Tutorial on Seismic Reflection CDP Data Processing in the *RadExPro Plus* software

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Content

Introduction

This tutorial is intended for the users, who begin to process seismic reflection CDP data in the **RadExPro Plus** program. All standard stages of basic CDP processing are discussed, from the introduction of geometry to stacking, that is the so-called minimal processing sequence. It is assumed that the user is already familiar with the theory of the CDP reflection method and with the fundamental technology of processing such data.

The processing is conducted on an example of the real data, which can be downloaded from our Web-site: http://radexpro.ru/upload/file/tutors/CDP/inpdata.zip
The archive contains initial data for the work: a fragment of an on-shore seismic profile, recorded in SEG-Y format (file *line_1.sgy*), with the trace headers containing source point and receiver point numbers, and two ASCII files, *rec_geom.txt* and *sou_geom.txt*, containing coordinates of the receivers and sources, respectively.

Furthermore, you can load the final project, which is a result of executing all steps, described in the tutorial: http://radexpro.ru/upload/File/tutors/CDP/MyProject.zip

Note that the facilities of the software, of course, are not limited to the minimal processing sequence described here. We consciously did not consider more complicated tasks such as, for example, horizontal velocity analysis, migration, calculation and analysis of seismic attributes, etc. You can find the information about these and other procedures of data processing and analysis in the "User Manual" to the program.

Data input, assigning geometry, binning

Creating a RadExPro Plus project

All reflection data processing in the **RadExPro Plus** is performed within the framework of *projects*. A project is a complex of initial data, intermediate and final processing results, processing flows, all organized into a common database used by the software. The projects are stored in separate folders on disk. When a project is created, the new folder for it is created automatically. A project can be transferred from one computer to another by simple copying of the folder (in case that all the data used are stored inside this folder).

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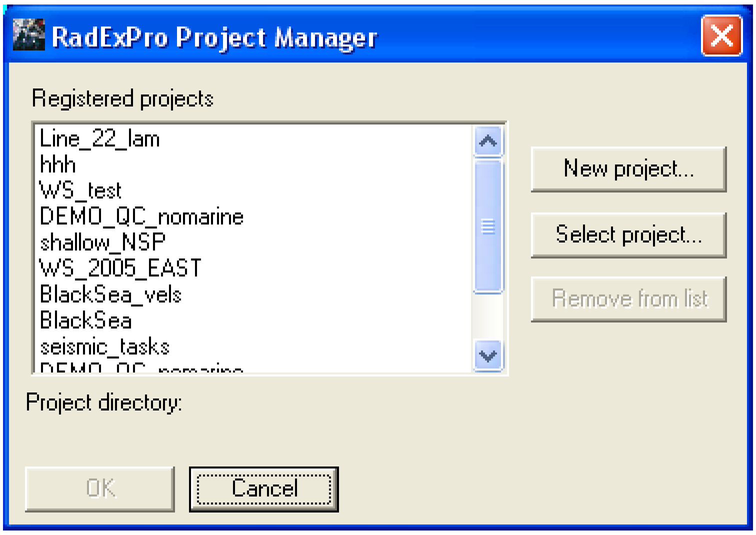
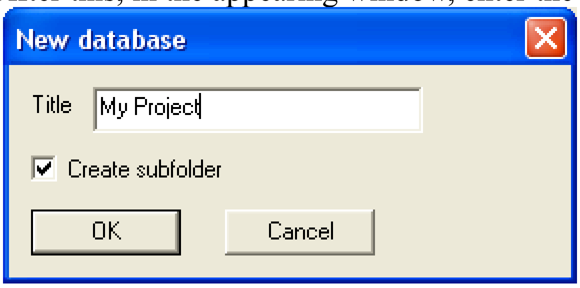
Let us create a new processing project. Start-up the software. To do this select **RadExPro Plus Total 3.75** command in the Windows Start menu.

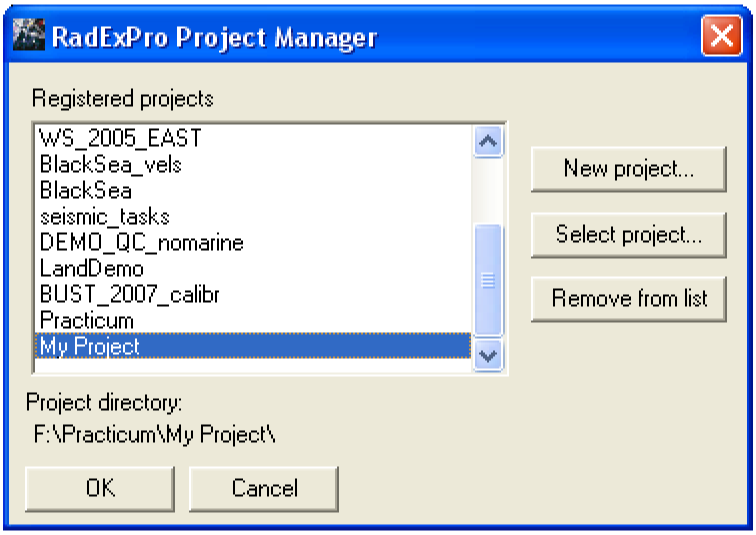
When the **RadExPro Plus** starts, the **Project Manager** dialog opens, containing the list of registered projects.



Click the button **New Project** and select a parental folder on the disk, where the subdirectory with the project will be created. After this, in the appearing window, enter the new project name.

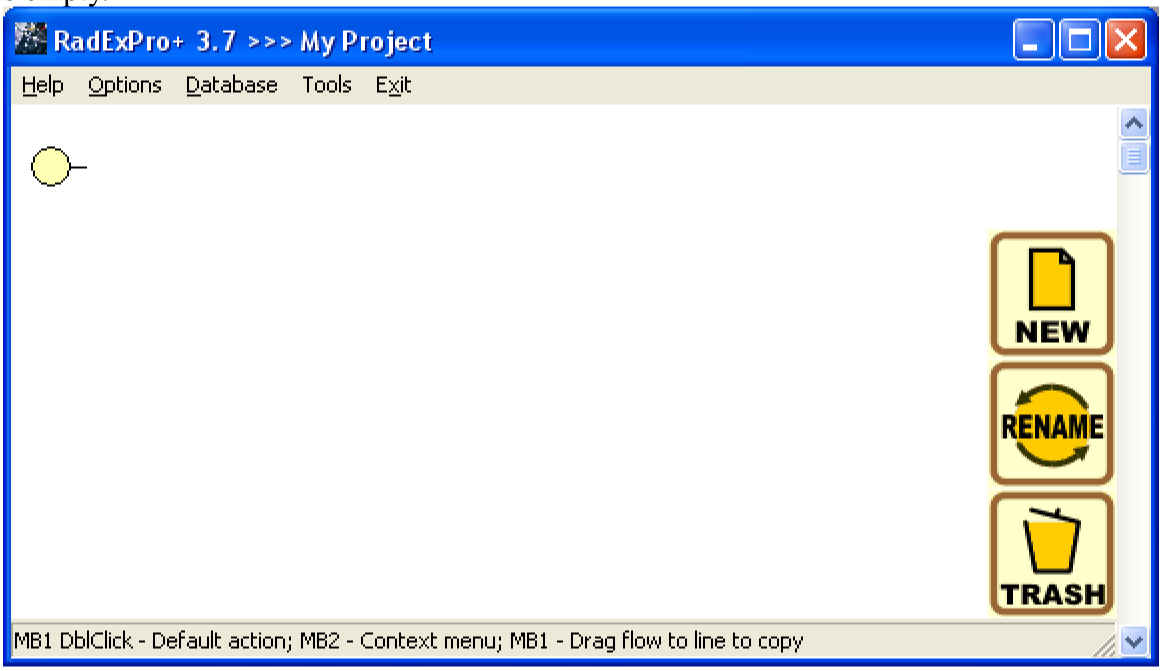


Make sure that the option **Create subfolder** is selected and click **Ok**. In the selected folder, the subdirectory with the project name will appear. Also the project will appear in the list of available (registered) projects.



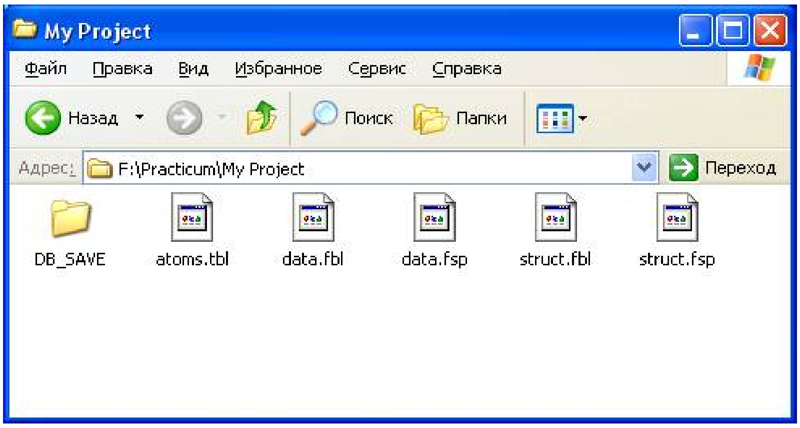
Select it and click **Ok**.

The main window of the **RadExPro** program, containing the project tree, will appear. By now this tree is empty.

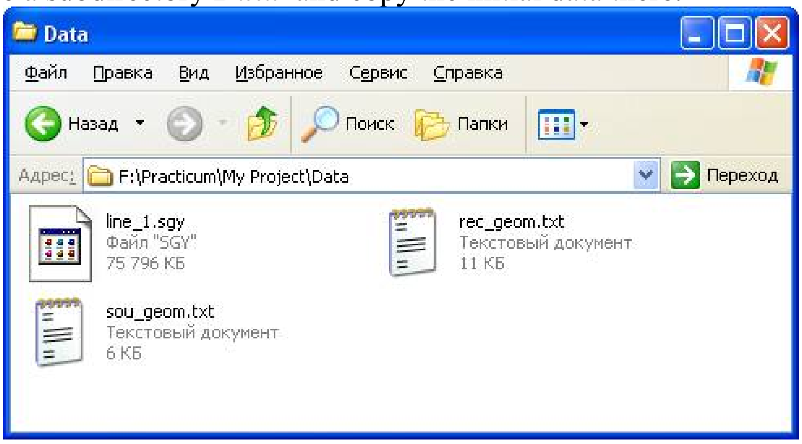


Loading raw data into the project

Using Windows Explorer, enter the project folder:

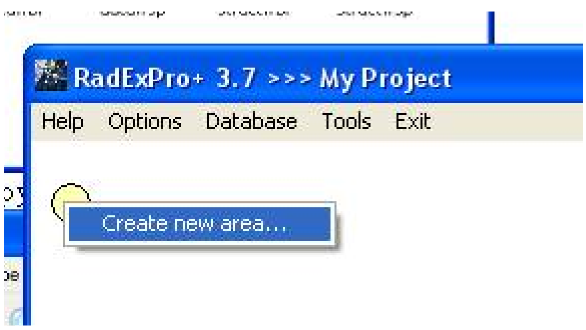


In this folder, create a subdirectory **Data** and copy the initial data there.

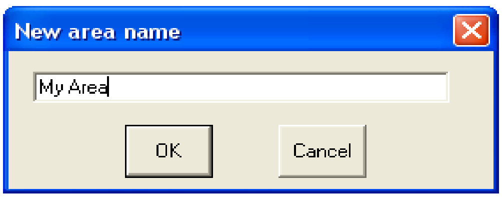


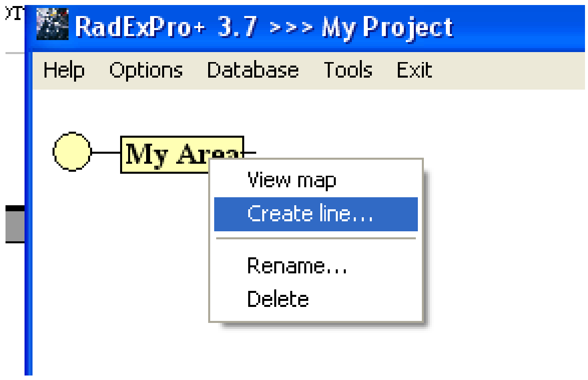
Storing the data inside the folder of the project allows the software to use relative paths to the data files instead of the absolute ones. This makes the transfer of projects from one computer to another much easier.

Return to the main window of the **RadExPro** program. A **RadExPro** database has 3 structural levels. The upper level corresponds to a study *area*, the middle level - to a *line*, and the lower one - to a processing *flow*. Right-click with the mouse on the yellow circle (that is the root of the project tree), select option **Create new area** in the context menu, and enter a name of the area where the field work was conducted. .

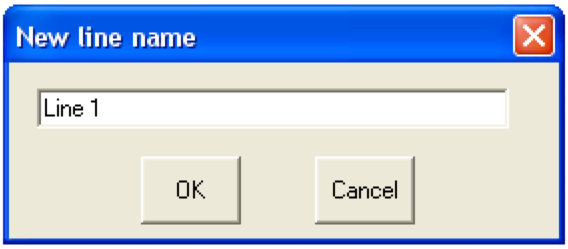


The following figure shows the window, where the name of the area should be entered :



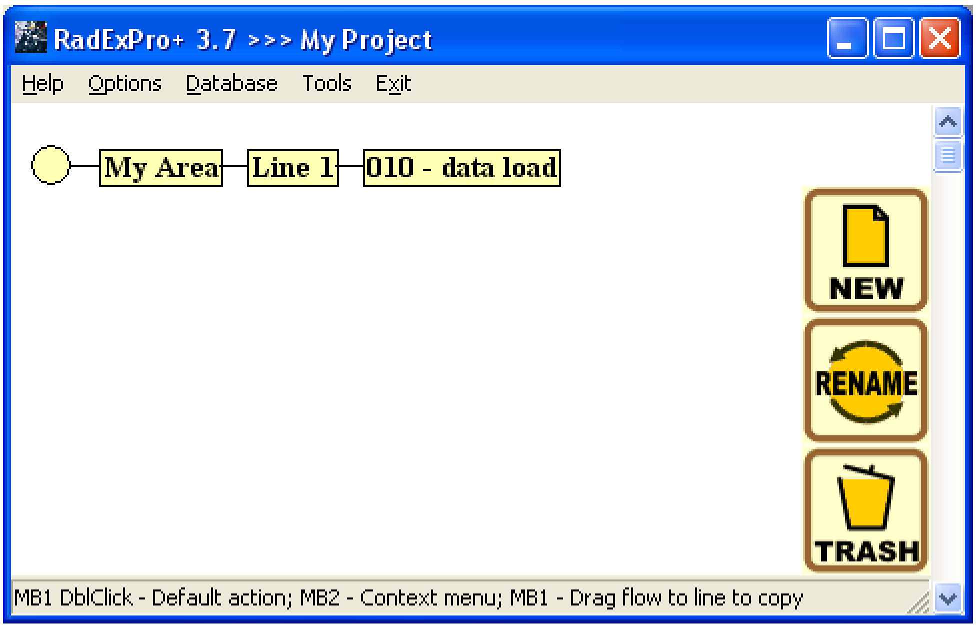


Similarly, right-click with the mouse on the yellow rectangle with the name of the area, select **Create line** command and create a new line. The name of the line is assigned the same way.

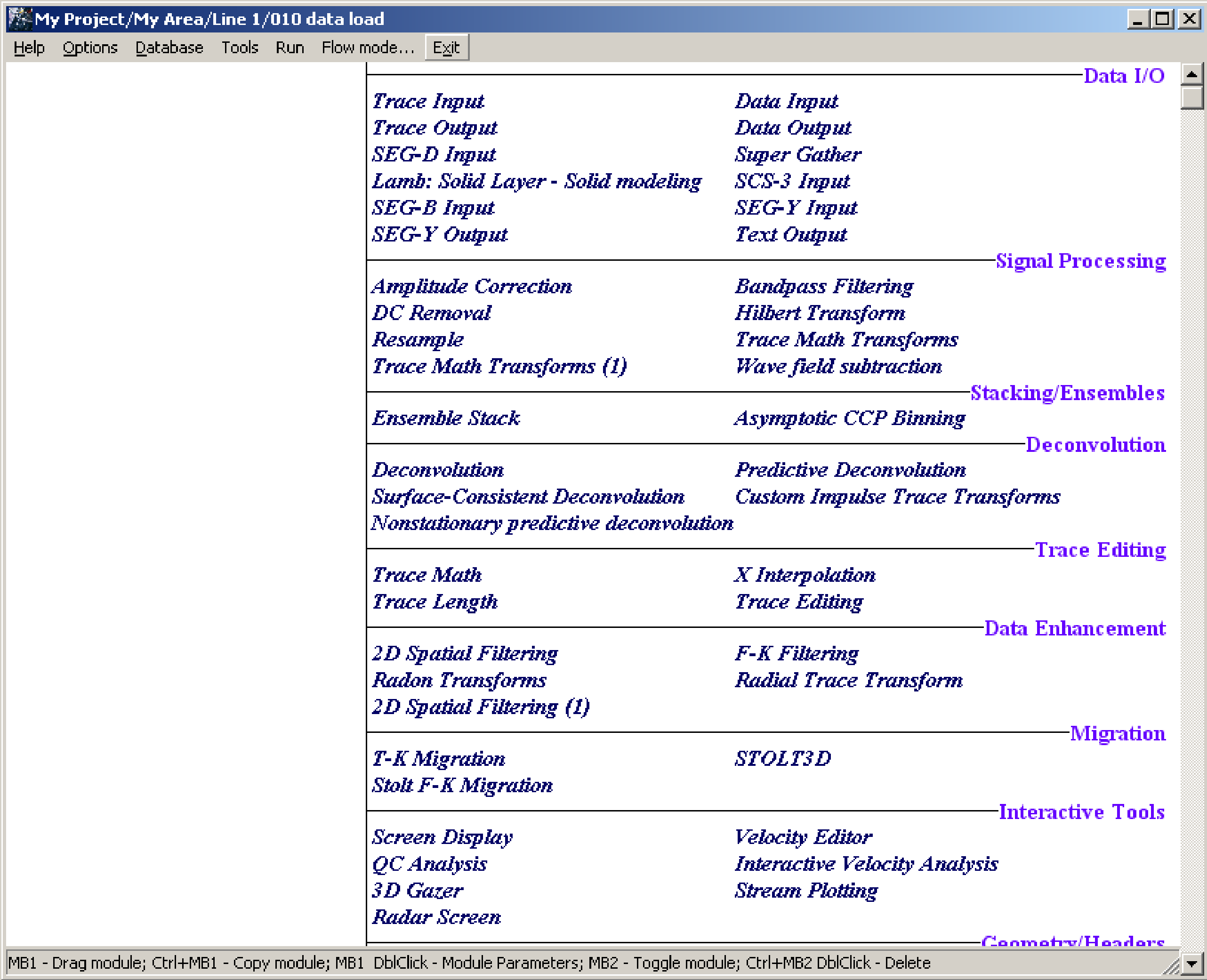


The database allows storage of several areas within one project. Each area may contain several lines, each line may contain several processing flows that are applied to the data of this line.

The same way you created the area and the line, create a processing flow and name it *010 - data load*. It is recommended to that you start the name of each flow with a number. The process of seismic data processing has several stages, carried out consecutively. Since the **RadExPro Plus** program sorts the structural elements of the database alphabetically, it is reasonable to number the flows so that they would be displayed in an accurate logical sequence.



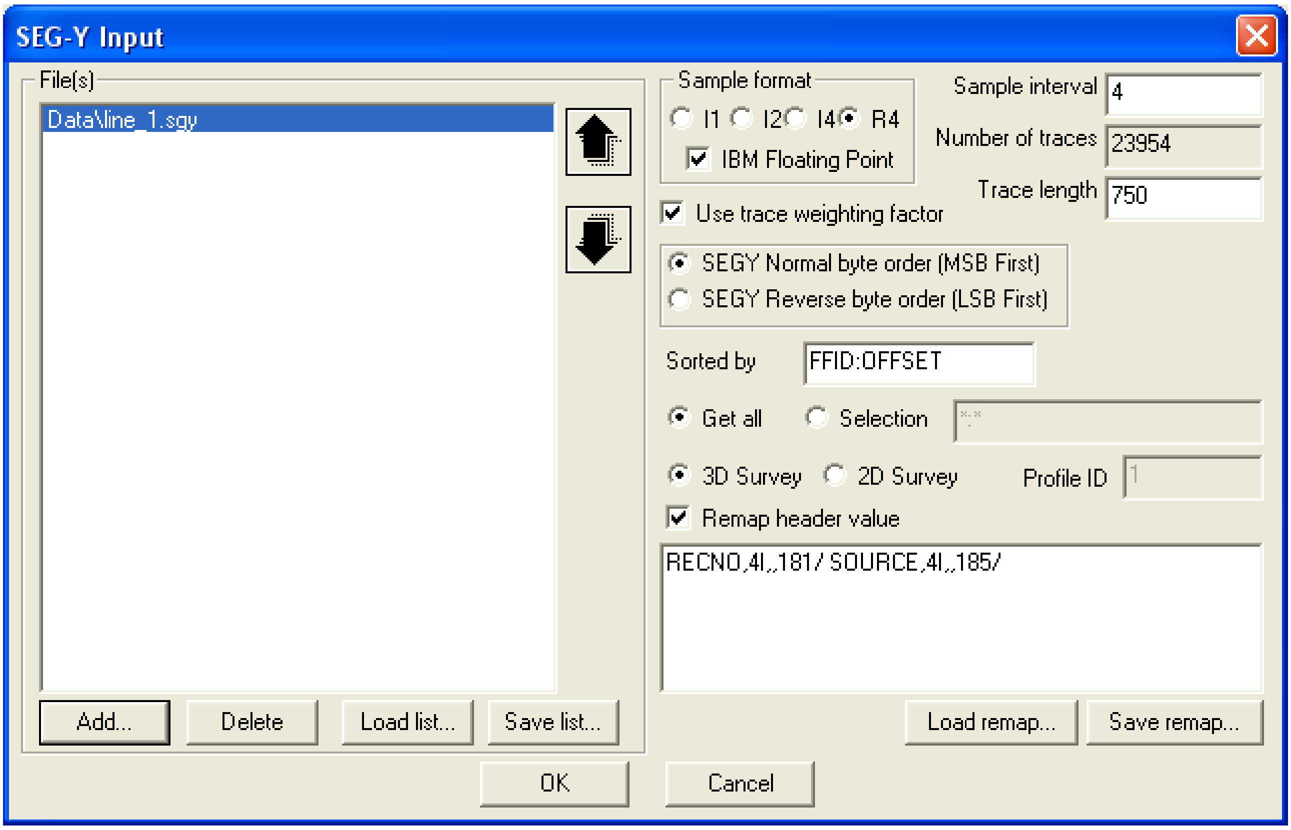
Double-click the left mouse button on the flow name to enter the flow editing mode. The window of the flow editor will open. On the left side of the window is the flow itself (it is empty so far), on the right side is the library of available processing routines (modules), divided into groups.



Create a flow, consisting of the modules **SEG-Y Input** and **Trace Output** (both are located in group **Data I/O**). This flow will read the data from a SEG-Y- file and record them into the project database a "dataset"-object of the database..

Modules are added to the flow one by one. To add a module into the flow just drag it over from the library on the right to the area of the flow on the left. At this moment, a parameter dialog of the module will be opened (later, when the module is already in the flow, the same routine parameter dialog can be called up by a double-click of the mouse on the module name in the flow). While already in the flow, the routines can be moved up and down relative to each other by simple drag-and-drop.

In **Data I/O** group find the **SEG-Y Input** module and add it into the flow. When adding the routine, assign the parameters of data reading in the opened dialog box. Click the **Add...** button and select our test data file *line_1.sgy*. For training purposes, the information about source and receiver positions in this file is stored not in the standard SEG-Y trace header words, but in the reserved space of the trace headers. In order to read the traces header information recorded in non-standard positions within the SEG-Y trace headers, enter a remap of the header fields. For this, switch on the **Remap header value** option and enter the following text *RECNO,4I,,181/ SOURCE,4I,,185/*.



Remap of header fields. Some seismic data formats allow trace header remapping, that is storage in the trace headers of some values, not provided by the standard. Sometimes the values are recorded in a non-standard format of number representation or in a non-standard position within the header. As a rule, contemporary software packages provide a possibility to indicate explicitly from what byte from the beginning of a header and in what format to read the values saved this way. In the training file *line_1.sgy*, the header fields containing the number (picket) of source and receiver position are recorded as integer 4-byte numbers in bytes 181-184 and 185-188 are saved this way. The remap string shown above will allow for reading them from there and saving into the RECNO and SOURCE header fields of the RadExPro Plus database.

RadExPro header fields. The RadExPro software uses its own set of header fields for storing auxiliary information about seismic traces. The values of header fields are associated with the trace and can be perceived an array of named variables linked to the trace.

When creating a new project, the default set of header fields generated is quite similar to the SEG-Y trace header. (See the correspondence of the RadExPro header fields and SEG-Y trace header in the description of module SEG-Y Output in the "User's manual"). However, further the header fields can be edited – you can add new fields, remove or re-name the existing ones.

A part of the header fields are standard and it is strongly not recommended to change their meaning (for example field DT must always store the value of the sample interval). Other fields can be used at your discretion. In the new (or existing, but not used) header fields different information can be recorded, for example the arival time of a wave as picked on this trace. You can perform mathematical operations with the values of the header fields, convert them into picks, etc.

