Program for one-dimensional interpretation of data obtained by VES and VES-IP (ground and marine measurements).

ZOND-IP

User manual

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Program functionality

«Zond-IP» is a computer program for 1D interpretation of profile data obtained by various modifications of VES. Friendly interface and ample opportunities for data presentation allows solving assigned geological problem with maximum efficiency.

«Zond-IP» is an easy-to-use instrument for automatic and semiautomatic (interactive) profile data interpretation and can be used on IBM-PC compatible PC with Windows system.

Vertical electrical sounding method (VES) is one of the oldest methods of electrical exploration. It was first used in the twenties of XX century. Relative simplicity and clearness of VES caused its wide spread use and development all around the world [MSU, 2007].

Nowadays electrical soundings are still the most popular exploratory methods. Other modern technologies are based on VES. For example, electromyography is based on the same principles as “classical” electrical soundings. Contrast of object physical properties relative to host medium is required to use geophysical methods. For electrical resistivity exploration which includes VES it means that object (body, layer, stratum) resistivity must significantly differ from host medium resistivity [MSU, 2007].

Electrical resistivity (ER) (units are the ohm*meter (Om*m)) is a measure of how strongly rocks oppose the flow of electric current and is the most universal electromagnetic property. In rocks and ores it varies within wide limits: from 10^{-3} to 10^{15} Om*m. For the most widespread sedimentary, volcanic, and metamorphic rocks ER depends on mineral composition, physical-mechanical and water properties, salt concentration in groundwater, in a less degree on their chemical composition, and on other factors (temperature, depth of occurrence, metamorphism degree, etc.) [Hmelevskoj, 1997].

Electrical resistivity of minerals depends on their crystal bonds. Dielectric minerals (quartz, micas, feldspars, etc.) which mostly have covalent forces are characterized by very high resistivity (10^{12} - 10^{15} Om*m). Semiconductor minerals (carbonates, sulfates, haloids, etc.) which mostly have ionic bonds are characterized by high resistivity (10^{4} - 10^{8} Om*m). Clay minerals (hydromicas, montmorillonite, kaolin, etc.) have ion-covalent bonds and are characterized by quite low resistivity.

Ore minerals (native and some oxides) have electronic conduction and carry current very well. First two groups of minerals create “rigid” matrix solid material. Clay minerals create “plastic” matrix solid material that is able to adsorb bound water whereas rocks with “rigid” minerals can adsorb only solutions and free water (water that can be extracted from rock).

Electrical resistivity of free groundwater changes from Om*m unit fractions in case of high total salt content to 1000 Om*m in case of low one. Chemical composition of dissolved salts does not really matter that is why electrical exploration allows assessing only total salt content. Electrical resistivity of bound water that is adsorbed by solid particles of rocks is very low and does not change greatly (from 1 to 100 Om*m). Its constant mineralization (3-1 g/l) explains this fact. Average mineralization of ocean water is 36 g/l.

Pore water (bound and free) has very low electric resistivity in comparison to matrix of the majority rocks, that is why electric resistivity of rocks is almost independent of their mineral composition but depends on porosity, fracturing, and water saturation. Increase of their values causes decrease of electric resistivity because ion content in groundwater grows. This is the reason why electroconductivity of the majority of rocks is ionic (electrolytic).

Rise of temperature in 40^0 causes resistivity decrease in half. It can be explained by ion mobility increase. Resistivity of rocks increases unevenly at freezing as free water becomes almost dielectric and electroconductivity is determined only by bound water that freezes at very low temperatures (below -50^0 C). Increase of resistivity in different rocks while freezing varies: several times in clays, up to 10 times in hard rocks, up to 100 times in clay and sandy loams, and up to 1000 times and more in sands and coarse rocks.

Despite the fact that resistivity depends on numerous factors and varies within wide limits in different rocks, main laws of ER are well determined. Volcanic and metamorphic rocks are characterized by high resistivity (from 500 to 10000 Om*m). Among sedimentary rocks high resistivity (100 – 1000 Om*m) can be found in rock salts, gypsums, limestones, sandstones, and some other rocks. As a rule, in detrital sedimentary rocks the more grain size is the higher resistivity rock has, that is ER depends on clayiness on the first place. In passing from clays to clay and sandy loams and sands resistivity changes from unit fractions and first Om*m to tens and hundreds of Om*m [Hmelevskoj, 1997].

Polarizability coefficient expresses ability of rocks to polarize that is to accumulate charge during passage of current and discharge then after current interruption. Coefficient η is measured in percents as ratio of voltage that remains in potential circuit some time after current interruption (usually 0.5-1 sec.) to voltage in this circuit during passage of current.

Polarization is a complex electrochemical process that progresses in rocks during passage of direct or low-frequency alternating (up to 10 Hz) current. Ores with electronic conduction (sulphides, sulphosalts, some native metals, individual oxides, graphite, and anthracite) are characterized by the highest polarizability. These IP potentials origin is connected with so called concentrated and electrode polarization of ore minerals. Polarizability coefficient is up to 2-6 % above water-encroached loose sedimentary rocks where clay particles are present. Their polarizability is caused by deformation of external plates of double electrical layers which form at solid-liquid contact. The majority of volcanic, metamorphic, and sedimentary rocks saturated with mineral water have low polarizability [Hmelevskoj, 1997].

The main idea of VES is quite simple. Electrical array is assembled on the ground. It usually contains two current and two potential electrodes (fig. 1).

Electrical field and current respectively arises in the ground. ***Amperemeter*** cut in the circuit is used to measure current strength in current circuit. ***Voltmeter*** is used to measure electric potential difference which arises in potential electrodes M and N.

Electrical properties of rocks located within depth of current penetration can be judged by exploration results. Depth of current penetration depends mainly on distance between current electrodes.

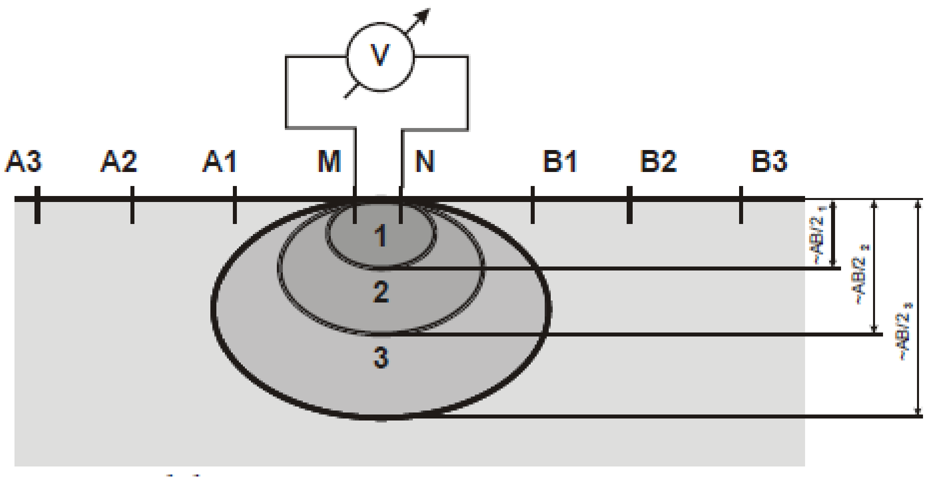


Fig. 1 Scheme of VES measurements

Apparent resistivity is calculated on basis of measurement results [MSU, 2007].

The program solves forward and inverse problems for arbitrary arrays on the surface of horizontally-layered medium. Layer thickness (in meters), electrical resistivity (in Om*m) and polarizability (in percent) are layer parameters.

Potential of point source is calculated using the following equation when solving forward problem:

$$U(r) = \frac{\rho}{\pi}\left(\frac{1}{r} + \int_0^\infty R(m) \cdot J_0(mr)dm\right)$$

Apparent polarizability is calculated using Komarov-Seigel:

$$\eta_\kappa = \frac{\rho_K(\rho)}{\rho_K[\rho \cdot [1 + \eta/100]]} \cdot 100\%$$

System requirements

«ZOND-IP» program can be installed on PC with OS Windows 98 and higher. Recommended system parameters are processor P IV-2 GHz, memory 512 Mb, screen resolution 1024 X 768, color mode – True color (screen resolution change is not recommended while working with data).

As far as the program actively uses the registry, it is recommended to launch it as administrator (right click on program shortcut – run as administrator), when using systems higher than Windows XP.

Program installation and deinstallation

«ZOND-IP» program is supplied on CD or by internet. Current manual is included in the delivery set. Latest updates of the program can be downloaded from website: www.zond-geo.ru.

To install the program copy it from CD to necessary directory (for example, Zond). To install updates rewrite previous version of the program with the new one.

Secure key SenseLock driver must be installed before starting the program. To do that open SenseLock folder (the driver can be downloaded from CD or website) and run InstWiz3.exe file. After installation of the driver insert key. If everything is all right, a message announcing that the key is detected will appear in the lower system panel.

To uninstall the program delete work directory of the program.

Program registration

For registration click “Registration file” item of the main menu of the program. When a dialog appears, fill in all the fields, select registration file name, and save it. Created file is transmitted to specified in the contract address. After that user receives unique password which is connected with HDD serial number. Input this password in “Registration” field. The second option is to use the program with supplied SenseLock key inserted in USB-port while working. Install device drivers before working with SenseLock key.

Adopted definitions

Ro_a – apparent resistivity, $\rho_a = G \cdot \frac{\Delta U}{I}$, where *G* is array coefficient.

Eta_a – apparent polarizability, $\eta_a = \frac{\Delta U^{ВП}}{\Delta U^{ПР}} \cdot 100\%$, in percent.

Separation: *AB/2* for Schlumberger, Wenner and symmetrical array; *AM* for two-electrode array; *AO* for three-electrode array; *O'O* for dipole-dipole array.

Pseudodepth – approximate investigation depth connected with array coefficient (array separation in this case).

Sounding site – position of current circuit center for Schlumberger, Wenner and symmetrical array; for other arrays sounding site is indefinite (usually it is position of fixed electrode).

All geometric values are specified in meters.

Creation and opening of data file

To start up «Zond-IP» it is necessary to create data file of certain format which contains information on acquisition geometry and measured values of apparent resistivity and polarizability. One profile data usually corresponds to one file.

In case of using multi-electrode arrays it must be remembered that sounding curve is considered as data element in «Zond-IP» program. That's why data should be represented as a set of sounding curves.

Text data files of «Zond-IP» format have «*.zlf», «*.zlp» and «*.ves» extensions. The program also supports files of induction sounding with vertical magnetic dipole format *.vmd. See **data file format** for details. The program also supports text files of IPI2WIN program.

For correct running of the program data file must not contain:

- curves with less than 3 separations;
- incorrect symbols of records separator (TAB and SPACE use only);
- absurd data values.

Desirably, total record number should be no more than 5000 in one file.
Model of previous interpretation loads together with field data while opening «*.zlp» file.

Data file format

Program presents universal data format which contains information on array geometry, coordinates and relative elevations of sounding stations.

«Zond-IP» *data files* have *.zlf extension.

First three lines contain information on measurement parameters which are the same for the whole profile.

First line – must contain the following records separated by space or tab.

First record – is reserved by «ZondIP1d» program for frequency or seabed operations (8 values). Second record – (0-5) – type of array:“0” – Schlumberger, Wenner (length of potential circuit must be specified for it), three-electrode array; “1” – dipole-axial array; “2” – two-electrode array; “3” – three-electrode multi-purpose array; “4” – four-electrode multi-purpose array; “5” – any multi-purpose array (fig. 2).

Sequence of records in line for different arrays is as follows:

“0” – 0 0 1 (third record specifies shift of potential circuit relative to current circuit along Y axis (set if necessary, usually in case of IP measurements in frequency mode)).

“1” – 0 1 Len_dip, where Len_dip – length of current circuit.

“2” – 0 2.

“3” – 0 3 delt_y dircosX dircosY, where delt_y – shift of observations profile along Y axis, dircosX and dircosY – direction cosines of potential circuit.

“4” – 0 3 Bx By delt_y dircosX dircosY, where Bx and By – coordinates of second current electrode, delt_y – shift of observations profile along Y axis, dircosX and dircosY – direction cosines of potential circuit.

