GEOEXPLORER SSV

Version 1.0.3

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.

this page has been intentionally left blank

Warning!

This software is provided for business and research purposes. It must be used in a computer system in conjunction with suitable electronic devices, by qualified personnel in compliance with applicable laws regarding construction, civil engineering, mechanics and electronics.

The use of the software to record geophysical data and/or evaluate risk levels and mechanical properties of the soils is reserved to qualified and specialized personnel such as doctors in engineering, architecture and physics who have attended specialization courses in geophysics and structural analysis.

The developer of GEOEXPLORER SSV assumes no responsibility for any loss, injury or damage of any kind when the software is used in a context of vital importance or without the technical expertise needed to validate the obtained data.

this page has been intentionally left blank

Table of contents

1 Introduction

The software SSV (Vertical Seismic Survey) has been developed with the aim of analyzing near vertical reflection to identify reflection that are related to layers that could be potential water reservoir. It allows to use different tools, like FFT and filters, for the creation of a 1D depth model.

2 SSV

To use the software is mandatory to plug the dongle license and open the software from the GEOEXPLORER suite.

Illustration 1

The main window can be described as:

1. Menu bar (red box)
2. Elaboration tool (yellow box)
3. Visualization data tabs (blue box)
4. Visualization processed data tabs (orange box)

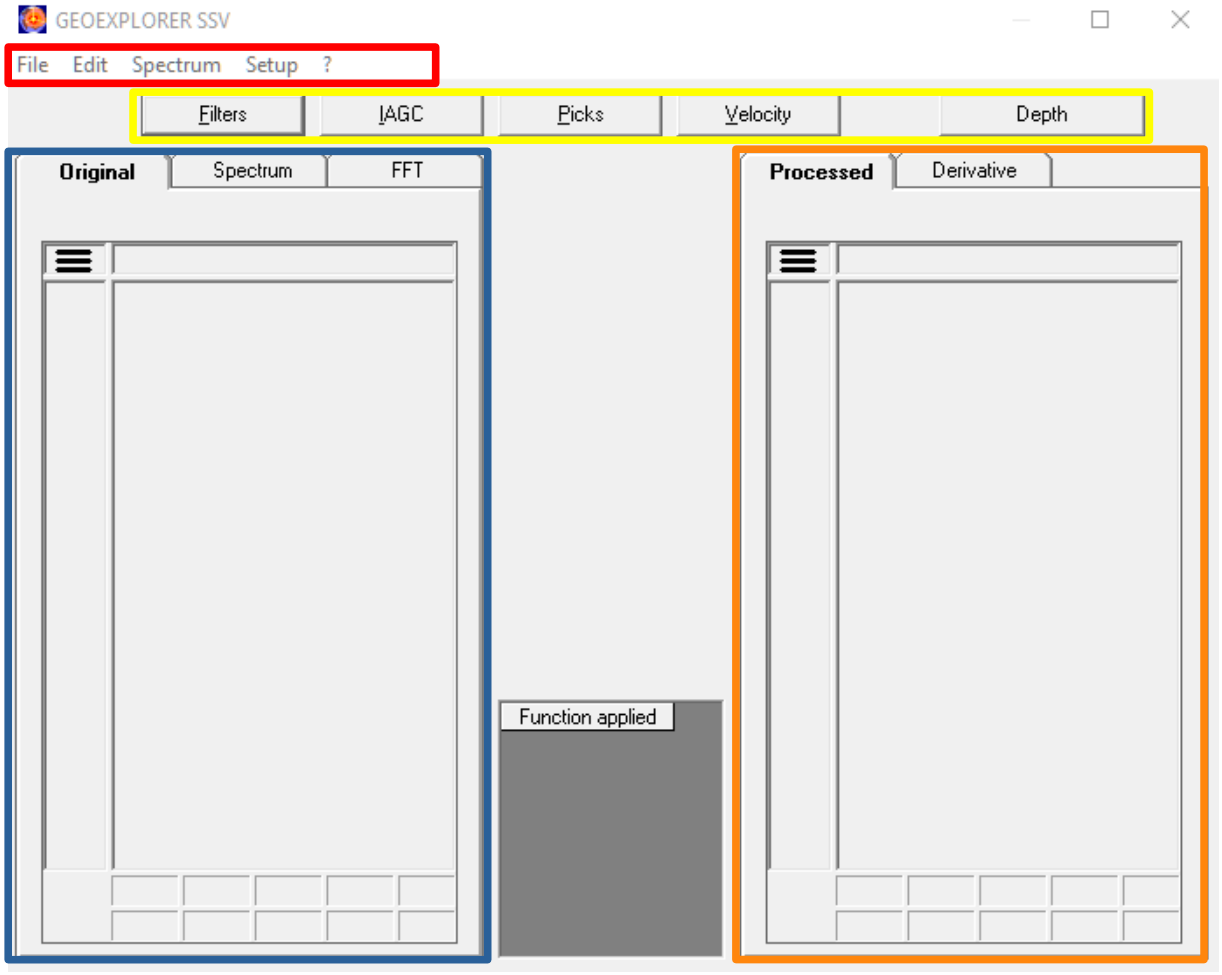


Illustration 2

3 Menu bar

The menu bar contains different options that allow to load the data, change the visualization of the data, or the data used in the visualization.

3.1 File menu

In this menu is possible to open *.drm* files, with the *Open* option.

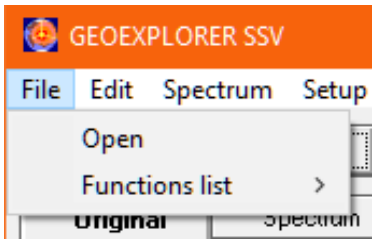


Illustration 3

The *Function* option allows to load or save the processing and save the processed data.

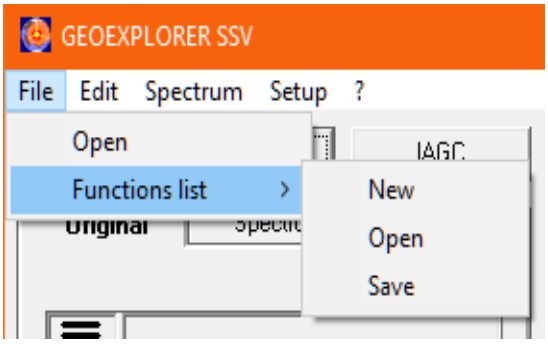


Illustration 4

3.2 Edit menu

The *Edit* menu allows to cancel the last operation done, to repeat the canceled operation done or to reload the raw data.

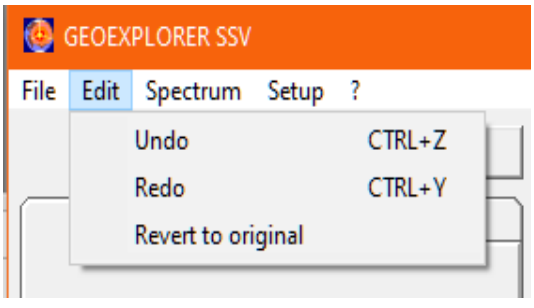


Illustration 5

3.3 Spectrum menu

The S*pectrum* menu allows to modify the spectrum representation (blue box). This tab shows the energetic distribution in time-frequency representation.

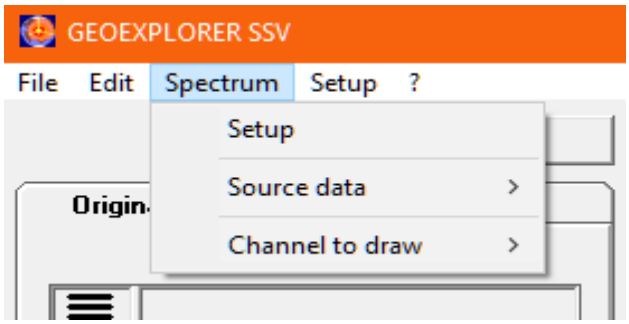


Illustration 6

Setup

This window allows to modify the visualization and computation of the spectrum.