After the **SEG-Y Input** module, add into the flow the module **Trace Output**, which will save the data from the flow into the database. Name the object, which will contain these data as "*line 1 – raw*" and place it at the second level of the database into the *Line 1* (as shown in the following

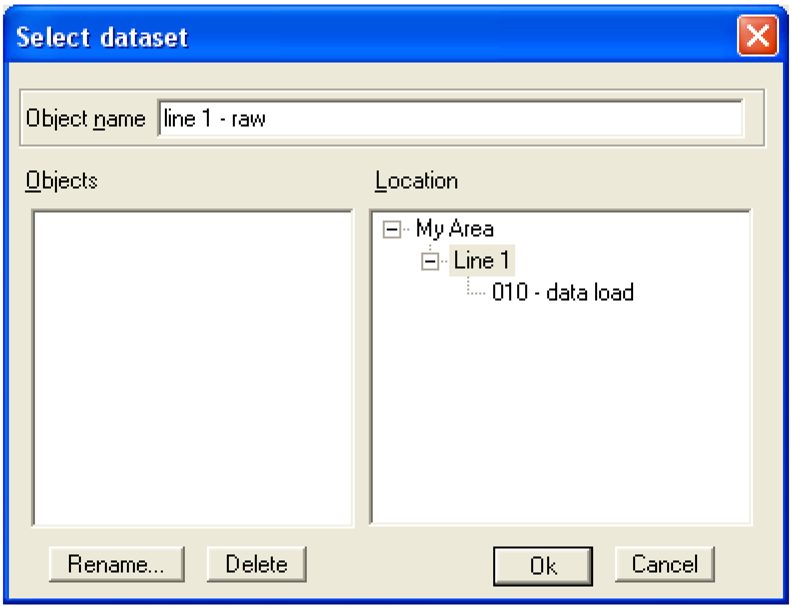
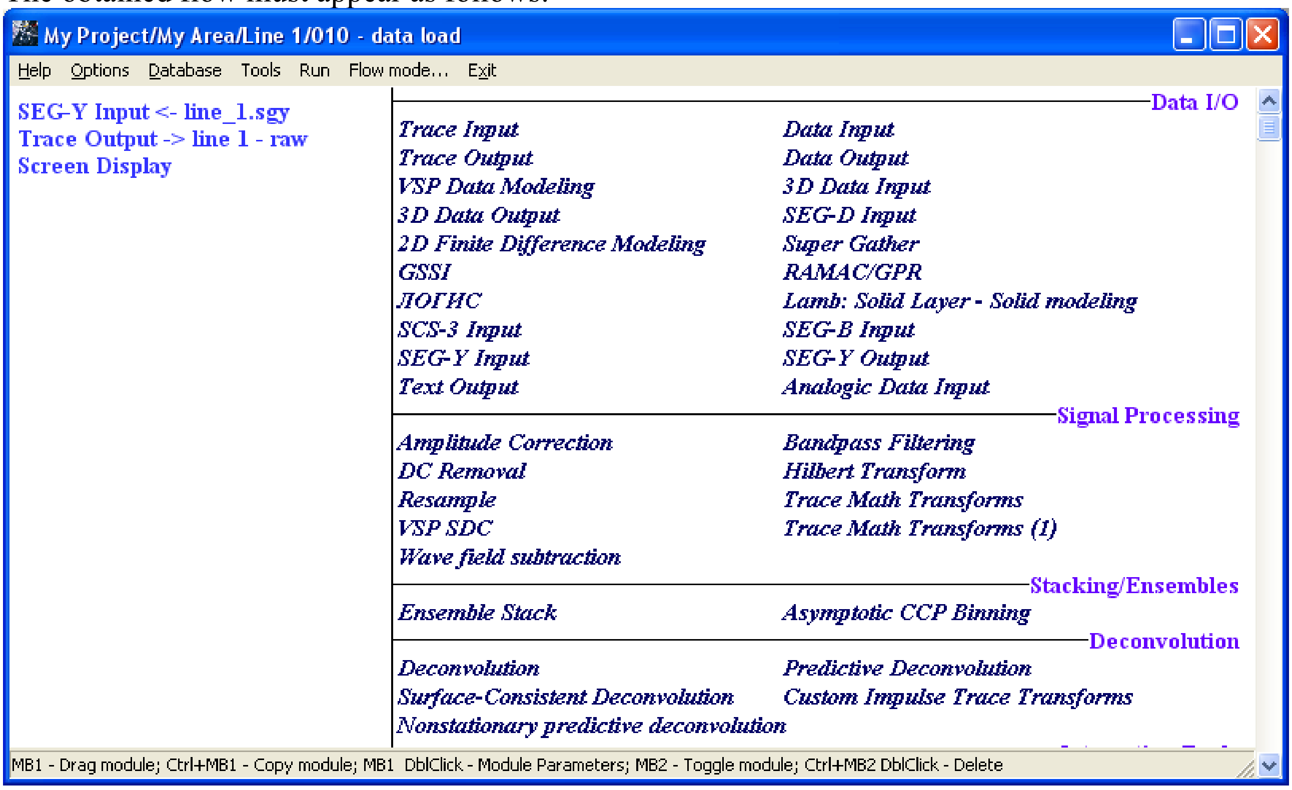
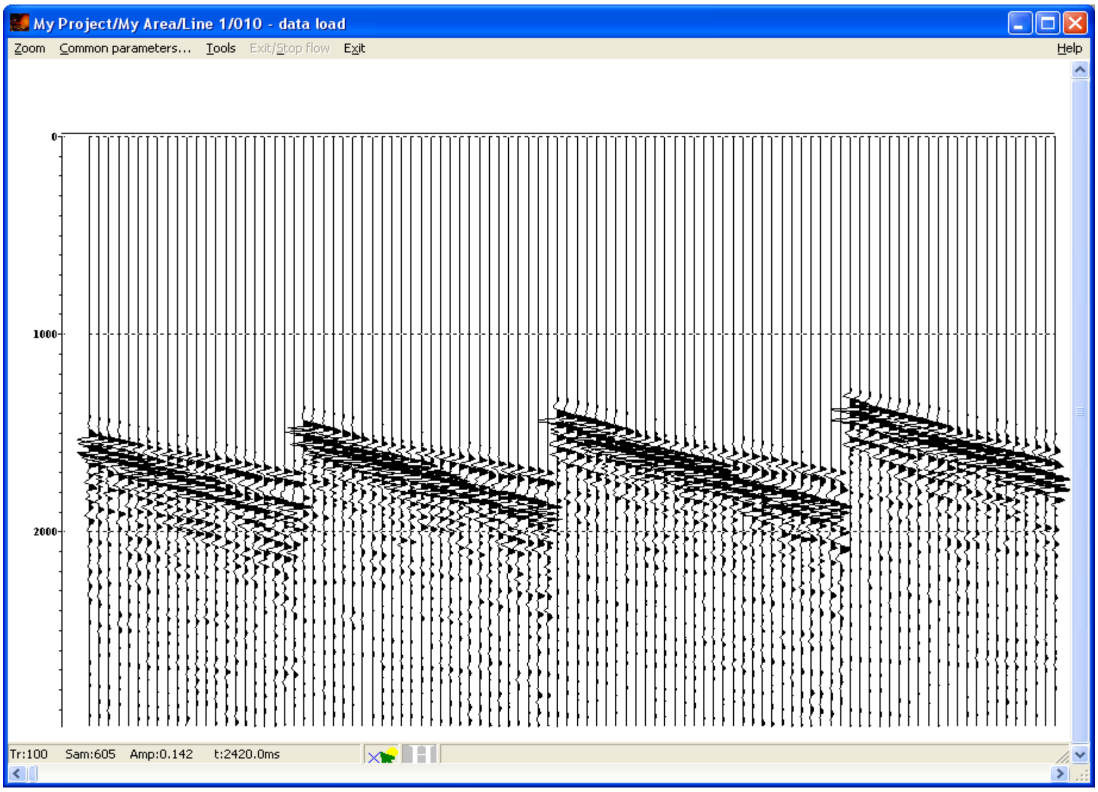


figure).

Besides, for the control, after module **Trace Output**, add into the flow the **Screen Display** module. The obtained flow must appear as follows:



For executing the flow select the **Run** menu command. As a result, the **Screen Display** window should open, showing the data being entered, while the data will be read from the disk file and recorded into the database. The window **Screen Display**, which should appear on the screen, is shown below.



Important!: When the volume of the data read from the file is great (comparable or exceeds the volume of RAM or just around 1 Gb or more), it is necessary to use Framed mode, which allows to read the data into the memory not as a whole, but by pieces (frames). To turn into this mode and to determine the size of the frames use the Framed mode... command available from the flows editor main menu.

Note about the names. A name of any object of the database (seismic dataset, processing flow, etc.) must reflect its essence, but not consist just of several letters. The name of a seismic dataset should consist of 2 parts –the identifier of initial data and the processing stage of the data. Thus, when entering the field data, the name *line 1 - raw* was selected here.

Geometry assigning and binning

Assigning geometry to seismic data means that for each trace a number of values are determined, which, then, are saved in the specified header fields of the dataset in the project database. The list of the necessary values and the header fields corresponding to them are given below:

1. Source point (also called 'shot point' or SP) number (header field SOURCE)
2. SP coordinate(SOU_X)
3. Receiver point (RP) number (RECNO)
4. RP coordinate (REC_X)
5. Distance between the source and the receiver (OFFSET) and the modulus of this value (AOFFSET)
6. Unique field record number (FFID)
7. Channel number (CHAN)

Note. The list given above corresponds to one-dimensional geometry. Generally speaking, the header fields SOU_X, SOU_Y and REC_X, REC_Y can be used for describing the coordinates of SP and PP. However, as the observations in the training file were carried out along one line only, it is proposed to use only one coordinate X, X axis is directed along the profile.

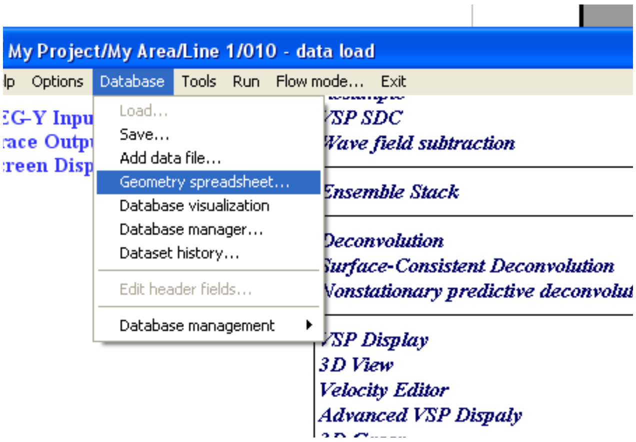
While the FFID, CHAN, SOURCE and RECNO header fields were filled when reading the data from the initial SEG- Y file, the coordinates of SP and RP should be imported from the test files, and the distances between SP and RP should be calculated.

In practice, absolutely any combination of the filled trace headers can be met. For example, the data can be transmitted into processing with empty headers. In this case they should be formed with the use of tools, available in the processing software package.

The situation, in which the initial seismic data contain the numbers of field records and channels, while the connection between the field record numbers and SPs, as well as between the channel numbers for each shot and the RPs is to be calculated is rather widespread. However, for simplification of geometry assigning for training purposes, the data already contain the numbers of pickets shot points and receiver points, and only the coordinates are to be imported..

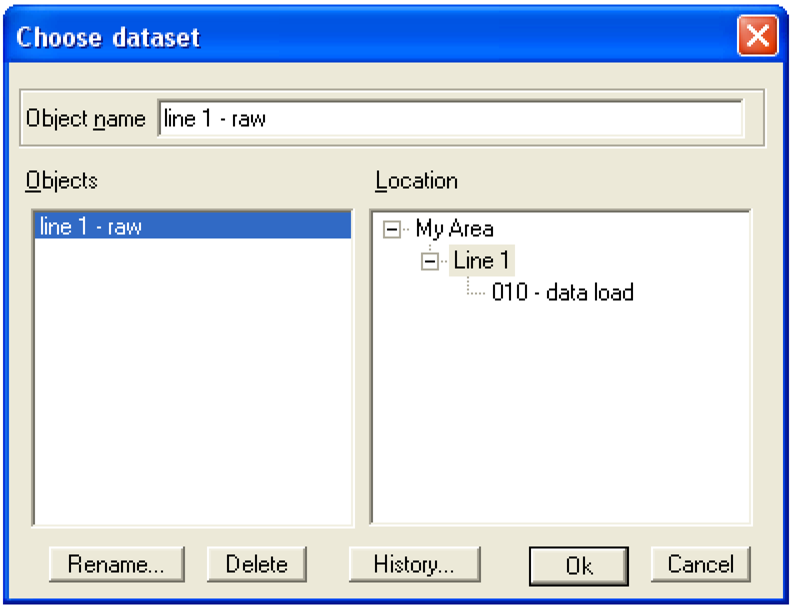
Import of coordinates of source and receiver points from a text file

For manipulations with trace header field values, including import of the values from ASCII tables, in the **RadExPro** software the **Geometry Spreadsheet** tool is used.

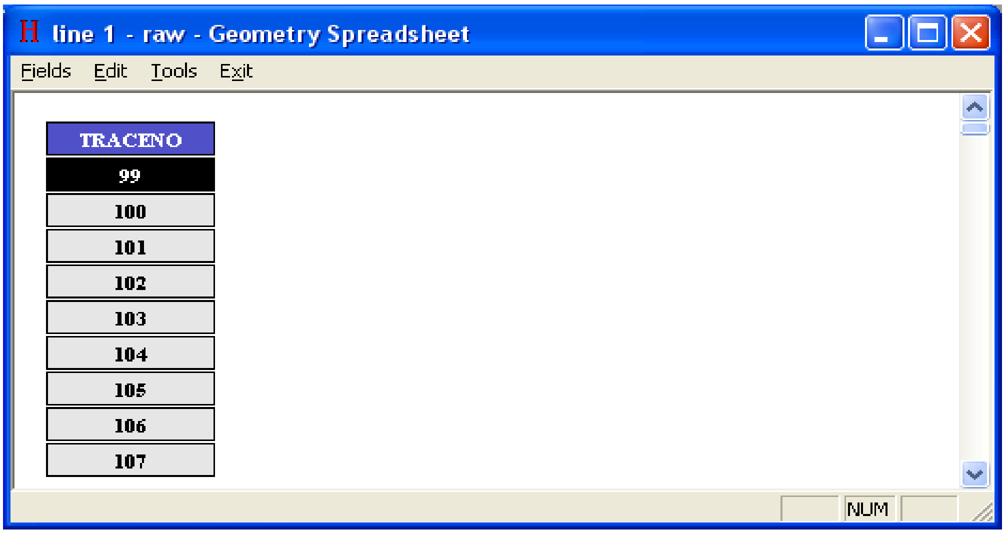


Select the **Database/Geometry Spreadsheet...** entry in the menu.

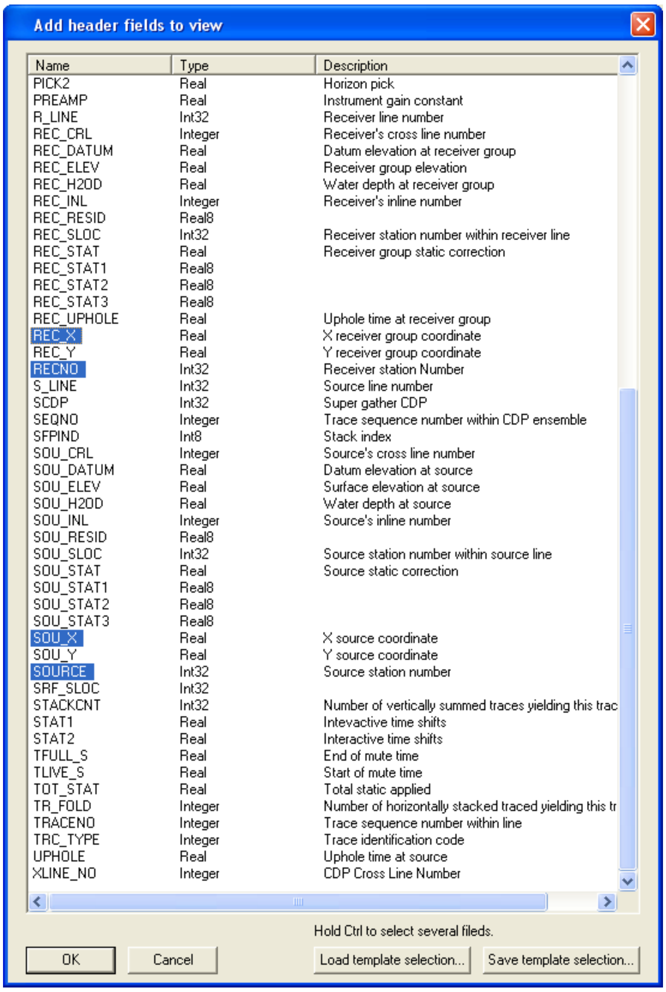
Then, in the opened dialog, select the seismic dataset, geometry of which is to be edited.



The following figure shows the **Geometry Spreadsheet** window.



In order to display the required header fields (all header fields declared in the database already exist, but are not displayed) use the **Fields/Add fields...** option of the menu In the opened dialog box, keeping the Ctrl key pressed, select the following header fields: SOURCE, SOU_X, RECNO, REC_X



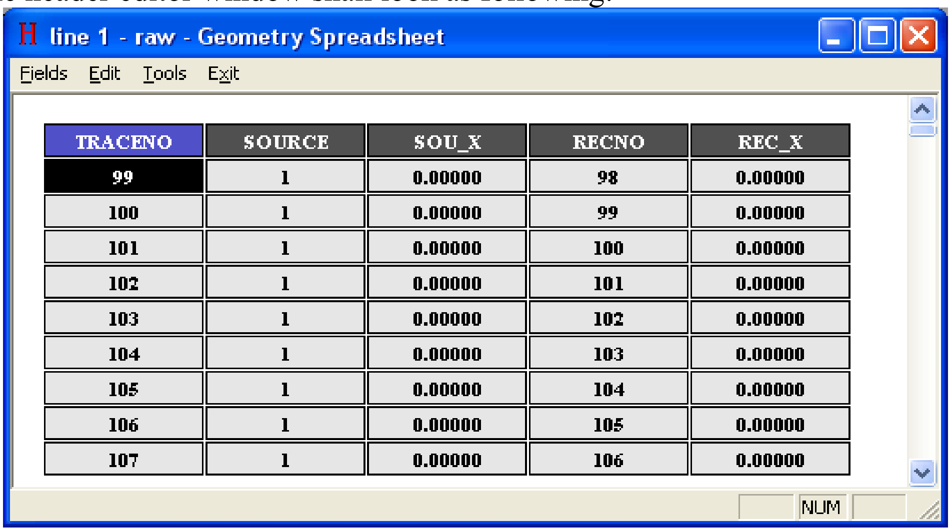
Add header fields to view

Name	Type	Description
PICK2	Real	Horizon pick
PREAMP	Real	Instrument gain constant
R_LINE	Int32	Receiver line number
REC_CRL	Integer	Receiver's cross line number
REC_DATUM	Real	Datum elevation at receiver group
REC_ELEV	Real	Receiver group elevation
REC_H2OD	Real	Water depth at receiver group
REC_INL	Integer	Receiver's inline number
REC_RESID	Real8	
REC_SLOC	Int32	Receiver station number within receiver line
REC_STAT	Real	Receiver group static correction
REC_STAT1	Real8	
REC_STAT2	Real8	
REC_STAT3	Real8	
REC_UPHOLE	Real	Uphole time at receiver group
REC_X	Real	X receiver group coordinate
REC_Y	Real	Y receiver group coordinate
RECNO	Int32	Receiver station Number
S_LINE	Int32	Source line number
SCDP	Int32	Super gather CDP
SEQNO	Integer	Trace sequence number within CDP ensemble
SFPIND	Int8	Stack index
SOU_CRL	Integer	Source's cross line number
SOU_DATUM	Real	Datum elevation at source
SOU_ELEV	Real	Surface elevation at source
SOU_H2OD	Real	Water depth at source
SOU_INL	Integer	Source's inline number
SOU_RESID	Real8	
SOU_SLOC	Int32	Source station number within source line
SOU_STAT	Real	Source static correction
SOU_STAT1	Real8	
SOU_STAT2	Real8	
SOU_STAT3	Real8	
SOU_X	Real	X source coordinate
SOU_Y	Real	Y source coordinate
SOURCE	Int32	Source station number
SRF_SLOC	Int32	
STACKCNT	Int32	Number of vertically summed traces yielding this trac
STAT1	Real	Intevactive time shifts
STAT2	Real	Interactive time shifts
TFULL_S	Real	End of mute time
TLIVE_S	Real	Start of mute time
TOT_STAT	Real	Total static applied
TR_FOLD	Integer	Number of horizontally stacked traced yielding this tr
TRACENO	Integer	Trace sequence number within line
TRC_TYPE	Integer	Trace identification code
UPHOLE	Real	Uphole time at source
XLINE_NO	Integer	CDP Cross Line Number

Hold Ctrl to select several fileds.

OK | Cancel | Load template selection... | Save template selection...

As a result the header editor window shall look as following:



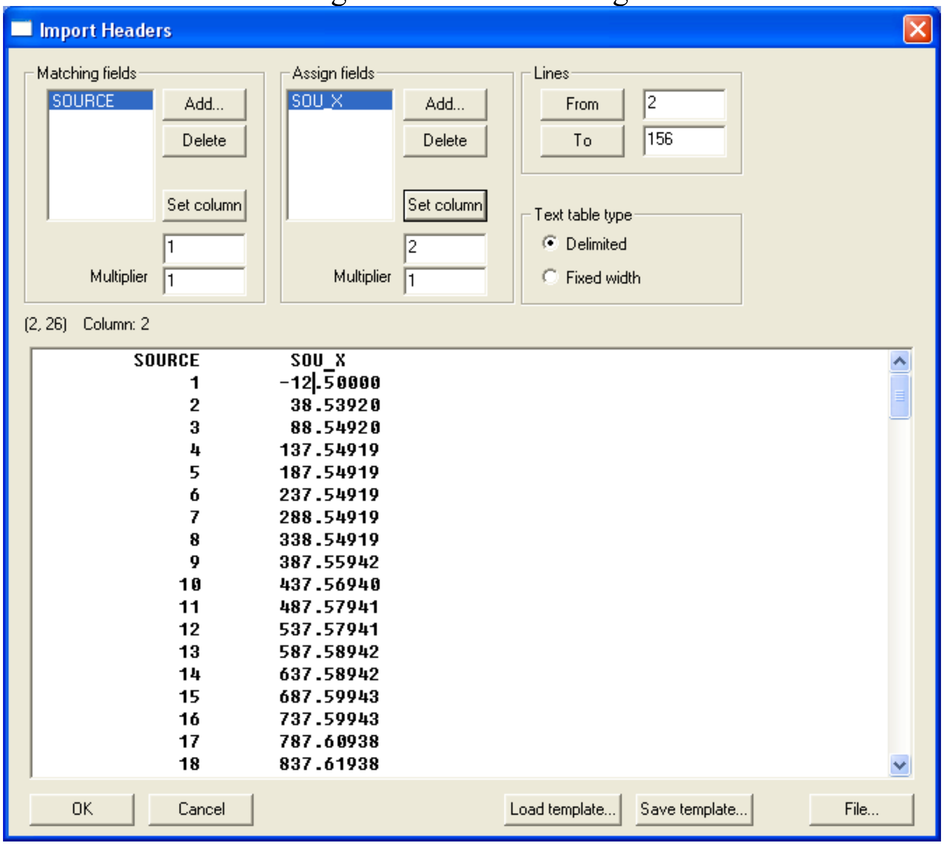
line 1 - raw - Geometry Spreadsheet

Fields Edit Tools Exit

TRACENO	SOURCE	SOU_X	RECNO	REC_X
99	1	0.00000	98	0.00000
100	1	0.00000	99	0.00000
101	1	0.00000	100	0.00000
102	1	0.00000	101	0.00000
103	1	0.00000	102	0.00000
104	1	0.00000	103	0.00000
105	1	0.00000	104	0.00000
106	1	0.00000	105	0.00000
107	1	0.00000	106	0.00000

NUM

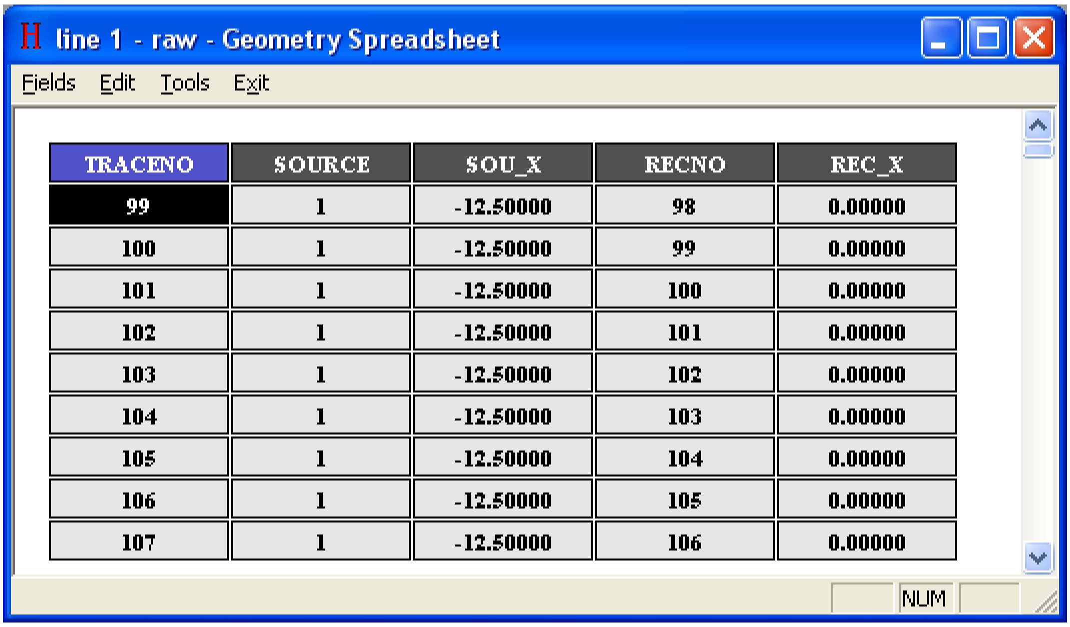
Select the **Tools/Import** menu command. The dialog with the import parameters will open. Open the file *sou_geom.txt* there and define the rules of filling header fields. For this add to the **Matching fields** list the field SOURCE (for that, click the appropriate **Add** button and select it from the list). To the **Assign Fields** list add the SOU_X field . Then specify the columns of the text file from which the indicated fields should be read. They shall be set in the text lines under **Set column** buttons. (By the way, if you set the cursor into the appropriate column and click **Set column**, the number of the column will be automatically entered there). Finally, the range of the lines should be indicated, from which the program will obtain the values. This shall be done in **Lines** field: set **From** and **To** values. The correct settings are shown on the figure below.



When importing the values of the header fields from the text file, the program works as follows. For each line of the text file, all the matching fields as well as the assign fields are read from the specified columns. In the specified seismic dataset all the traces with the values of the matching header fields being *precisely* equal to the values from the read line are determined. Then, the values from the read line are entered into the assign fields of these traces.

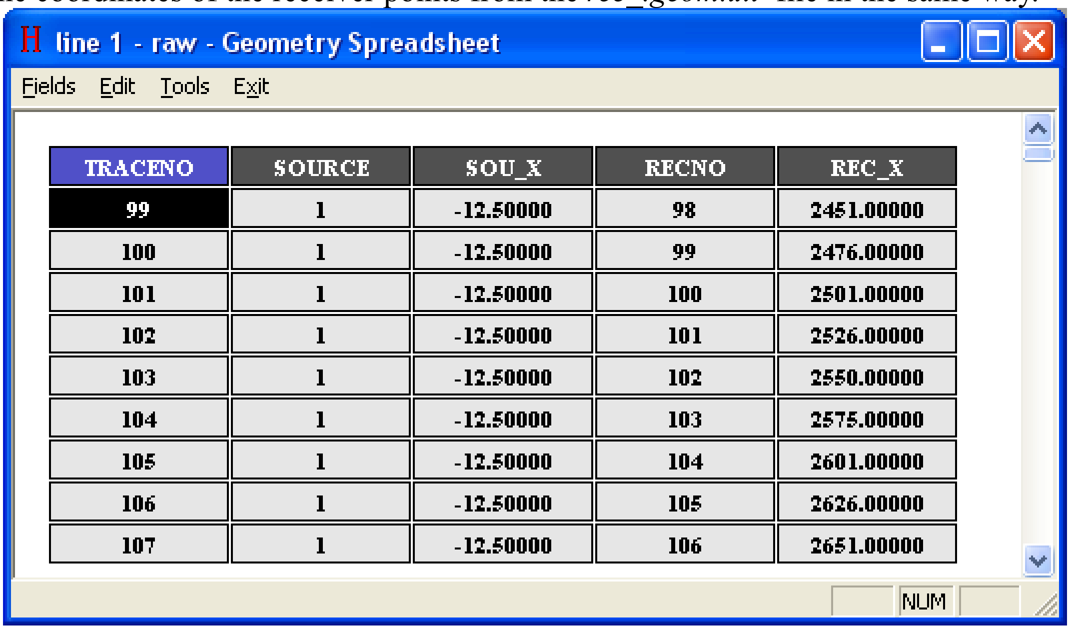
Important!: Among other things, this means that the matching fields are better to be integer (this fact shall be taken into account when the files with the geometry are formed).

Click the **OK** button to assign the header fields. The result is shown below.



TRACENO	SOURCE	SOU_X	RECNO	REC_X
99	1	-12.50000	98	0.00000
100	1	-12.50000	99	0.00000
101	1	-12.50000	100	0.00000
102	1	-12.50000	101	0.00000
103	1	-12.50000	102	0.00000
104	1	-12.50000	103	0.00000
105	1	-12.50000	104	0.00000
106	1	-12.50000	105	0.00000
107	1	-12.50000	106	0.00000

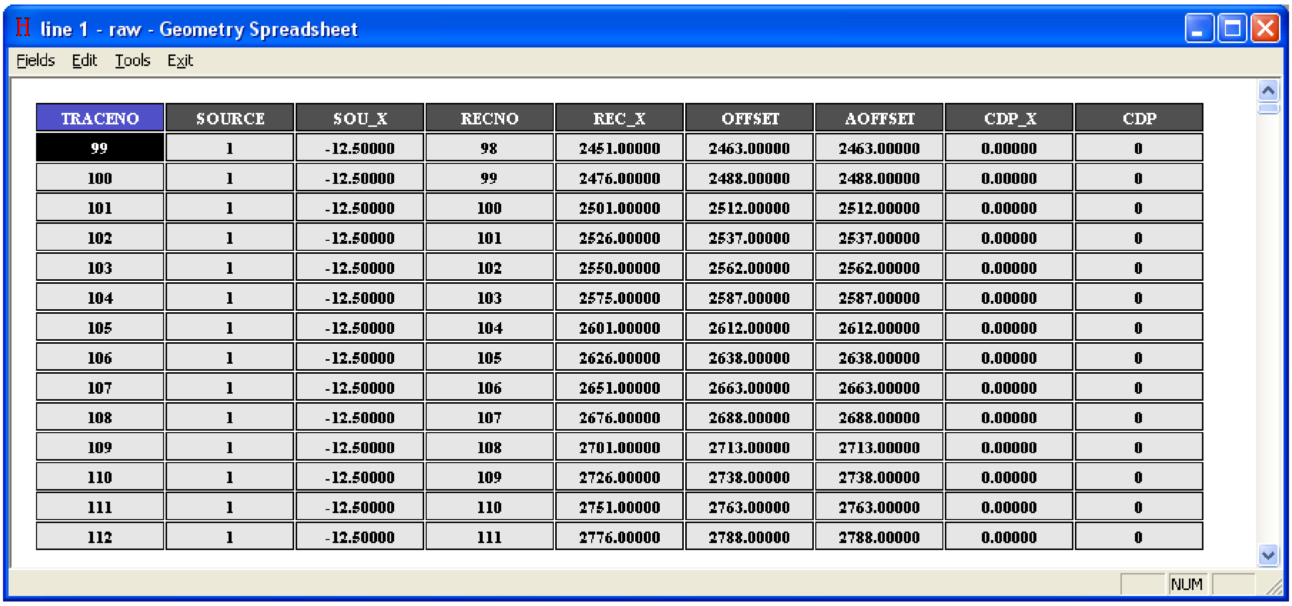
Import the coordinates of the receiver points from the *rec_.geom.txt* file in the same way.