Multi-purpose arrays (3, 4). Coordinates of first current electrode is equal to zero. Separations are set without regard to shifts relative to first current electrode. Measurements are performed along X axis in positive direction. Direction cosines specify orientation of potential circuit relative to profile. Shift of observations profile is performed in positive direction along Y axis. Generally speaking multi-purpose arrays are not needed (in the latest version of the program). They can be replaced by arbitrary array of type (5).

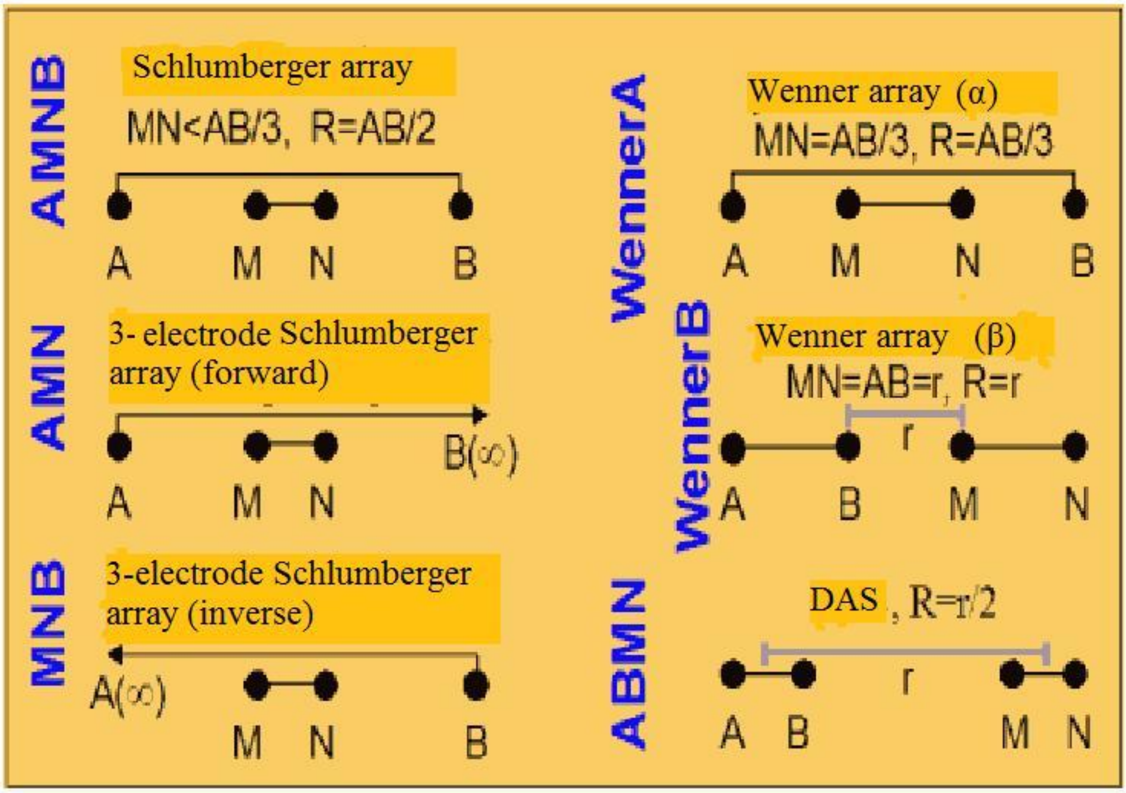


Fig. 2 VES arrays

If seabed measuring system is selected, that is all electrodes are located on the bottom, then first line must contain number 8. Water resistivity is set in the next line after key "water". Sounding depth is specified in sounding description block instead of elevation value, with negative sign. Example of bottom system description:

8 0

Water 30

Second line – contains measurement separations. For arrays of type "0", "3" and "4" separation is equal to distance between first current electrode and center of potential circuit. For dipole-axial array (1) it is equal to distance between dipole centers. User can define separations himself for arbitrary array (5). For two-electrode array (2) it is equal to distance between potential and current electrodes.

If arbitrary array is used then its description is as follows.

Arbitrary array of type "5" implies definition of current and potential electrodes positions explicitly. When describing this type of array, X and Y electrode coordinates must be specified in lines which follow separation description. Separations are user-specified, that is random (they are used for curves visualization only). Electrode coordinates are set in lines which start with certain key that explains the program what type of coordinate they contain and to which electrode they refer. The following keys are available: Ax, Ay, Bx, By, Mx, My, Nx, Ny. If electrode is missing then it value is replaced by * symbol. Y coordinates are specified only if necessary. Example of type “5” array description:

0 5

1 2 3 4 5 // separations – user-specified.

Ax -1 -2 -3 -4 -5 //X –coordinates of A electrode for each separation.

Bx -2 -3 -4 -5 -6 //X – coordinates of B electrode for each separation.

Mx 1 2 3 4 5 //X – coordinates of M electrode for each separation.

Nx 2 3 4 5 6 //X – coordinates of N electrode for each separation.

As you can see Y electrode coordinates are missing in this example. They can be specified in the same way as X coordinates.

Third line – can contain values of potential line separations.

If third line is missing then potential line separation are considered infinitesimal. It is recommended to specify potential line separations as long as the program takes into account potential line length for forward problem solution. For arbitrary array (5) this line is not set.

User can view array geometry on plan (main menu option Electrodes array).

If complex arrays with changing from station to station separations are used then all unique pairs (separations of potential and current line) present on profile must be specified in the second and third lines according to above mentioned rules.

Sounding station description blocks follows. They contain information on each sounding site on profile.

Sounding station description block

First line – indicates beginning of sounding station description block (must contain «{» symbol).

Second line – sounding station name.

Third line – supplementary sounding parameters.

First record – sounding station coordinate along profile. Second record – relief elevation or depth (positive number for ground survey and negative - for seabed (in meters)).

Fourth and fifth lines contain field data.

Each line must start with code-key which shows the program what type of data follows this key.

Keys which control data type have the following values:

«Ro_a» – apparent resistivity.

If seabed system (8) is used then in order to avoid mistakes normalized signal (measured signal to current ration) is specified in this line.

«Eta_a» – apparent polarizability.

If «_w» is added to the key then certain measurement weights are specified in current line.

Number and order of records in lines must strictly correspond to separation geometry described in the second line of the file. If measurement at any separation is missing then its values is replaced by «*» symbol.

Sixth line – indicates end of sounding station description block (must contain «}» symbol). Description of the next sounding station follows starting with «{» symbol and so on.

The program also supports files with the extension *.ves. This format is useful for the field data preparation in a text editor. Below is an example of the file format *.ves:

```
frequency 4.88
name: pr1pk1
XYZ: 10 0 0
ab/2 mn rk
1     1  100
2.5   1  101
5     1  90
8     1  80
10    1  70
25    1  80
50    1  90
80    1  101
name: pr1pk2
XYZ: 10 10 0
```

The first line contains the frequency (Hz), the second - the site name, the third line indicates the coordinates followed by a table of layout parameters and values of apparent resistivity. After the block containing the information for the first point, the next block for the next point follows. It starts with the field NAME, etc.
The field names in the file can be written both in Russian and in English. Values of the polarizability can also be specified.

```
frequency 4.88
name: 1
X 10
Y 0
Z 0
ab / 2 mn rk nk
1 1 100 2
2.5 101 2
5  1 90  2
8 1 80 2
10 1 70 2
25 1 80 2
50 1 90 2
80 1 101 2
```

This format is automatically generated by the program when selecting File/Save data/Observed data files. In the created file all changes made during editing of data are recorded.

Zond-IP supports files of induction soundings with vertical magnetic dipole format *.vmd. These files contain information about the geometry of the setup, the location and height of sounding sites.

The first line - should contain the source/receiver height.
The second line - should contain values of separations (distance between the receiver and the source dipole) on which the measurements were made, sorted in ascending order.
The third line - should contain frequencies (Hz) at which the measurements are made, sorted in descending order.

When using complex observing systems with varying from point to point separations, the second line has to contain all the unique separations that were used on the profile formatted according to aforementioned rules.

Following records contain information about every sounding site on the profile, combined in blocks as described below.

Sounding station block description

The first line - indicator of description block starting of sounding sites (should contain the entry "{").

The second line – name of sounding site.

The third line - additional parameters of sounding.

The first record - coordinate sounding site along the profile, the second record - the excess relief (positive number, the minimum height is equal to 0, the other is calculated as the excess over it (in meters)).

The fourth and following lines contain actual the field measurements. Each line must start with code-key which shows the program what type of data follows this key.

The values of the control keys controlling the type of data:

«Hz / Hr" N "» - relationship of magnetic field components measured at a frequency recorded under number N in the third line of the file.

The number and sequence of records in the rows must strictly conform observing system described in the second and third lines of the file. In absence of measurement at any separation, its value is replaced with the symbol "*". In absence of measurements on some of the frequencies, the row with index of this frequency is skipped.

If «_w» is added to the key - in this line, the set weight of individual measurements. **The last line** - the end indicator of the sounding site description (must contain the entry "}"). Recording stations should be carried out in the same sequence as they are located on the profile (in the coordinate ascending order).

Field data entry dialog (VEZ Notepad)

The dialog is meant for new data entry and can be found in the main menu of the program **File/VEZ Notepad**. Figure 3 shows dialog window of **VEZ Notepad** option.

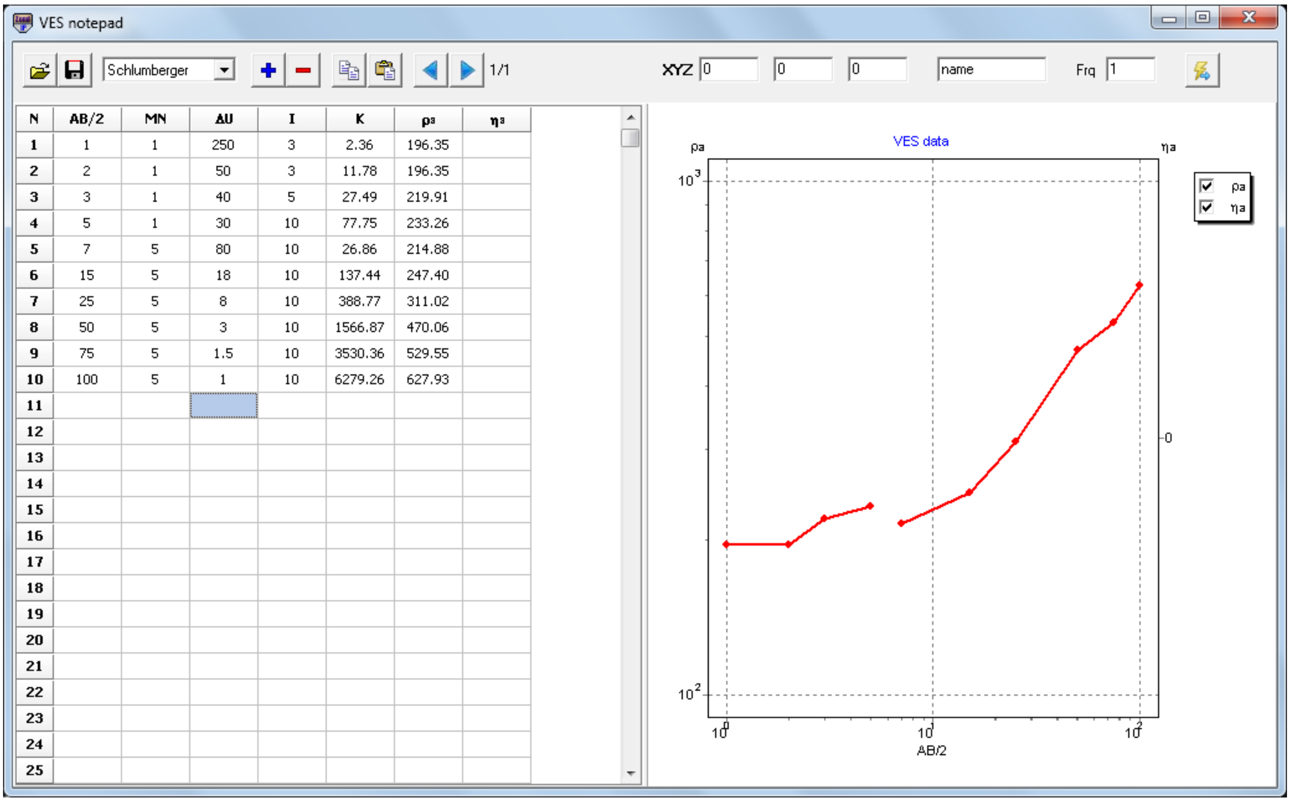
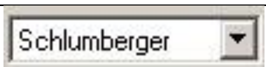
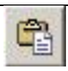


Fig. 3 Dialog window **VEZ Notepad**

Main menu of the window contains the following buttons:

	Open data file for single sounding or data base for several in *.txt format
	Save file for single sounding or data base for some soundings as *.txt format
	Select array type.
	Add sounding point.
	Delete sounding point.
	Copy data in a table
	Paste data from buffer (copied, example, in MS Excel)
	Proceed to next point.
	Start inversion.

