_1).

The first step is to apply the elevation static correction to select the *datum* that can be put over the highest elevation of a geophone or shot. Using the elevation information in the *header line* it is possible to compute the thickness of the air (V_0)and change the V_0 using the refraction velocity V_2. From here it is possible to correct for every geophone the correction to use to put virtually the geophones at the datum elevation. The refraction correction has the aim to compute the refraction velocity to change the weathering velocity (V_1) with it (V_2), with the limits already know with the elevation correction. From this step is mandatory to correct the thickness variation of the weathering layer.

Because in general it is used a higher *datum* and $V_2>V_1>V_0$, the result of the correction will shorten the refraction time and the seismograms will be translated upward.

To do this process is necessary to select the *picking* of the direct wave and the first refracted waves using the tool static correction or setting manually the velocity values the crossover time, set the *datum* and the shot elevation it is possible to perform the static correction.

Please note: this correction is applicable only if previously the elevation information are stored in the header file for every single geophone and shots

5.3 Filters

The frequency filters can be classified as band pass, band stop, high pass and low pass in relation if they are filtering above or below a frequency, or inside or outside of chosen frequency band.

Every kind of filter is applied to every single trace following this principle: to reconstruct a phase zero wavelet with an amplitude spectrum that will match one of the four specified filters. This allows to create three kinds of filter: single band-pass, time depending filter and time and space variable filter. On a regular processing the first filter is commonly used. The aim of the usage is to let pass a specific band pass and remove the other bands by defining the amplitude of the filter that will operate on the traces:

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

where f_l e f_h are the frequency thresholds.

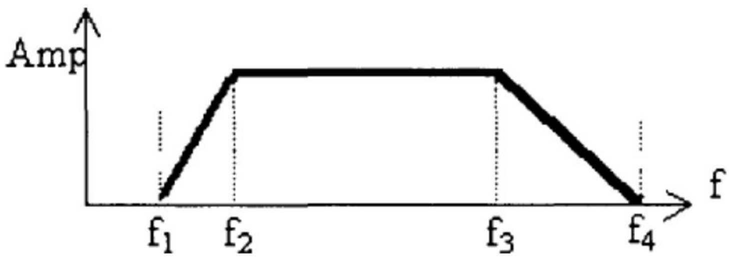

Illustration 54

To clean the data and avoid artifacts, the filter needs a taper in the two external side of the frequency thresholds.

In the software is possible to choose the 4 frequency values (f_1, f_2, f_3 e f_4) or the two threshold s (f_2 e f_3) and the taper (filter order). The more the order is low the lower will be the possibility to have artifacts.

To avoid this problem keep the order of the filter inside the range of I°, II° (this is the natural taper of a geophone) and III° degree, but is important to try different combination of filter to improve the result. To understand what could be the better configuration the use of the function FFT is recommended.