TRACENO	SOURCE	SOU_X	RECNO	REC_X
99	1	-12.50000	98	2451.00000
100	1	-12.50000	99	2476.00000
101	1	-12.50000	100	2501.00000
102	1	-12.50000	101	2526.00000
103	1	-12.50000	102	2550.00000
104	1	-12.50000	103	2575.00000
105	1	-12.50000	104	2601.00000
106	1	-12.50000	105	2626.00000
107	1	-12.50000	106	2651.00000

Calculation of the distances between the shot and receiver points, coordinates of CDP points, binning

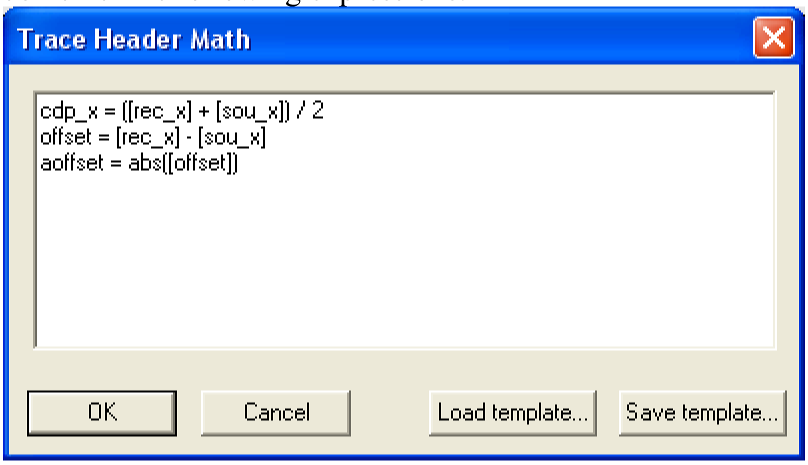
Using the **Fields/Add fields** menu entry add to the spreadsheet the following fields: OFFSET (source- receiver distance), AOFFSET (the absolute value of the offset), CDP_X (coordinate of the CDP), CDP (CDP point number).



TRACENO	SOURCE	SOU_X	RECNO	REC_X	OFFSET	AOFFSET	CDP_X	CDP
99	1	-12.50000	98	2451.00000	2463.00000	2463.00000	0.00000	0
100	1	-12.50000	99	2476.00000	2488.00000	2488.00000	0.00000	0
101	1	-12.50000	100	2501.00000	2512.00000	2512.00000	0.00000	0
102	1	-12.50000	101	2526.00000	2537.00000	2537.00000	0.00000	0
103	1	-12.50000	102	2550.00000	2562.00000	2562.00000	0.00000	0
104	1	-12.50000	103	2575.00000	2587.00000	2587.00000	0.00000	0
105	1	-12.50000	104	2601.00000	2612.00000	2612.00000	0.00000	0
106	1	-12.50000	105	2626.00000	2638.00000	2638.00000	0.00000	0
107	1	-12.50000	106	2651.00000	2663.00000	2663.00000	0.00000	0
108	1	-12.50000	107	2676.00000	2688.00000	2688.00000	0.00000	0
109	1	-12.50000	108	2701.00000	2713.00000	2713.00000	0.00000	0
110	1	-12.50000	109	2726.00000	2738.00000	2738.00000	0.00000	0
111	1	-12.50000	110	2751.00000	2763.00000	2763.00000	0.00000	0
112	1	-12.50000	111	2776.00000	2788.00000	2788.00000	0.00000	0

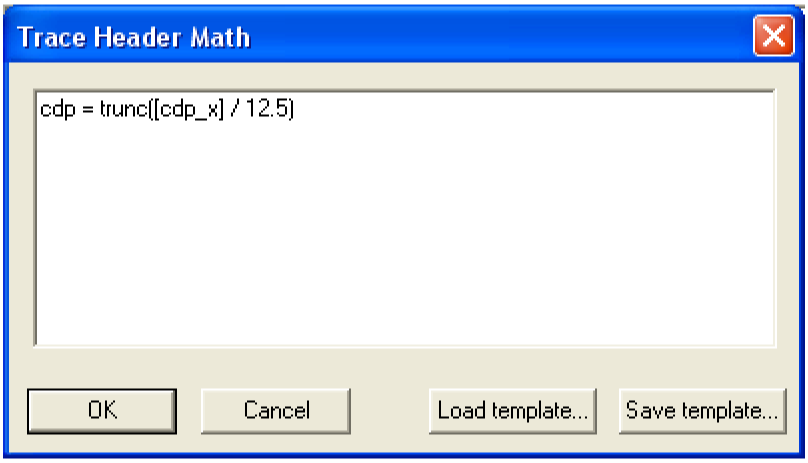
For calculation of the specified values use the **Trace Header Math** tool, dedicated to mathematical operations with header field values. The **Trace Header Math** is available from the menu **Tools/Header Math**.

In the open dialog box enter the following expressions:

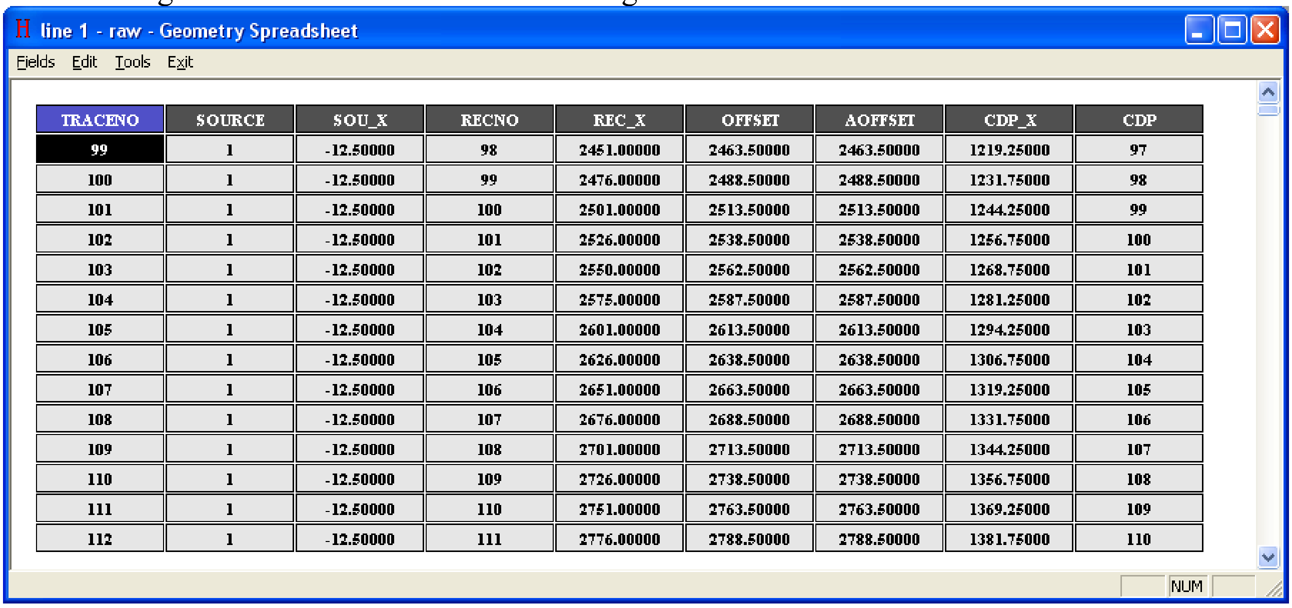


and click the **OK** button.

The numbers of the CDP gathers will be calculated, on the basis of the CDP coordinate and desired size of a bin. As the distance between the receivers was ~25 m, and the shot interval was ~50 m, the bin size should be selected as 12.5 m. For calculation of the CDP numbers, in the same **Trace Header Math** window enter the following expression:



The resulting table should look like the following:



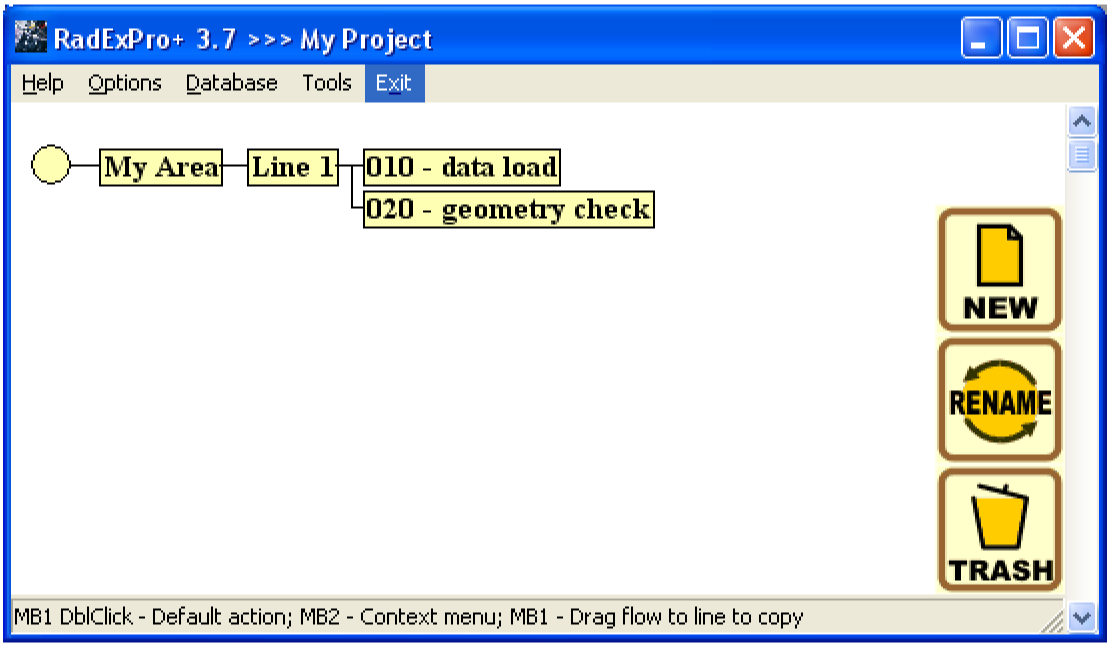
TRACENO	SOURCE	SOU_X	RECNO	REC_X	OFFSET	AOFFSET	CDP_X	CDP
99	1	-12.50000	98	2451.00000	2463.50000	2463.50000	1219.25000	97
100	1	-12.50000	99	2476.00000	2488.50000	2488.50000	1231.75000	98
101	1	-12.50000	100	2501.00000	2513.50000	2513.50000	1244.25000	99
102	1	-12.50000	101	2526.00000	2538.50000	2538.50000	1256.75000	100
103	1	-12.50000	102	2550.00000	2562.50000	2562.50000	1268.75000	101
104	1	-12.50000	103	2575.00000	2587.50000	2587.50000	1281.25000	102
105	1	-12.50000	104	2601.00000	2613.50000	2613.50000	1294.25000	103
106	1	-12.50000	105	2626.00000	2638.50000	2638.50000	1306.75000	104
107	1	-12.50000	106	2651.00000	2663.50000	2663.50000	1319.25000	105
108	1	-12.50000	107	2676.00000	2688.50000	2688.50000	1331.75000	106
109	1	-12.50000	108	2701.00000	2713.50000	2713.50000	1344.25000	107
110	1	-12.50000	109	2726.00000	2738.50000	2738.50000	1356.75000	108
111	1	-12.50000	110	2751.00000	2763.50000	2763.50000	1369.25000	109
112	1	-12.50000	111	2776.00000	2788.50000	2788.50000	1381.75000	110

To save the changes in the database on exit from the **Geometry Spreadsheet** select **Yes**, or use the **Edit/Save changes** menu option.

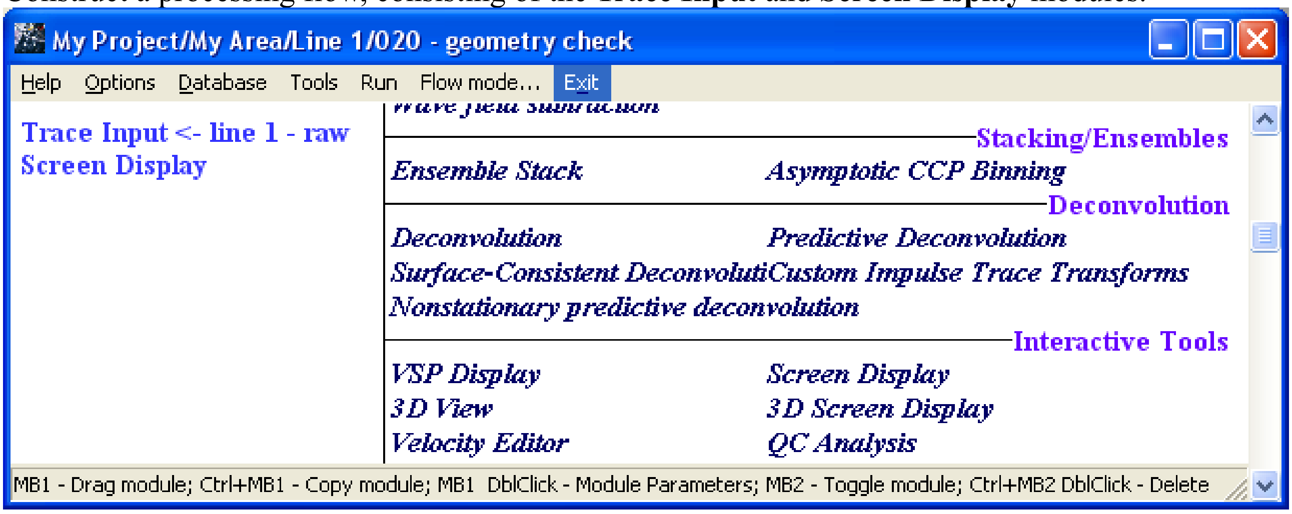
Sorting the data by CDP and control of the assigned geometry

To verify the correctness of geometry assigned, make the following.

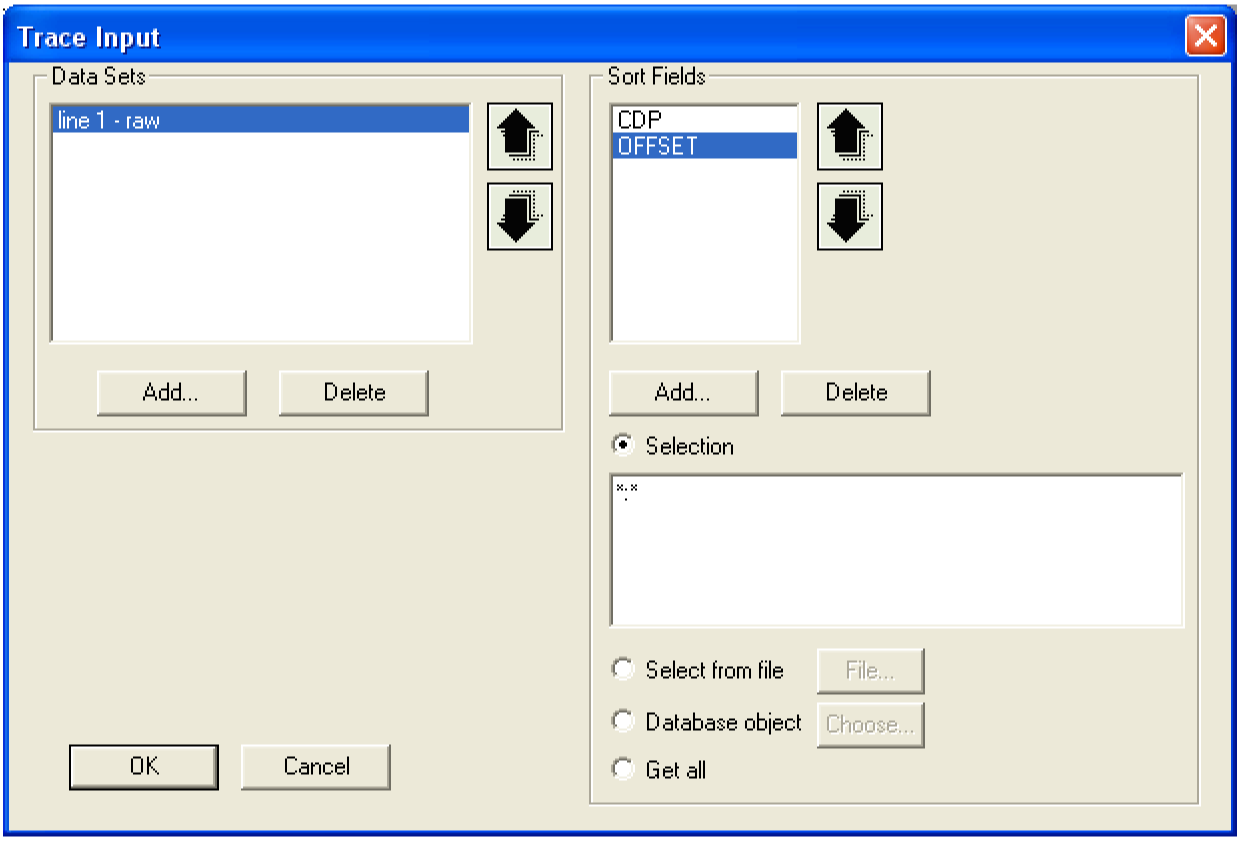
Create a new flow, name it *020 - geometry check*



Construct a processing flow, consisting of the **Trace Input** and **Screen Display** modules.



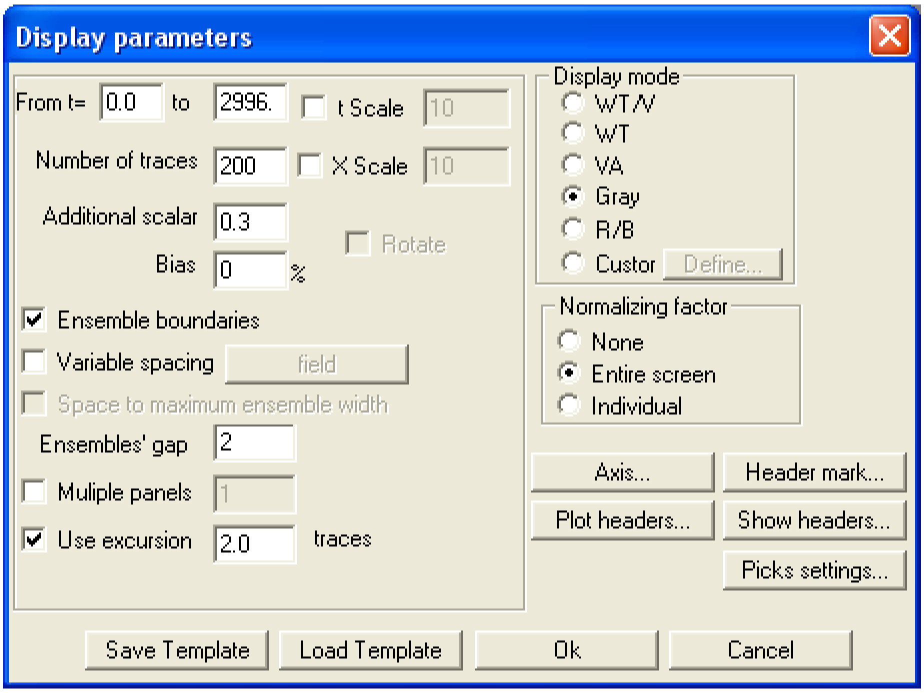
The **Trace Input** should enter the data into the flow sorted by, primarily, CDP and, secondarily, OFFSET (hereinafter, we will use CDP:OFFSET notation to describe this sorting). For this, set the routine parameters as shown on the following figure.



Due to this selection of the **Sort Fields**, the traces will be entered into the flow ordered by their CDP number. Within each ensemble with identical CDP number, the traces will be ordered by the OFFSET.

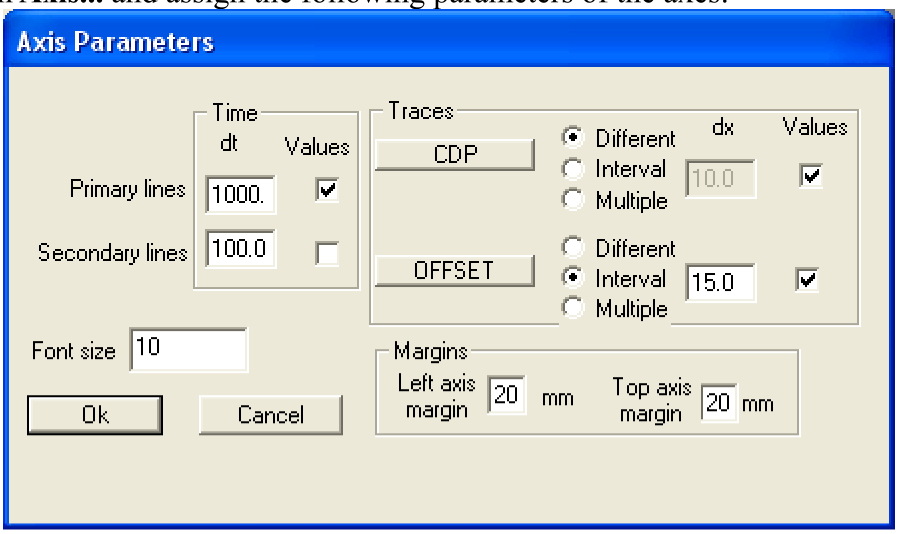
The text line specifying a trace selection mask for each of the sorting keys should be entered in the **Selection** field. Selection parameters for each of the keys are separated by a colon. In this case, *:* means that for each of the two sorting keys, all available traces will be entered into the flow sorted according to the sorting key values in ascending order.

In the **Screen Display** module assign the parameters as shown on the figure below.

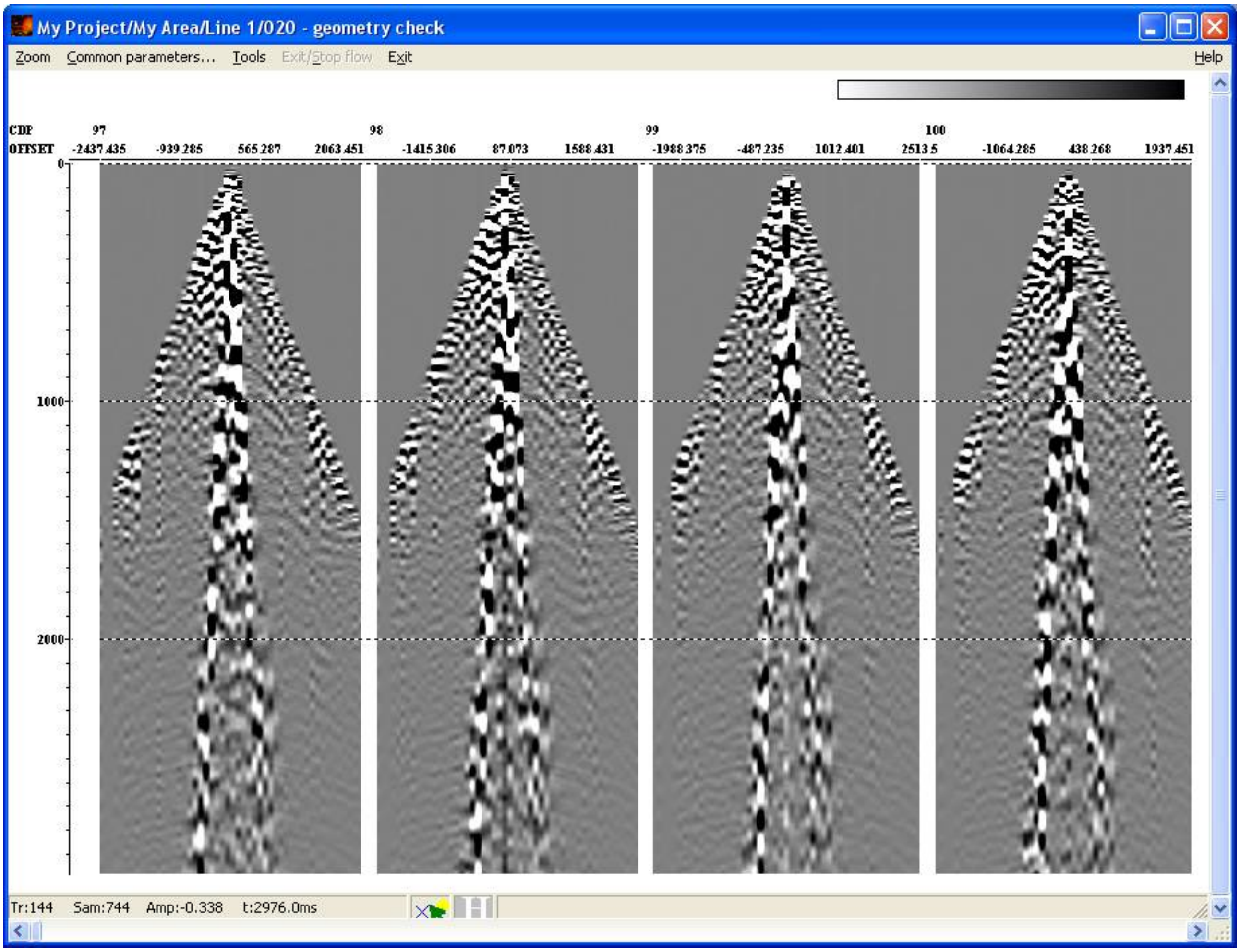


If the **Ensemble boundaries** parameter is switched on, the ensembles of traces will be separated on the screen by empty spaces. The ensemble in the **RadExPro** is defined by the first sorting key assigned in the **Trace Input**, that is, in this case, by the value of the CDP field.

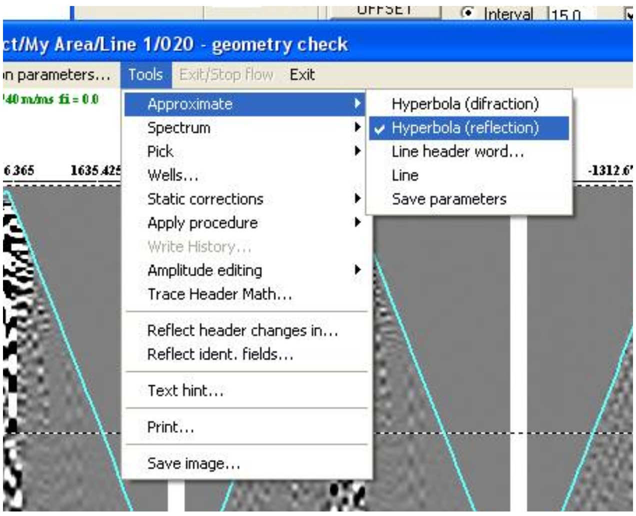
Click the button **Axis...** and assign the following parameters of the axes:



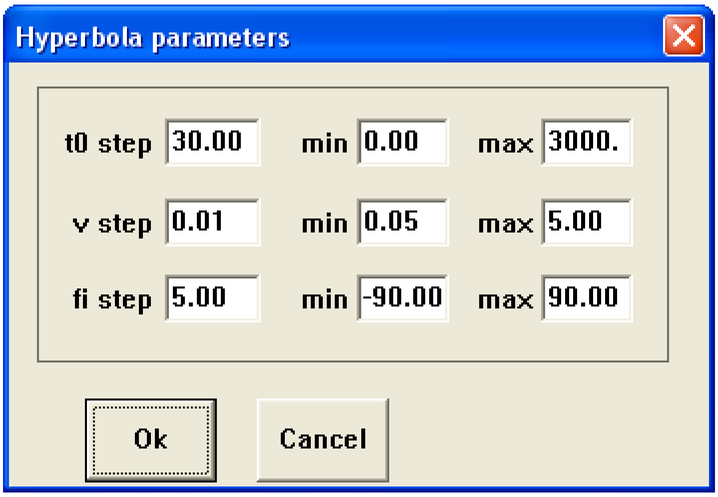
Execute the flow using the **Run** command of the menu. The raw data sorted by CDP:OFFSET (CDP gathers) will be displayed on the screen.



To control geometry assigning display the theoretical travel times of reflected wave calculated from header field values. To do it use the **Tools/Approximate/Hyperbola (reflection)** entry of the **Screen Display** menu.