It is possible to copy data from MS Excel to the program table.

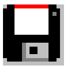
Use XYZ field to specify coordinates of sounding station and its name (field *«name»* in fig. 3).

Field **Frq** – set of current frequency. It allows performing calculation taking account frequencies. It is recommended to use when current frequencies are more than 20 Hz.

Table in the left part of the window contains the following graphs. First one or two columns (depending on array type) are meant for array geometry specification. For Schlumberger array: AB/2 is equal to half of current line length, MN is potential line length; for three-electrode Schlumberger array: AO is equal to AN/2, MN is potential line length; for Wenner array AB/2 is equal to half of current line length; for dipole-dipole array OO is distance between centers of current and potential line, MN is current line length; for pole-pole array AO is equal to distance between current electrode and array center. Next columns contain measurement data: ΔU – voltage, I, A – current strength, K – array coefficient (calculated automatically), ρ_a, Om*m – apparent resistivity (can be specified or calculated automatically), η_a – apparent polarizability.

Use  button to create new sounding site. When all parameters are set, press  button to start inversion.

Interpretation results saving

Profile interpretation result is hold in *Zond-IP project files* (extension *.zlp). This file contains name of file with field data, fitted parameters and parameters variation limits for each sounding. Use  button in the tool bar or corresponding menu option to save interpretation result. If autosave option is on interpretation result is saved automatically in selected periods of time. Theoretical curves can be also saved in *.zlf format.

There are a few options to save data:

Project data file	Save measured values and current subsurface model.
Calculated data file	Save calculates values.
XYZ model	Save subsurface model as table file.
Section file	Save current model in Section format. This file type can be used as background.
Project with calculated	Replace the observed data with calculated in the project.

Model in columns	Save current model as parameters table in DAT format.
Observed data files	Save observed data file taking account made editing (*.ves extension)

Data export

«ZOND-IP» allows exporting data to MS Excel, Auto CAD and also creating file for further using in other Zond programs. This function can be found in **File/Export to** tab.

The following options for data export are available:

Excel report	Create a file containing reporting information for each sounding sites, measured and calculated data, coordinates of sounding site, parameters model, etc.
Excel map	Create a file containing station names, their coordinates and the resistivity values (calculated) and bottom position of each layer on each sounding point (useful creating area maps of parameter distribution).
CAD section	Models export in Auto CAD file with *.dxf extension.
Pseudo BH data	Create a files set corresponding sounding points, in the borehole data format
MOD1D file	Save model as a *.mod1d file for further using in other Zond program.

When selecting **Export/Pseudo BH data** creates a data set in format of log data and lithology. These data are useful as, for example, supporting data for other methods interpretation of Zond programs, or for data interpretation on adjacent profiles. In this case, the data is loaded as lithologic columns. Their color scale is corresponding to the resistivity values (Fig. 4).

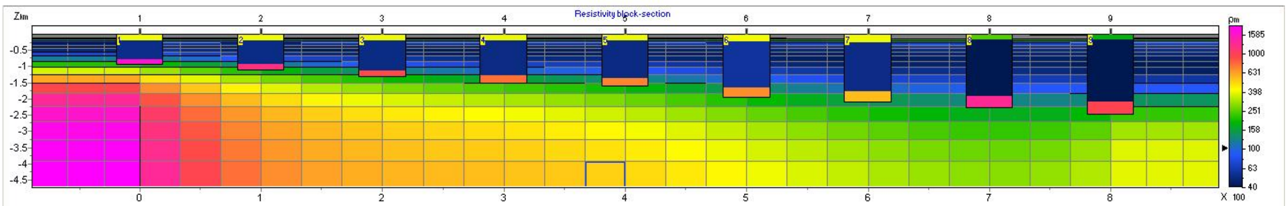


Fig. 4 Example of the option using Export/Pseudo BH data

To compare the results of different methods it is possible to use MOD1D file export function. When using the file in another Zond program or for other profile in areal survey saved in a such way model will be loaded as a new model.

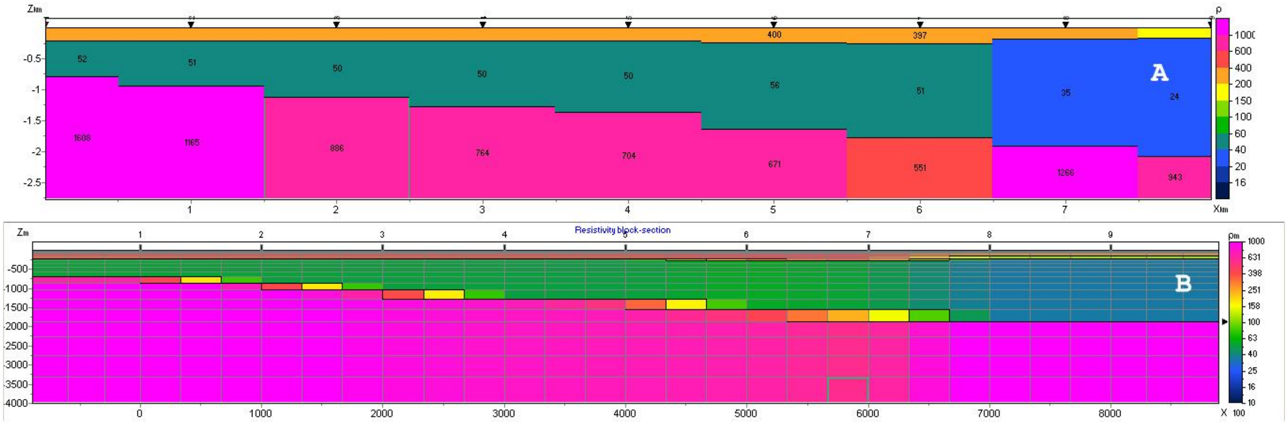


Fig. 5 Example of using option Export/MOD1D file. A - the original model, B - the result of importing file *.MOD1D in ZondMT2D program

Program workflow guide

Program Main Window

When «*.zlf» file is created, load it using button or corresponding menu item. After successful loading of the file functional buttons to work with data are activated in the main window toolbar and short information on first sounding station appears in the right section of status panel (fig.6). While moving the cursor in created windows, coordinates which correspond to axes in every window are displayed in the left section of status panel. Use the first system button of the window, marked in plan as “objects setup”, to open context menu which allows running setup dialog for each object in the window. Methods of editing are described in detail in the following chapters (**Model editor**, **Section**, **Parameters table**, **Pseudosection**, **Profile plot**, **Graph of theoretical and observed curves**).

Second and third buttons serve to proceed from one sounding station to another.

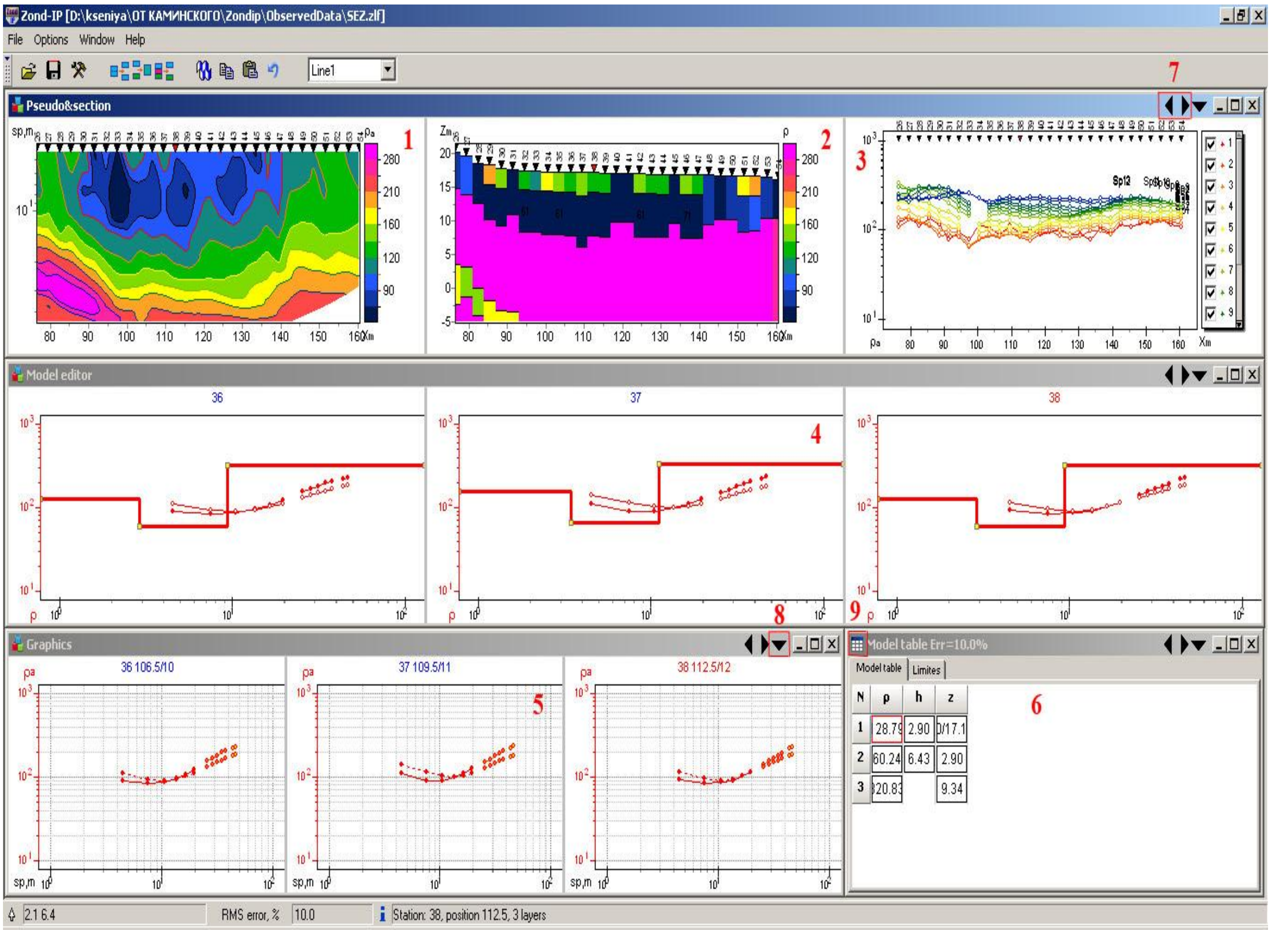


Fig. 6 Program main window. Numbers mark the following windows: 1 – pseudosection,

2 – section, 3 – profile plots, 4 – model editor, 5 – graph of theoretical and observed curves, 6 – parameters table; 7 – buttons to proceed from one sounding station to another, 8 – objects setup button, 9 – advanced options button.

Style sheet

Use tab **Widow** in program main window to select style. Library has four options of objects configuration.

In **Interpretation** style (fig. 6) user simultaneously operates with four windows: first one contains pseudosection, section and profile plots (displayed parameter can be chosen), spaced by floating slider; the second one contains graphs (from one to three) of model setup; the third window contains parameters table, and the fourth - graph of theoretical and observed curves.

Graph of theoretical and observed curves and profile plots window are absent in **Standard** style.

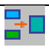
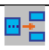
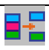
Graph of theoretical and observed curves is absent in **Profile** style.

One window is used instead of two first windows in **User** style. User specifies parameters to display objects.

Options **Tile vertical** and **Tile horizontal** allow changing the location of the program open working windows. Option **Default** resets of windows settings to the default for the selected viewing style.