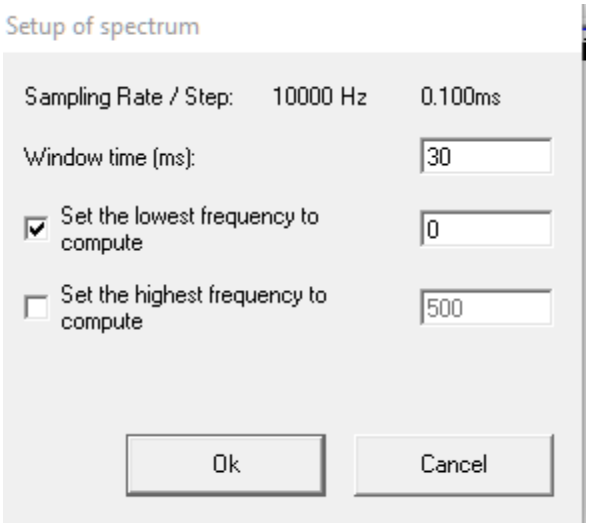


Illustration 7

Window time (ms): It is possible to modify the computation window time

> *Please note: the window length defines what will be the lowest frequency computed and is not related to what will be show. The lowest frequency is also influenced by the SPS of the data.*

Set the lowest frequency value to compute: allows to define what is the lowest value to represent.

Set the highest frequency value to compute: allows to define what is the highest value to represent.

Source data

This option allows to choose what channel will be used for the *Spectrum* tab.

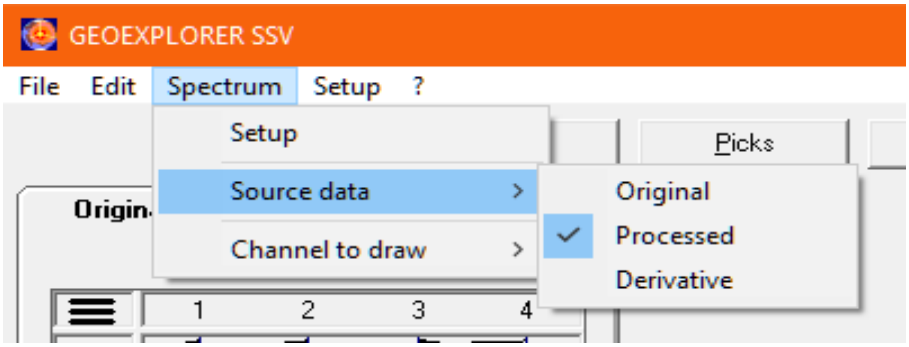


Illustration 8

The software uses the *Processed* option as default.

Channel to draw

Allows to select what channel to use for the *Spectrum* tab

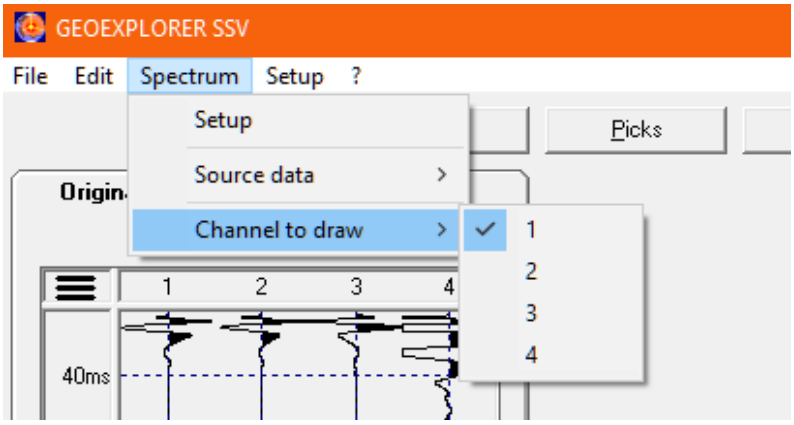


Illustration 9

The software use the channel 1 as default.

3.4 Setup menu

Here is possible to modify various aspect of the software, like the work folder.

File

With this window is possible to select the *Work folder,* what is the file extension for SEG-Y and SEG-2 files and the possibility to choose the file name when saving a new file.

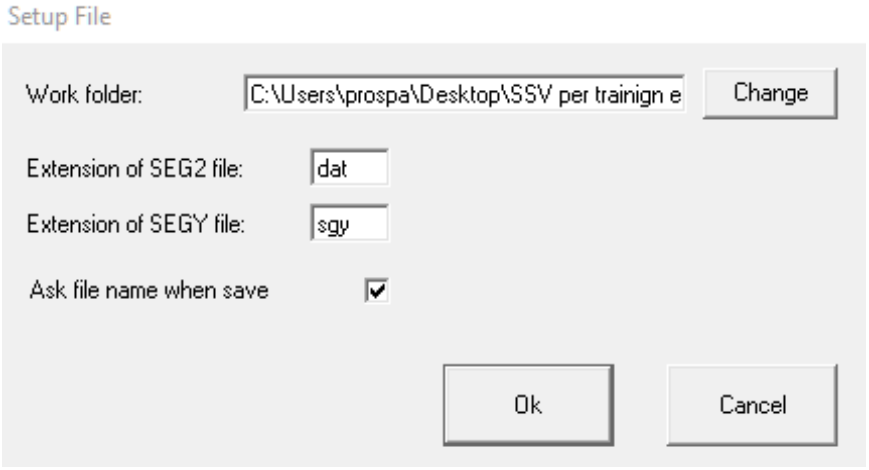


Illustration 10

Visualization

This window allow to modify the seismogram visualization. Seismograms are shown in the same way as the DoReMi software does.

For more details refer to the GEOEXPLORER DoReMi user manual.

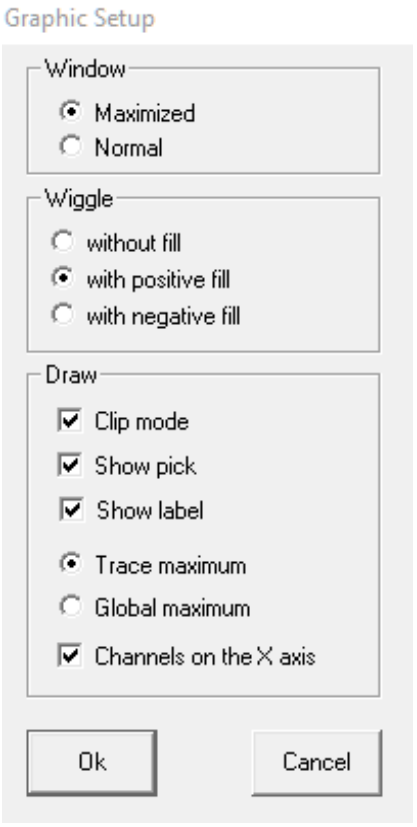


Illustration 11

Language

This window allows to chose the software language.

Illustration 12

?

This menu opens the software info window.

Illustration 13

3.4.1 Elaboration tools

The SSV software has different tools that can be used to improve and highlight the reflections.

3.4.1.1 Filters

The software allows to apply different kind of filters.

For more details refer to the GEOEXPLORER DoReMi user manual.

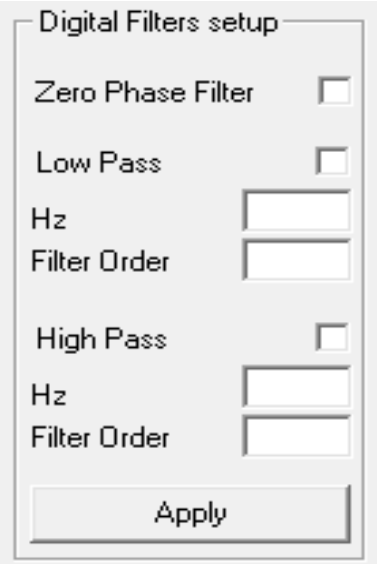


Illustration 14

3.4.1.2 IAGC

Illustration 15

This function of instantaneous gain is a tool that allows to mitigate the geometrical energy spread.

3.4.1.3 Picks

This functions shows the picking list and allows to edit the picking values and directly add a new pick.

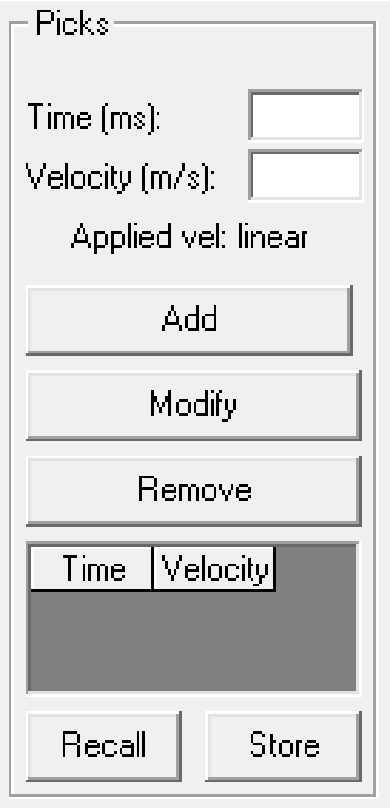


Illustration 16

3.4.1.4 Velocity

This tool allows to choose the velocity method and parameters for the depth conversion:

- Constant velocity.
- Velocity linear function.