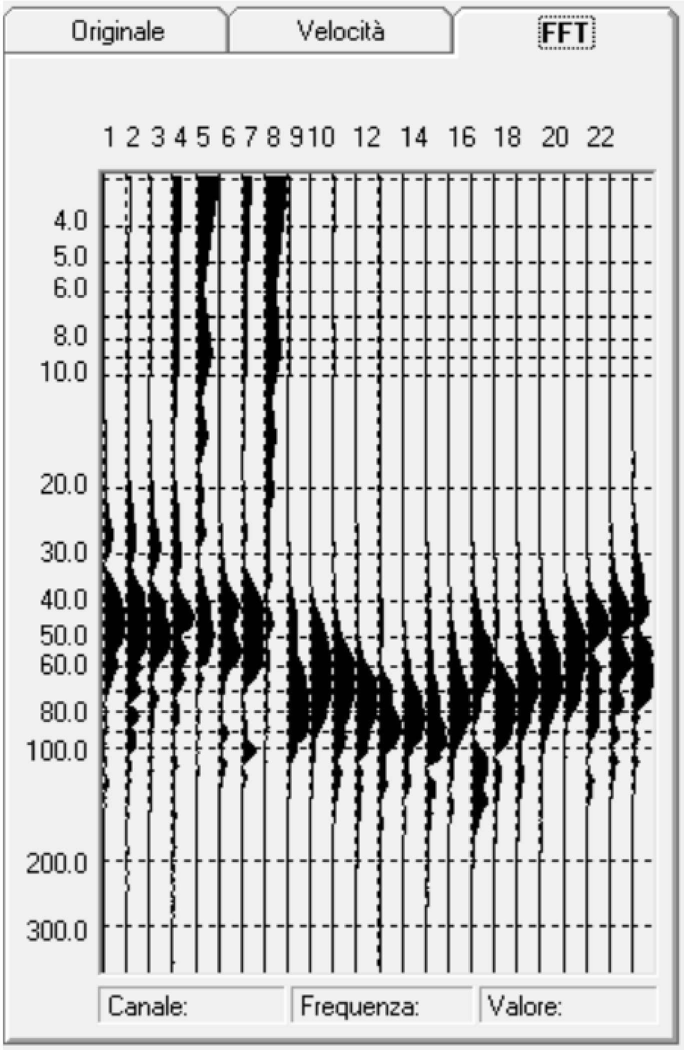

Illustration 55

Once verified the frequency X and Y is useless to go over those values because there is no information outside those limits. A wide band selected will have a very small effect on the dataset, but a very narrow values will delete a lot of information giving you at least a mono frequency traces.

Below some example of filtering:

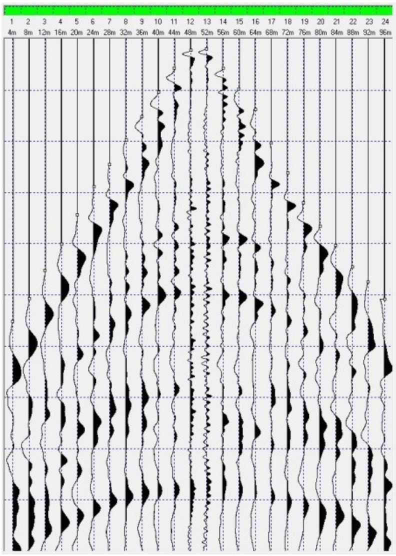

Illustration 56

No filter

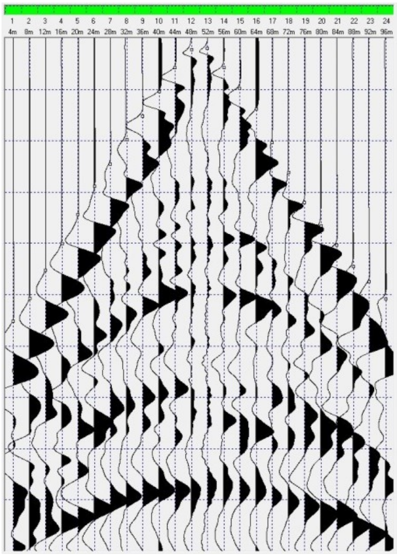

Illustration 57

Low pass filter 40Hz I°

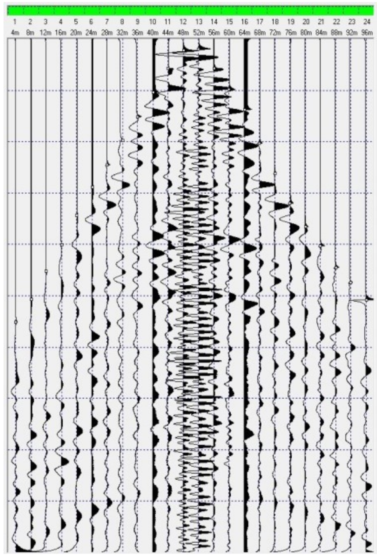

Illustration 58

High pass filter 90Hz I°

Choosing the right bandwidth of the filters is the key to improve the quality of the data. Keeping only the low frequencies or the high frequencies do not improve the time resolution, it is mandatory to keep both information, high and low frequencies.

To resolve two close reflectors is important to try different band pass filter. If you have 2 reflectors at 24 ms using a band pass of 20-60 Hz is enough, but if the reflectors are at 12 ms a band pass of 20-100 Hz will be needed.

The signals can be recorded with different kind of geophones, vertical or horizontal, with different kind of frequencies (4.5 – 10 – 14 – 24 – 40 – 50 – 100 Hz) or with different kind of sources (sledgehammer, seismic cannon, vibrosize, drop weight) but the principles of the filtering are still valid.

The noise can be the surface waves (that the frequencies general are below the 20 Hz), the electric power line (50 Hz) for analog seismographs, the wind or anthropic noise at high frequencies.

Choosing the right band pass filter, frequencies and tapers, it is possible to remove a big part of the noise improving the data quality giving a comprehensible data for the interpretation.

To a better understanding of the filter refer on the GEOEXPLORER DoReMi.

5.4 IAGC (Instantaneous Automatic Gain Control)

The amplitude of the signal is time depending for these reasons:

1 The signal traveling through the ground from the source lose energy . This phenomena is knows as spherical divergence. The same amount of energy is distributed on a bigger surface.