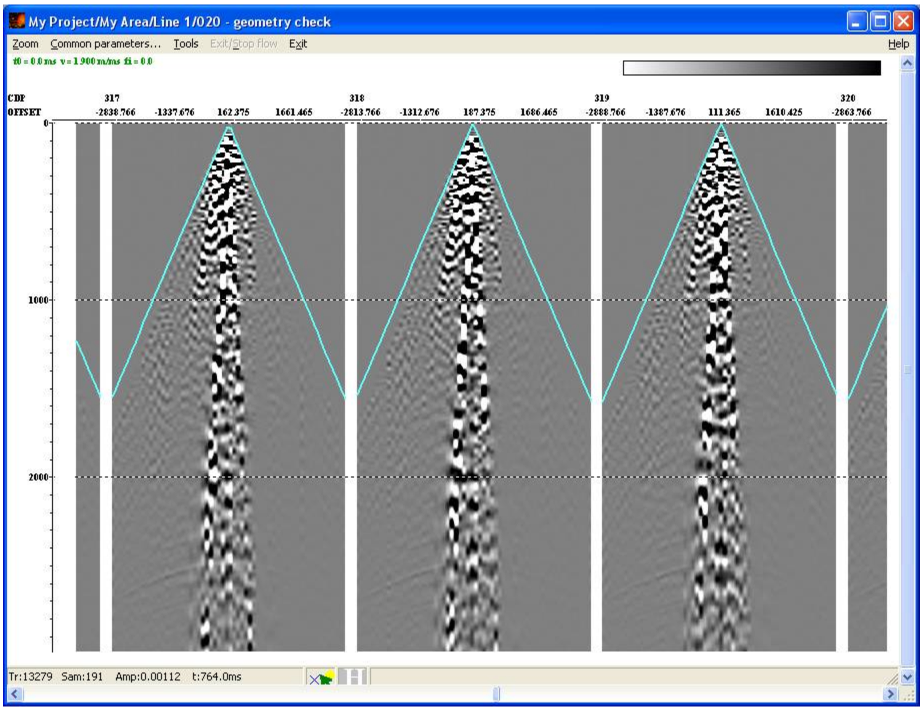


Use the default parameters of the travel-time hyperbola:



On the screen the travel time curve of a wave reflected from the boundary of a half-spaces is depicted by a blue line. Current parameters of the medium and the boundary are displayed in the upper left corner of the **Screen Display** window.

Using the arrows on the keyboard (right/left) change the velocity in the medium, until the approximate coincidence of the blue line and the observed first arrivals is achieved.



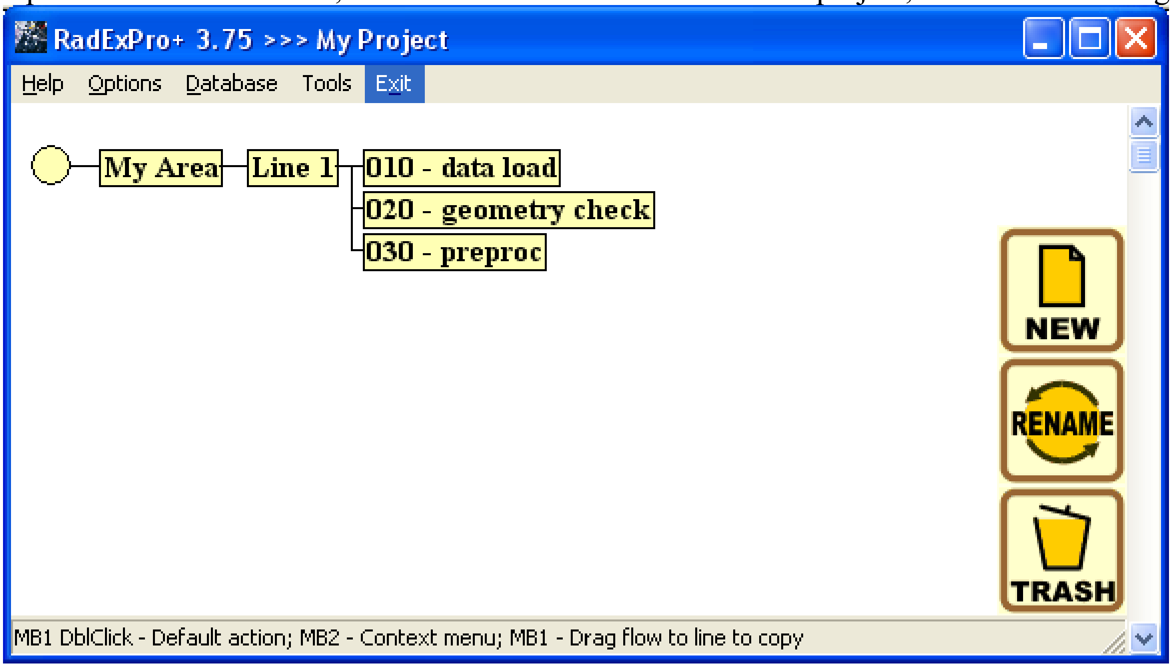
If it is possible to attain good matching of the observed direct wave by the theoretical travel times for all CDP gathers, then the distances between the SP and the RP were calculated correctly.

If the matching cannot be attained (for example, the observed travel times appear to be shifted relative to the theoretical positions), this indicates an error in the geometry of the traces. Then assign the geometry again or find and correct the error some other way.

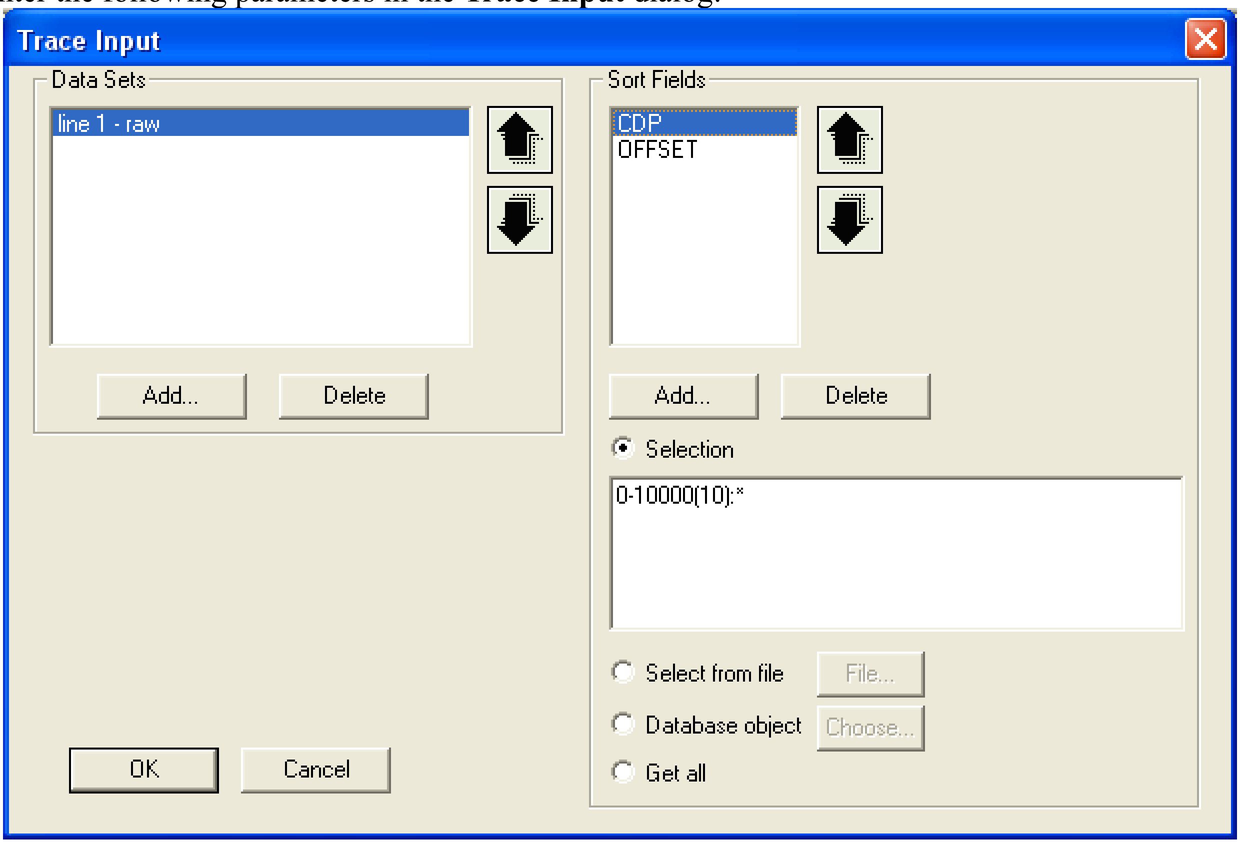
Data analysis and trace by trace processing

Sorting traces by CDP and analysis of the wave field

To preprocess the seismic data, create a new flow in the **RadExPro** project, as shown on the figure.



Put the **Trace Input** and **Screen Display** routines into the *030 - preproc* flow.
Enter the following parameters in the **Trace Input** dialog:



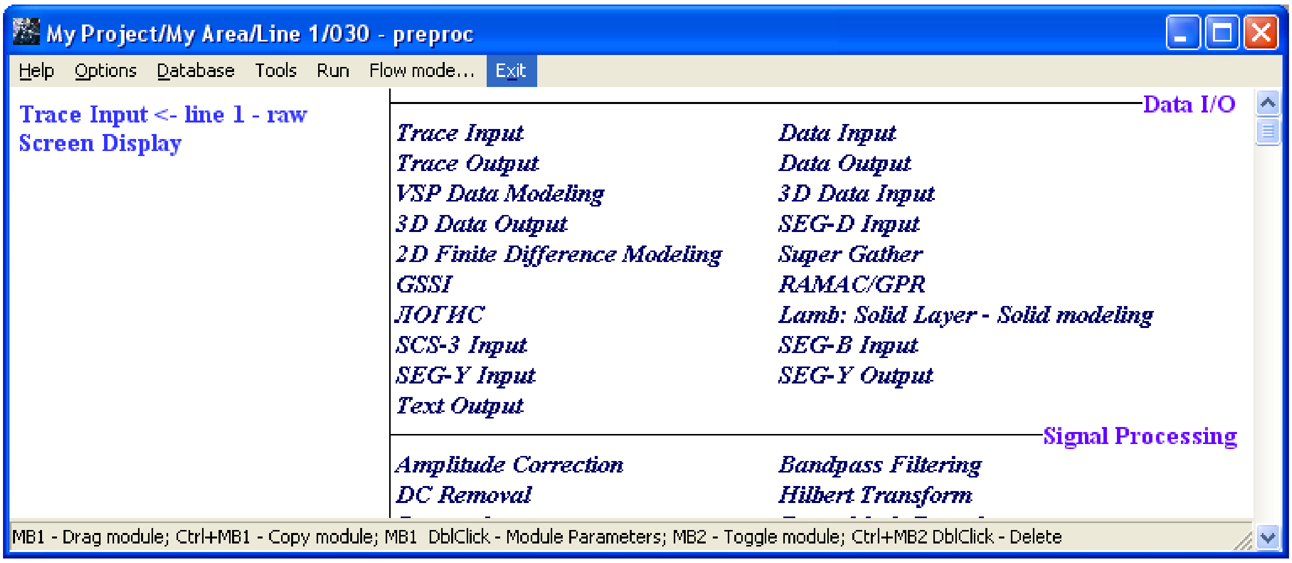
The *0-10000(10):** as a sorting rule means the following:

- From all CDP gathers, which fall into the range of 0-10000 (but these are all CDP gathers in

the dataset), only those with the numbers divisible by 10, will be taken;
- Within the CDP ensembles, the traces will be sorted by the values of OFFSET in ascending order.

This sorting is necessary now to decrease the amount of data (in 10 times) on the stage of testing of the processing parameters. Because of this sorting it will be possible to control the result of the processing not on a single ensemble but on a number of CDP gathers evenly selected along the line.

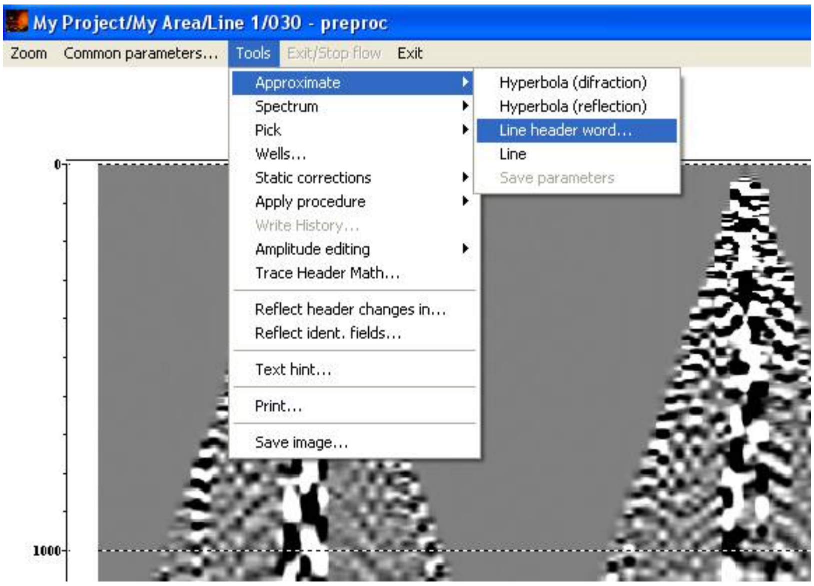
Assign the parameters of the **Screen Display** to have some 3-5 gathers on the screen. The flow will look as follows:



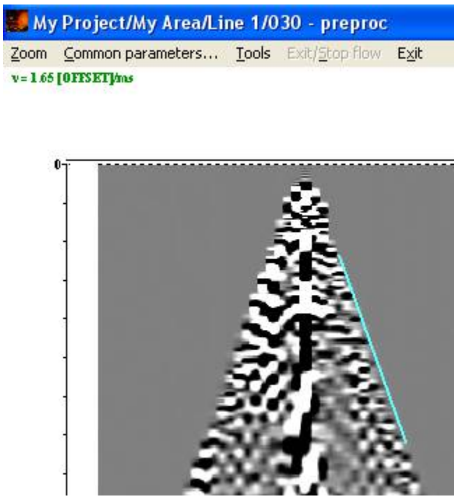
Execute the flow, the CDP gathers will appear on the screen.

Examine the gathers on the screen and try to identify the types of the observed waves. Find the direct wave, reflected waves, surface waves.

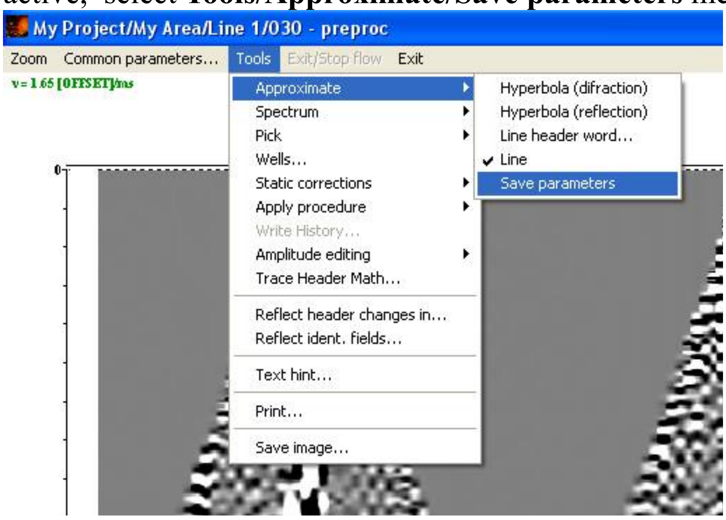
Estimate the velocity of the direct wave, the group velocity of the surface waves. For this, use the the **Screen Display** “Line”-tool allowing to fit theoretical travel times of the direct wave to the data. Since velocity is calculated as distance from the source divided by the arrival time, first it is necessary to indicate the header field, which will be used for calculation of the distance between the traces when calculating the apparent velocity. Use the point of menu **Tools/Approximate/Line Header word...** and select the field OFFSET.



For evaluating the apparent velocity use **Tools/Appoximate/Line**. In order to fit the line to the data assign the beginning of the approximated section on the screen by left click of the mouse, then the end of the section - by right click. The current value of the apparent velocity will be shown in the green line in the top left corner of the screen.

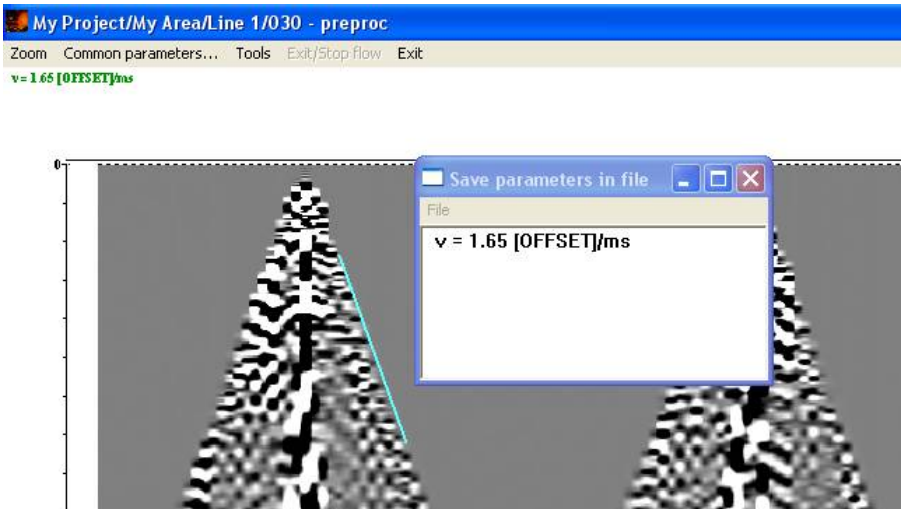


Record the obtained values of velocities into a text file. It can be made automatically. For that, while the Line-tool is active, select **Tools/Approximate/Save parameters** menu entry.

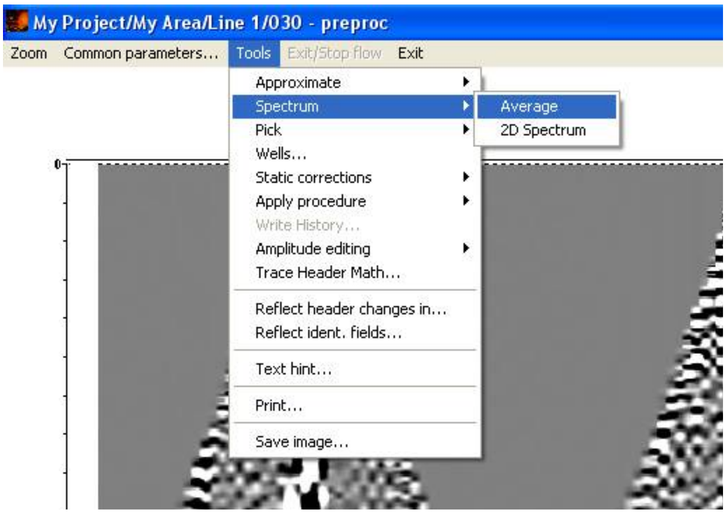


Additional window with an editable text field will open. Copy the current velocity there by pressing *Ctrl+Q* while the **Screen Display** window is in focus. You can copy as many values as you like.

Comments can be added to the copied values in the window, just type them manually. When you are finished with the velocities, save the file, selecting the command **File/Save** in the menu of additional window and then close the window.

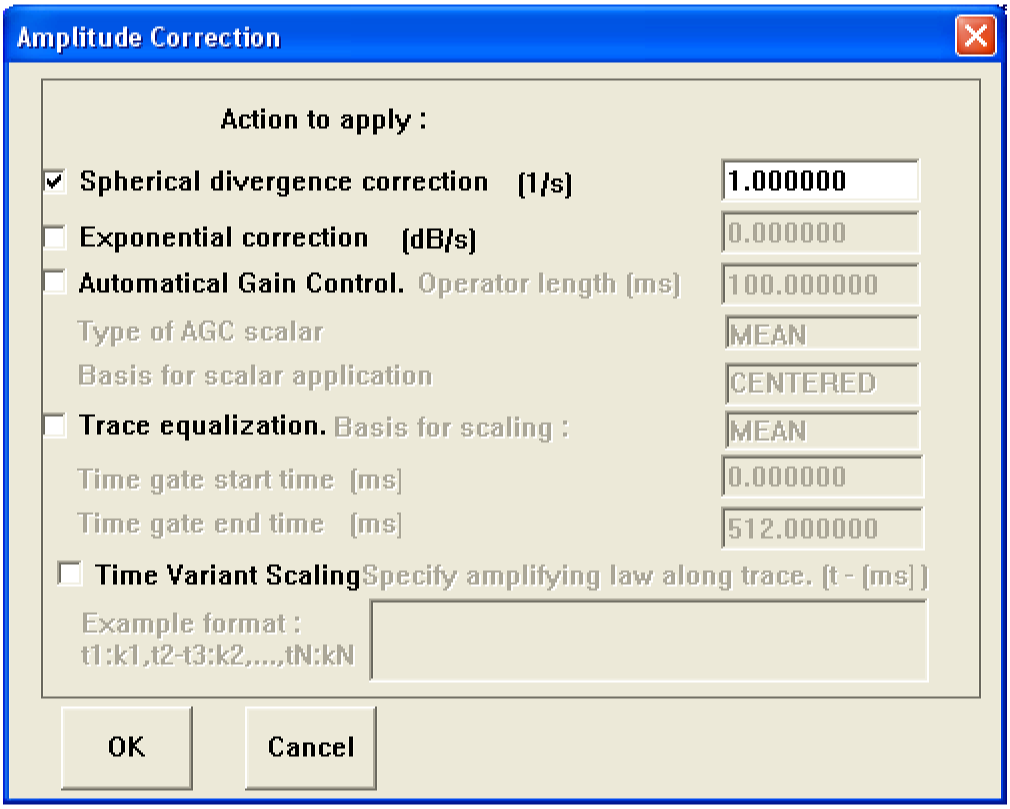


Estimate the spectrum of different parts of the record. For this use the **Tools/Spectrum/Average** menu command.



Correction for amplitude attenuation

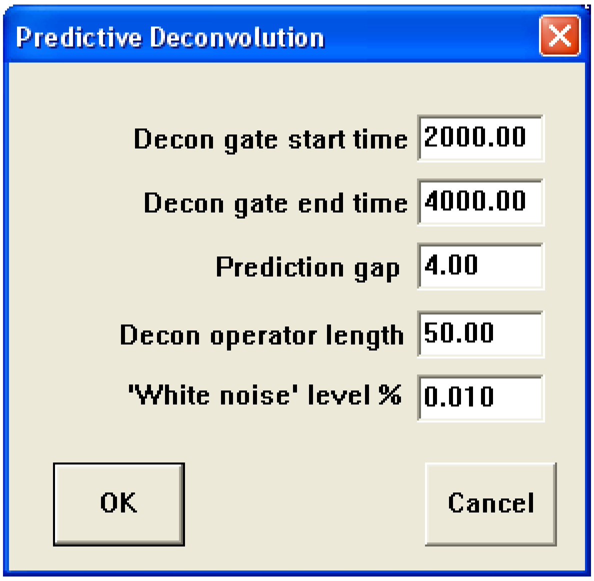
To compensate amplitude attenuation add the **Amplitude Correction** module into the flow. Place it between the modules **Trace Input** and **Screen Display**. Changing the parameters of the module and each time executing the flow, you can test different types of amplitude corrections. For purposes of the subsequent processing, spherical divergence correction is a good choice. In order to apply this correction, set the parameters of the module as shown on the figure below.



Compare the appearance of the data before and after the spherical divergence correction. For this, run the flow two times - with the active and "commented" **Amplitude Correction** module. (to “comment” the module right-click it with the mouse). As a result, two **Screen Display** windows appear on the screen, one of which contains corrected data, the other one – initial data.

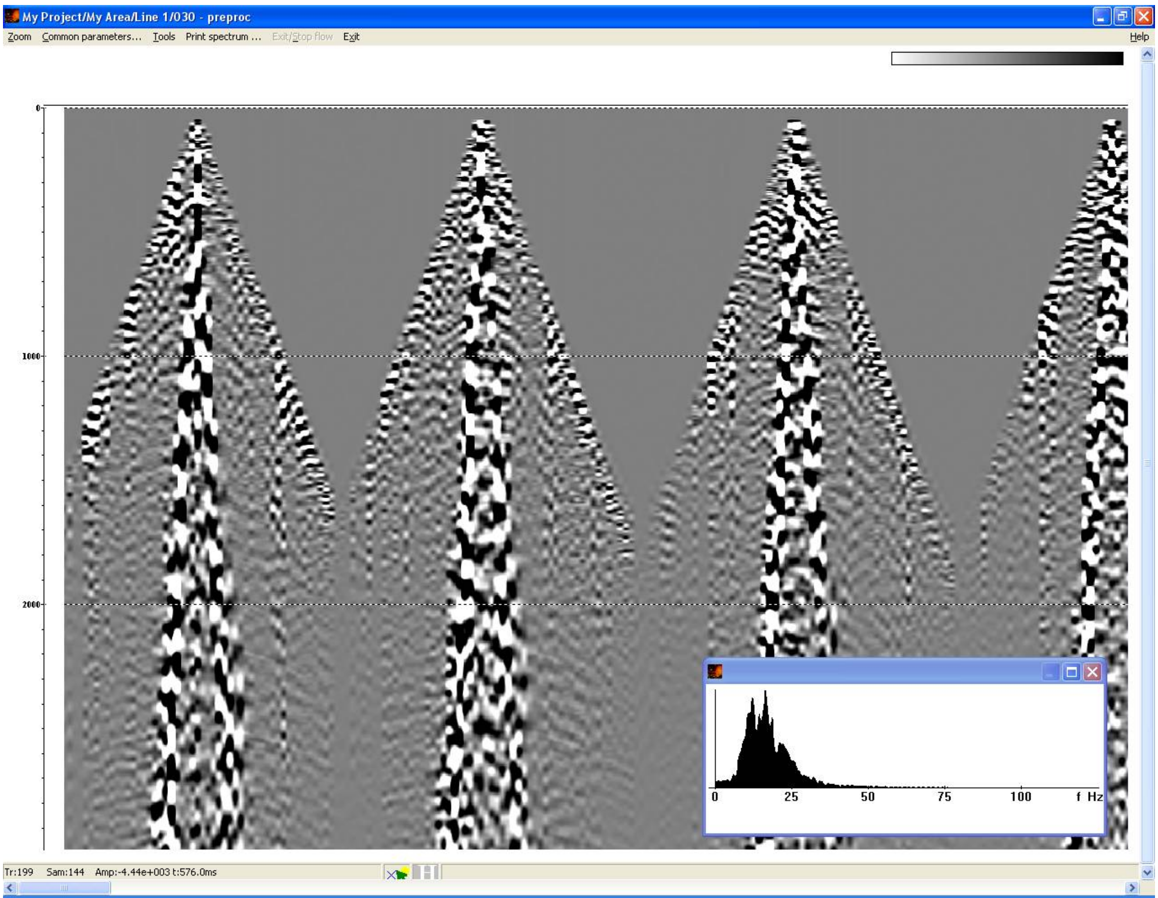
Spectrum spreading

After the correction for spherical divergence, add the module **Predictive Deconvolution** to the flow. When the purpose of the predictive deconvolution is spectrum spreading, it is reasonable to set prediction gap equal to one sample, to select the filter length close to the length of the wavelet and to assign the window for the calculation of the deconvolution operator in such a way that it contains the target reflections. Basing on these considerations, some initial parameters can be assigned as follows:

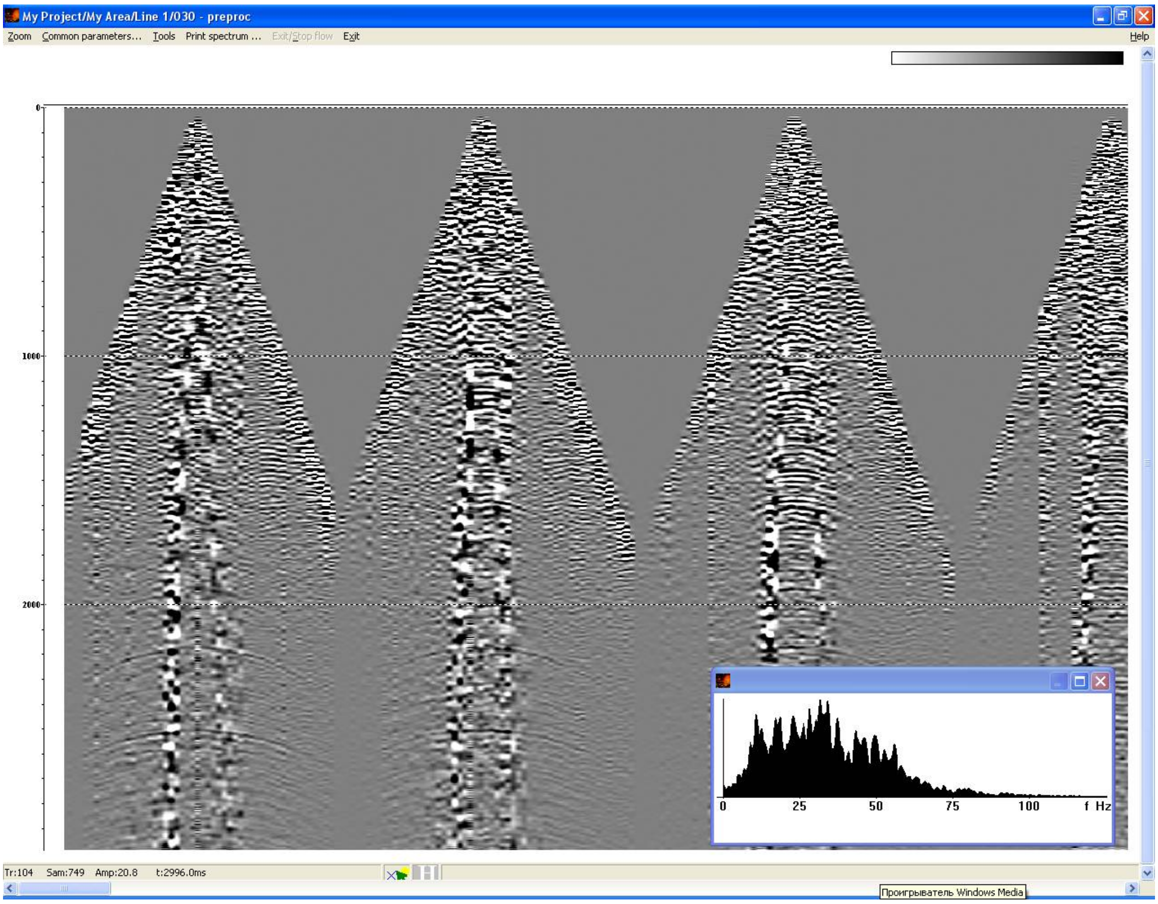


Experiment with different parameters, research how the level of white noise influences the result. The following two figures demonstrate the data before and after the use of predicting deconvolution.