  Please note: this function use the Dix equation for the interval velocity computation.

- Single.

  Please note: with this method the velocity set on the Picks tool will be used for the depth conversion.

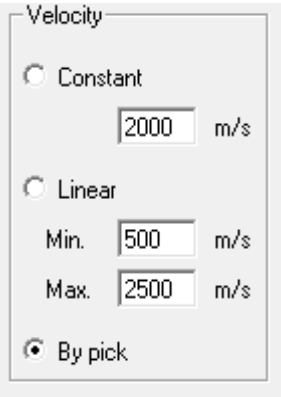
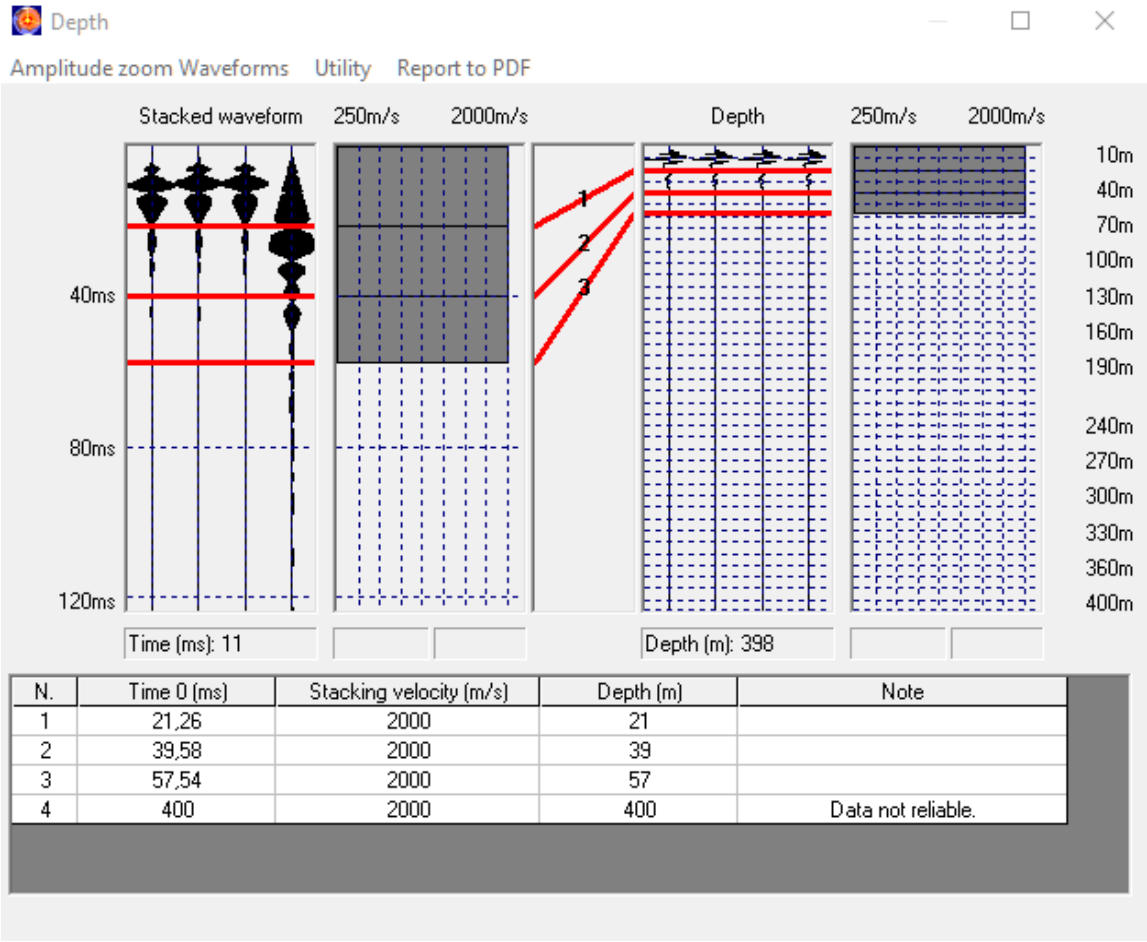


Illustration 17

3.4.1.5 Depth conversion

The depth conversion uses the velocity profile, selected as explained on the chapter before, opening the depth conversion window. For more information see the chapter 3.4.4 Depth conversion page 19.



N.	Time 0 (ms)	Stacking velocity (m/s)	Depth (m)	Note
1	21,26	2000	21	
2	39,58	2000	39	
3	57,54	2000	57	
4	400	2000	400	Data not reliable.

Illustration 18

3.4.2 Visualization data tabs

The left box has 3 tabs:

- Original.
- Spectrum.
- FFT.

3.4.2.1 Original

This tab shows the original data.

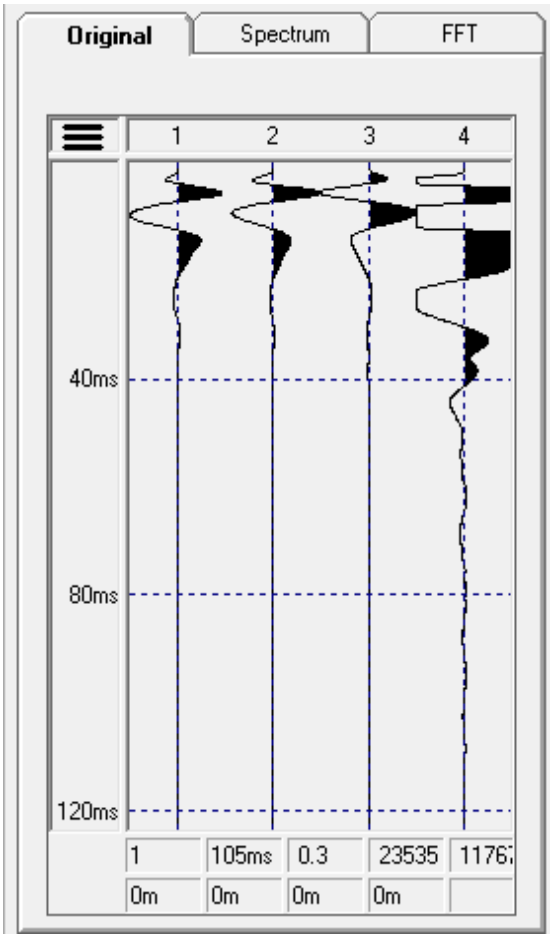


Illustration 19

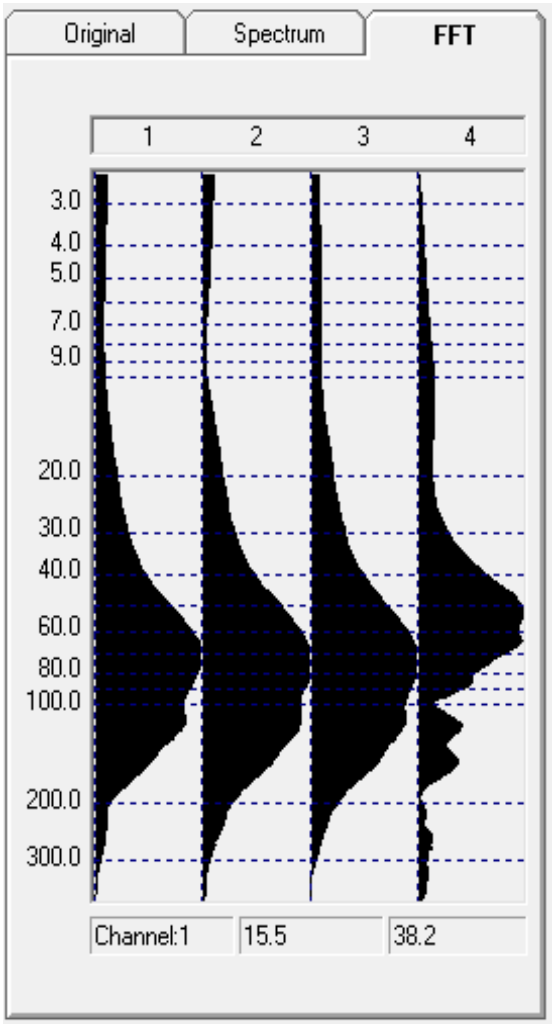


Illustration 20

3.4.2.2 FFT

This tab shows the FFT of every channel allowing to evaluate the filters parameters.