2 When the signal pass through a reflective surface, the energy is split in refracted waves and reflected waves and it generates even P and S waves.

3 The other phenomena is the scattering; the soil is not a homogeneous material, so when the waves pass through those variation the wavefront is distorted and deflected in different directions.

To compensate this natural effect a gain function is applied. This type of correction is dependent from the acquisition and from the data. To apply this correction (IAGC) it must be chosen the time window, all the samples inside this window are used to compute the root mean square for the amplitude and after a normalization this value is used to multiply the first sample.

After this operation, the window is translated of one sample and computed again as explained before. This process is done for all the traces and for all the samples.

Below are shown some examples of the IAGC

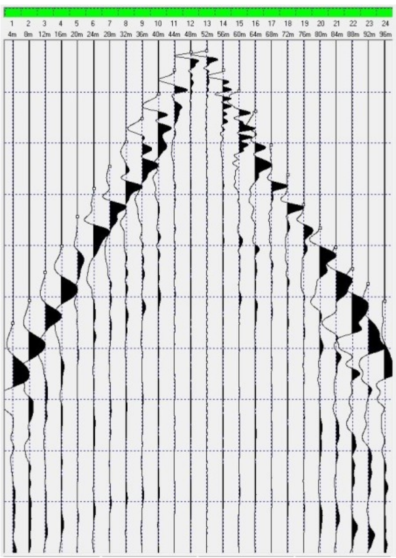

Illustration 59

No IAGC

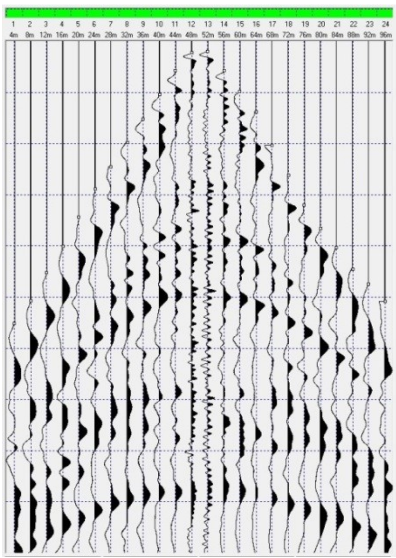

Illustration 60

50 ms IAGC

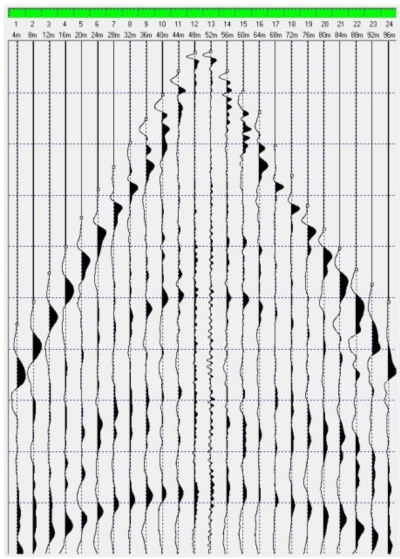

Illustration 61

200 ms IAGC

It is quite easy to understand that applying a long windows, or a windows of the same length of the recorded data, the change are minimal or no one, but with a small window the output of the elaboration will be an amplitude homogeneous trace.

As for the filters is really important to try different window settings to obtain a better data quality.

The rule to follow in general is with a short seismograms where the reflection are concentrated on the top of it is important to work with windows of 20 to 100 ms. With a long recording (1 – 3 s) the value to use are between 100 to 400 ms.

5.5 Deconvolution

The deconvolution is a function that is based on the statistical properties of the signal and noise, allowing to “compress” the wavelet, so the reflected signal, improving the vertical resolution and deleting the multiples.

Following the convolutional model the signal generated is modified by the soil. The soil works as a filter deleting frequencies decreasing the information that are stored in the signal.

The dataset will contains multiples; those reflection are related on signal trapped in the weathering layer between the surface and the first reflector or think hard layer that create strong reflected signal.

This noise is summed with the primary reflection on the top of the seismogram but with low amplitude and curvature for the longer pathway that they have done.

To reduce the multiples effect and to improve the signal resolution the predictive deconvolution is a tool that try to reconstruct the signal without the multiples.

The first step of this process is to do the autocorrelation of every trace allowing to evaluate the signal periodicity. On the autoacellerogram is possible to evaluate the *lag* that is present between the primary reflection and the multiple, then it is possible to do the picking where it starts the repetition (see the picture below).