Before the deconvolution:

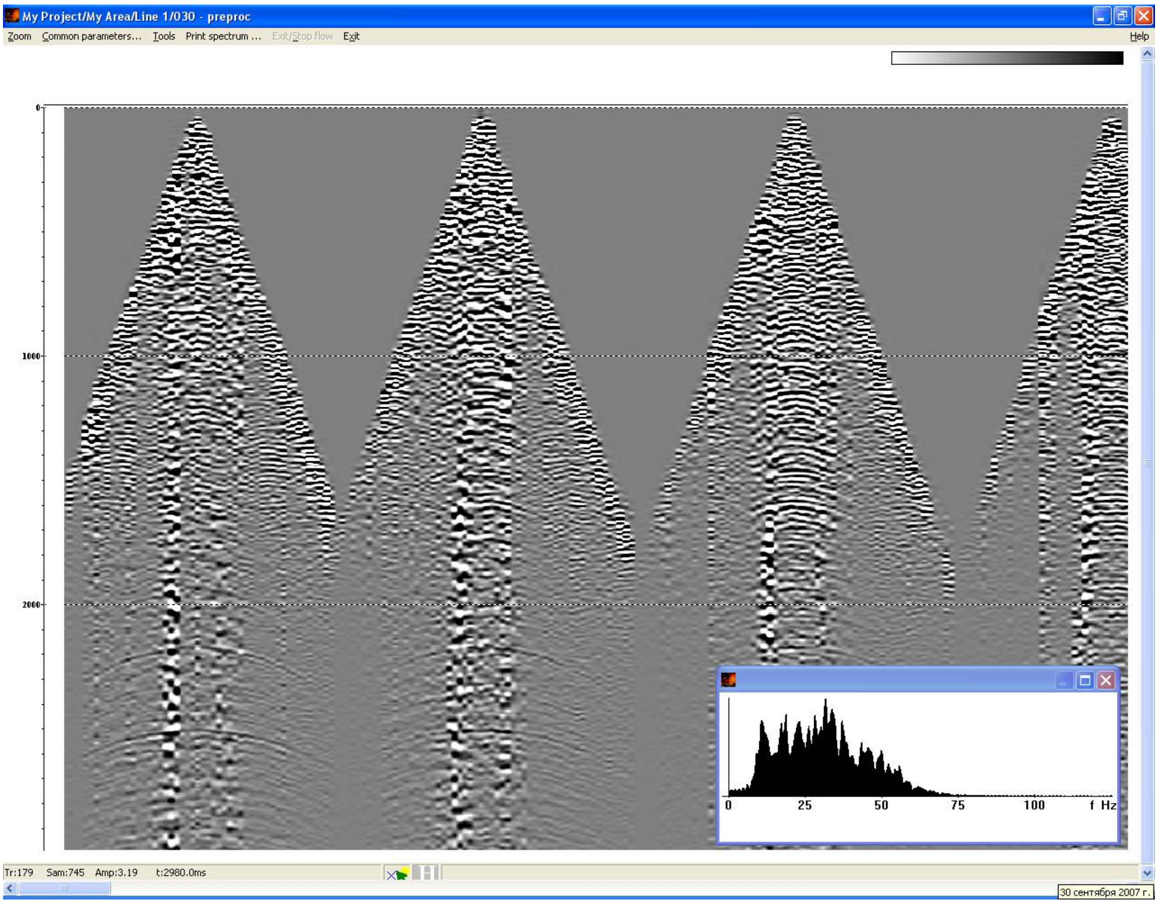


After the deconvolution:



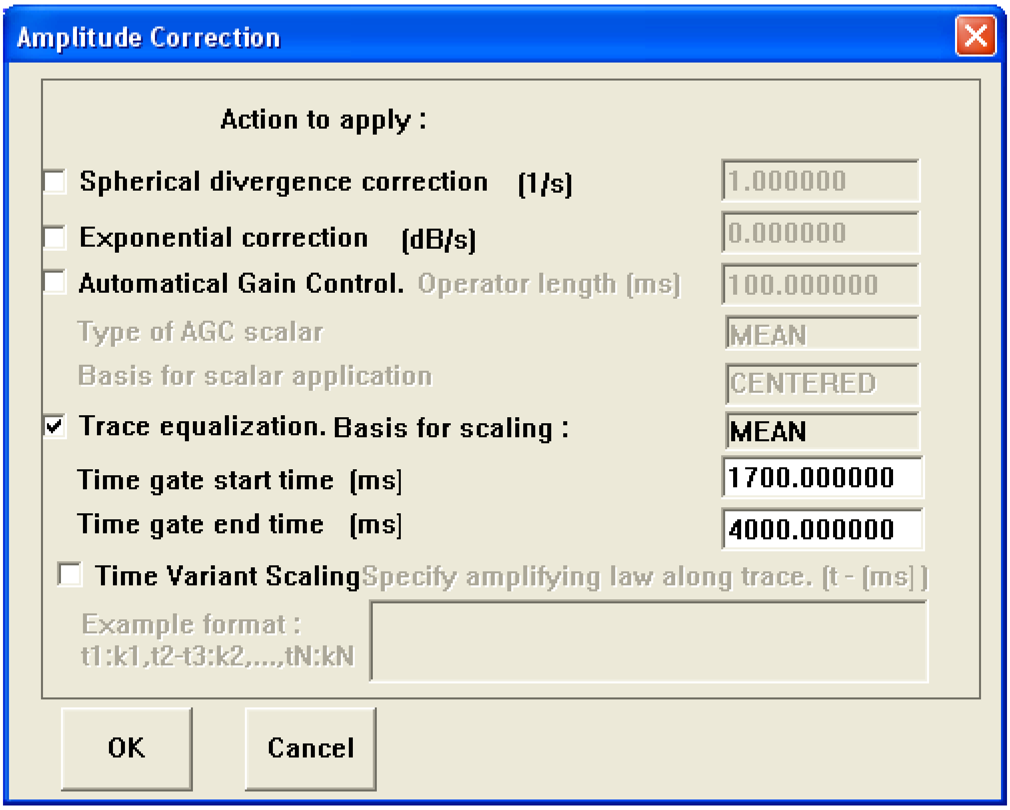
Bandpass filtering

Bandpass filtering is to be used after the deconvolution, aimed to decrease the level of low-frequency and high-frequency noise and to shape the spectrum of the trace to achieve a simple wavelet. Add the module **Bandpass Filtering** into the flow after the deconvolution routine. In the parameters of the module select Ormsby's filter with the following parameters: 5-10-40-80 Hz. Several CDP gathers after the bandpass filtering with these parameters are shown on the following figure.



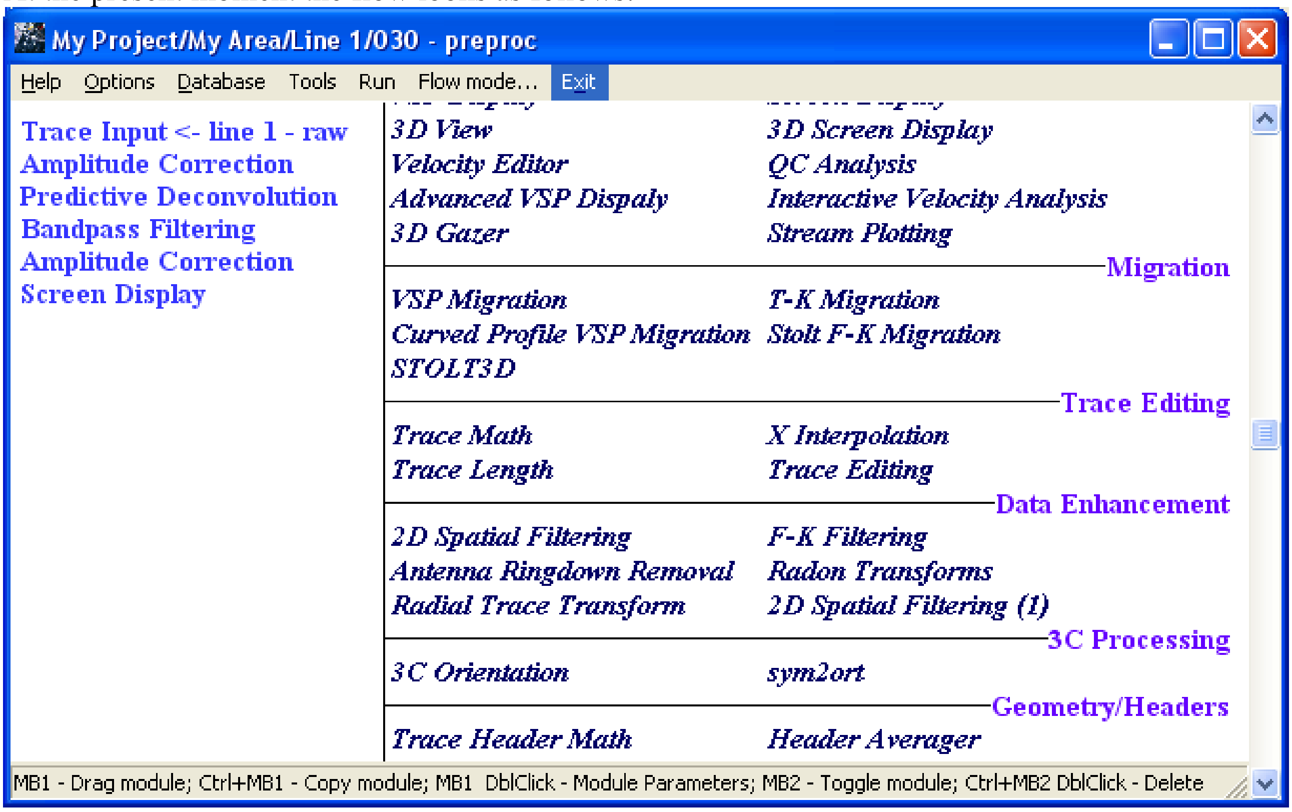
Trace amplitude equalization

The amplitudes, recorded by each seismic receiver is influenced, among other things, by the conditions around the source and the receiver. When the data is not aimed for the dynamic interpretation (for example, for the purposes of AVO- analysis) it is not necessary to use the complex procedures of the surface-consistent amplitude corrections, instead you can try to reduce the differences between traces by the simple traces equalization. To do this add the module **Amplitude Correction** into the flow again with the following set of the parameters:



Note, that the window we select here for estimation of the average amplitude of each trace contains the target reflections and does not contain trace sections before the first arrivals.

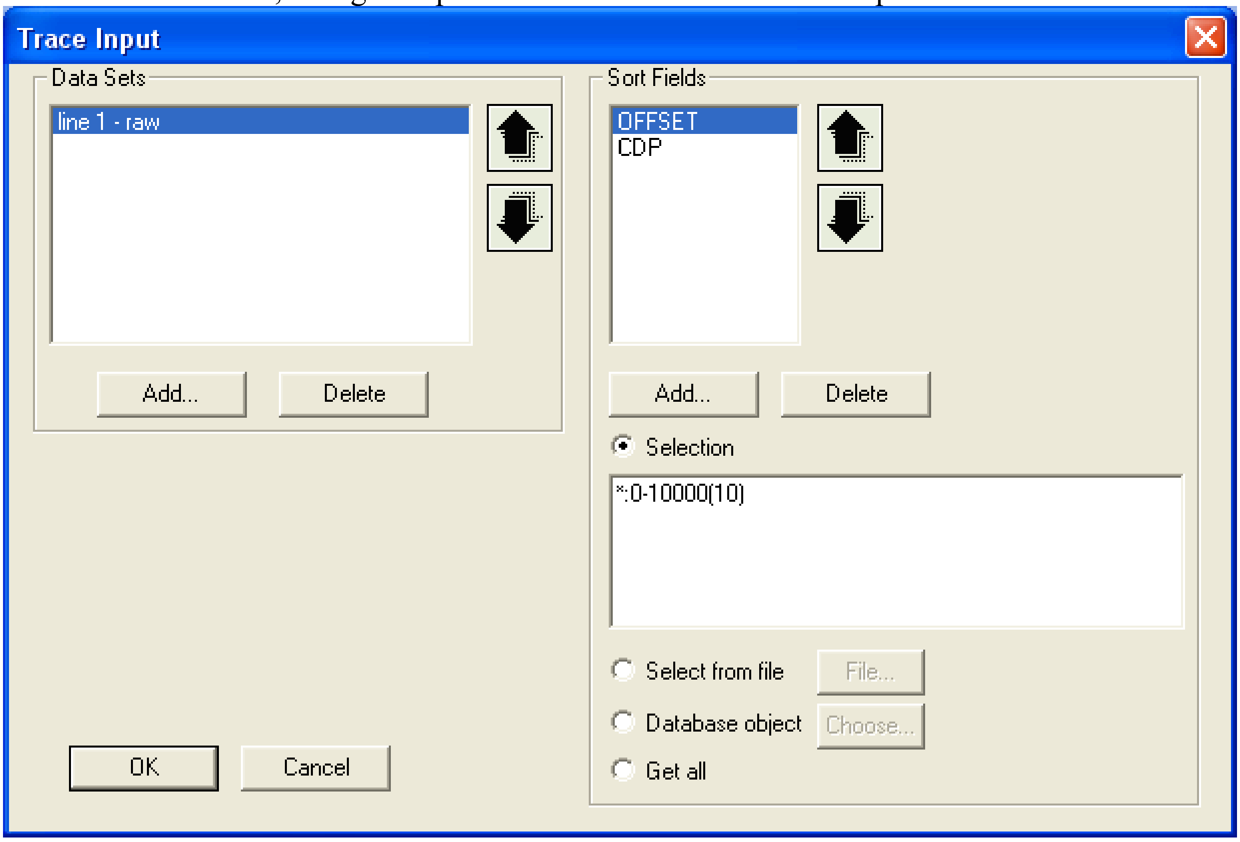
At the present moment the flow looks as follows:



Assigning muting parameters

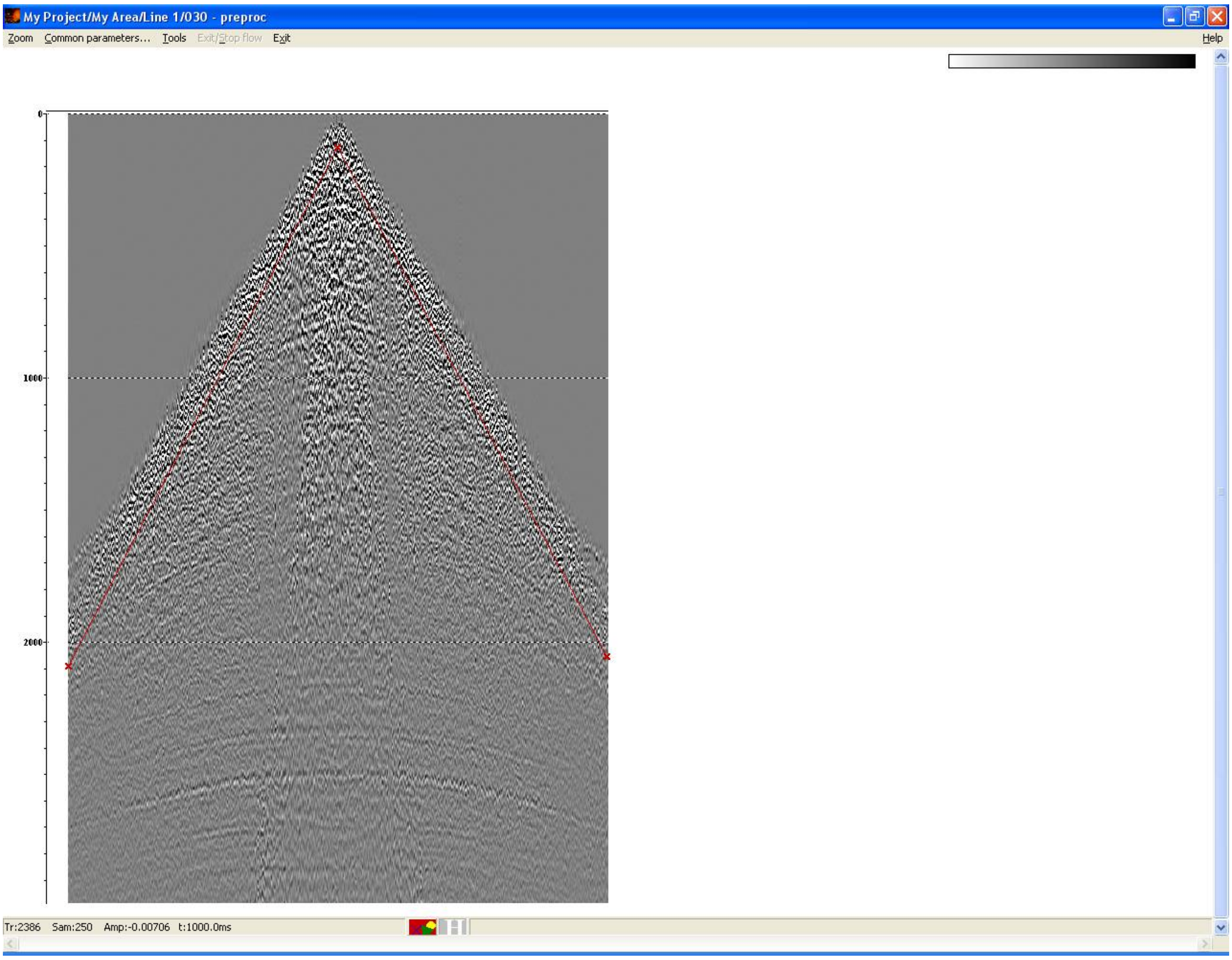
Since our processing is aimed to obtain a seismic section of reflected waves, in this case, direct wave is, obviously, shall be considered as noise. The most effective method of suppression of this noise is the top muting from the beginning of the trace to the time, equal to the direct wave arrival time, plus some time after it, containing the wavelet of the direct wave.

In order to assign this muting, re-sort the traces in the module **Trace Input** temporarily in the order OFFSET:CDP. To do it, change the parameters of the module Trace Input as follows:



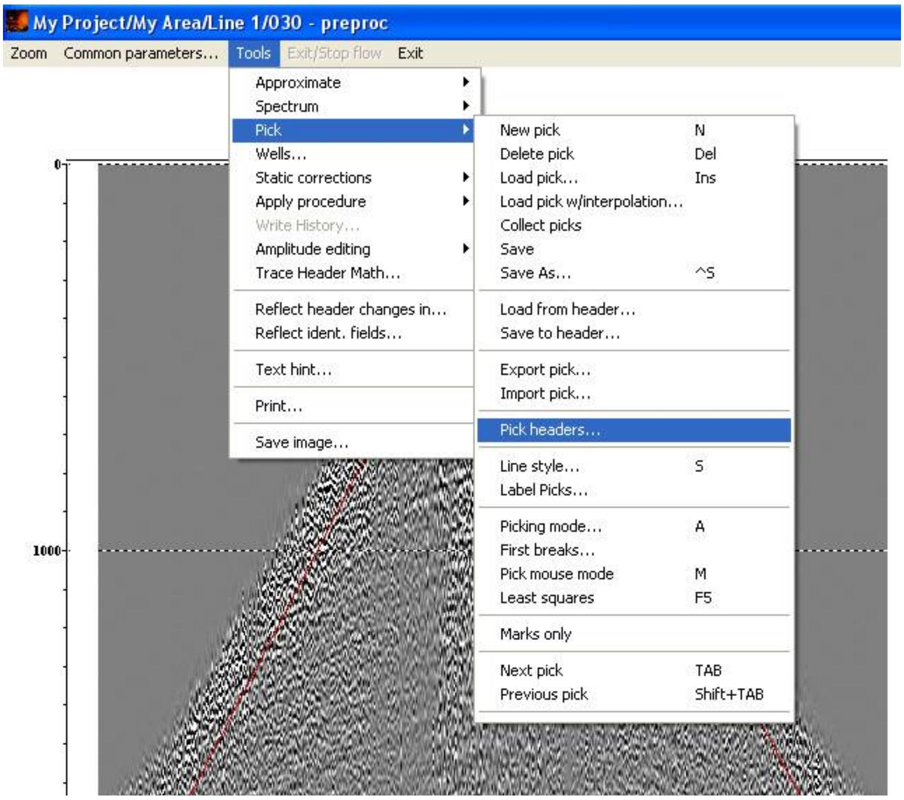
Execute the flow; the traces, sorted out in ascending order of the OFFSET header field will be shown on the screen. Such a gather (called, common-offset gather) allows convenient assigning the muting time, which will be suitable for all CDP gathers.

To do it, create a new pick object (**Tools/Pick/New Pick** menu command of the **Screen Display**), then pick the time of muting approximately as shown on the figure (direct wave arrival time plus ~100-200 ms).

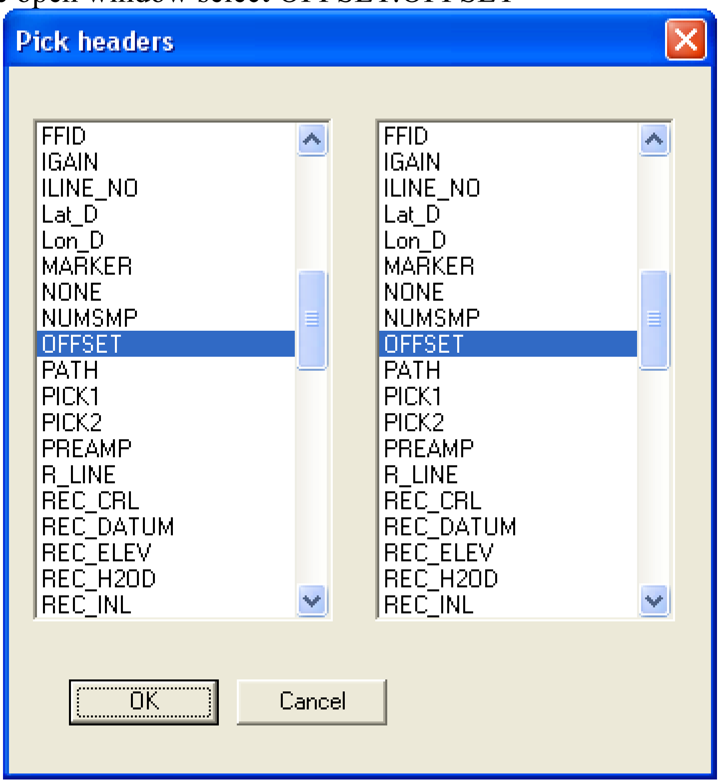


A pick in the **RadExPro** is the collection of the time values matched by two header fields, as it is considered that it is always possible to find two header fields that will unambiguously identify a trace (for example, number of CDP and offset, or shot point number and channel number). In this case, however, we want the time of the muting to be suitable for all CDP gathers and depend only on the offset. Therefore we must bind the pick to only one header field - OFFSET.

To do it, select the **Tools/Pick/Pick Headers** entry of the **Screen Display** menu



In both columns of the open window select OFFSET:OFFSET

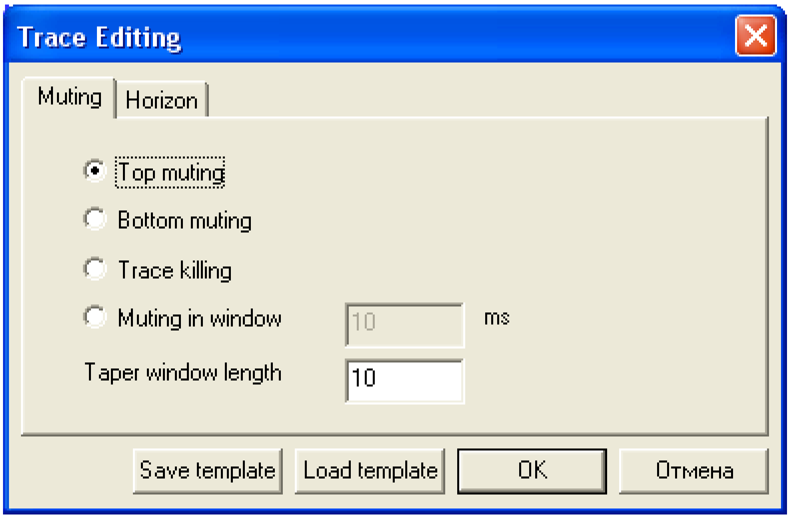


Then click the OK button and save the pick with the **Tools/Pick/Save As...** command of the **Screen Display** menu. Indicate the name of the pick as *top_mute*.

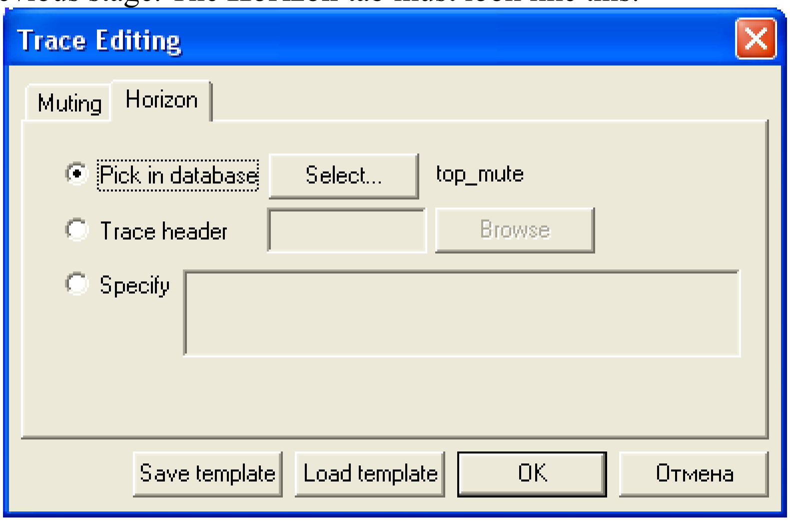
Top muting

In the flow *030 - preproc* return to the initial sorting (CDP:OFFSET) changing respectively the **Trace Input** parameters.