3.4.2.3 Spectrum

This tab shows the time-frequency spectrum for the frequency analysis. It is possible to set up the parameters on the *Spectrum* menu (see Chapter 3.3 Spectrum menu page 8).

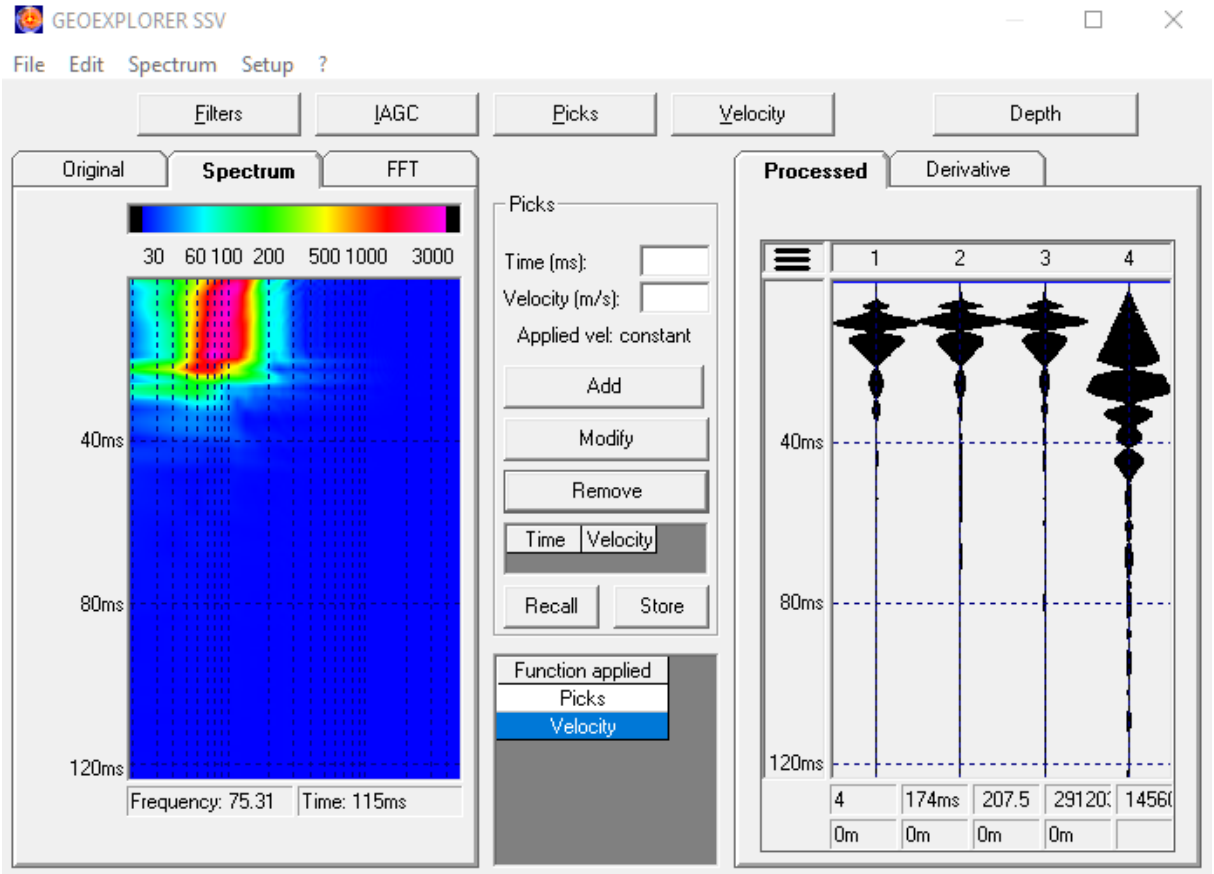


Illustration 21

By the right click on the processed waveform is possible to open the menu that gives you the possibility to change the start of the spectrum computation or the interval where you want to compute the spectrum (*Compute the spectrum from here* or *Compute the spectrum around here*).

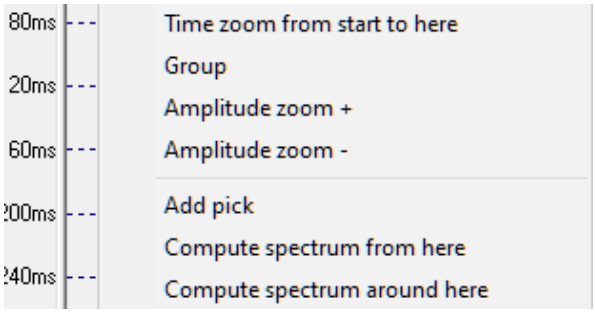


Illustration 22

Moving the mouse over the spectrum the software will plot a straight red line to highlight the time position of the right tab, helping on the picking.

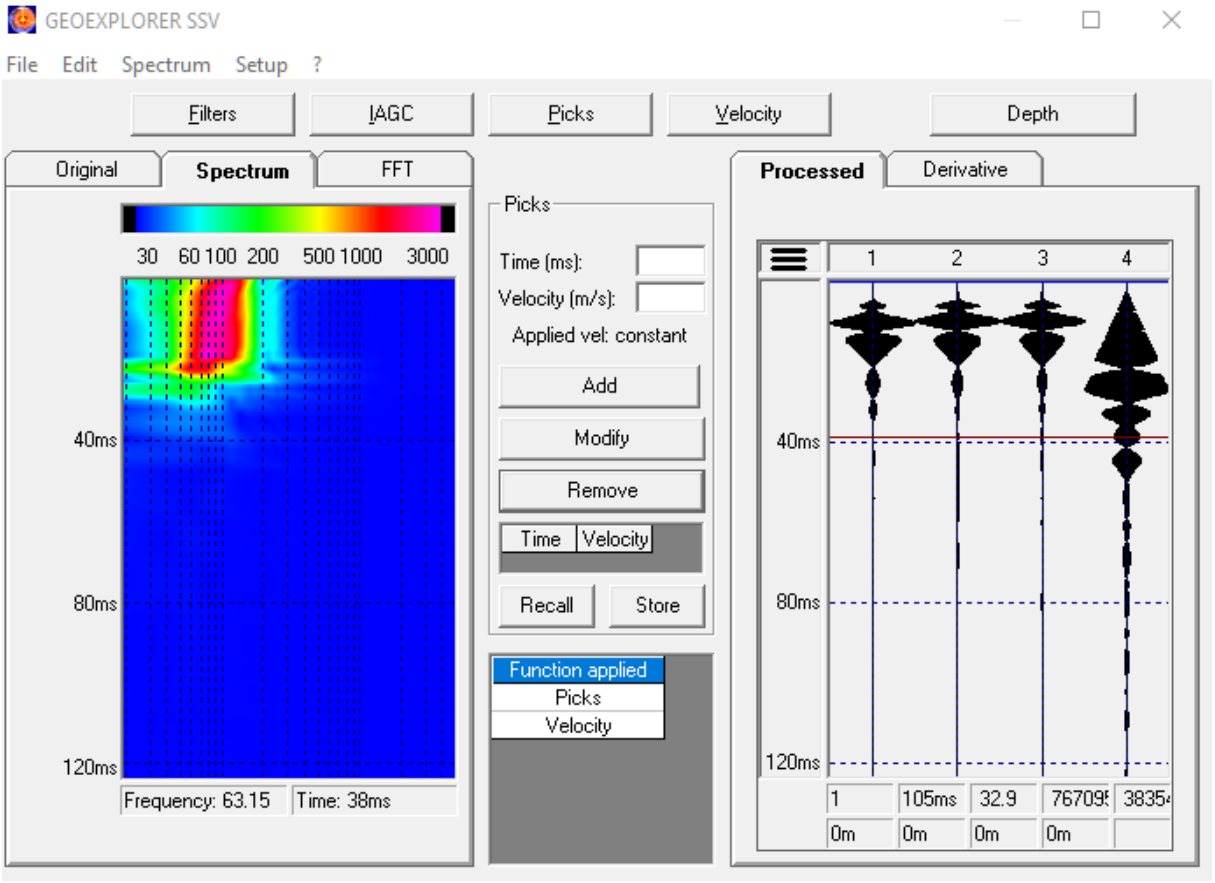


Illustration 23

With the right click is possible it is possible to open the Picking menu. The picks will populate the table in the *Picks* tool (see chapter 3.4.1.3 Picks page 12).