Main Window Toolbar

The toolbar is meant for quick run of the most frequently used functions. It contains the following functional buttons (from left to right):

	Open data file
	Save interpretation result or calculated curves.
	Run parameters setup dialog.
	Merge two layers with summary thickness.
	Add layer. User-selected layer is divided into two layers with equal thicknesses (in logarithmic scale).
	Delete selected layer.
	When clicking the **right** mouse button: display a pop-up menu in which it is necessary to choose for which items inversion will be performed: *current* - for current point, *to end* - from the current point to the profile end, *to start* - from the current point to the profile beginning. By clicking with the **left** mouse button inversion starts for the selected profile area or the current point
	Copy model at current stake to buffer.
	Paste model from buffer and use it at current station [left click] or at all following stations [right click].
	Cancel previous step.
	Select profile (when working with areal data).

Main menu functions

The following table lists items found in the Menu with their corresponding functions:

File	Open data	Open «*.zlf» or «*.zlp» data file.
File	Save data	Save interpretation result or theoretical curves.
File	Edit data	Open and edit currently used data file in Notepad.
File	Program setup	Run parameters setup dialog.
File	Project information	Open dialog of adding new information about the current project (Company name, work place, the project name, equipment, operator, etc.).
File	Load MOD1D/2D	Load model file *.mod1d or *.mod2d format, saved before in other ZOND programs.
File	Export to	Export data. It is available some export options of calculated and field data (more).
File	Print preview	Run print dialog of model and data (more).
File	Registration file	Create registration file.
File	Registration	Enter registration password.
File	Russian	Program menu in Russian.
File	English	Program menu in English.
File	Recent	Open one of recently opened projects.
File	Exit	Exit program.
Options	VEZ Notepad	Open field data entry dialog (more).
Options	Set lines/coordinates	Set profile line (when working with areal data).
Options	Plane data	Display contour map of selected parameter (more). Recommended for areal data.
Options	BiLog equal scale	Set equal logarithmic scale for axes in windows displaying sounding curves.
Options	3D sections	Run dialog of 3D model visualization. Works with areal data (more).
Options	Load borehole data	Load lithology file.
Options	Create/Edit borehole data	Create/edit lithology file (more).
Options	Remove borehole data	Delete lithology file.
Options	Set boundaries	Set geological boundaries (more).

Options	Smooth model	Smooth model
Options	MT Data	Module of joint interpretation of MT (AMT, RMT) and VES data. (more)
Buffer	Model 1,2…5	Save 1 to 5 calculated models in buffer for further using.
Buffer	Open	Open in a single window saved models (more)
Window	Tile vertical	Order windows vertically.
Window	Tile horizontal	Order windows horizontally.
Window	Zond “Standart”	Load “Standart” style.
Window	Zond “Profile”	Load “Profile” style.
Window	Zond “User”	Load “User” style.
Window	Zond“Interpretation”	Load “Interpretation” style.
Window	Default	Set default parameters for current style
Help	About	About program.
Help	Context	Display manual.
Help	Check for updates	Check upgrades on zond-geo.ru
Help	Error! Clear setting	Restart program when appearances error

“Hot” keys

[Space]	Run data inversion process for current station.
[S]	Add layer. User-selected layer is divided into two layers with equal thicknesses (in logarithmic scale).
[M]	Merge two layers with summary thickness.
[D]	Delete selected layer.
->	Proceed to next station.
<-	Return to previous station.
[Escape]	Stop inversion process.

Program setup dialog

The dialog serves to adjust autosaving options and specifics of starting model definition, set default values and inversion parameters. Use  button in the toolbar or corresponding menu item (**File/Program setup**) to run it.

Tab Options

Tab Options

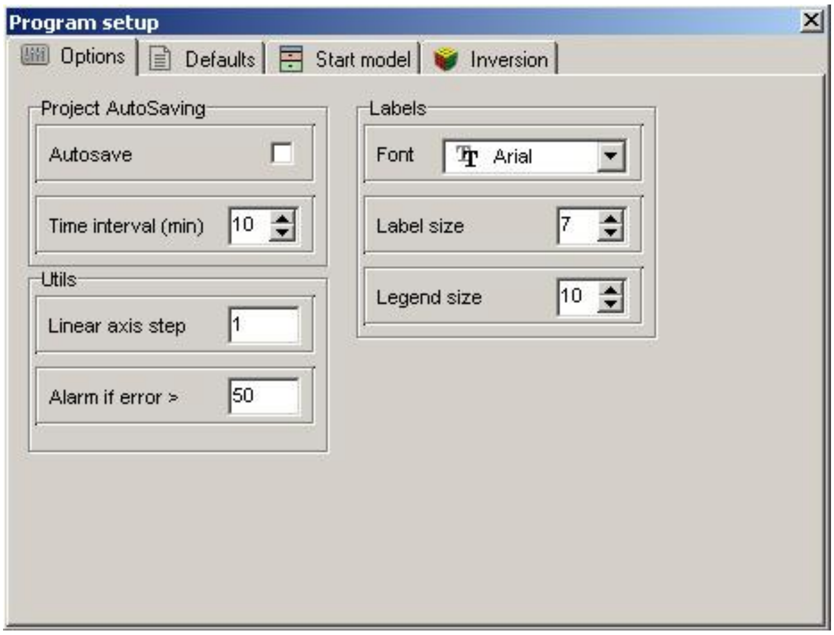


Fig. 7 Window **Program Setup**, tab **Options**

Field **Project AutoSaving** – sets autosaving mode for open project.

Option *Autosave* enables autosaving for open project in certain time intervals.

Field *Time interval* sets time interval (in minutes) for autosaving (file is saved with the same name but with “Temp” added).

Field **Labels** – sets parameters of used fonts.

Field *Font* sets font style for marks on axes, curves, etc.

Field *Label size* sets font size for marks on axes, curves, etc.

Field *Legend size* sets font size used to display parameters names.

Field **Utils** – sets additional parameters.

Field *Linear axis step* sets necessary step for axes. This option is used for axes scaling.

Field *Alarm if error >* runs confirmation dialog of profile inversion if station value of RMS error exceeds specified in the field value.

Tab Defaults

This tab serves to set different parameters used while working with model. Rows correspond to types of layer parameters (properties and thickness), columns correspond to options (fig. 8).

First row *Value* – default values (used for starting model).

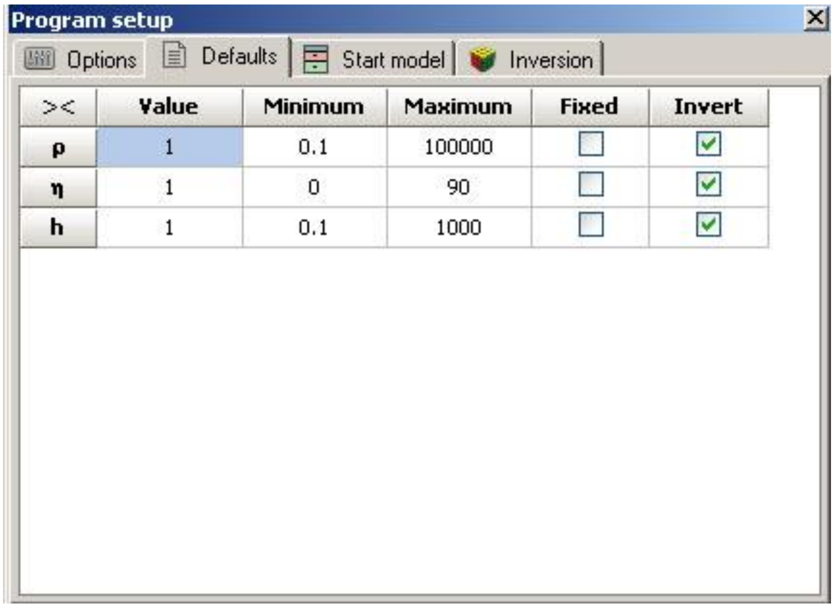


Fig. 8 Window **Program Setup**, tab **Defaults**

Second column *Minimum* – smallest extreme of default parameters (used for parameters fixing).

Third column *Maximum* – superior limit of default parameters (used for parameters fixing).

Forth column *Fixed* – defines if parameter of specified type should be fixed after file reading or not. This option is not available in case of loading project file.

Fifth column *Invert* – defines if parameter is corrected during inversion or not.

Tab Start model

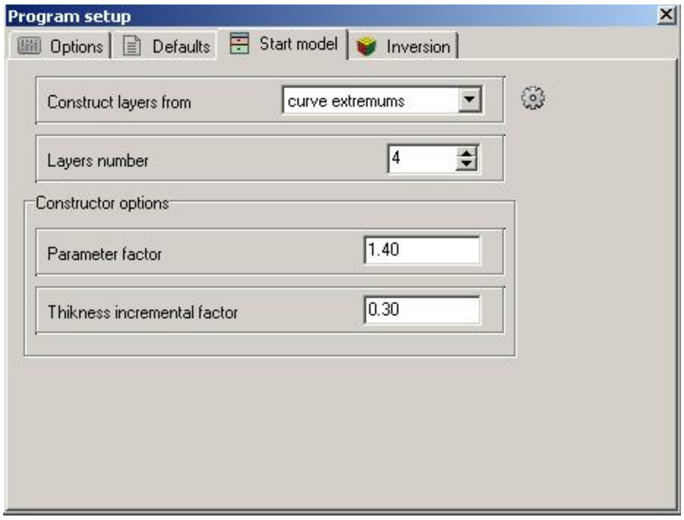


Fig. 9 Window **Program Setup**, tab **Start model**

Current tab is used as starting model constructor during field data reading.

Field **Construct layers from** sets algorithm which determines positions of layer boundaries.

Value *Curve extremums* – boundary positions are determined by field curves (from extremum analysis). Maximum number of layers is specified in *Layers number* field.

Value *incremental factor* – default values are used to specify thickness of layers. Thickness of each layer is equal to thickness of the previous one multiplied by *Thickness incremental factor*. Number of layers is specified in *Layers number* field.

Field **Constructor options** contains options used to specify starting model parameters.

Field *Parameter factor* sets coefficient which maximums are multiplied by and minimums are divided by (ranges from 1 to 4). This coefficient increases starting model contrast which is very important if curves do not have asymptotes.

Field *Thickness incremental factor* – sets coefficient which layer thicknesses are multiplied by (ranges from 0.2 to 1) or coefficient of thickness increase for each following layer in *incremental factor* mode (ranges from 1 to 2).

When starting model parameters are set use  button to apply them to current project without closing parameters setup window.

Tab Inversion

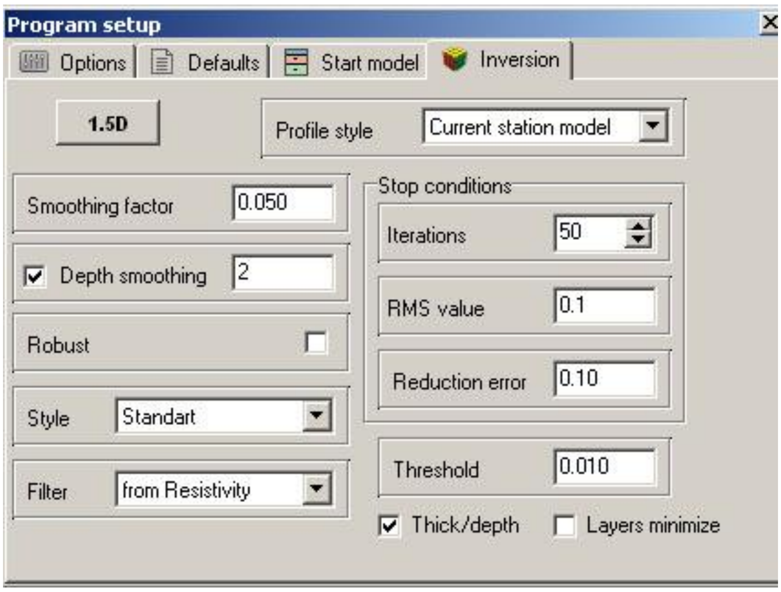


Fig. 10 Window **Program Setup**, tab **Inversion**

Field **Profile style** sets inversion style of profile inversion.

Value *Current station's model* – current station model is used as starting model for inversion.

Value *Start station model* – model of inversion start station is considered to be starting model for inversion for all other points.

Value *Previous station's model* – previous station model is used as starting model for inversion.

Field **Smoothing factor** sets staring value of smoothing parameter. It depends on many factors: condition number of Jacobian matrix, signal to noise ratio of data, and number of model parameters definitions. It is an empiric value. For noisy data or for smooth parameters distribution greater values of smoothing factor are chosen: 0.05 – 10; for precise measurements it ranges from 0.005 to 0.01.