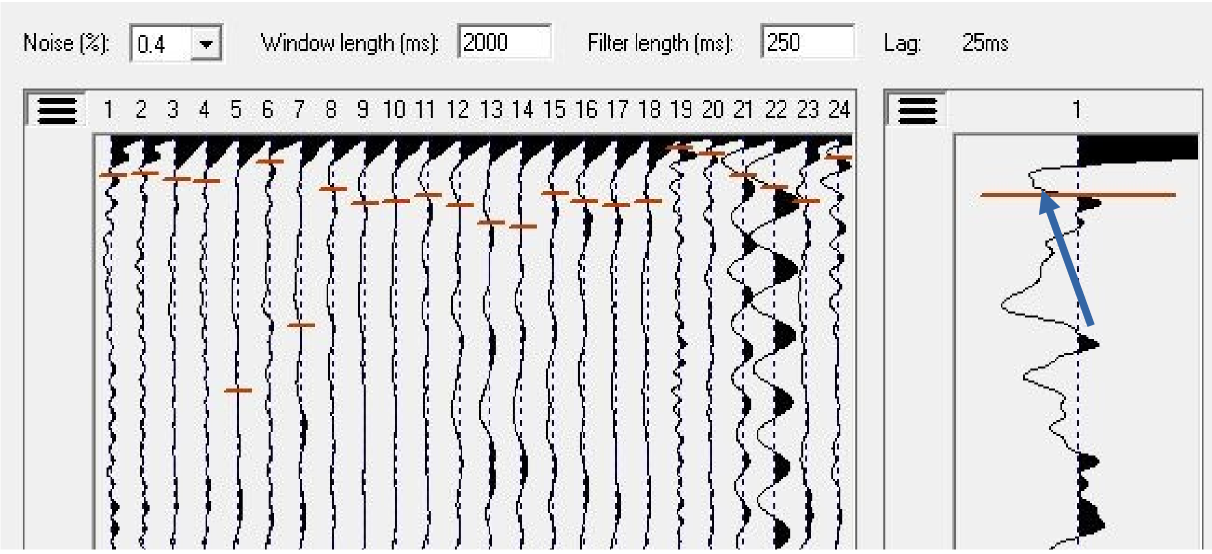

Illustration 62

The second step is to decide the autocorrelogram window length for the filter computation. The window length will affect the computation time. As always is important to choose different values to optimize the result.

The third step is to select the filter length. This values affect the computation time. A longer window will improve the quality of the elaboration. As mentioned before try different values is important. As general rule, it is good to have a 10 times filter window length in comparison to the *lag*, but in specific case a longer window could be better.

The last variable to handle is the white *noise*. It is important to set a good value to stabilize the deconvolution process and it is function of the noise of the signal. A noisy seismogram needs less *white noise* in comparison to a clean dataset. If the aim of the deconvolution is not to remove multiples but increase the resolution, so the bandwidth it is possible to use the *spiking deconvolution*.

To do that the Lag value must to be reduce to the firs sample; for example is the SPS is 2000 Hz the sample time spacing will be: 1/2000=0.0005 sec = 0.5 ms.

So for a spiking deconvolution it must to be set 0,5ms. On the autocorrelogram in the program is possible to select directly the *spiking deconvolution* option to perform this tool. The other values can be left as the default or modified by the user to improve the quality.

Below two examples of deconvolution.