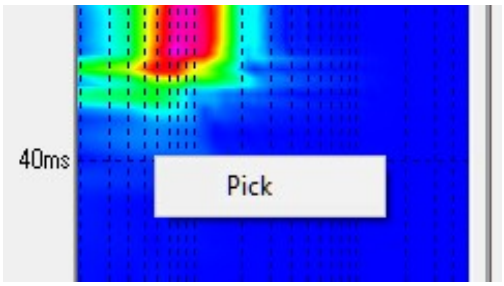


Illustration 24

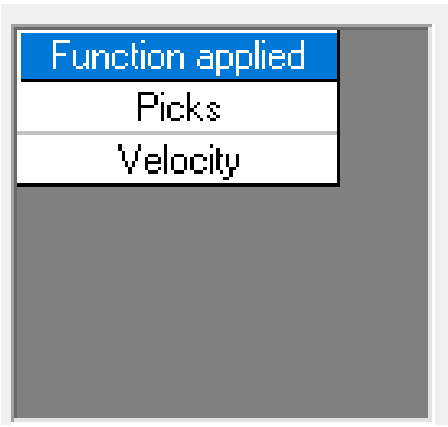


Illustration 25

Please note: on the center, between the various representations, there is the list of the functions applied during the processing.

3.4.3 Visualization processed data tab

The right box has 2 tabs:

- Processed.
- Derivative.

3.4.3.1 Processed

This visualization allows to see the data with applied tools. This visualization is characterized by a symmetrical visualization of the waveforms that improves the recognition of the reservoir reflection improving the high frequency content.

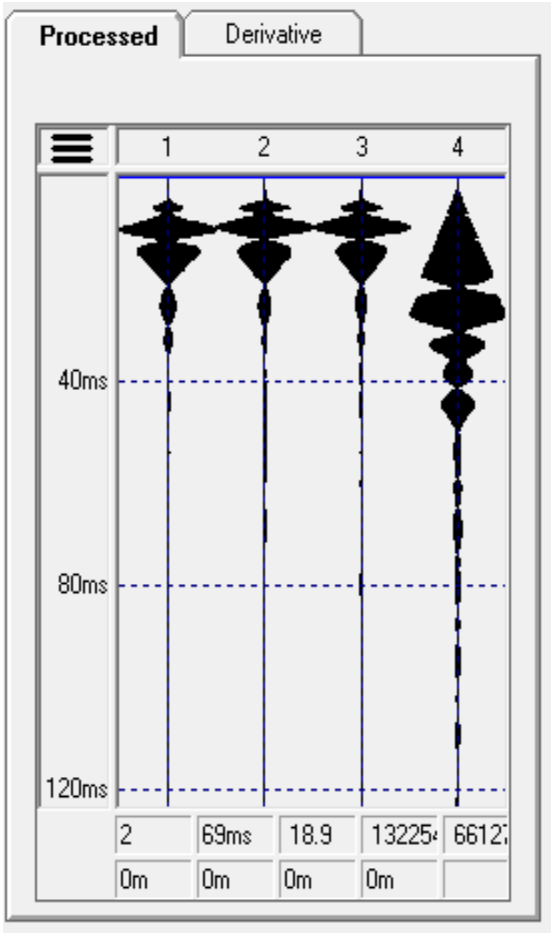


Illustration 26

3.4.3.2 Derivative

This tab allows to see the data with a certain grade of derivation, from 1 to 4 degree.

This function improves the higher frequency content.

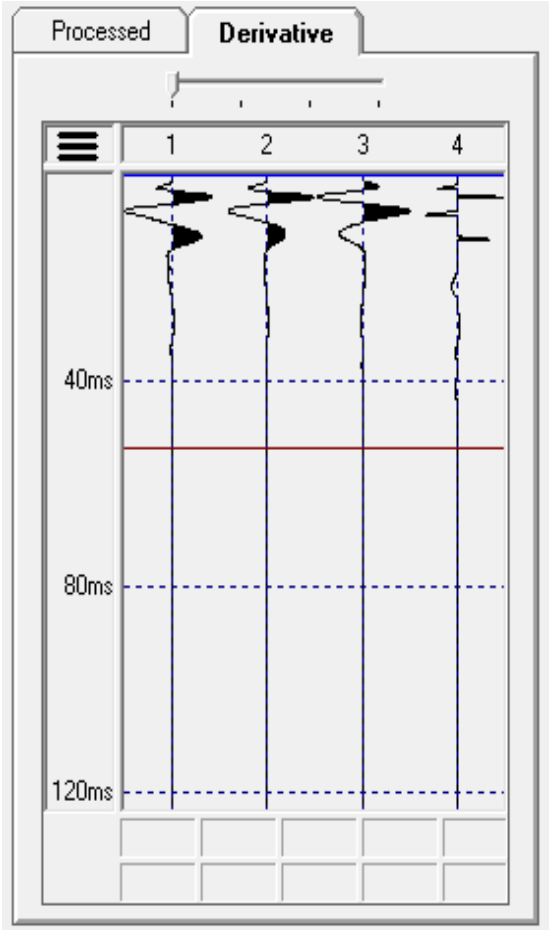


Illustration 27

Please note: every seismogram representation have the menu that allows to change the seismogram visualization.

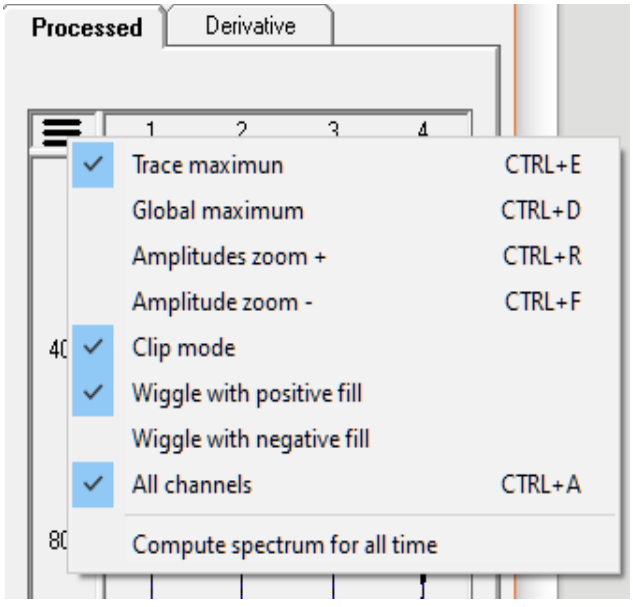


Illustration 28

3.4.4 Depth conversion

As written on the chapter 3.4.1.5 Depth conversion page 13, this tool opens the depth conversion window.

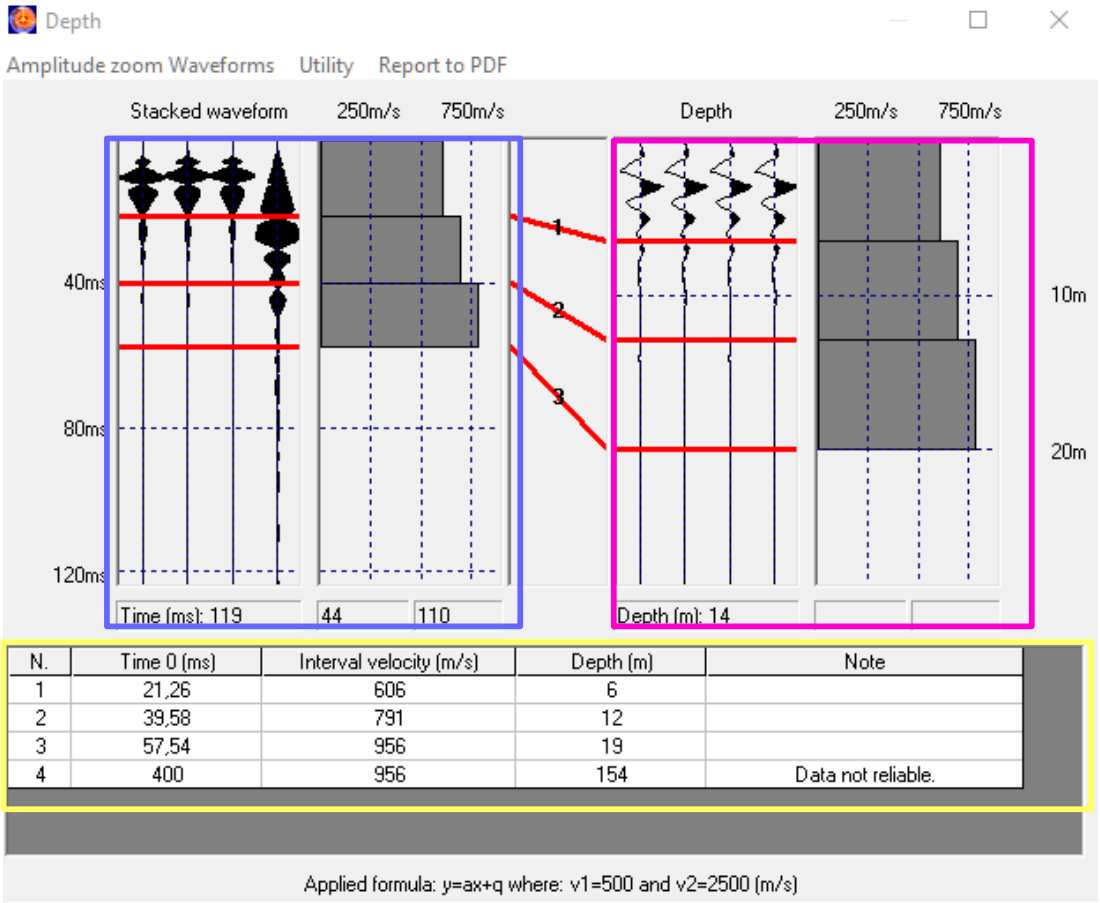


Illustration 29

This window contains the processed 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 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 is possible to see the value of T_0, 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.*