Models created using three different values of smoothing factor (0.01 – blue, 0.1 – red, 1 – black) are shown below (fig. 11).

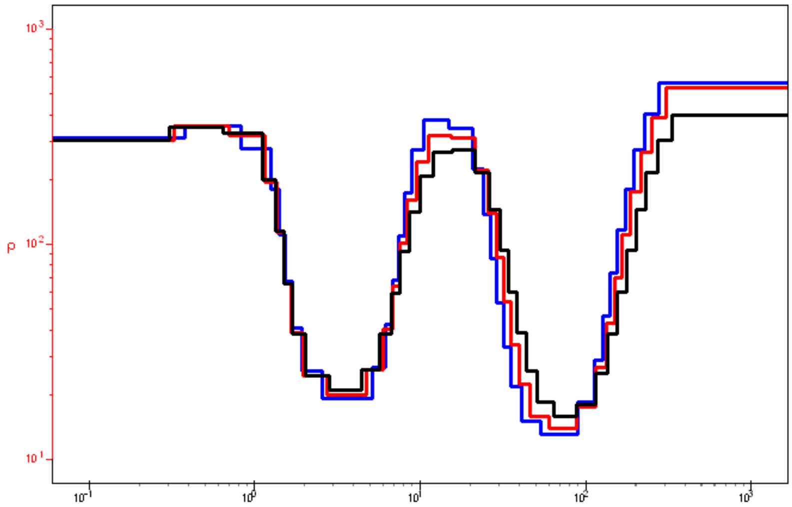


Fig. 11 Models with different values of
Smoothing factor (0.01 – blue, 0.1 – red, 1 – black)

Field **Stop conditions** sets rules which stops inversion.

Field *Iteration* sets maximum number of iterations. Automatic interpretation process stops when it's achieved.

Field *RMS value* sets minimum RMS error. Automatic interpretation process stops when it's achieved.

Field *Reduction error* sets discrepancy value. Inversion process stops if this value repeatedly increases (in specified value (%)) for three sequential iterations.

Option **Depth smoothing** sets degree of model depth smoothing (if this option is on). The greater its value is (1 – 10) the more parameters of adjacent layers are averaged with depth. This option is used if *Smooth* field is chosen in procedures of section parameters recovery window **Style**.

Option **Robust** – this option is used if data contain certain significant errors, connected with systematic measurement errors.

Option **Style** sets type of procedure for section parameters recovery.

Value *Smooth* – inversion by least-square method using smoothing operator and complementary contrast minimization. This algorithm results in the smoothest parameters distribution. This type of inversion is recommended for initial stages of interpretation. But number of model layers must significantly exceed number of layers in real model. It is preferable to have more than 10 layers of fixed thickness.

Value *Standard* – inversion by least-square method using damping factor regularization. It results in model with sharp boundaries. Careless usage of this algorithm leads to results instability and increase of RMS increase. The best option is to consider this algorithm specifying and use it after inversion by *Smooth* algorithm.

Value *Focused* – inversion by least-square method using smoothing operator and additional contrast focusing. It results in piecewise smooth parameters distribution, that is model consists of layers with equal resistivity. This type of inversion is recommended for initial stages of interpretation. But number of model layers must significantly exceed number of layers in real model. It is preferable to have more than 10 layers of fixed thickness.

Careless usage of this algorithm leads to algorithm discrepancy and model instability.

Figure 12 shows models created using three different inversion algorithms (standard – black, focused – blue, smooth – red).

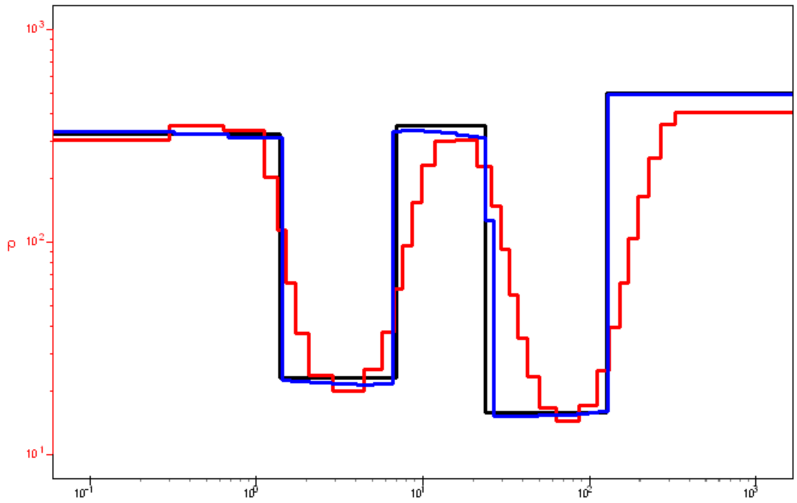


Fig. 12 Models created using different inversion algorithms (*Standard* – black, *Focused* – blue, *Smooth* – red)

Option **Threshold** sets maximum contrast value of adjacent layers. When this value is achieved parameters of adjacent layers are not averaged (thus boundary is considered to exist between layers). It's an empiric value (0.001-1). Low values of this parameter lead to algorithm discrepancy (it's recommended to increase it). High values result in smooth distribution.

Figure 13 shows models created using two different values of parameter *Threshold* (0.01 – black, 0.1 – red).

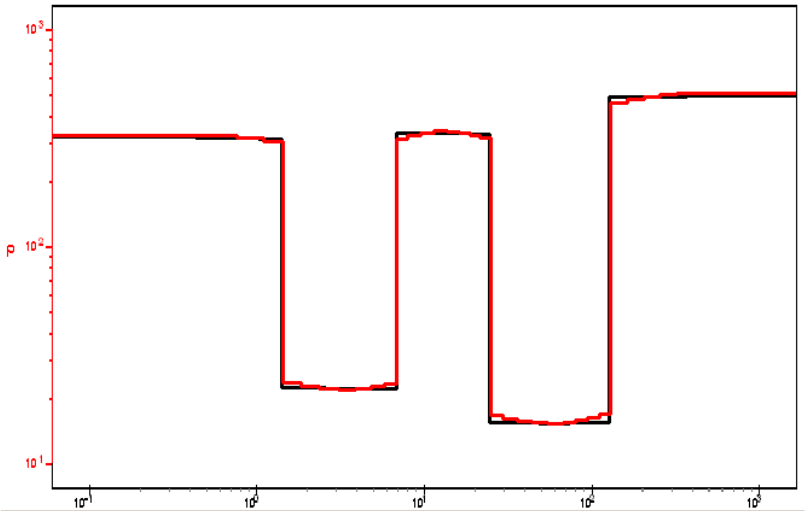


Fig. 13 Models created using two different values of contrast parameter ***Threshold*** (0.01 – black, 0.1 – red)

Option **Layers minimize** sets minimum number of layers. It is used combined with multilayered section and focusing inversion. This algorithm minimizes number of layers. Multilayered (10-15 layers) model and focusing inversion are chosen (smoothing factor~0.1).

During inversion layers with similar parameter are merged and inversion process continues with lower number of layers.

Option ***Thick/depth*** sets thickness (if this option is active) or depth (if not) fitting. Depth fitting is useful if depths of boundaries are known and fixed. It is recommended to assign depth default values for profile inversion with depth fitting.

Option ***Filter*** sets the way to create focusing filter.

Value *from Resistivity/from Polarizability* – filter for all types of parameters is created basing on apparent resistivity/apparent polarizability model.

Value *from any* – filter for each type of parameters is created basing on this parameter model.

Button 

runs dialog of special profile inversion algorithm.

For this algorithm subsurface model is considered to be horizontally layered or near-horizontally layered (with smooth boundaries) at the bottom. Top part of the section can change greatly from point to point (fig.14). A few adjacent soundings which have common bottom part and variable top part are used for inverse solution. Fitting is conducted simultaneously for all curves in the window and central point has the greatest weight for discrepancy calculation (fig.15).

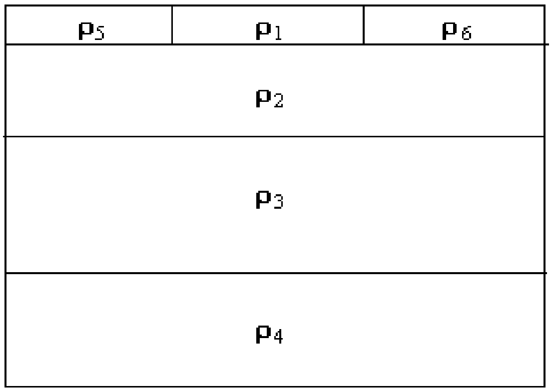


Fig. 14 Sunsurface model for 1.5D inversion

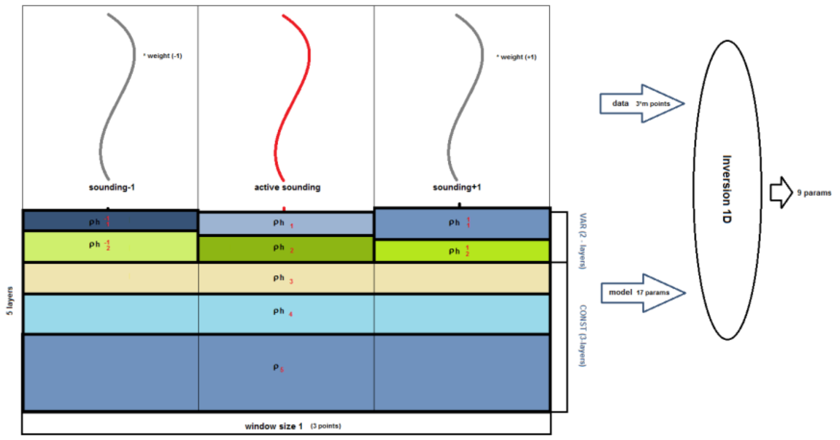


Fig. 15 Scheme of 1.5D inversion

Additional parameter - offset to prevent P-effect is assigned to each curve in the window. This parameter is minimized for all curves during fitting and thus it significantly decreases P-effect influence.

Current algorithm differs from standard inversion in additional parameters and construction of smoothing operator. Parameters which model P-effect have less weight compared to the others. Main characteristics of the algorithm are given below.

- Fitting is conducted simultaneously for all curves in the window and central point has the greatest weight for discrepancy calculation.
- P-effect of each curve is selected during inversion process.
- Own model with common bottom part and variable top part corresponds to each curve.

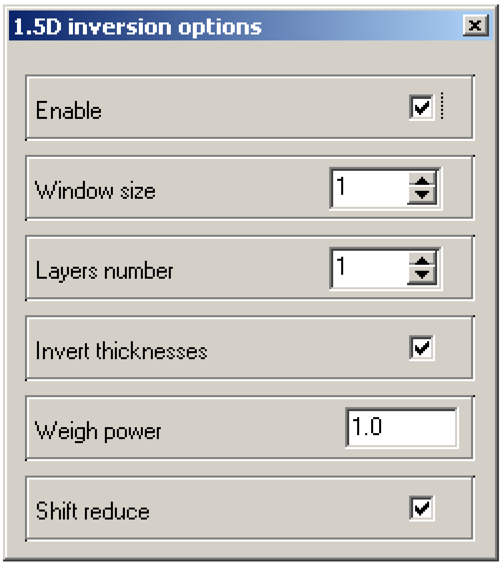


Fig. 16 Parameters window of 1.5D inversion

Option **Enabled** enables current algorithm.

Option **Window size** sets window size for the algorithm. Value 1 means three soundings in the window, 2 - five soundings in the window.

Option **Layers number** sets number of layers which model top (heterogeneous) part of the section.

Option **Inverse thickness** indicates if thicknesses of first layers which model top (heterogeneous) part of the section are fitted or not.

Option **Weight power thickness** sets coefficient of curve weight decrease depending on the distance from the central curve in the window (0 – all curves in the window have the same weight).

Option **Shift reduce** indicates if P-effect is taken into account during inversion or not.

Figure 17 shows results of this algorithm (A) compared to results obtained by standard procedure (B).