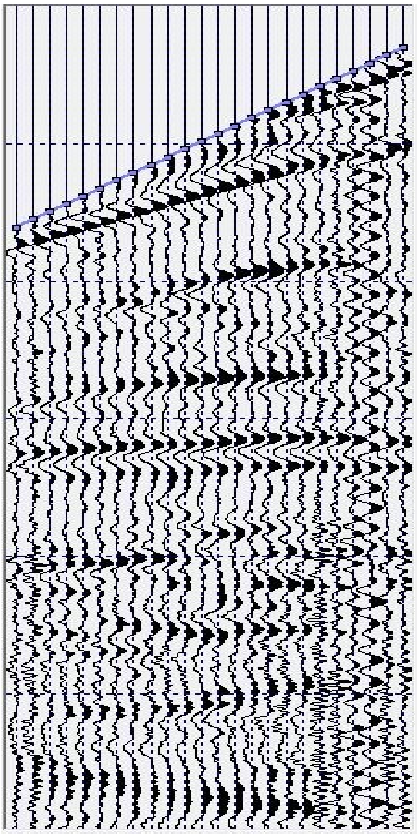

Illustration 63

No deconvolution

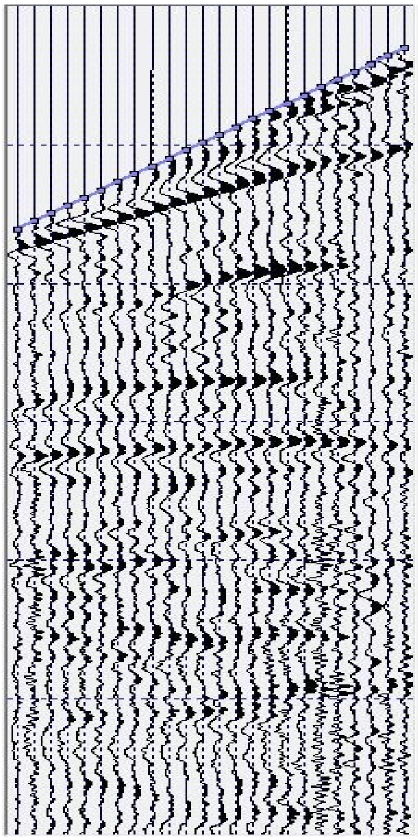

Illustration 64

With deconvolution

5.6 Muting

The *muting* allows to delete the first break. It is cosmetic function deleting all the noise before the first breaking. It allows to delete the noise below the last useful signal too.

The function has the effect of enhance the velocity spectrum, avoiding the possibility to pick the refraction as a reflection.

It can be used even to delete the part of the seismogram that, after the *Normal Move Out*, some part of the seismogram has been stretched.

5.7 *Velocity picking and Normal Move Out correction (Normal Move Out)*

One of the most used technique if the velocity spectrum analysis. The main idea is to plot the coherence on a graph velocity and "t_0" (t_0 is the arrival time of the reflection on the vertical from the surface).

The principle is to compute, following hypothetical reflection hyperbolas, on a CMP (*Common Mid Point*) or on the CSG (*Common Shot Gather*), with a small window the coherence of the data.

The *Stack velocity* can be picked on the spectrum and this velocity will be used for NMO correction, the picking is done on the maximum values of coherence that you can see on the spectrum.