At the bottom of the window is possible to see what velocity model has been used for time-depth conversion.

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

3.4.4.1 Report

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

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

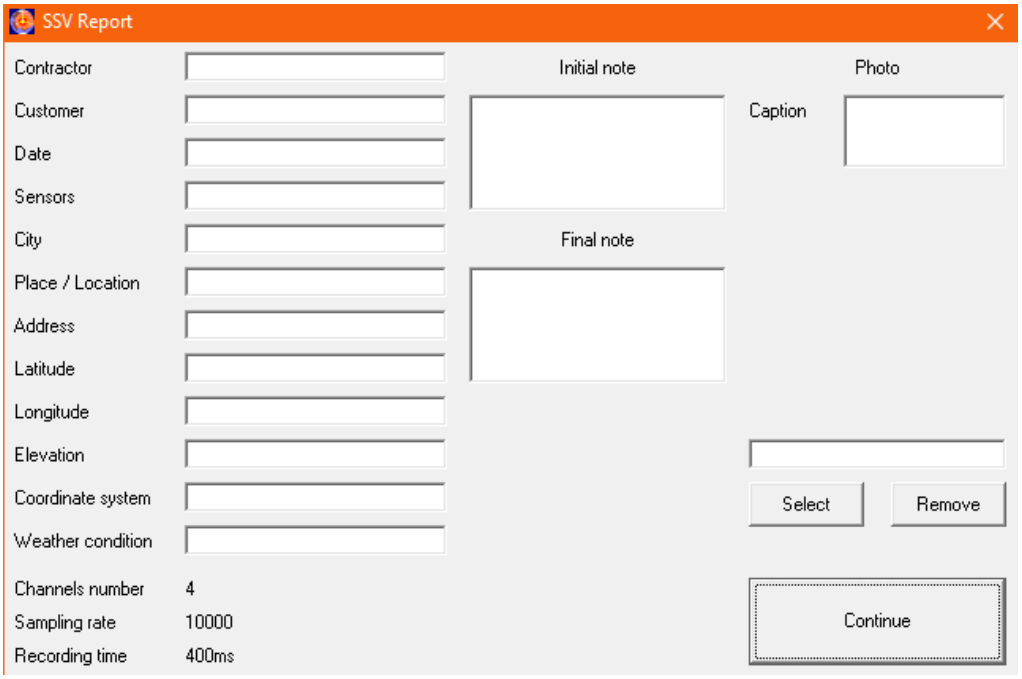


Illustration 30

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.
- *Initial* and *Final 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.
- *Caption*: photo description

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.

4 Introduction to SSV

The need to identify possible water reservoirs and estimate their depth with an easy, quick and practical approach, with depth usually between 30m and 300m below the surface, can find valuable help in survey techniques such seismic reflection. This kind of investigation required a study of reflected signal in the morphological waveform sinusoidal development and in the analysis in the spectral domain to identify specific seismic facies related to the granulometry and sorting grade. A better soil characterization needs a synergy between reflection with other techniques like geoelectrical survey, VLF, etc.

The seismic reflection technique is used in different specific field (oil&gas) and with the development of digital technology now we have a large amount of scientific articles and experience that every experienced user can use to analyze the data with high level of detail with a low cost and time for the seismostratigraphy interpretation.

The improvement of seismographs, sensors, campaign methodologies and analysis techniques, have contributed to greatly increase the signal / noise ratio of the recorded data and consequently the resolution of the investigations carried out, that the effectiveness in microzonification studies, water search, soil characterization has been proved by numerous scientific articles. The reflection technique is one that has improved with this technological improvement.

It is important to point out that the reflection technique and the SSV are techniques that need to have a very strong theoretical knowledge over the signal processing, general physics and various acquisition techniques witch are the basis for the right acquisition process and elaboration. The data processing, that in the SSV is strongly simplified, needs this basis to understand the effect of the various tools on the data. We suggest to do not underestimate the complexity and study on various books and courses to deeply understand the technique.

Given that the theory underlying the processing and acquisition is vast, in this document we have tried to provide indications to obtain an effective processing of the data recorded even using simplified tools.

The robustness of the interpretation, in terms of individuation of reflections of interest requires a process that uses various tools in a **non-standardized and univocal way**. It is therefore necessary to acquire a good quality dataset and a good processing skills with a very clear geologic picture of the place and strong geological skills and experience.

We suggest to perform this technique, especially for the person that are starting with it, to practice this technique in different geological settings with stratigraphy data and/or well.

This manual has the purpose to give the minimal knowledge of the tools in the SSV software, acquisition process and interpretation.

We remind that the IAGC is a tool that works in the amplitude time domain, modifying the amplitude with the time (see chapter 3.4.1.2 IAGC page 12) and the SSV algorithm works on the seismogram representation as described in the *Pacini et al. 2000* and it works on the amplitude differential.

5 Data acquisition

The seismic reflection acquisition is strongly dependent on the data quality because the technique works on the seismograms. The quality of the data can depends on the local noise level, possible geometry, topography, source, geological settings, etc. so it is mandatory to know how to set up the acquisition process, choose the right parameters, geophones, source, etc.

5.1 Acquisition parameters for SSV

5.1.1 Geometry

In comparison to standard reflection techniques and classical geophysical techniques where are needed a large amount of channels and space, the SSV need a very minimal system and a very small geophones spread.

For a good quality of the data, considering the traditional acquisition process, is recommended to use at least 4 channels; to improve the signal to noise ratio is recommended to use a large number of geophones (4 channels with 3 geophones each like in the picture).

The geophone disposal is as grid, but is possible to use a different geometry since the acquisition can be considered near vertical.

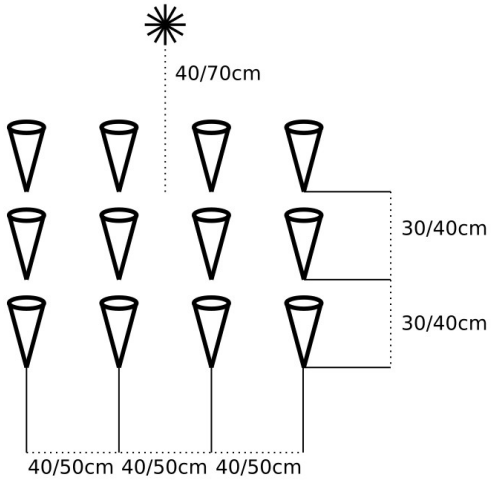


Illustration 31: Acquisition geometry example SSV

5.1.2 Acquisition parameters

To choose the right acquisition parameters you must consider the time that the waves will need to reach the target and come back as near vertical reflection.

So is needed to estimate the depth of the target and the mean velocity to set the recording time considering that the signal will travel in the soil in the two directions (two way travel time).

The method use compressional waves (*Torre et al. 2017*). In the bibliography is possible to consider the Vp increasing with depth and from the oil&gas field the range can be constrained between 1000 m/s and 3000 m/s (that are commonly reached in the aquifer search).

With the decennial experience the total recording length suggested is around 400ms. This time window allows to record data that can reach a depth of 150-200 m with a good graphic representation. For the FFT analysis is suggested to increase this value for a better resolution of the FFT.