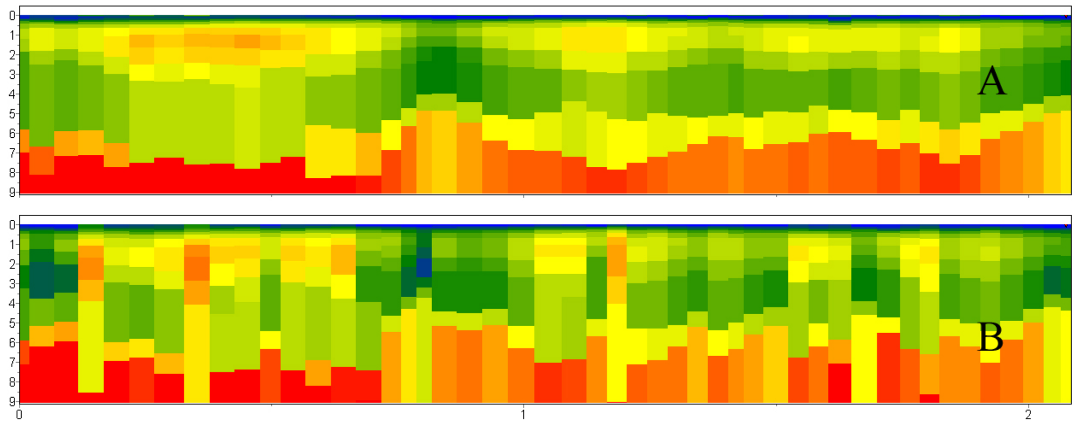


Fig. 17 Results of 1.5D inversion algorithm (A) compared to results of standard 1D inversion (B)

Field data interpretation

«Zond-IP» program allows solving 1D forward and inverse problems of VES. Program automatically selects resistivity values and layer thicknesses. It is also possible to fix parameters and specify their variation limits and define weights of certain measurements.

Linear filtering algorithm is used for forward modeling and Newton's method is used for inverse modeling.

Interpretation mode is available when data file is read.

Data inversion

This option is used for quick data inversion of one or all profile stations. Newton's method is used for minimization of least-square deviation between calculated and observed curves. Right-click the button on the toolbar. A pop-up menu will be shown, where it is necessary to choose for which items inversion will be performed: *current* - the current point, *to end* - from the current point to the end, *to start* - from the current point to the beginning of the profile. After selecting points, left-click the button .

Information on current relative misfit between calculated and observed curves is shown in the status bar. Inversion stops when current relative misfit between calculated and observed curves or number of iterations reach predefined values.

Inversion gives non-unique solution since calculated curves can be identical for different models. So it is necessary to take into account a prior information on geoelectrical section when specifying starting model. If a prior information is reliable it is advisable to fix known parameters or limit their change range in starting model and to add geological boundaries.

Program objects

Interactive interpretation is performed in the following objects: **Model editor**, **Section**, **Parameters table**, visualization is performed in the following objects: **Pseudosection**, **Profile plot**, **Graph of theoretical and experimental curves**. These objects appear automatically as soon as data is loaded.

Model editor

It serves to display observed and calculated sounding curves and to visualize and edit calculated model parameters curve.

Model editor window is shown in figure 18. Red and blue lines with filled circles are experimental curves of apparent resistivity (left red axis) and polarizability (right blue axis) versus separation in meters (bottom horizontal axis). Calculated model is displayed in red solid line.

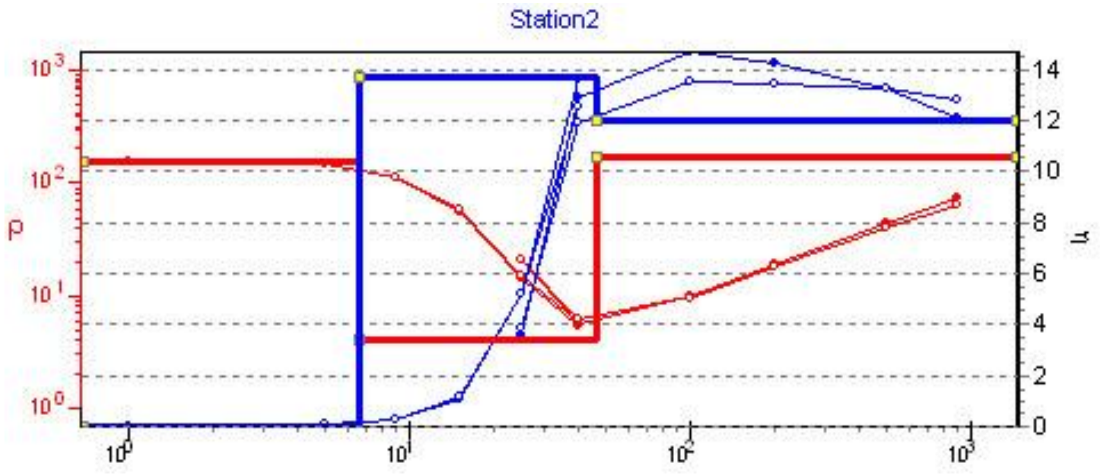
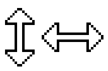


Fig. 18 Model editor window

Graphical parameters of observed, calculated and model plots are specified in graphics editor dialog (right click+[SHIFT] on plot). Axis parameters are specified in axes editor (right click+[SHIFT] on axis).

Window can contain one, two or three similar graphs which allow editing models at three neighboring stations at once.

Model parameters can be changed via mouse. In order to do that place mouse cursor on model curve (cursor shape must change  at that moment) and with left button pressed drag selected part of curve. Green circle on selected curve indicates active layer.

Alteration of vertical curve pieces positions corresponds to alteration of model geometry (that is thicknesses [right button] and depths of layers tops [left button]).

Alteration of horizontal curve pieces positions corresponds to alteration of model layer parameters.

Double click in object area to run context menu which contains the following options:

Print preview	Run print dialog.

Display legend	Display/hide legend.
Setup	Run object parameters setup dialog.
Left axis resistivity	Display apparent resistivity for left axis.
Right axis polarizability	Display apparent polarizability for right axis.

Option **Setup** runs curve parameters setup dialog (fig. 19).

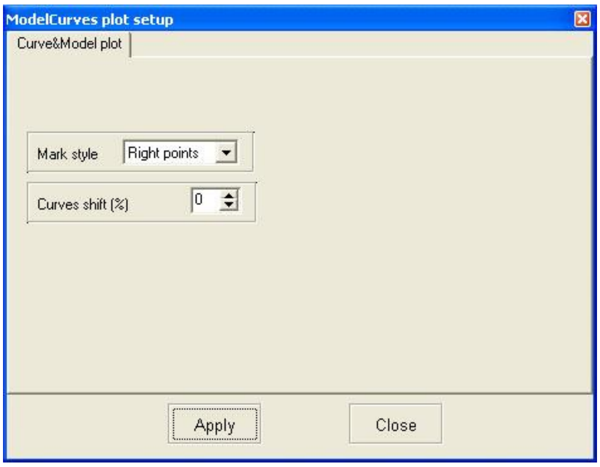


Fig. 19 Curve parameters setup dialog

Field **Marks Style** sets positions of graph's marks.

Value *Left points* – to the left of graph.

Value *All points* – from point to point.

Value *Right points* – to the right of graph.

Field **Curves shift** sets shift (in percent of logarithmic decade) between adjacent curves.

Data Editor (Graph of theoretical and experimental curves)

It is displayed if **Interpretation** style is selected (tab **Window**). Window can contain one, two or three similar blocks – graphs. On default left axis usually corresponds to red curves and right one corresponds to blue ones. If only one measurement type is used in the program then right axis is missing .

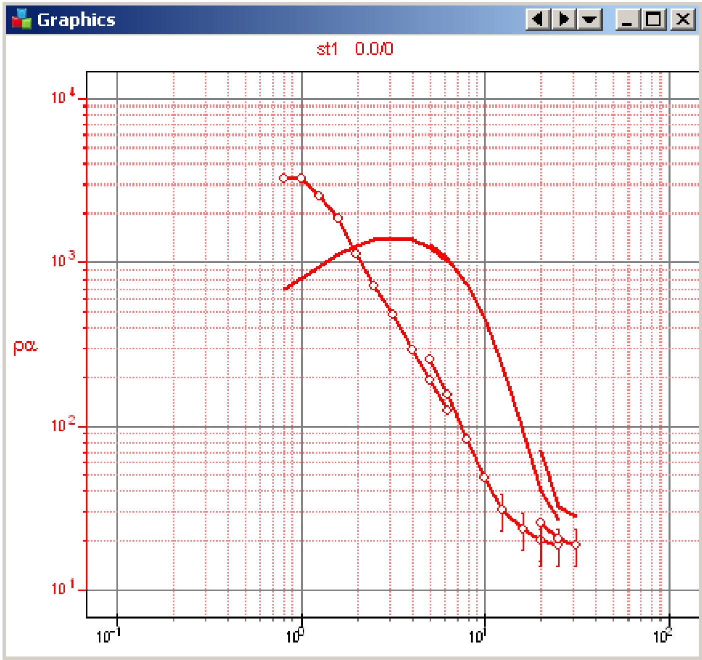


Fig. 20 Graph of theoretical and experimental curves

Double click in object area to run context menu which contains the following options:

Print preview	Run print dialog.
Display weights	Display/hide point weight.
Display legend	Display/hide legend.
Setup	Run object parameters setup dialog.

Option *Setup* runs curve parameters setup dialog (fig.21).

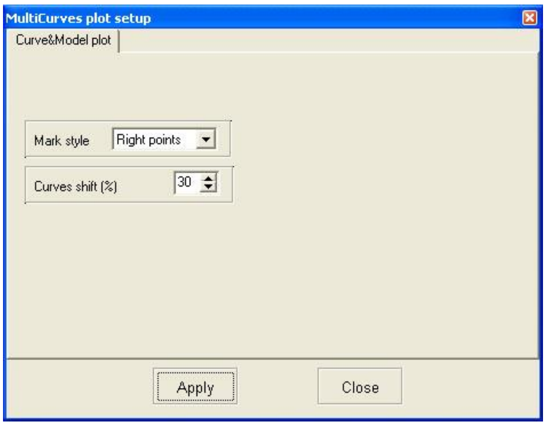


Fig. 21 Curve parameters setup dialog

Field **Marks Style** sets positions of graph's marks.

Value *Left points* – to the left of graph.

Value *All points* – from point to point.

Value *Right points* – to the right of graph.

Field **Curves shift** – sets shift (in percent of logarithmic decade) between adjacent curves.

[Options] button  runs complementary context menu.

Change orientation option changes positions of sounding curves for adjacent points: top-down and left-right.

MultiCurves Plot Setup option (fig.21) runs curve parameters setup dalog described above.

Set MultiCurves Plot number option sets number of adjacent sounding stations to display their curves simultaneously (from 1 to 3).

Right click in points of observed curves to run context menu which allows specifying weights of observed data:

Good point	Set weight 1 to active point.
Bad point	Set weight 0.5 to active point.
Very bad point	Set weight 0 to active point.
Good points >>	Set weight 1 to active point and to all points to the right of it.
Bad points >>	Set weight 0.5 to active point and to all points to the right of it.
Very bad points >>	Set weight 0 to active point and to all points to the right of it.
Good points <<	Set weight 1 to active point and to all points to the left of it.
Bad points <<	Set weight 0.5 to active point and to all points to the left of it.
Very bad points <<	Set weight 0.5 to active point and to all points to the left of it.
Delete point	Delete point.
Delete point>>	Delete point and all points to the right of it.
Delete point<<	Delete point and all points to the left of it.
Edit data	Edit curves.

Right or left click with [ALT] button pressed to increase or decrease point weight respectively.

Use scroll wheel with [ALT] button pressed to delete points. Change limits of deletion using scroll wheel.

Point weights are very important for model parameters inversion. Points with weight equal to 0 are not taken into account. Weight is calculated in the following way: = 1-dispesion/(observed value). Data weight can be specified in data file and is saved in project file.

Edit data option is used to edit sounding curves manually. When this option is selected dialog window **Edit data** appears (fig.22).