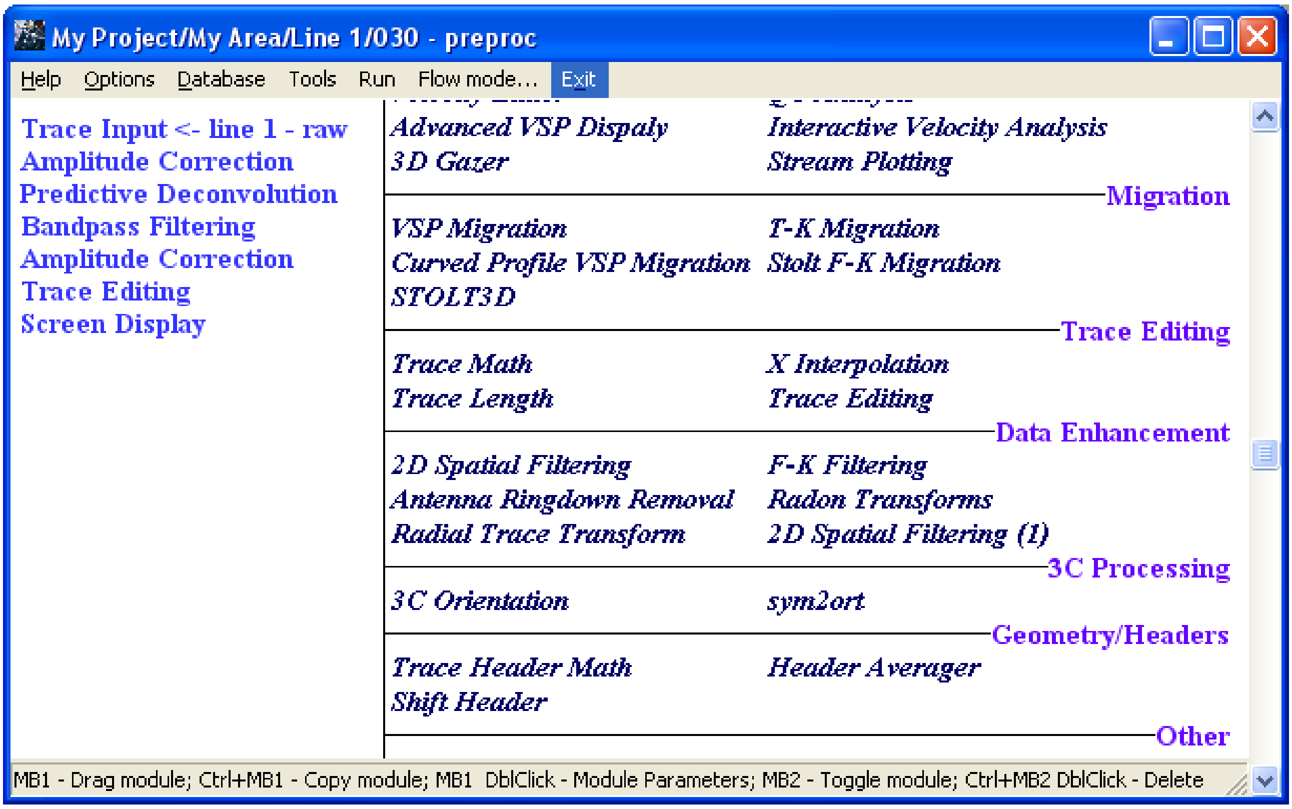
Add the module **Trace Editing** to the end of the flow (before the **Screen Display** module) with the following parameters:



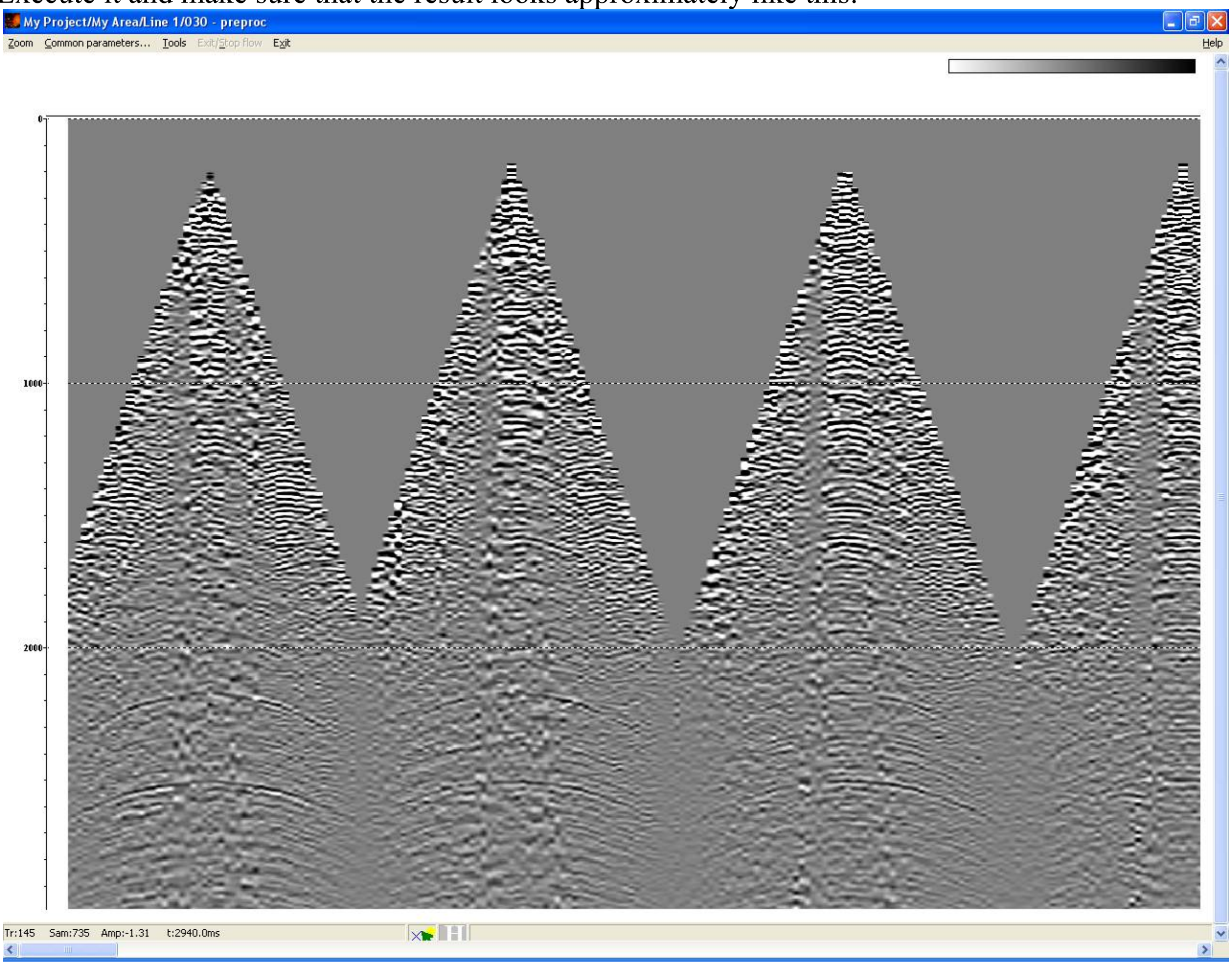
On the second tab specify the horizon that will define muting, as a database pick *top_mute*, which was saved at the previous stage. The **Horizon** tab must look like this:



Now the flow looks like the following:

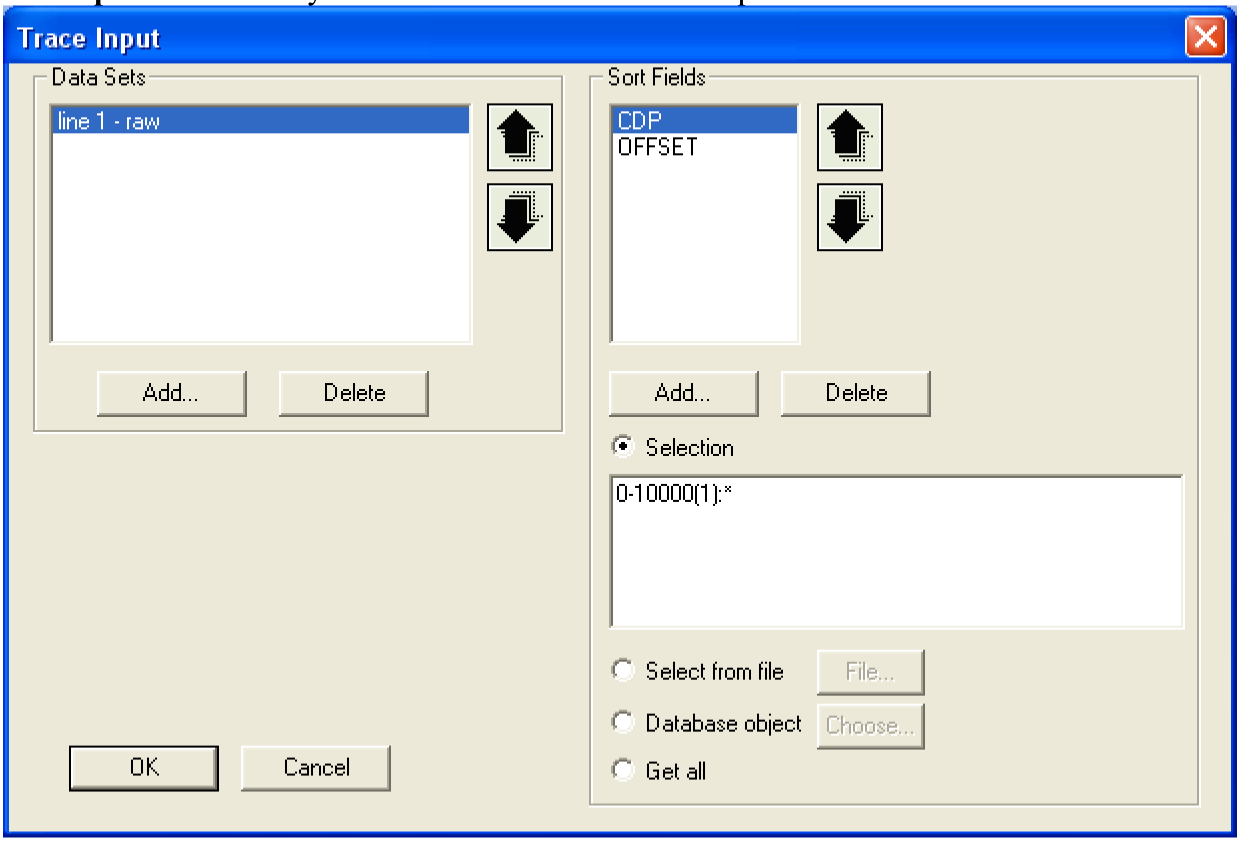


Execute it and make sure that the result looks approximately like this:

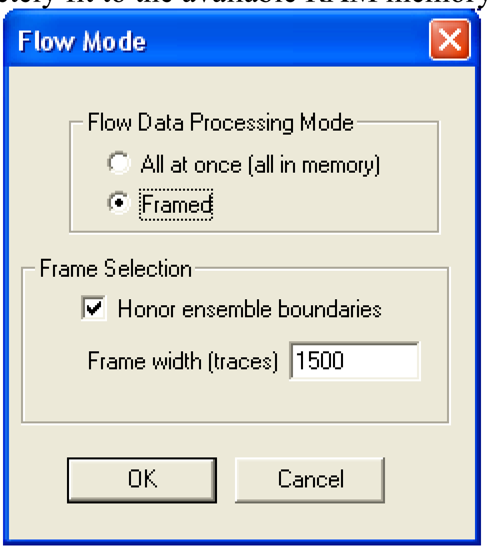


Execution of the preprocessing flow

At this point you may consider that the parameters of preliminary data processing are selected and you can execute the flow with the complete dataset. To do it change the parameters of the **Trace Input** in such a way that now the data from all CDP points enter the flow:



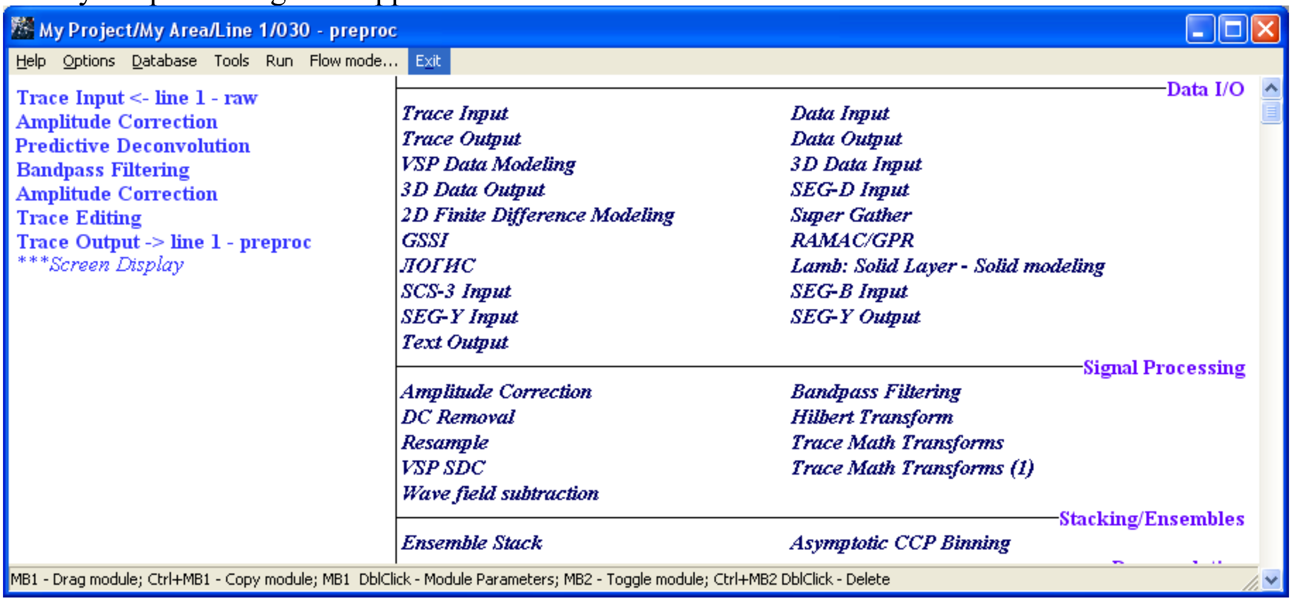
As the volume of data in the flow is rather large now, we have to execute it frame by frame. In the window of the flow editor select the **Flow mode** menu entry and assign the frame size so that the data of each frame were completely fit to the available RAM memory:



Add the module **Trace Output** to the end of the flow in order to save the results of the preliminary data processing. In the parameter dialog of this routine create a new dataset with the name *line 1 – preproc* where the data from the flow will be saved to.

Comment the **Screen Display**.

Finally the processing flow appears as follows:



Execute the flow.

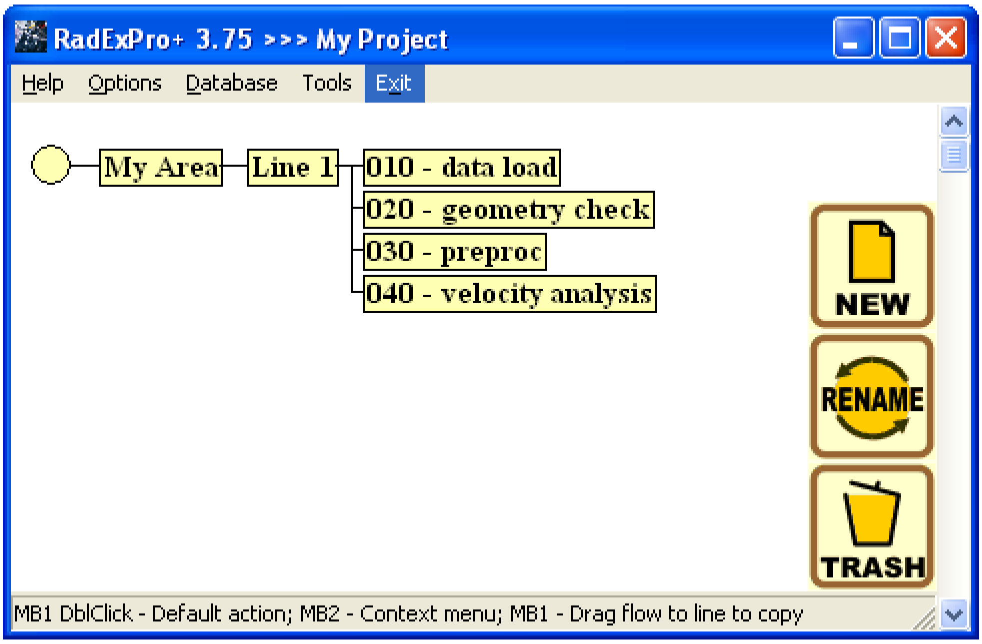
Velocity analysis and stacking

Preparation of the data for velocity analysis, super-gathering

As a rule, in order to increase the signal-to-noise ratio and obtain more coherent velocity spectra, velocity analysis is carried out on ensembles consisting of several adjacent CDP gathers (the so called super-gathers), rather than on separate single CDP gathers.

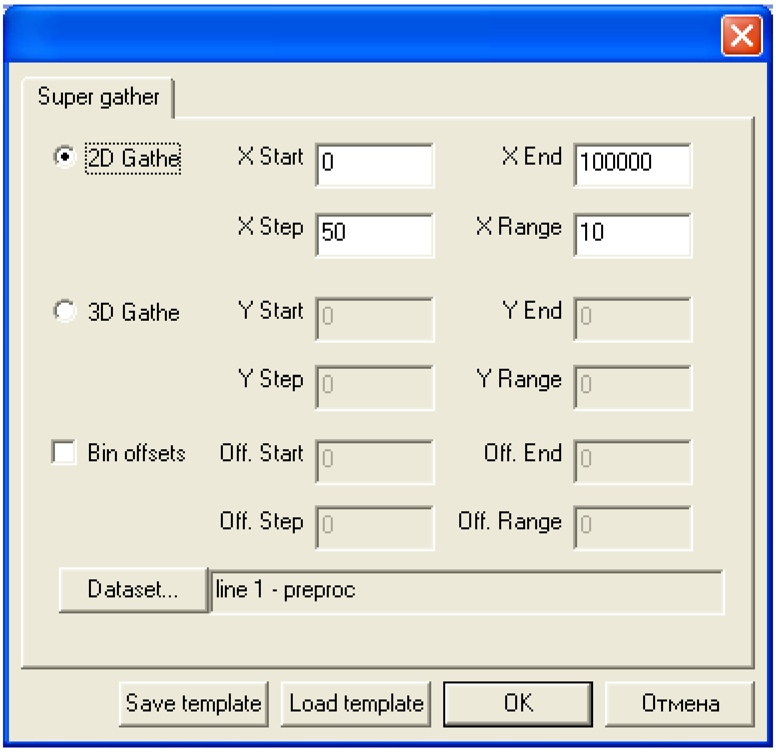
Another peculiarity of the data preparation to the velocity analysis is that the data must possess maximum signal-to-noise ratio, while the high vertical resolution of the record and the recovery of the dynamics are not important. Therefore, when preparing the data to the velocity analysis such procedures as automatic gain control in a relatively short window and bandpass filtering in a relatively narrow band (aimed to keep only the part of the spectrum with the the maximum signal-to-noise ratio) are often used.

Create the flow *040 – velocity analysis*.



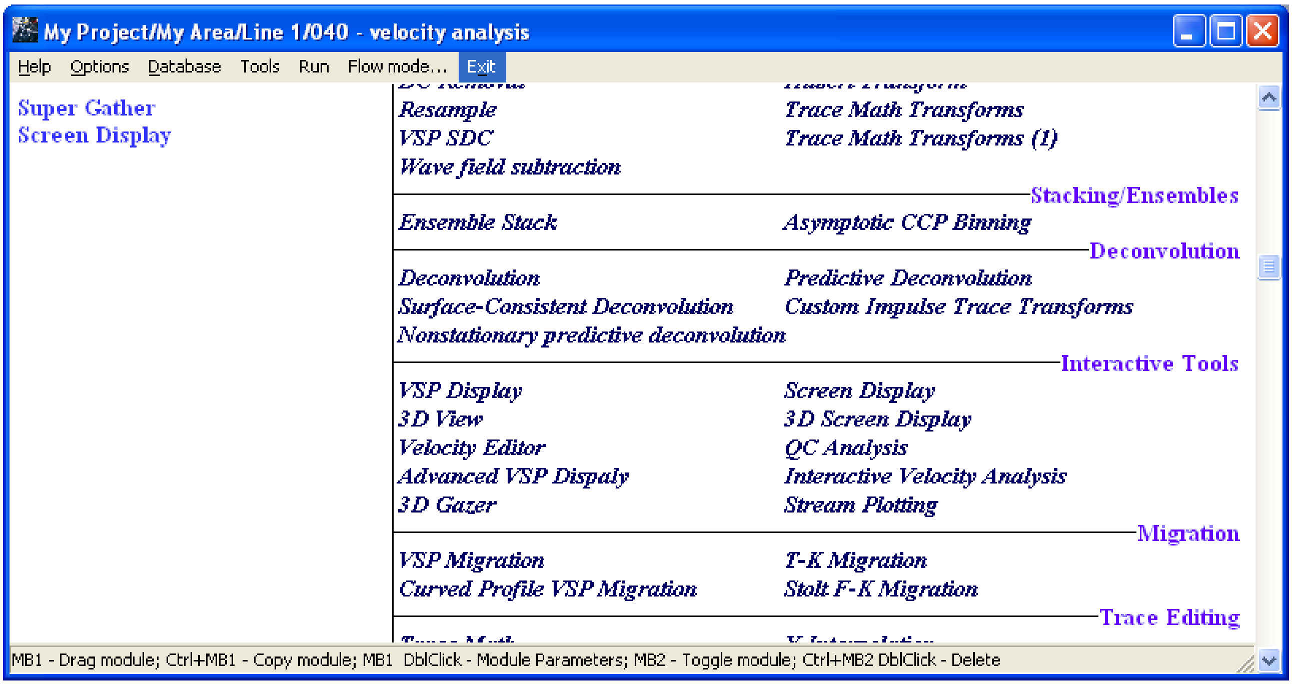
Place the **Super Gather** routine, which will form the super-gathers, in the beginning of the flow.

It is reasonable to select the **Super Gather** parameters approximately as shown on the following figure.

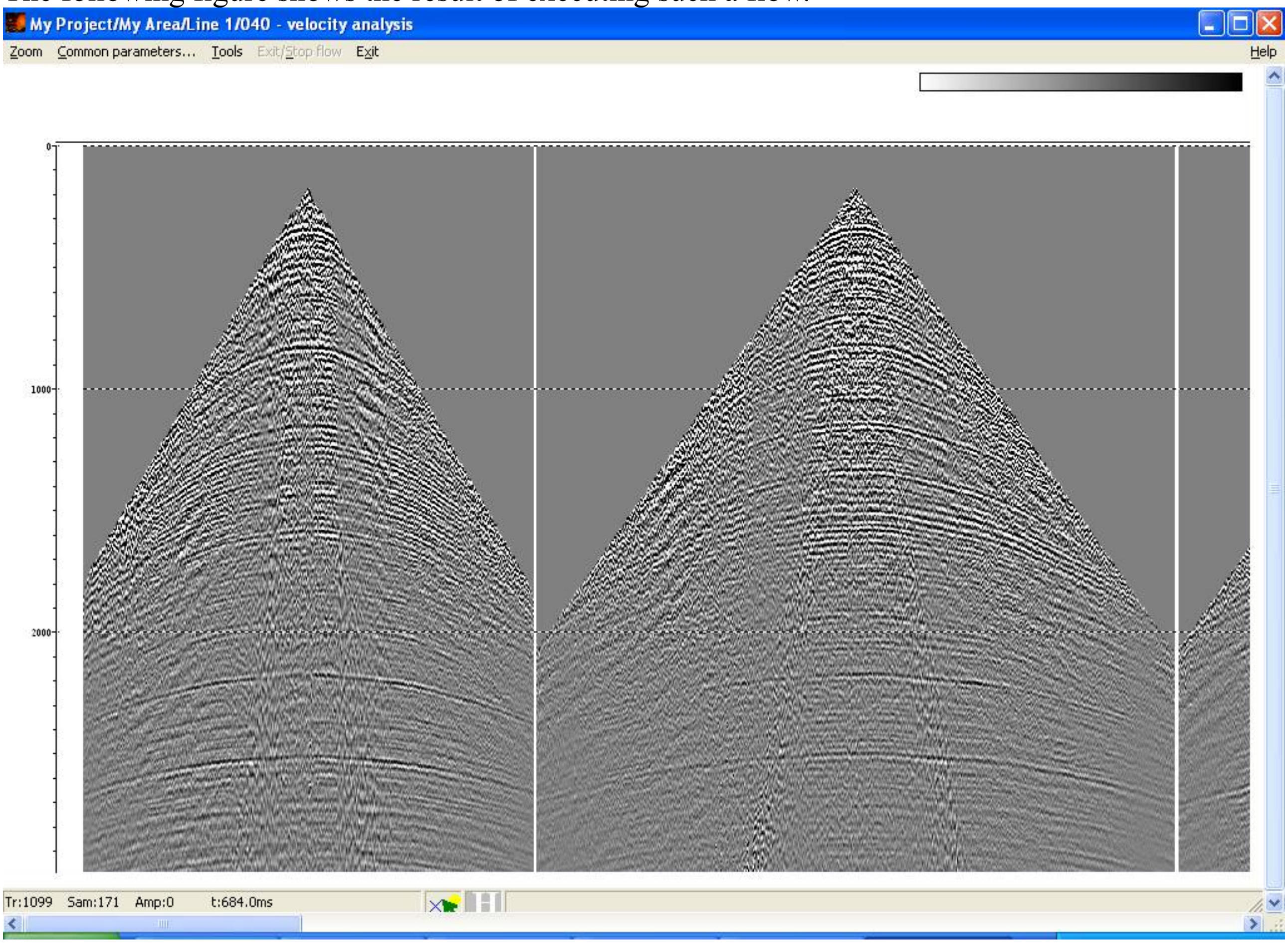


That is, the velocity analysis will be carried out with an interval of 50 CDP points, each super-gather will contain10 adjacent individual CDP gathers. The super-gathers are formed of the preprocessed dataset *line 1 - preproc* prepared at the previous stage.

If you add the module **Screen Display** into the flow after the **Super Gather** you will be able to see how the resulting super-gathers look like.



The following figure shows the result of executing such a flow.



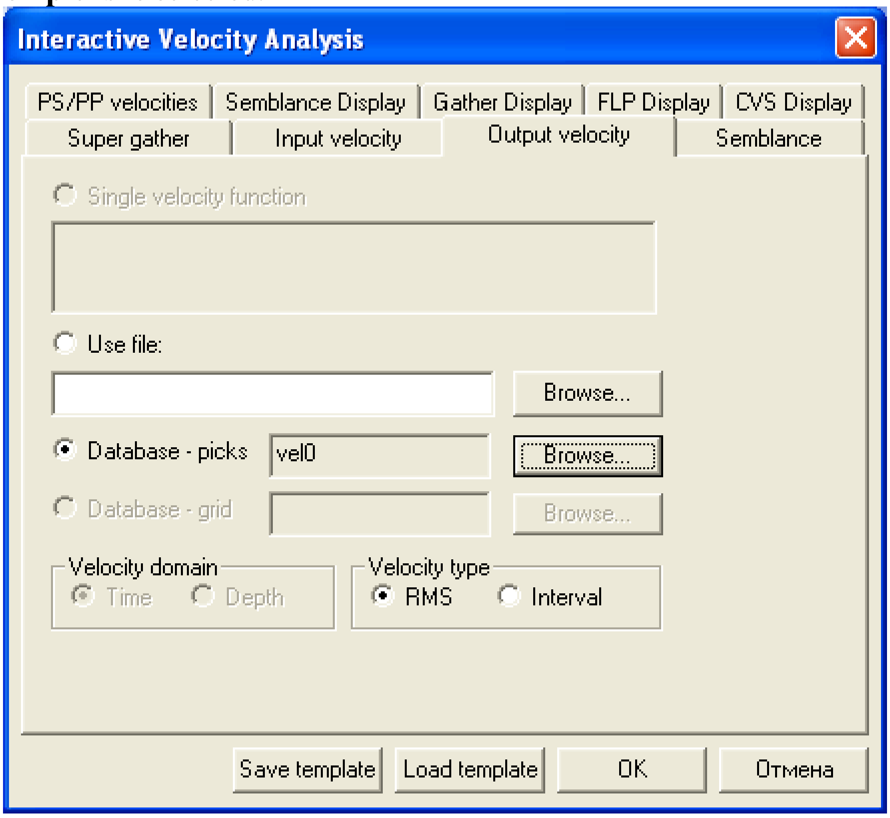
It is easy to see that, due to the use of a substantially larger volume of data, the phases of the reflected waves are outlined much more confidently than on single CDP gathers..

Velocity analysis

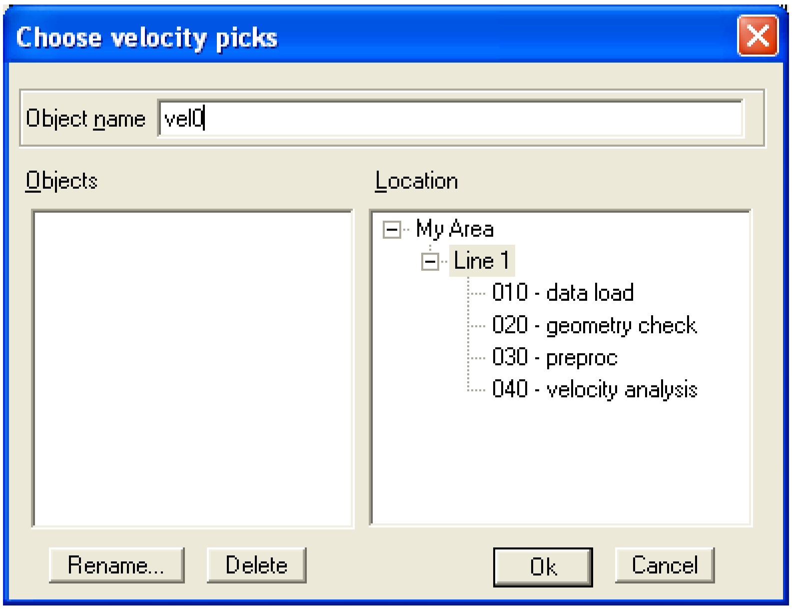
Comment the **Screen Display** module or remove it from the flow. For conducting the velocity analysis, add the **Interactive Velocity Analysis** routine to the end of the flow.

Let us discuss the assigning order and the reasonable values of the parameters of the module.