For the individuation of deep groundwater reservoir an adequate source is needed. LPgeognostica of Pacini L.U. 2004 (comunità Engeo e Assiago 2008) has carried out an acquisition with a target of 1340 m and AMASOIL MAROC has carried out a survey for 1500 m modeling a possible target at 238 m, later confirmed drilling a well for LPDECE.

For the SPS consider these two factors:

1. Commonly the bandwidth of interest is between 60 and 100 Hz; this means that is mandatory to have a sampling rate double of the interest frequency (around 200 Hz). Considering that in general the sampling rate is 10 times the Nyquist frequency it is suggested to work at least at 10000 Hz.
2. In the signal analysis for the FFT and for the time-frequency diagram it is suggested to work even with 20000 Hz for a better resolution at lower frequencies and have a digitalization of the waveform closer to the analogue waveform.

With a 16bit DoReMi version is suggested to use the GAIN function with a value greater the default minimum value but taking care to not clip the signal. Please refer to DoReMi manual for the setting of the GAIN function.

5.2 Geophones

The geophones usable for this technique must to have with an eigen frequency that will not filter the interest frequency mentioned before. Must to be vertical geophones because the compressional waves reflection is used with this technique.

It is suggested to use geophones that have a eigen frequency of maximum 50Hz.

Illustration 32

6 Data processing

The reflection technique is an imaging technique, this means is based on **subjective interpretation of displayed data.**

Are needed good interpretation skills and experience for the data modeling.

The processing purpose is to process the dataset to enhance the seismic reflection for the interpretation to evaluate the geological changes and domains. It is important to reduce the noise and disturbances.

This is possible in the SSV software with the filters and the IAGC. The usage of these tools need the understanding of how they works on the data and must to be used carefully.

6.1 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 filters 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 kind of filters: 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 band 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 33

To clean the data and avoid artifacts, the filter needs a taper in the two external sides 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 thresholds (f_2 e f_3) and the taper (filter order). The lower the order 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 combinations of filters to improve the result. To understand what could be the better configuration the use of the function FFT is recommended.

To understand what is the best bandwidth to use is mandatory to take a look on the FFT and understand what is the optimum frequency range. It is important to understand that the bandwidth is function of the litology; the higher frequencies are associated with rocky litology so filtering these information is not recommended. On the other side with soft soils filtering low frequencies can be problematic for the elaboration, losing some information.

For more details please refer to GEOEXPLORER DoReMi Manual.

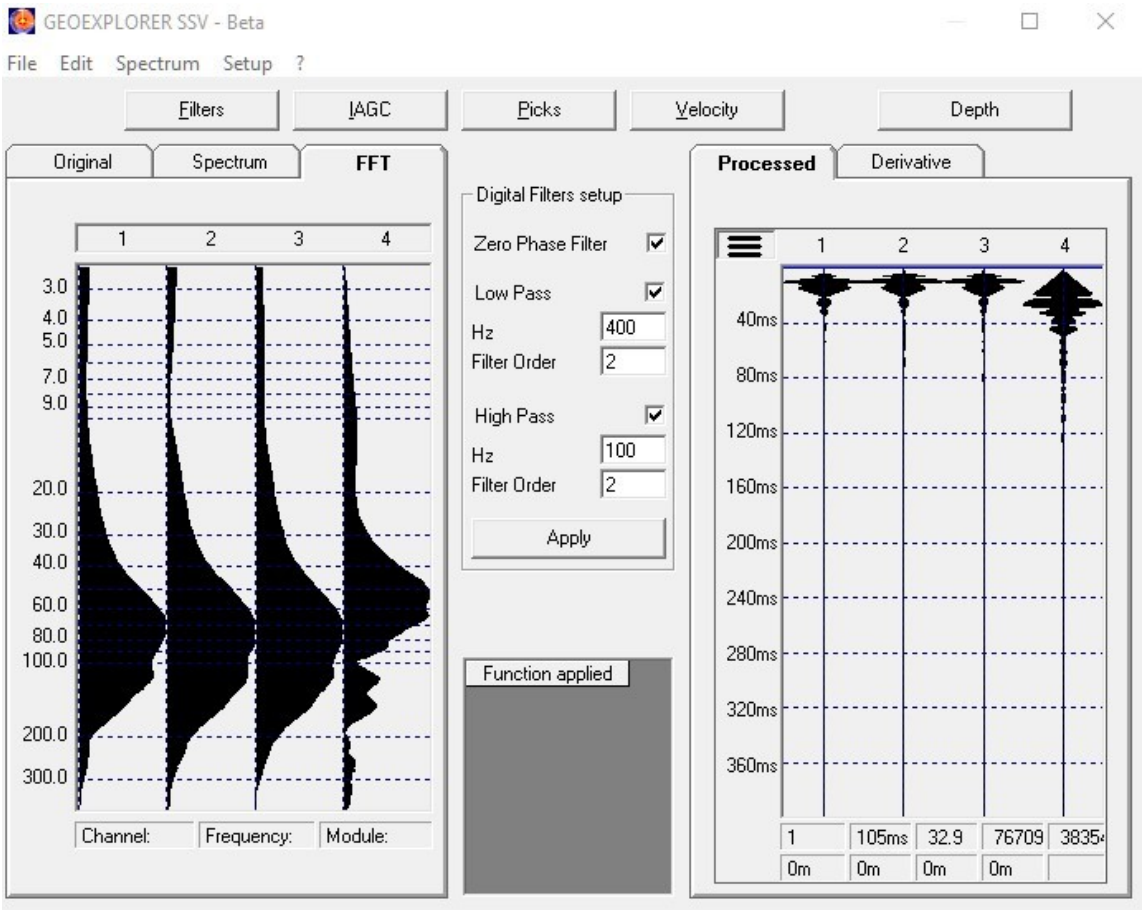


Illustration 34

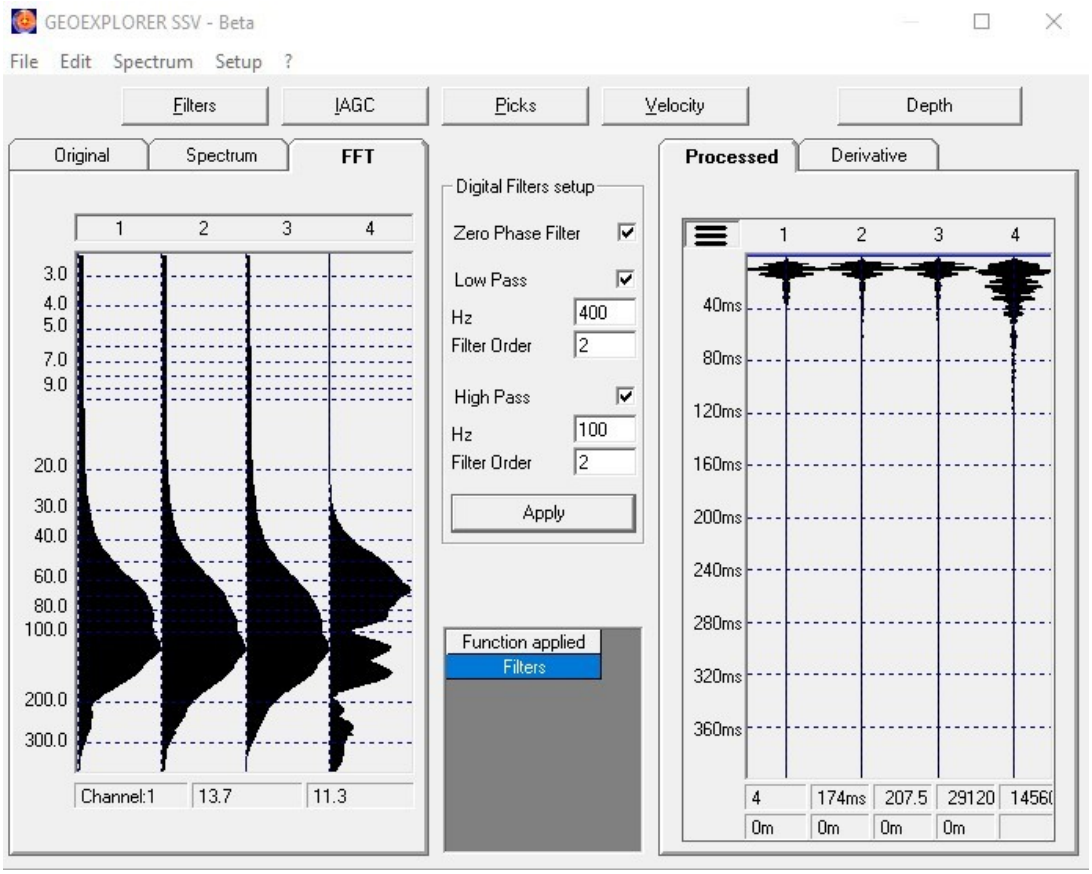


Illustration 35

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.