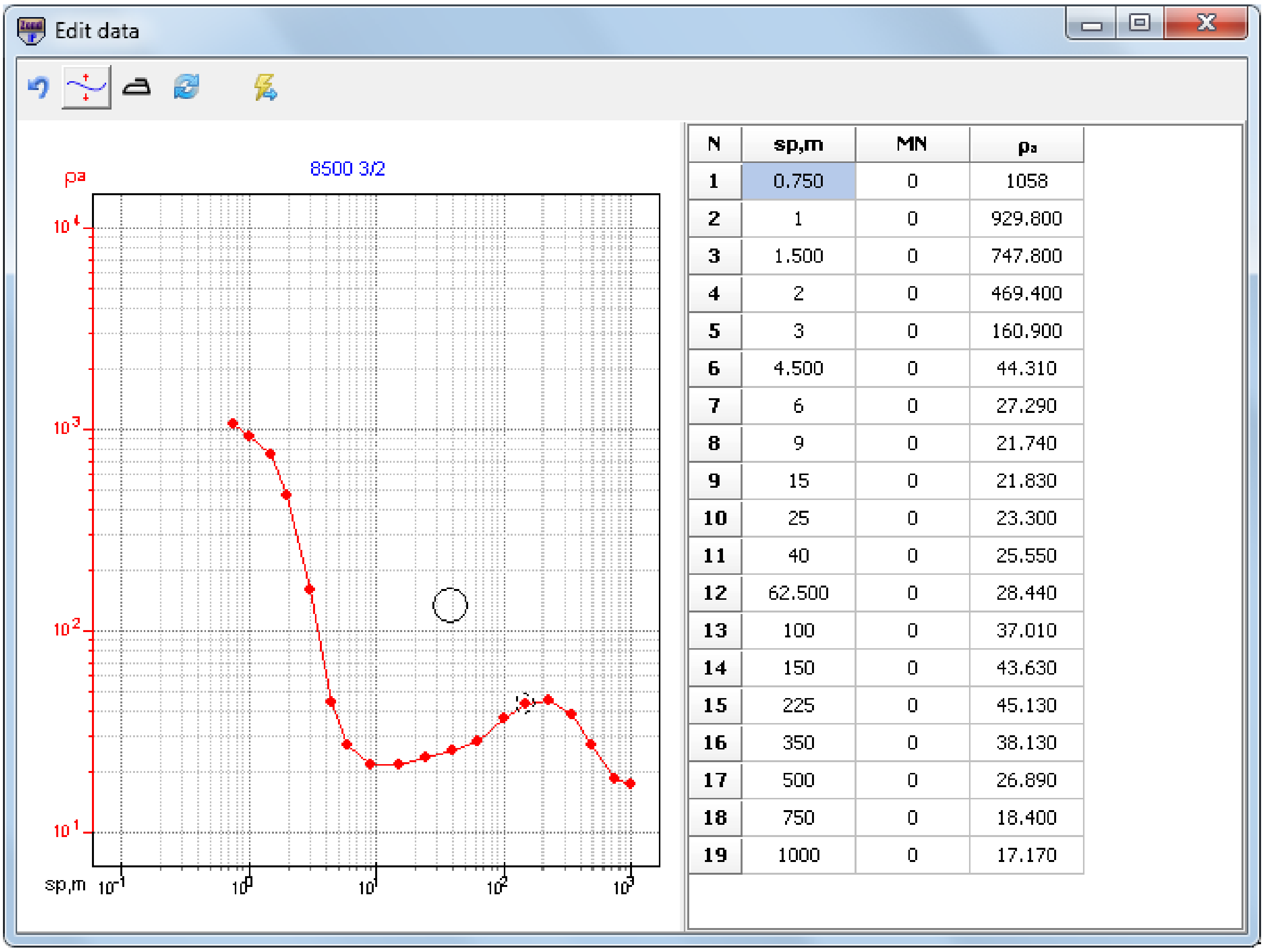
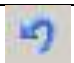
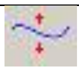


Fig. 22 Sounding curves setup window **Edit data**

Window toolbar contains the following buttons:

	Return to previous curve.
	Move the whole curve or its piece.
	Smooth the curve
	Redraw curve in other windows.
	Exit editing mode with saving.

The window consists of two parts. Editing curve is displayed in the left part. Separations and values of editing parameter are shown in the right one. Right click to delete point on the curve. Deleted point will be highlighted in grey in the table then. Left click to recover point. Use scroll wheel with [ALT] button pressed to delete points. Change limits of deletion using scroll wheel. After editing, press  button in the toolbar to start inversion.

Model table

Table editing window is used to change model parameters via keyboard. Table contains 3 or 4 columns (it depends on availability or absence of polarizability). Each table row contains properties of one layer only.

First column contains resistivity values of layers, the second one (if present) – apparent polarizability values, the third – thickness, and the last one – depth to layer top with sounding station elevation taken into account. The cell is light grey on default (color can be specified) if parameter variation limit is set. The cell is dark grey on default (color can be specified) if layer parameter is fixed.

Right click on table cells to run context menu (fig.23). If you right click on the first row (table heading) then selected menu option will be applied to specified parameter of all layers (cell is changed into col then). If you right click on the first column then selected menu option will be applied to all parameters of specified layer.

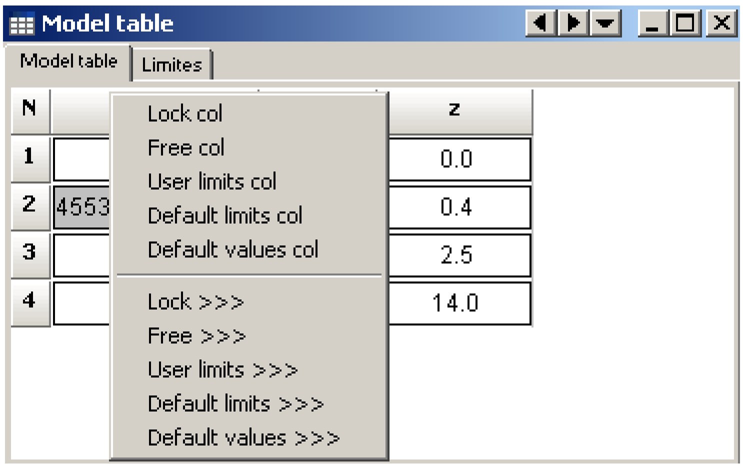


Fig. 23 Window **Model table**

Lock	Fix parameter.
Free	Unfix parameter.
User limits	Set user-specified variation limits.
Default limits	Set variation limits (on default).

Default values	Set default values.
Lock >>>	Fix parameter in current model and in all following models.
Free >>>	Unfix parameter in current model and in all following models.
User limits >>>	Set user-specified parameter variation limits in current model and in all following models.
Default limits >>>	Set default parameter variation limits in current model and in all following models.
Default values >>>	Set parameter default values in current model and in all following models.

Tab **Limits**

This tab serves to set parameter variation limits (fig. 24). Toolbar buttons are used to select parameter type to specify limits to. [Auto] button sets limits to all parameters of selected type automatically, according to their values and specified divergence percent. Model of selected parameter (black), its lower (red) and upper (blue) variation limits are shown in the graph.

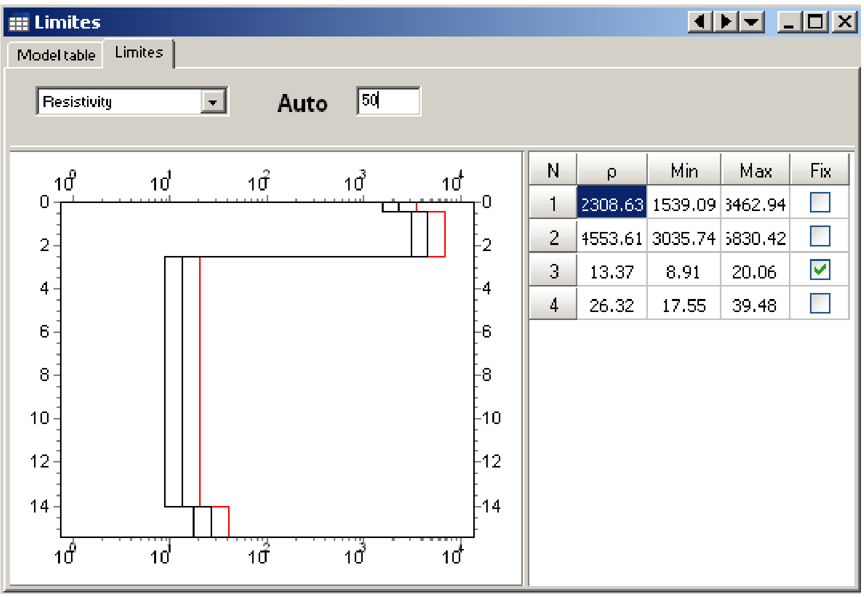


Fig. 24 Window **Model table**, tab **Limits**

Lower and upper limits of model parameters are edited via mouse. Variation limits can be edited in the table situated to the left of the graph.

Use button in the top right corner of the window to run complementary context menu (fig. 25).

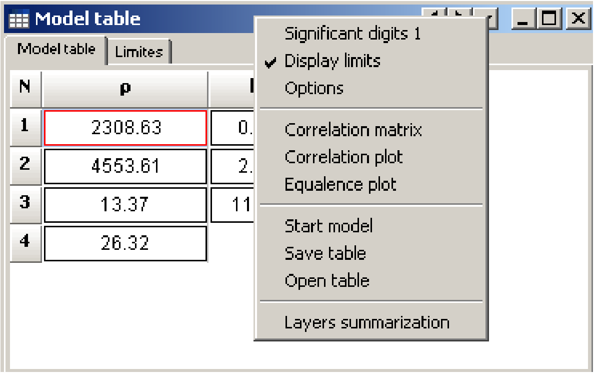


Fig. 25 Window **Model table**, complementary settings

Significant digits	Set parameter accuracy.
Display limits	Display/hide parameter variation limits.
Options	Run graphical parameters setup dialog.
Start model	Return to starting model.
Save table	Save current model as *.MDL file.
Open table	Load model from *.MDL file.
Correlation matrix	Display correlation matrix and confidence limits of model parameters.
Correlation plot	Run correlation plot window for two parameters.
Equivalence plot	Run equivalent models cloud plot window.
Layers summarization	Run layer summarization dialog.

Layers summarization dialog is used to convert multilayered models obtained by *Smooth* or *Focused* inversion into simpler geological models which contain less layers. Multilayered model which consists of 14-20 layers is convenient at the beginning of interpretation (fig. 26).

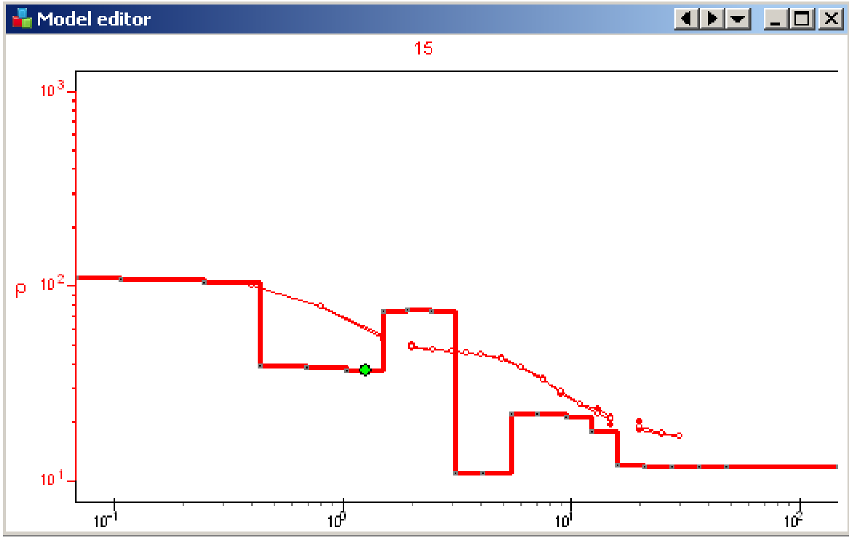


Fig. 26 Example of multilayered model

It is advisable to consider results of *Smooth* and *Focused* inversion as starting approximation for further more conscious interpretation. They give understanding of approximate geoelectrical subsurface geology. **Layer summarization** dialog helps to obtains simpler model (fig. 27) which is displayed in black line above initial model.