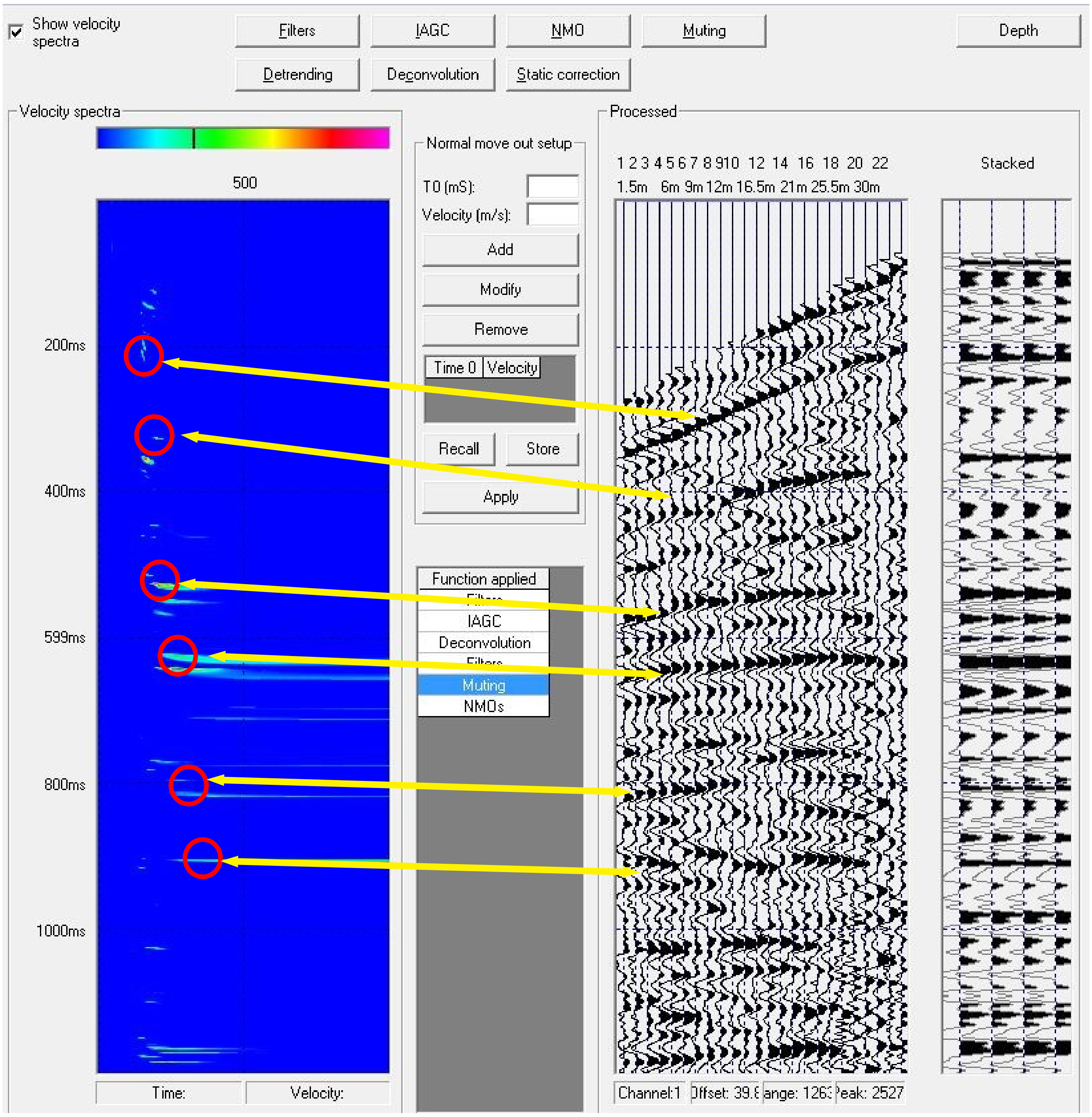

Illustration 65

Even in this phase of the elaboration is important to use different velocity spectrum parameters to enhance the spectrum visualization of the high value of coherence.

Every point picked has coordinates in time (T_0) and velocity (V) that define the position and curvature of the reflection hyperbola.