First, it is necessary to specify, where to save the resulting velocity pick. The output velocity field can be stored either in a text file or in a database "velocity-pick" object. We recommend that the output velocities are always saved as a database object. (Then all possible manipulations with them, such as export/import, can be made using the with the special tool **Database Manager**, available from the **Database/Database Manager** menu of the **RadExPro** main window). Therefore, in the module parameter dialog select the **Output Velocity** tab and make sure that the option **Database - picks** is selected.

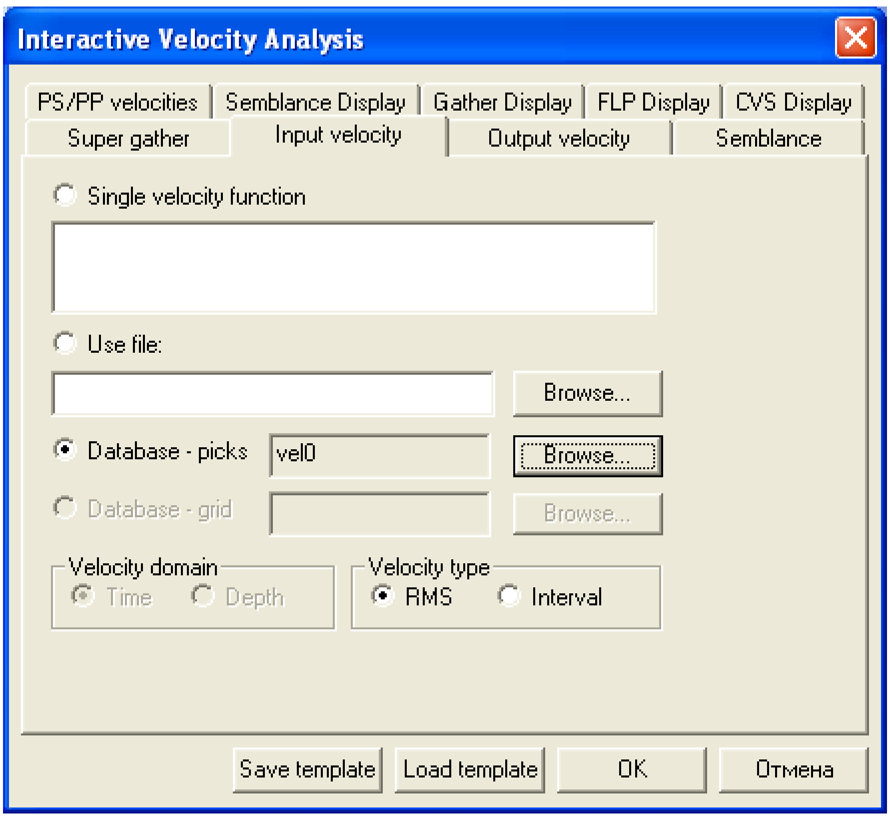


Click the **Browse** button corresponding to this option and in the appeared dialog box specify the database object name, where the velocity pick is to be stored, as shown on the following figure.



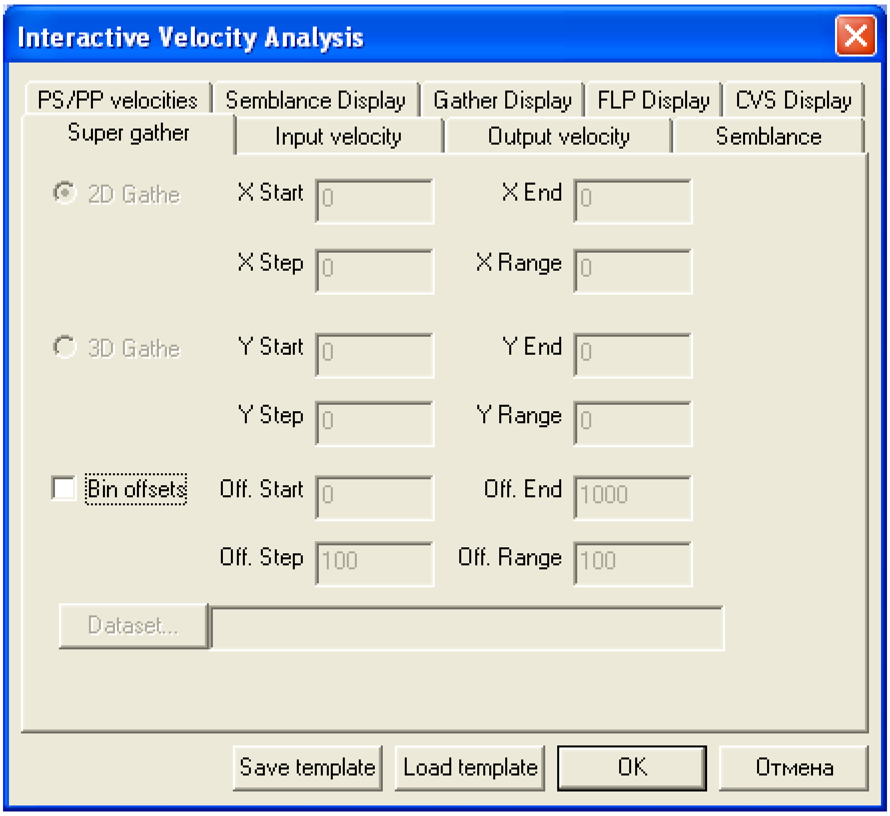
It is reasonable to store the velocity picks at the second level of the database, corresponding to the line.

Now specify the same velocity pick as an input velocity function. It will be useful if you decide to return to the velocity analysis later and to continue the work with the pick. For this in the **Input Velocity** tab assign the same parameters as on the previous one.

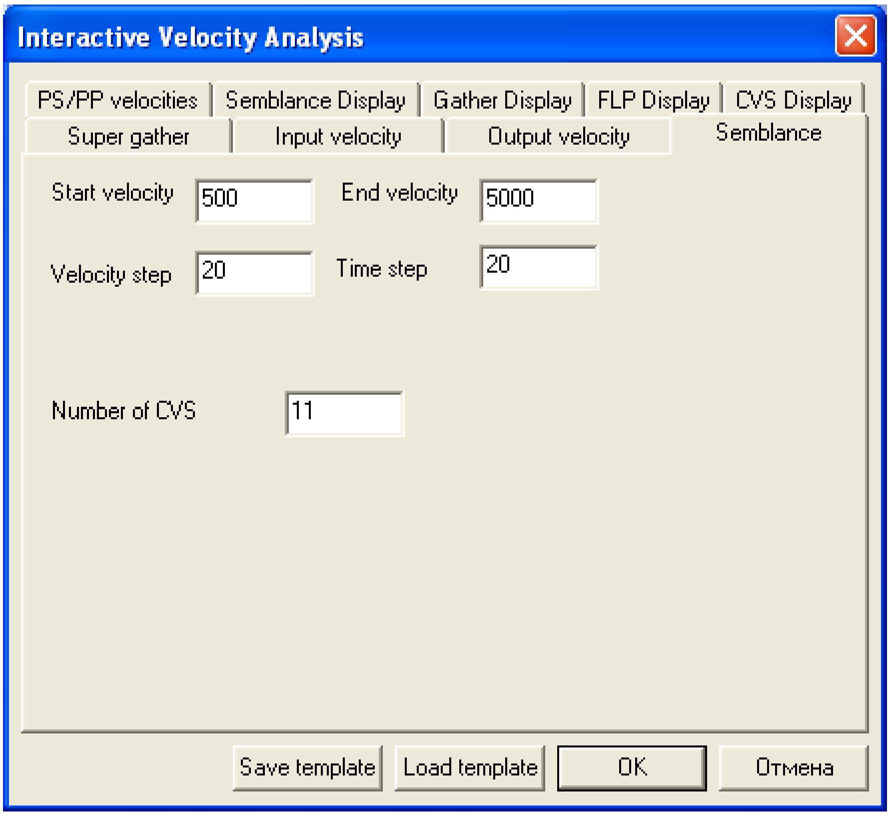


Important!: When assigning a new velocity pick, its name must be specified first on the **Output Velocity** tab and only then - on the **Input Velocity** tab. Otherwise the program reports an error message.

Now select the tab **Super gather** and switch off the **Bin offsets** option. This option allows for summing up the traces with the close offsets before calculating the velocity spectrum. This would result in much faster calculation of the velocity spectrum, however its coherency somewhat deteriorates.



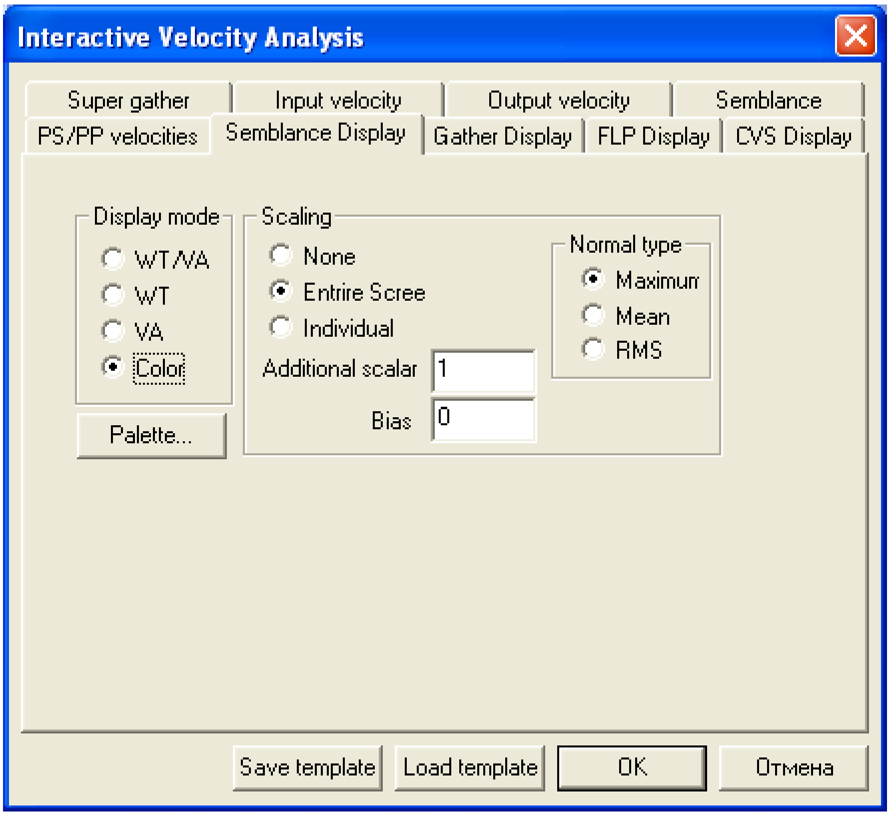
Select the tab **Semblance** to assign the parameters of the velocity spectrum calculation: the start and end velocities, the velocity step and the time step. The velocity spectrum will be calculated as a normalized for the specified range of velocities.



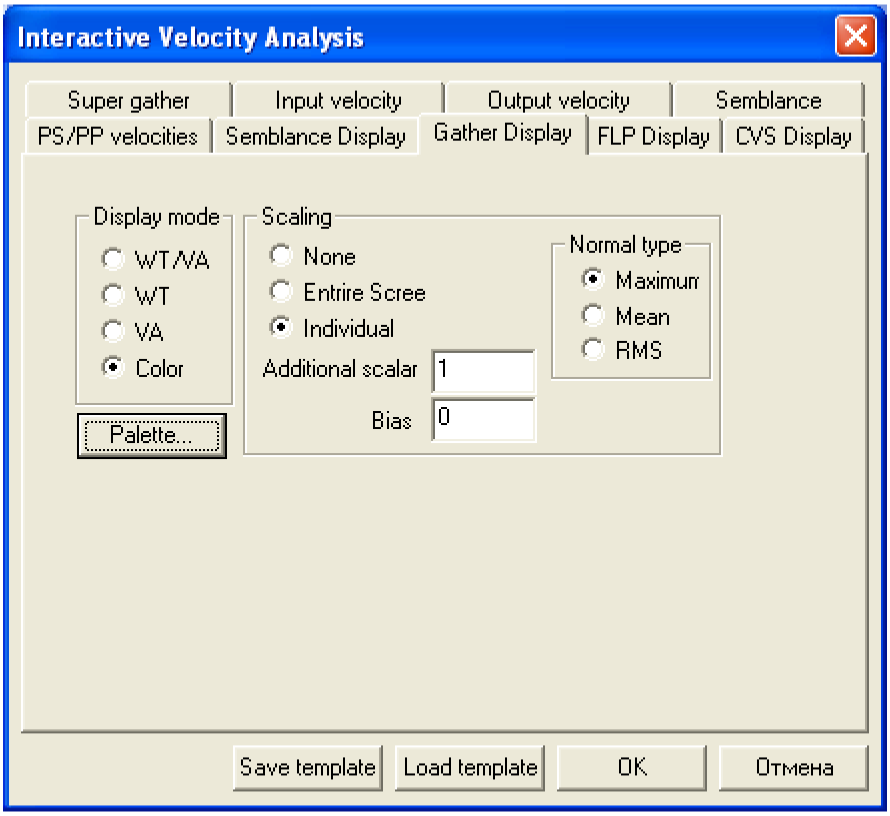
The parameters by default for the considered data set are completely acceptable.

The remaining dialog tabs are responsible for display parameters of different elements of the velocity analysis window.

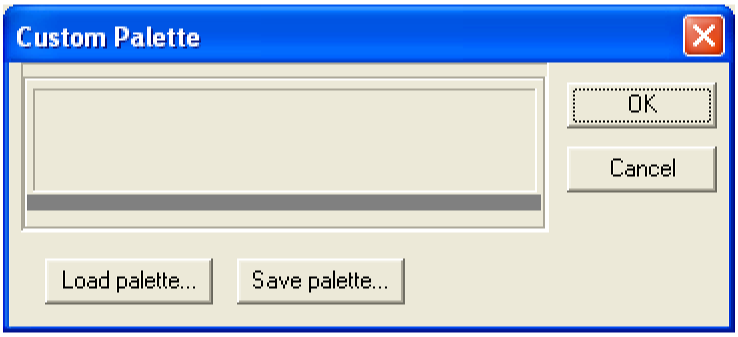
It is reasonable to keep the parameters by default on the **Semblance Display** tab responsible for the parameters of velocity spectrum display.



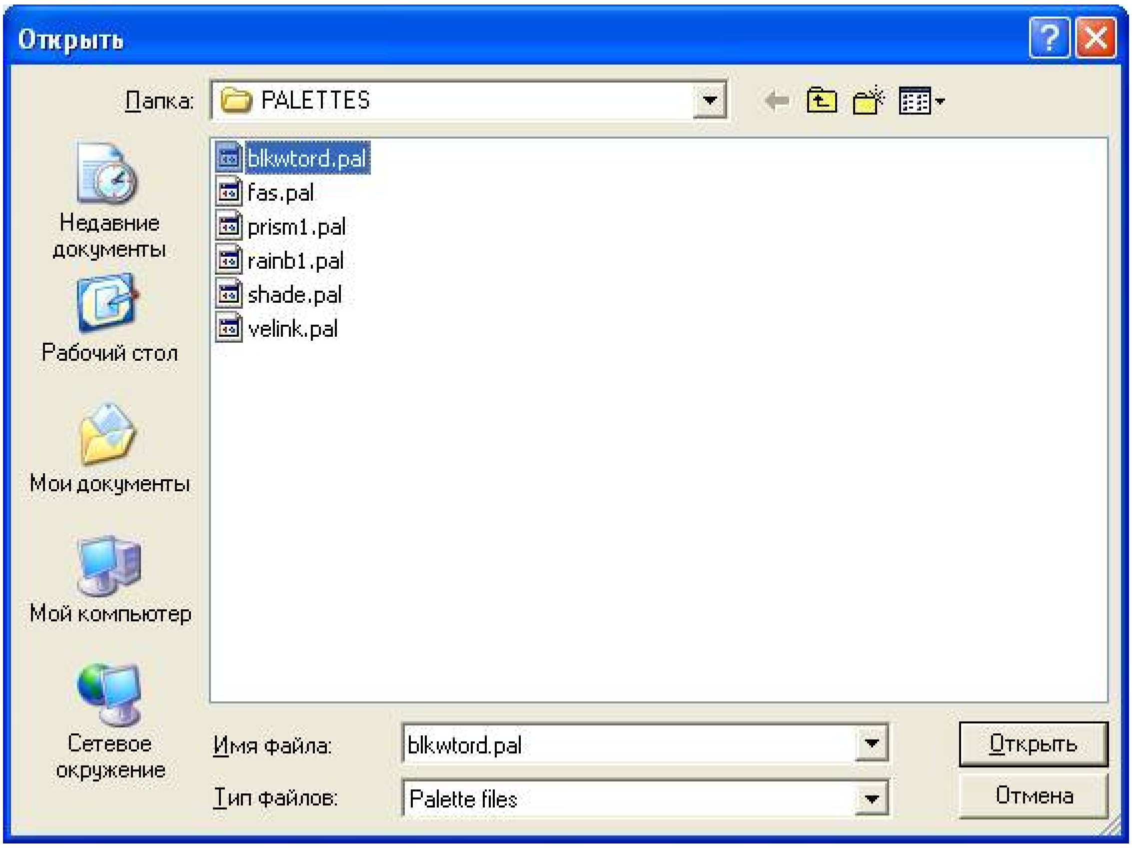
It is reasonable to display the traces of the current super-gather for which the velocity analysis is performed in color. Select any palette, in which the traces before and after the normal move-out (NMO) corrections will be conveniently observed (by default the gray-scale pallet is selected, here we are going to replace it by the black-white-orange pallet). For this, first select the **Color** option of the **Display mode** in the tab **Gather**.



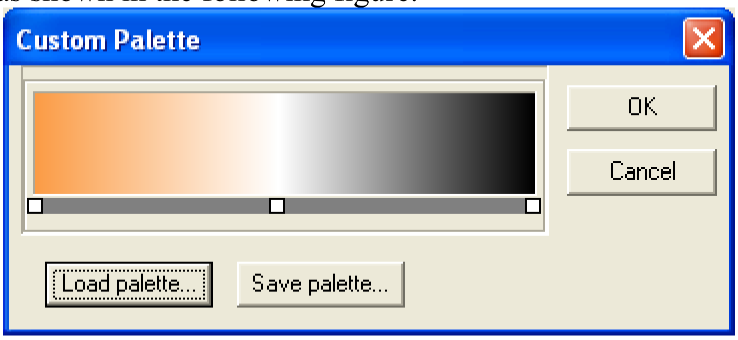
Then click the **Palette** button and in the appeared dialog box click on the **Load palette** button.



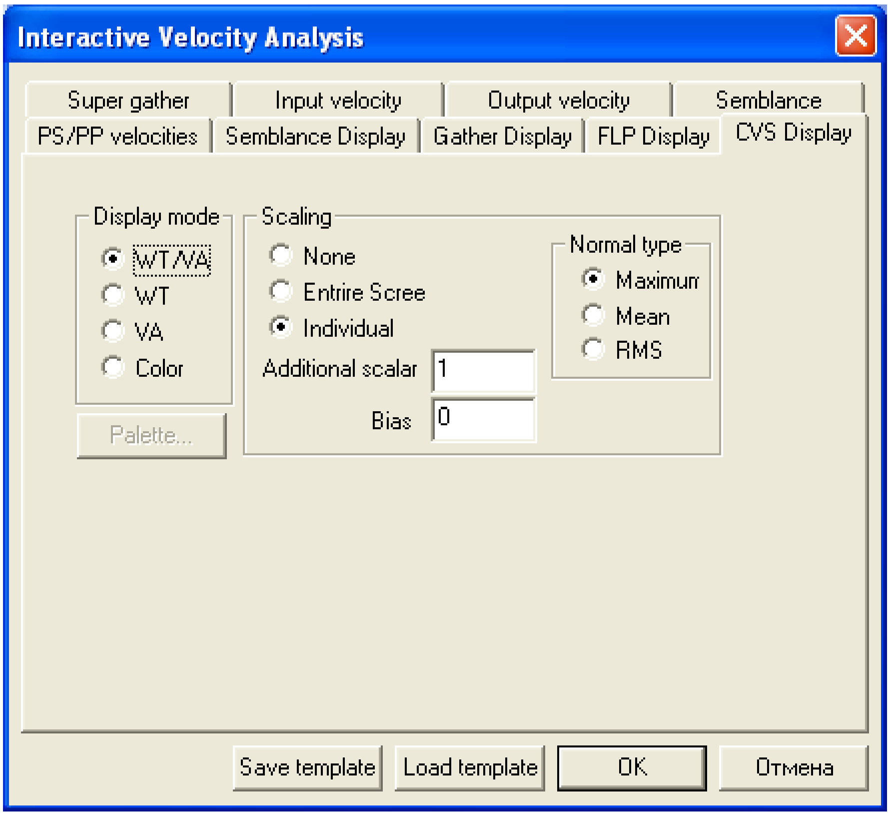
A set of the predefined palettes is stored in the folder, where the RadExPro package is installed, in *PALETTES* subdirectory. Select the palette *blkwtord.pal*.



The result should be as shown in the following figure.



The dynamic stack (**FLP Display**) and the panel of the constant velocity stacks (**CVS Display**) can be conveniently observed when the traces are displayed in wiggle trace/variable area (**WT/VA**) mode. Therefore the parameters for them can be kept as they are set by default.

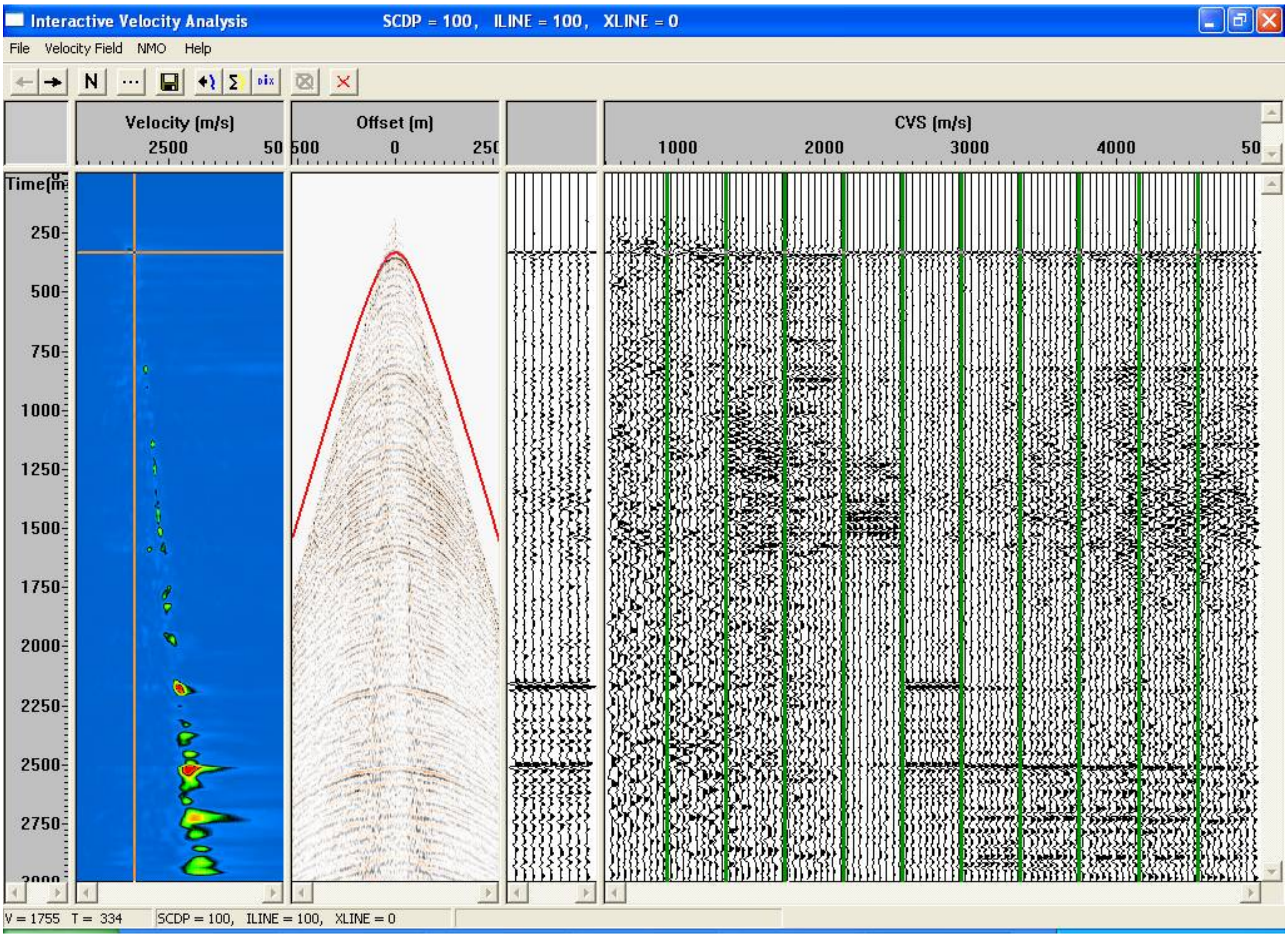


After assigning the parameters, execute the flow.

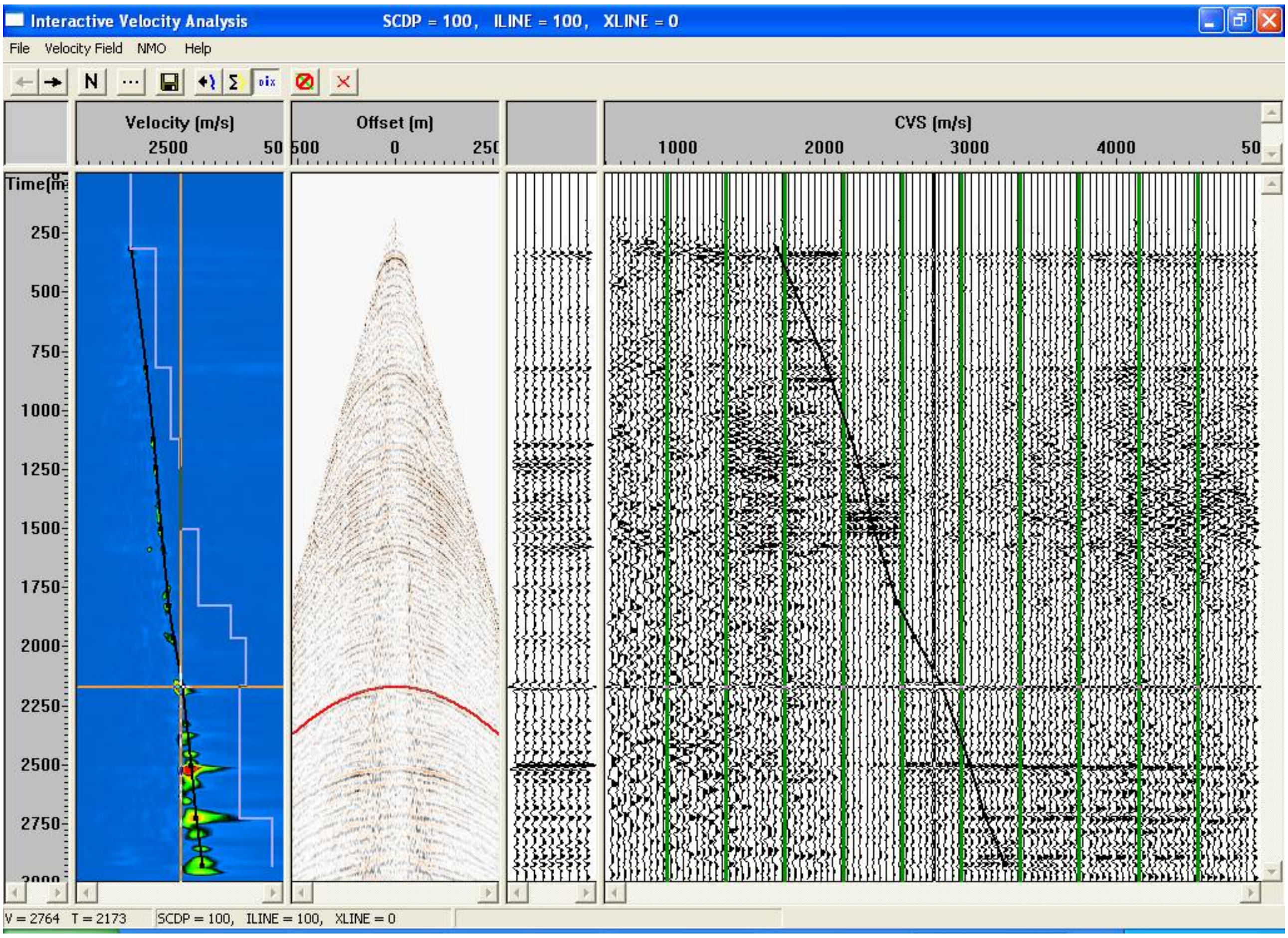
As a result, the interactive velocity analysis window will appear. It consists of 4 parts (from left to right): the semblance (velocities spectrum), the current super-gather, the dynamic stack and the constant velocity stack panels.

The dynamic stack consists of the traces, obtained as a result of stacking of the CDP gathers of the current super-gather corrected for NMO with with the current velocity pick. When the velocity pick changes, the stack is dynamically recalculated.