6.2 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 phenomenon is known 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 phenomenon is the scattering; the soil is not a homogeneous material, so when the waves pass through those variations 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 windows 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 windows is translated of one sample and computed again as explained before. This process is done for all the traces and for all the samples.

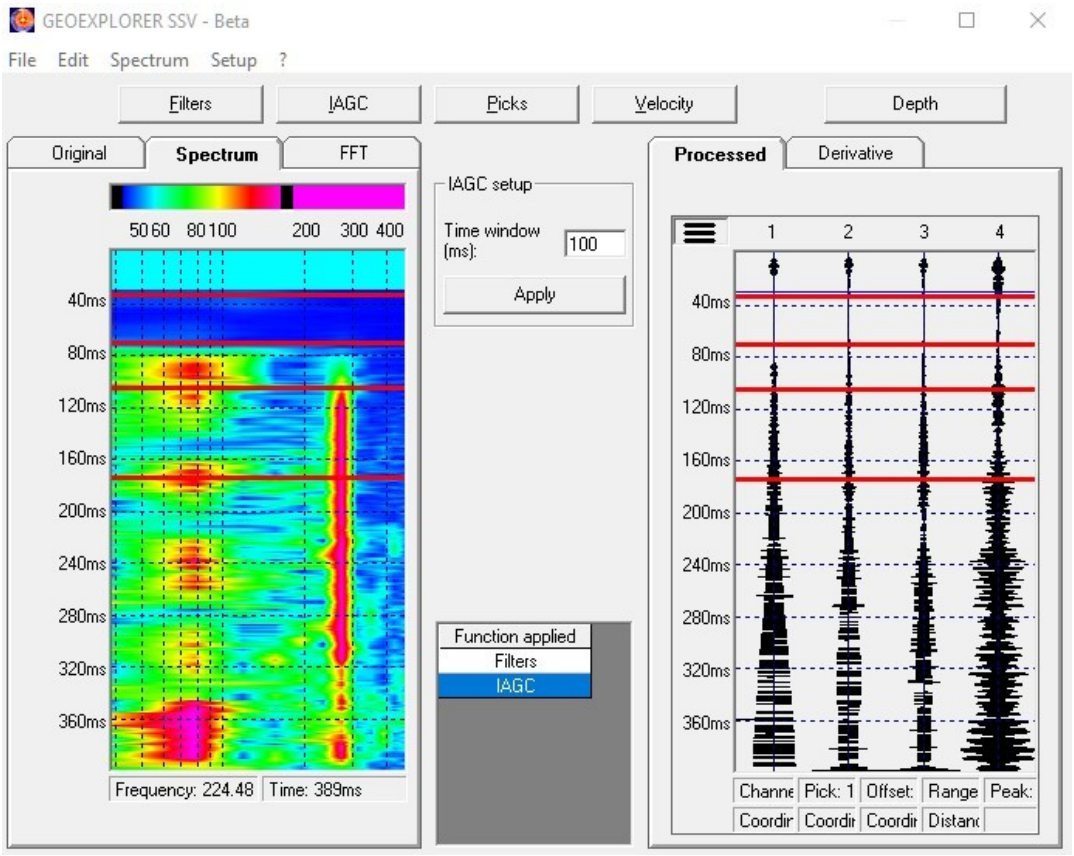


Illustration 36

It is quite easy to understand that applying a long window, or a window 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 usage 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 values to use are between 100 to 400ms.

6.3 Reflection Picking and Frequency/Time spectrum

Assuming that the soil is a homogeneous media, in the record must not to be reflection, consequently there will not be any increase of amplitude, and we must observe an amplitude decreasing, stabilizing with the time at the noise amplitude. Every increase of amplitude can be considered as possible reflection.

The interpreter must to understand if this signal can be a reflection or noise, or another signal.

The morphology of the waveform and its frequency content are the most important aspects to study for the understanding of the signal.

The lithological change, that causes the reflection, will give specific facies in the waveform (seismic facies). The reflection on the top of a porous media is dependent from a change in density and velocity.

This change will increase the high frequencies due to scattering phenomenon in a granular media. Generally sand or silt rocks have a frequency content below the 60 Hz, and fractured rocks or gravel will have high frequencies above the 60 Hz.

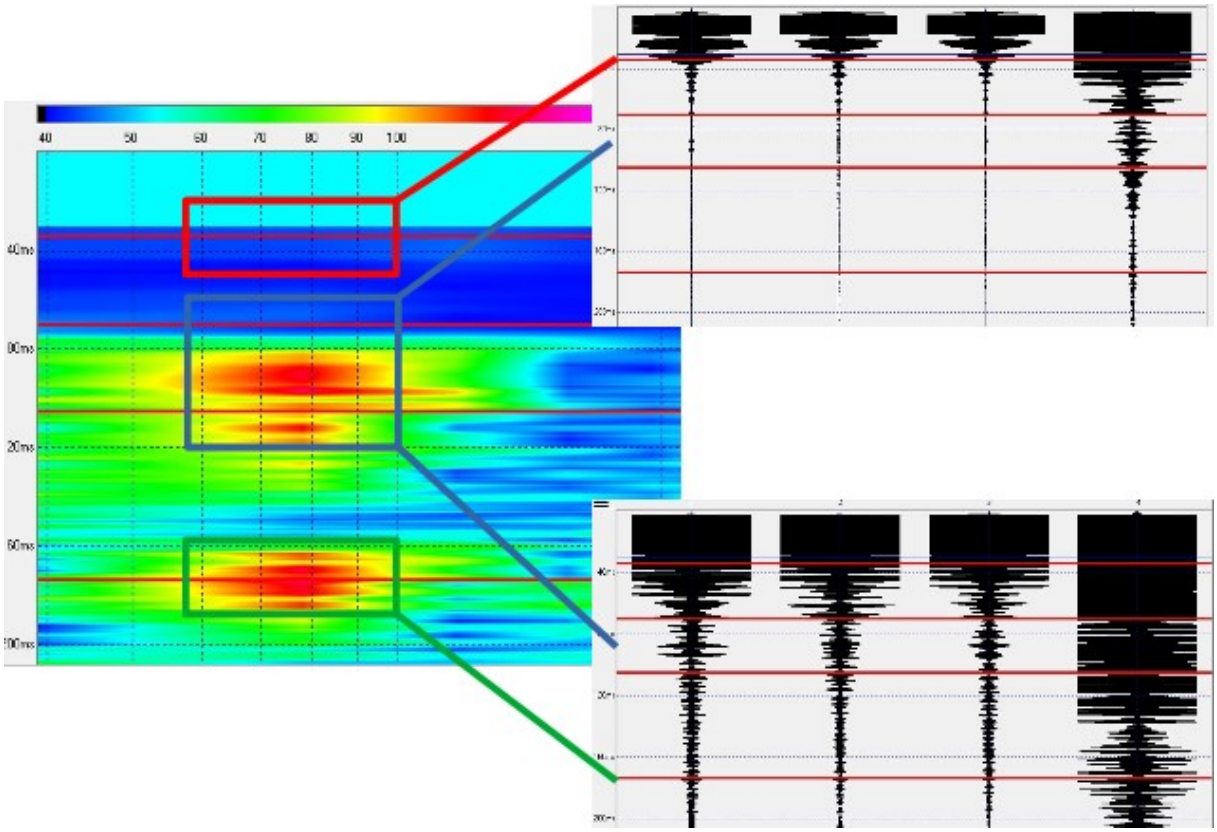


Illustration 37

6.4 Depth conversion

Depth conversion is one of the most critical step of the data elaboration. The software allows to use different methods for time-depth conversion. Considering the geological settings is possible to use a constant velocity, a velocity function where the software will compute the interval velocity, or directly the strata interval velocity.

The dataset used in this manuals gives the following model.

It is possible to notice that the 70 and 105 ms are related to fractured rocks that contain water.

Illustration 38

Illustration 39

Bibliography

Torre T., Marchetti E., Pacini L. – Anno accademico 2016-2017 – "*Efficiency analysis of a simplified method for reflection seismology exploration"* – Università degli studi di Firenze.

Pacini U., Pacini L., Masotti L., Biagi E., Calzolai M. – Anno accademico 1999-2000 – "*Prospezione sismica: progetto e realizzazione di un sistema di misura completamente gestito da personal computer"* – Università degli studi di Firenze.