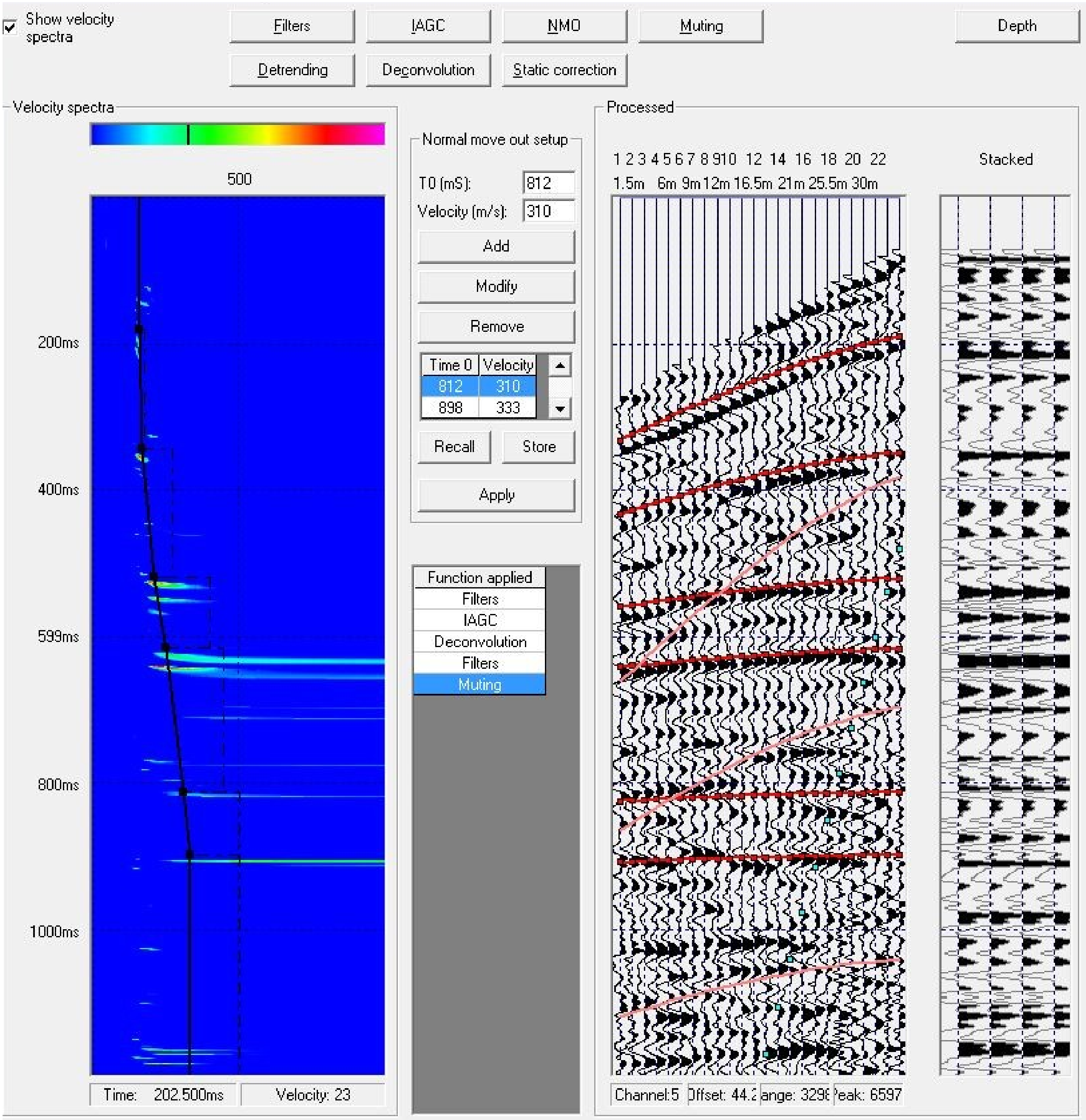

Illustration 66

Once the hyperbolas and then the velocities are matching the data is possible to apply the NMO on the seismic traces to linearize the reflection for the stacking. At this moment the processing can be considered concluded and it is possible to store processing and processed data.

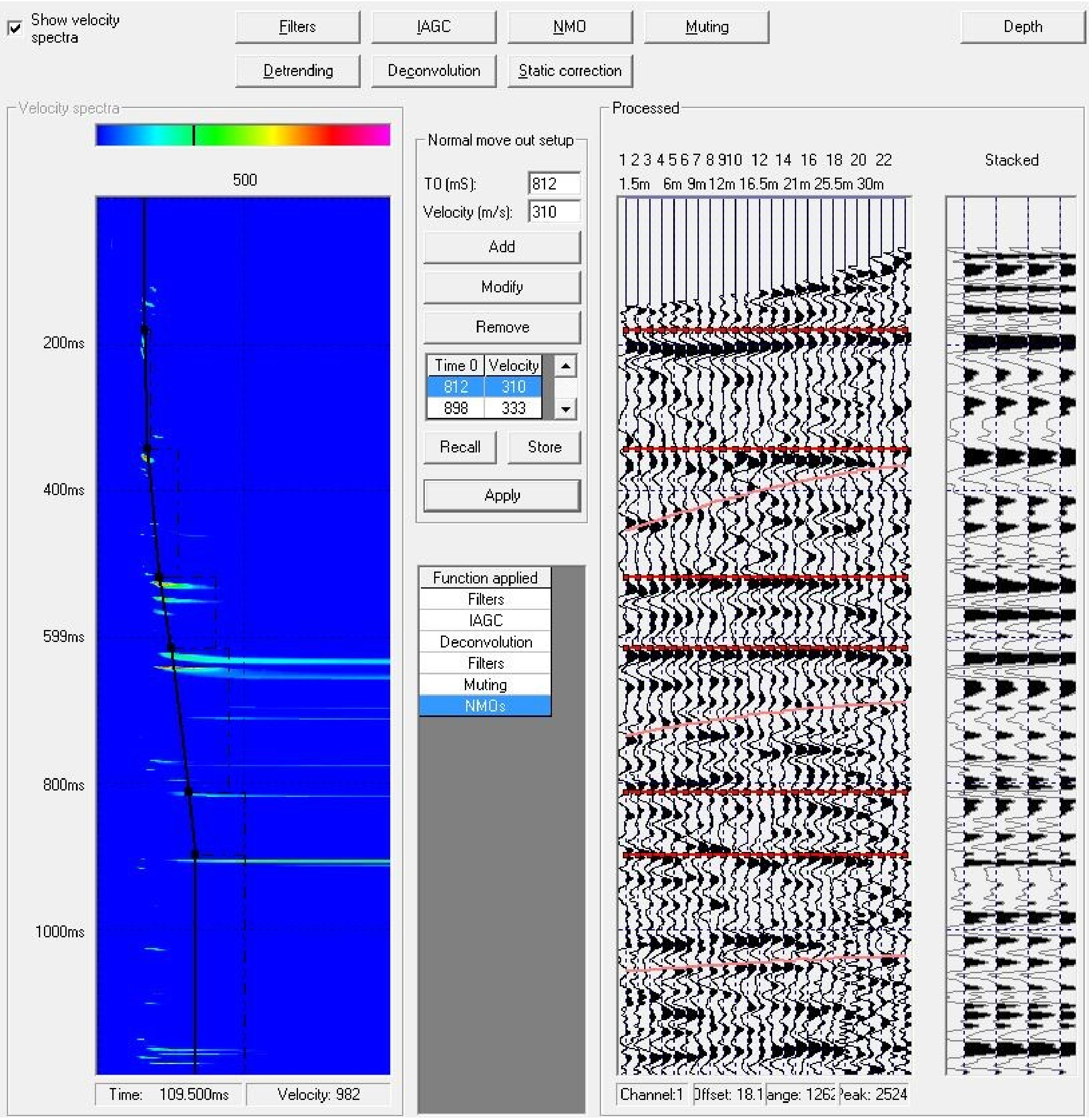

Illustration 67

So it is possible to stack the data and convert in depth using the interval velocity computed by the software.