The constant velocity panels show a series of stacked traces for a series of constant velocities. Each stack fragment here is obtained from the CDP gathers of the current super-gather corrected for NMO with one or another constant velocity.

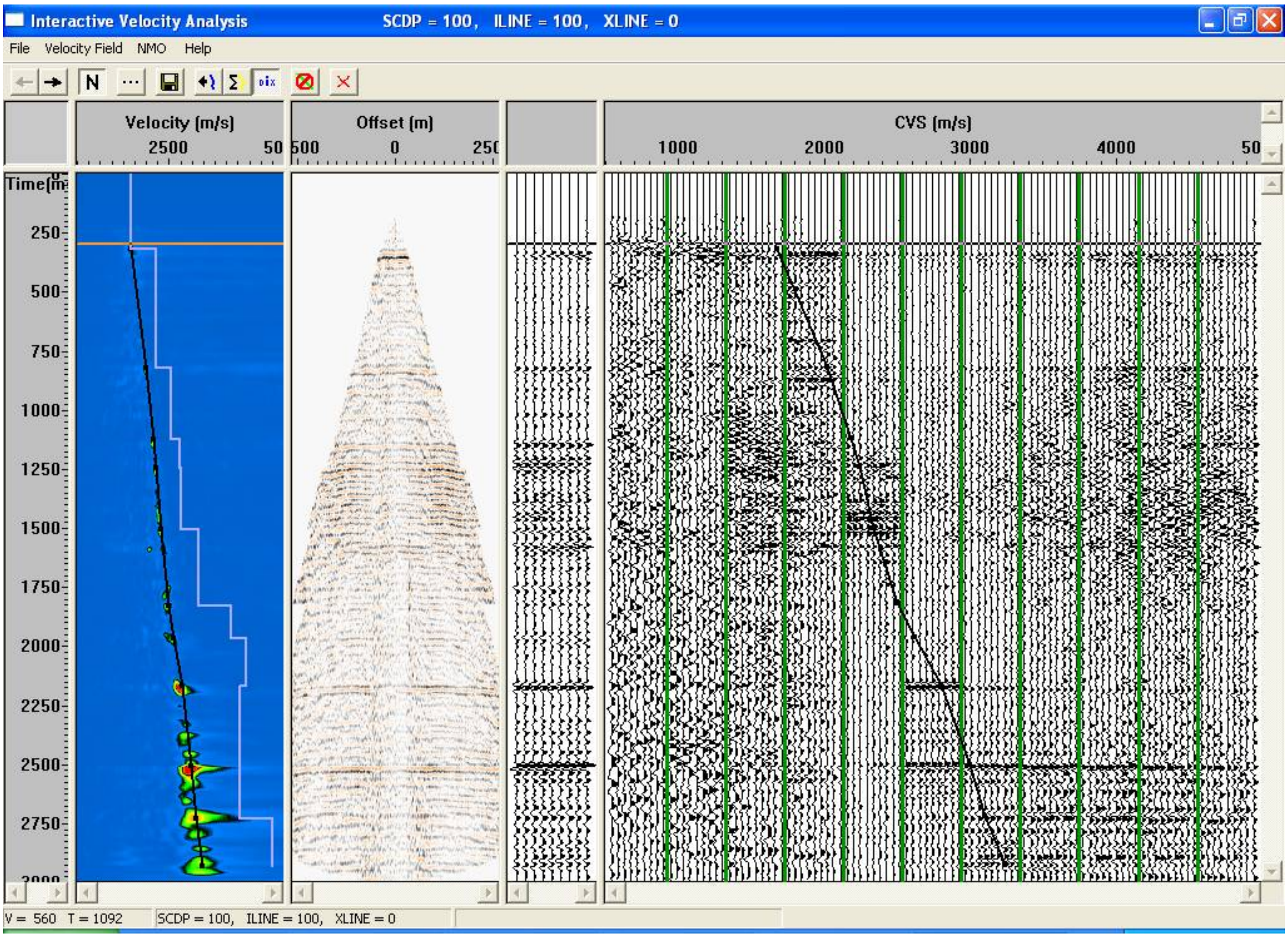


Velocity pick is made on the semblance panel. When picking, follow the maximums of the energy of the semblance. An example of a reasonable velocity pick for the above figure is shown below:



Additionally, the module **Interactive Velocity Analysis** allows accomplishing the following actions, useful for the QC of the velocity picking:

- The button **N** on the tool bar switches on the mode, when the current super-gather is dynamically corrected for NMO with the current velocity pick. At that, the travel time curves of the reflections ideally must become rectified (see the figure below).



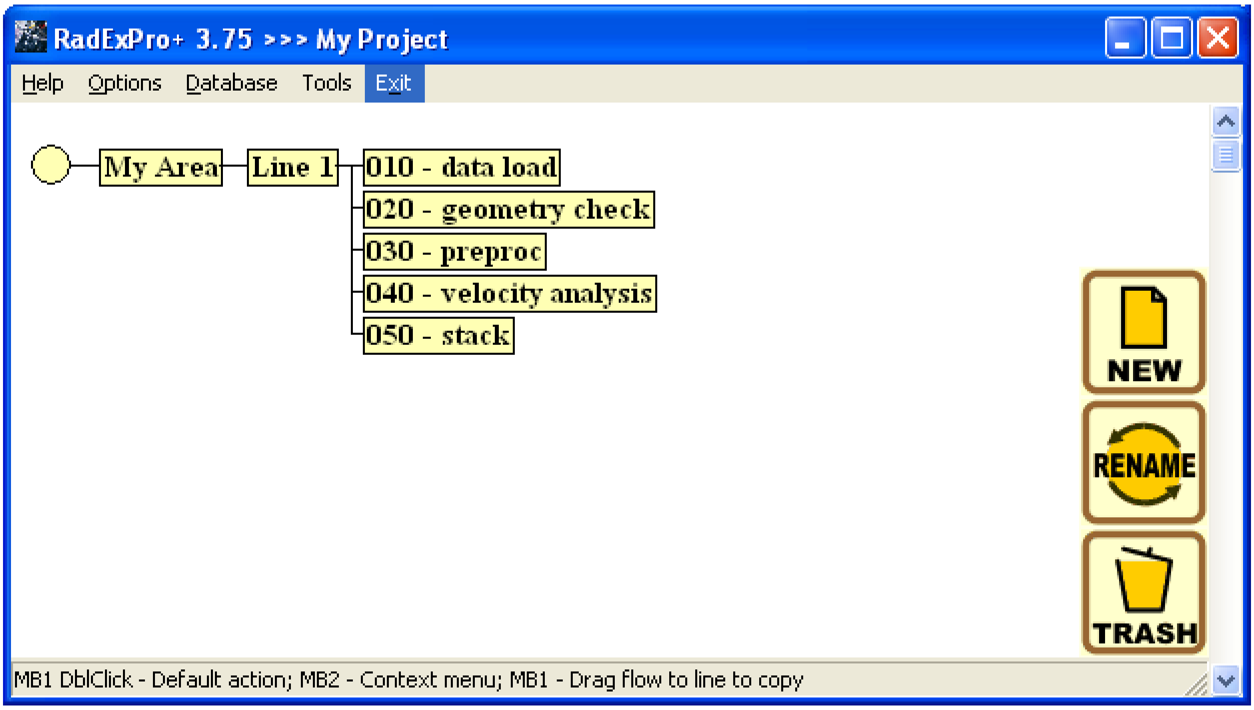
- Clicking the **Dix** button of the tool bar you may display the interval velocities calculated for the current velocity pick according to the Dix's formula (light-blue blocked curve on the figure). By the way, switching this option on and changing insignificantly the stacking velocity (barely moving one of the points of the velocity pick), you can see how extremely unstable is the conversion of the RMS velocities (that is what we actually pick) into the interval velocities. You can see that even the slightest changes in the stacking velocity can lead to sometimes catastrophic changes in the interval velocities. This effect is the greater, the less is the analyzed interval.

After the velocity pick for this super-gather position is assigned, it is possible to pass to the next position, clicking the button with the right arrow on the tool bar. If you carry out the velocity analysis in the framed mode, you can move through the super-gathers to the right or left within the current frame, otherwise – within the entire dataset.

Carry out the velocity analysis for all super-gathers, then before exiting the module press the **Save** button on the tool bar in order to save the created velocity pick.

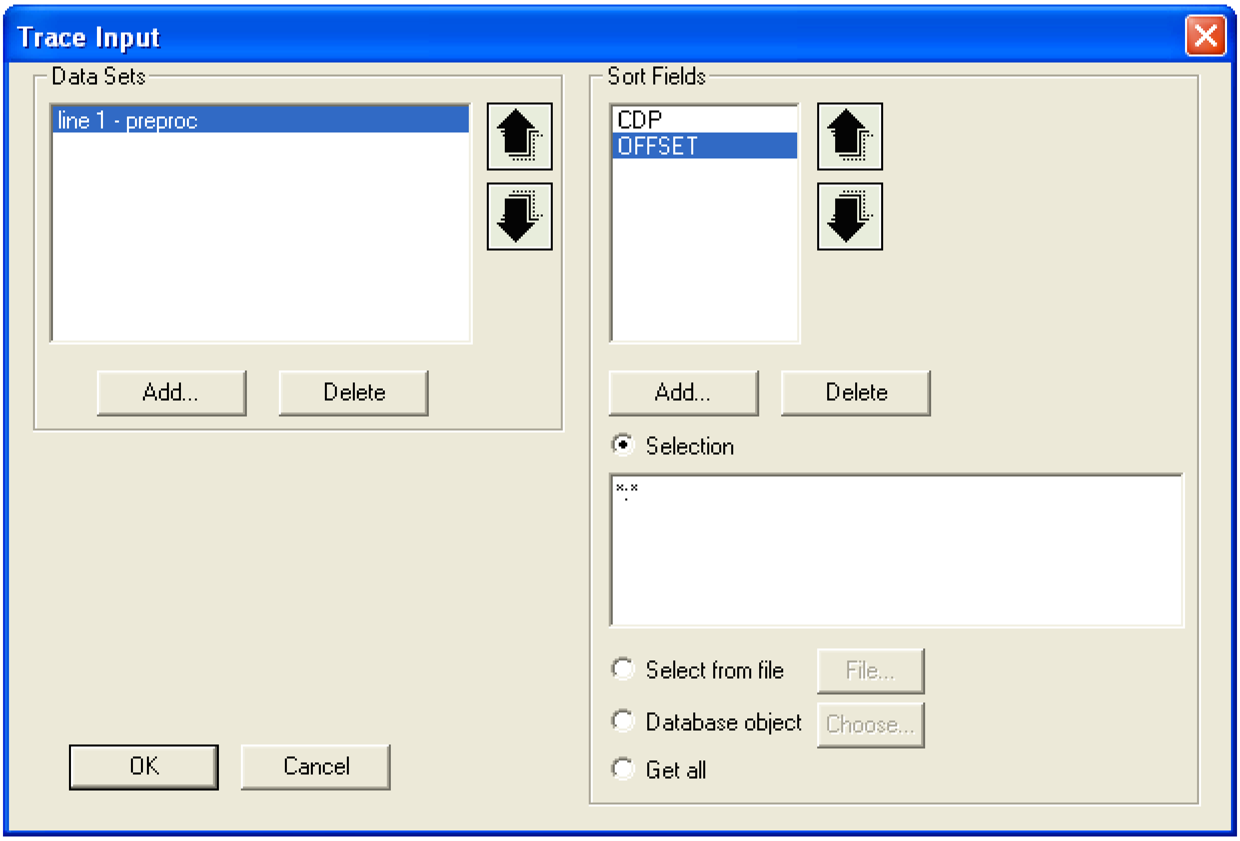
Stacking

Create the flow *050 – stack*.



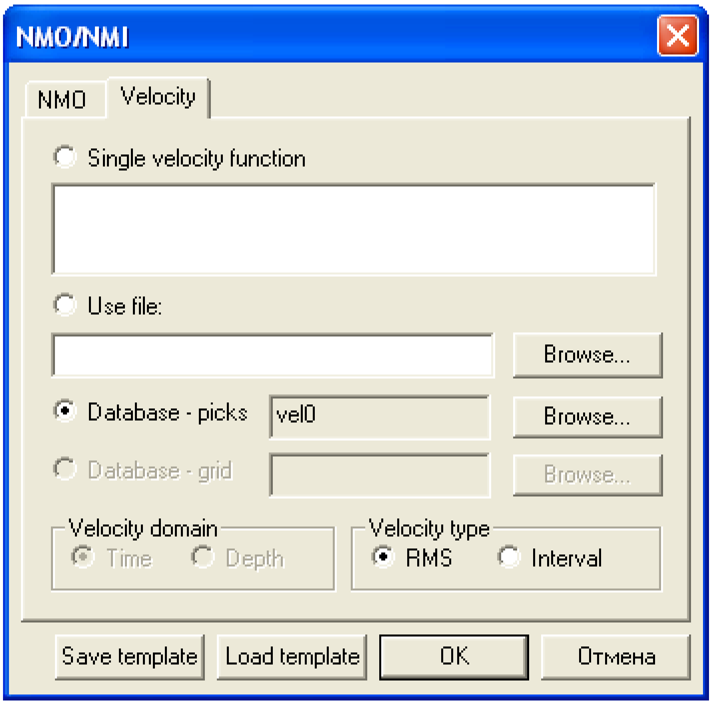
The flow must contain the following routines:

Trace Input, which enters the *line 1 - preproc* dataset into the flow in the CDP:OFFSET sorting order.



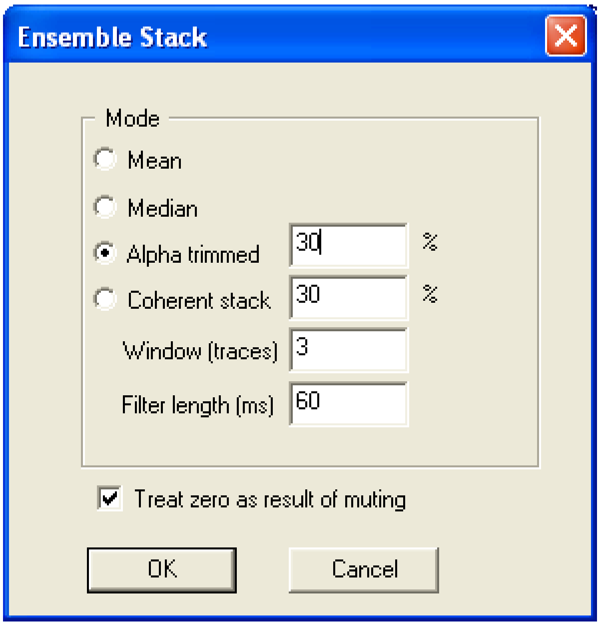
The **NMO/NMI** module to correct the traces for the NMO. The parameters of the module should be assigned as follows. Select the **NMO** mode in the **NMO** tab, set muting on the signal tension = 30 (i.e. those parts of the traces, which as a result of the NMO correction will be extended to more than 30%, will be reset to zero).

In the **Velocity** tab select the velocity pick, which was obtained as a result of the velocity analysis performed before.

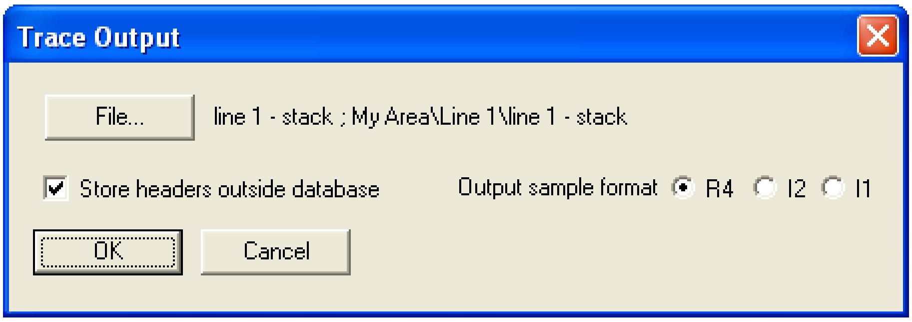


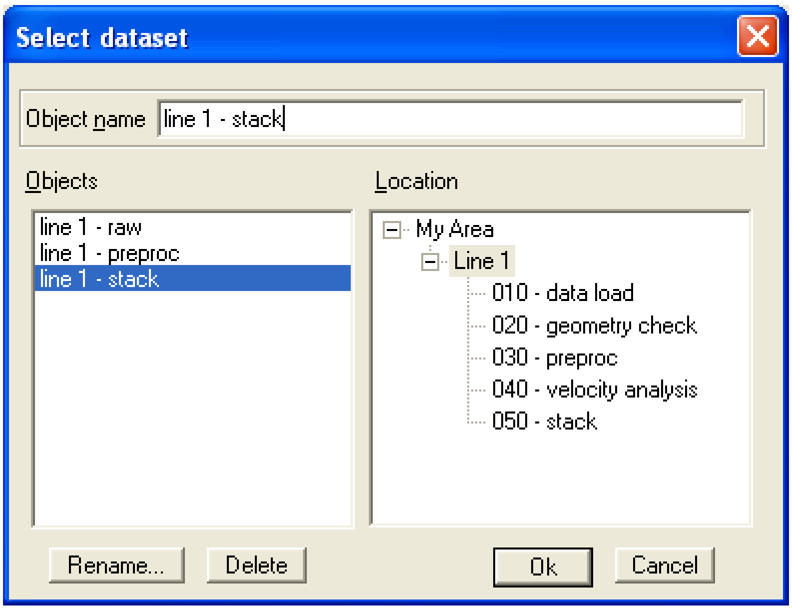
After the **NMO/NMI** module in the flow, place the **Ensemble Stack** routine. This module stacks horizontally all the traces within each ensemble in the flow. Since in this case in the **Trace Input** at the beginning of the flow the CDP header field was selected as the first sorting key, the CDP gathers will be considered as ensembles.

Assign the parameters of the **Ensemble Stack** module as shown on the following figure.

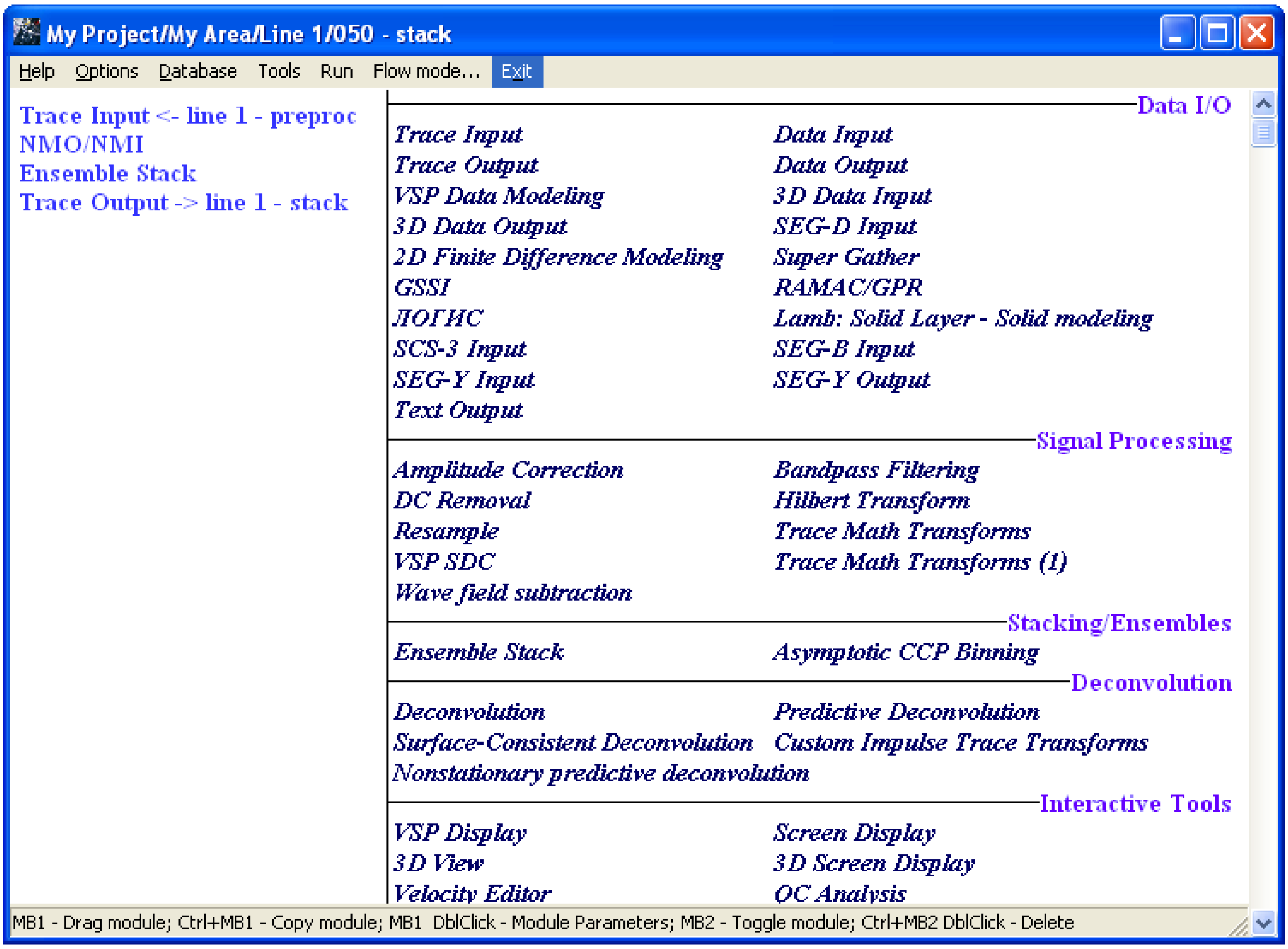


Finally, the **Trace Output** module should be the last one in the flow, it will save the results to the *line 1 – stack* dataset, which is also reasonable to be created at the second structural level of the database.

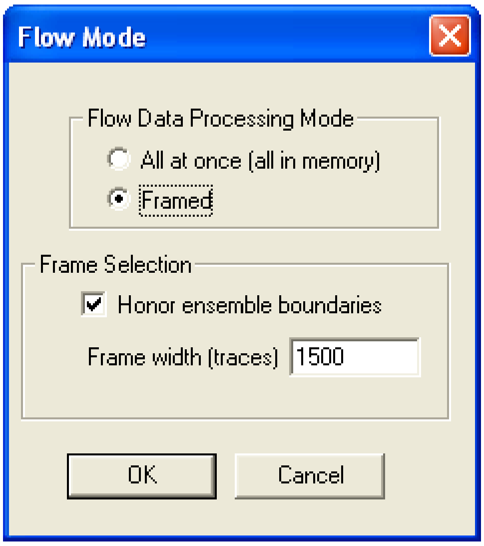




The flow looks now as shown on the following figure:



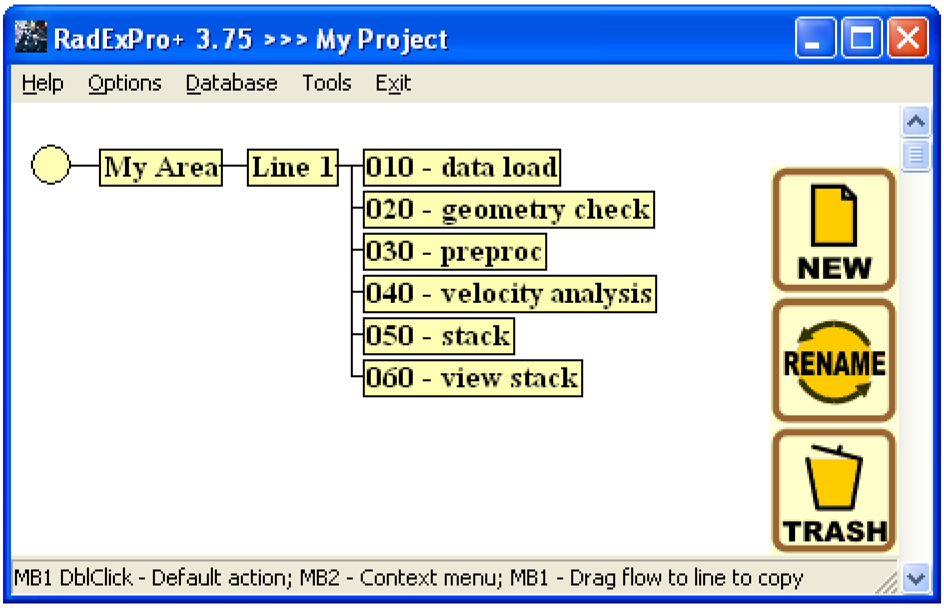
For executing this flow, switch on the framed mode. Set any reasonable frame width and make sure that the **Honor ensemble boundaries** option is on. This will ensure that each frame is completed until the last trace of the last ensemble in the frame.



Execute the flow.

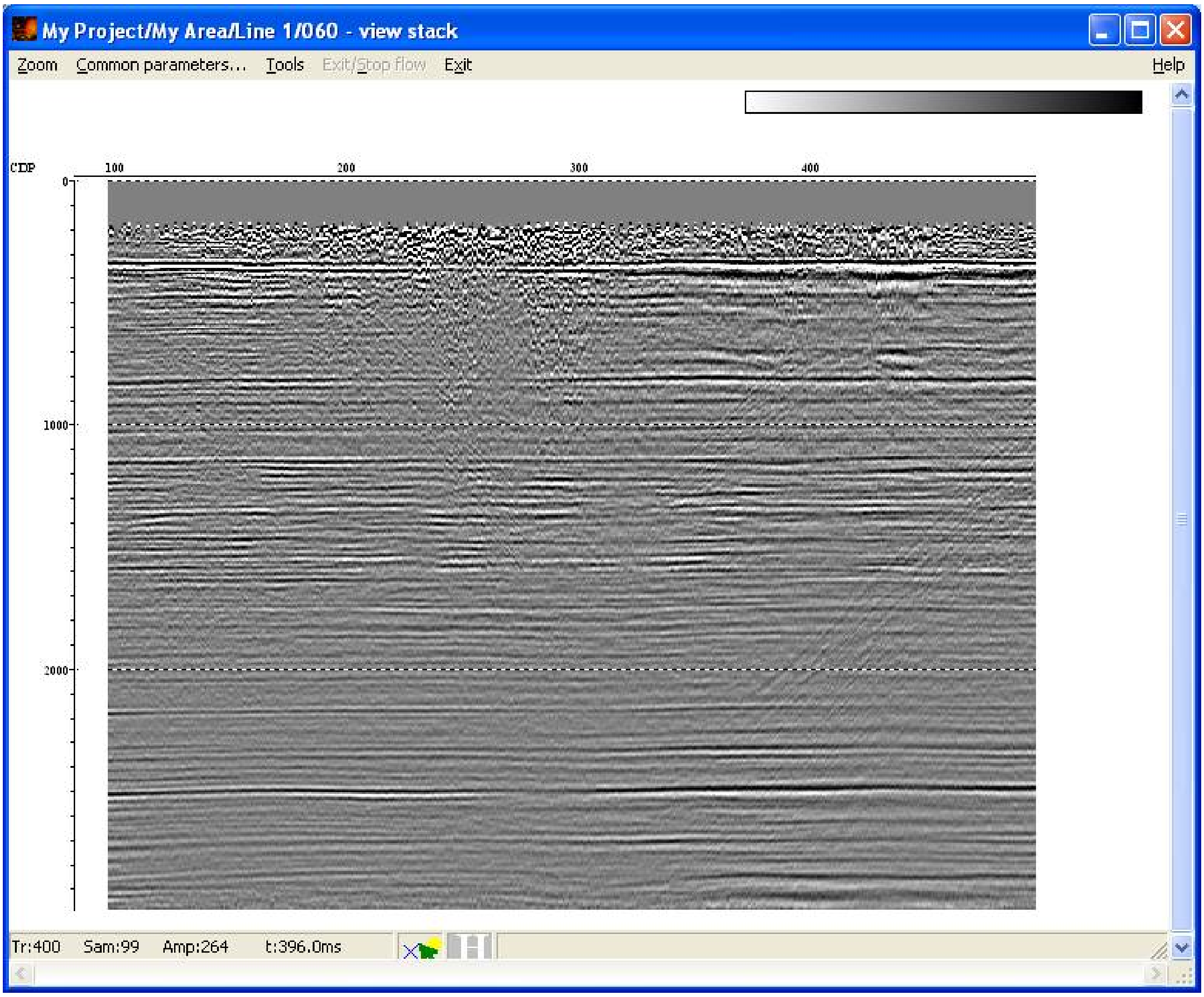
Display of the stack

Create the flow *060 – view stack*.



The flow should consist of the modules **Trace Input** and **Screen Display**. The **Trace Input** should read the obtained stack (*line 1 - stack*) sorted by CDPs.

The result should look approximately as shown on the following figure.


My Project/My Area/Line 1/060 - view stack
Zoom
Common parameters...
Tools
Exit/Stop flow
Exit
Help
CDP
100
200
300
400
0
1000
2000
Tr:400
Sam:99
Amp:264
t:396.0ms