The stacked trace allows to create a seismostratigraphy to define the geologic domain.

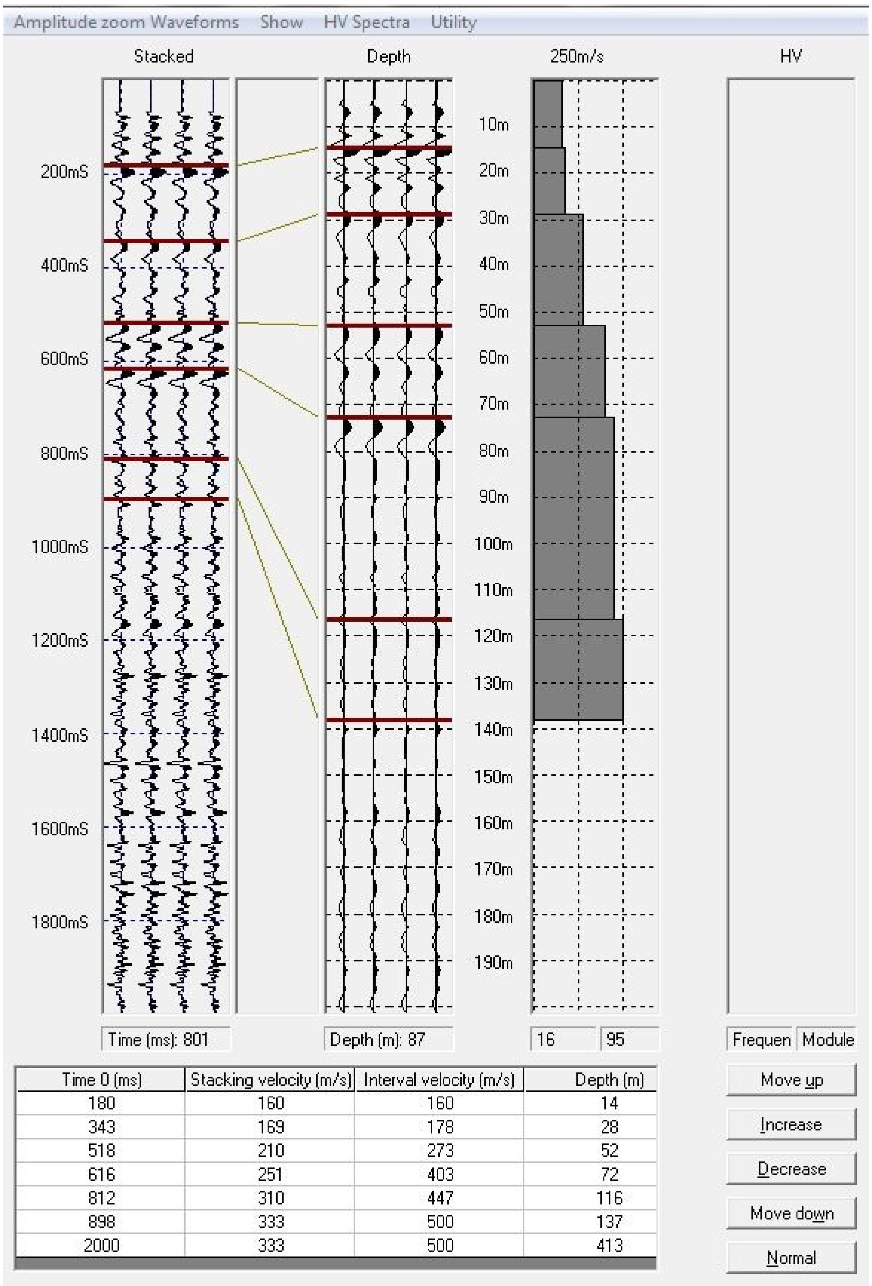

Illustration 68

So is possible to save the data for a new elaboration process to enhance the resolution. It is possible with a more sophisticated software to create a 2D section by merging the various 1D profile.

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