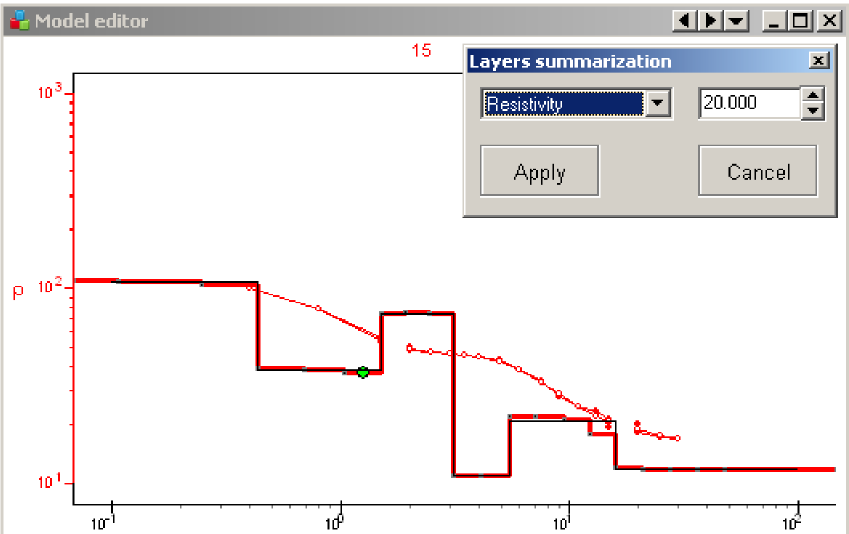


Fig. 27 Dialog **Layers summarization** (red line – multilayered model, black line – integrated model)

When specified in the field contrast parameter is achieved, two layers are merged.

After that some parameters can be fixed and *Standard* inversion or manual fitting is performed (fig. 28).

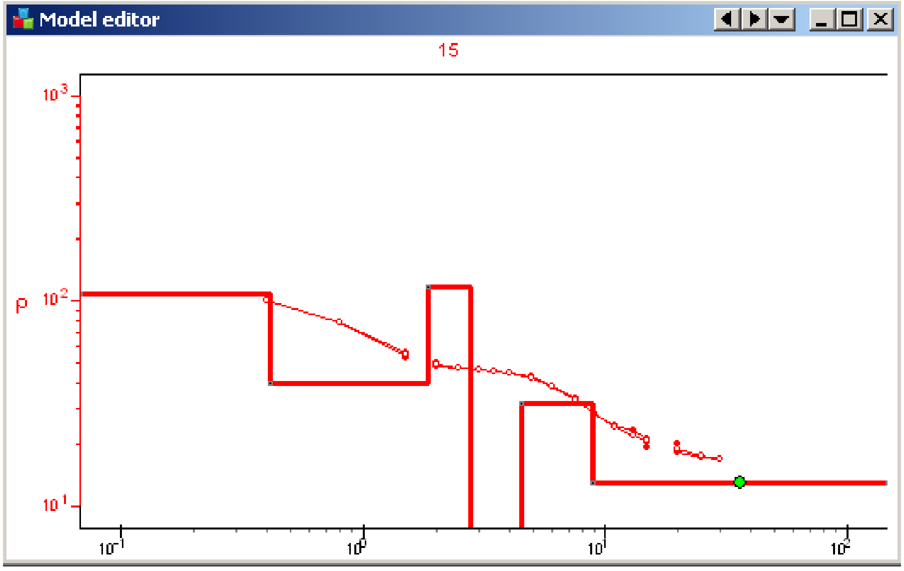


Fig. 28 Inversion results after usage of **Layers summarization** function

Equivalence analysis. In electrical exploration uniqueness theorem of inverse problem is proved if there are no mistakes in continuous measurements. In practice measurements are conducted within finite intervals with certain discretization and besides they contain mistakes. Presence of mistakes and incomplete data turn theoretical solution unique into practical solution non-uniqueness which means equivalence of different inverse problem solutions. Two geoelectrical sections are considered equivalent if relative data discrepancy does not exceed accuracy of field measurements or inversion misfit. Practically equivalence principle means that some section parameters cannot be defined during interpretation if some other section parameters are not known. Equivalence principle effect complicates data interpretation. Fixing certain parameters (on the basis of a prior data) can solve the problem.

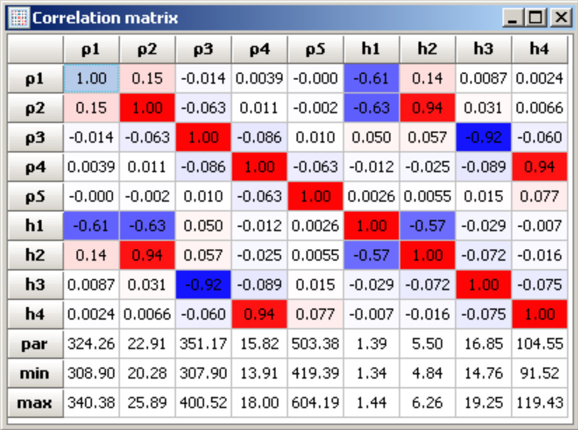
Equivalence principle analysis is based on two approaches – information-statistical for all model parameters by means of correlation matrix of coupling creation and direct calculation of equivalence domain for couple of section parameters with visualization.

One more option of equivalence analysis is creation of equivalent models cloud that is set of model curves which give similar theoretical curves.

Usually statistical estimation of equivalence for all parameters is performed first, then certain pairs of parameters with high correlation coefficients are studied.

Use **Correlation matrix** (fig. 29) option to run correlation matrix. Main diagonal of correlation matrix contains ones (two parameters with equivalent values, for example ρ1 and ρ1 have always correlation coefficient equal 1, and the parameter don't need to analyse). If correlation coefficient modulo is significantly less than unity then section parameters which were used to calculate it influence data differently and are defined with high accuracy. Thus their separate estimation is made possible.

If correlation coefficient modulo of parameters is close to unity then these parameters are jointly indefinable. In this case it is recommended to fix one of equivalent parameters if it is possible to receive independent information on it. In case of strong parameter correlation of adjacent layers it is advisable to fix one of correlative parameters or merge these two layers in one that is to simplify the model.


Correlation matrix

	ρ1	ρ2	ρ3	ρ4	ρ5	h1	h2	h3	h4
ρ1	1.00	0.15	-0.014	0.0039	-0.000	-0.61	0.14	0.0087	0.0024
ρ2	0.15	1.00	-0.063	0.011	-0.002	-0.63	0.94	0.031	0.0066
ρ3	-0.014	-0.063	1.00	-0.086	0.010	0.050	0.057	-0.92	-0.060
ρ4	0.0039	0.011	-0.086	1.00	-0.063	-0.012	-0.025	-0.089	0.94
ρ5	-0.000	-0.002	0.010	-0.063	1.00	0.0026	0.0055	0.015	0.077
h1	-0.61	-0.63	0.050	-0.012	0.0026	1.00	-0.57	-0.029	-0.007
h2	0.14	0.94	0.057	-0.025	0.0055	-0.57	1.00	-0.072	-0.016
h3	0.0087	0.031	-0.92	-0.089	0.015	-0.029	-0.072	1.00	-0.075
h4	0.0024	0.0066	-0.060	0.94	0.077	-0.007	-0.016	-0.075	1.00
par	324.26	22.91	351.17	15.82	503.38	1.39	5.50	16.85	104.55
min	308.90	20.28	307.90	13.91	419.39	1.34	4.84	14.76	91.52
max	340.38	25.89	400.52	18.00	604.19	1.44	6.26	19.25	119.43

Fig. 29 Window **Correlation matrix**

Last two columns of the table show confidence intervals for each parameter. Confidence intervals are considered reliability criterion for parameters definition and are connected with summarized sensitivity of section parameters. In case of large confidence interval parameter value is considered unreliable. When assessing the confidence interval width, the absolute values of the resistivity and thickness of the layers should be considered. In this example, the confidence interval for ρ1 is about 30 Om*m with the absolute value being 300 Om*m. It means, value is determined with an error of about 5%, which is quite acceptable. For ρ5 confidence interval width is about 200 Om*m at absolute value 500 Om*m. It means, error is rather large and is about 25%.

Double click on matrix cell to run correlation map (**Correlation plot**) of selected pair of parameters (fig. 30).

Correlation map of parameters pair represents contour map of discrepancy between theoretical data of current and calculated model. Assuming that current parameter values are centers of equivalence field, a few more forward solutions for parameters close to current point are calculated and maximum error of discrepancy between them and central point is estimated. In order to create correlation map for two parameters they are assigned set of values in certain range, data discrepancy with current model is estimated and contour map is generated. If parameter distribution is logarithmic then all above-mentioned actions are performed using parameters logarithms. Contours of maximum error values which represent equivalence principle domain geometry and range validity are shown in the equivalence map. Isometric equivalence domains indicate that there is no correlation between parameters estimations, oblong domains mean the opposite. Correlation analysis promotes successful revealing of equivalence between two parameters.

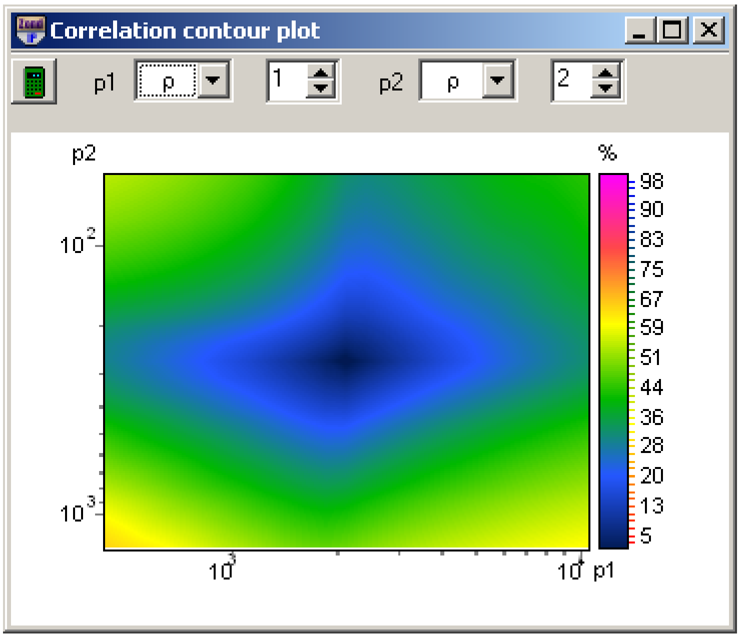


Fig. 30 Window **Correlation counter plot**

Color bar represents discrepancy to color ratio.

Field *p1* - sets type of first parameter for correlation analysis performance.

Field *p2* - sets type of second parameter for correlation analysis performance.

Following fields specify indices of these first and second layer parameters, for which Field *p1* sets type of first parameter for correlation analysis performance.

 - create correlation map.

Use **Equivalence plot** option to run equivalence model cloud plot window. It implements quite resource-intensive algorithm of equivalence model access scan within specified error range using curve-fitting method (fig. 31).

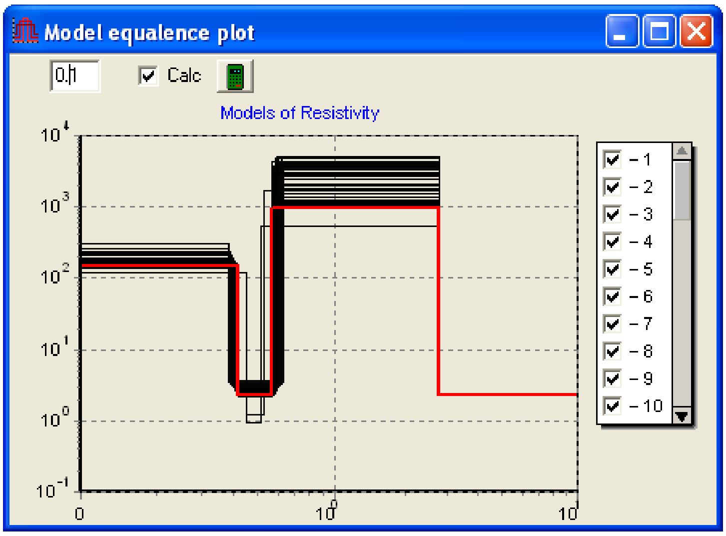


Fig. 31 Window **Equivalence plot**

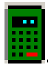
Minimum error values to consider model equivalent to current (field 0.1) must be specified. If *Calc* option is not ticked then equivalence models are calculated for model inversion error. Usually default values are specified so that they exceed current inversion error. Parameter for calculation is chosen then (Resistivity). After that access scan can be started . Algorithm result in set of model curves. Use scrolling to proceed from one curve to another.

Table graphical parameters setup dialog (**Options**)

Option **Lock** sets fixed parameter cell color.

Option **Range** sets cell color for parameter with specified variation limits.

Option **Free** sets cell color for parameter without specified variation limits.

Option **Min** sets color of parameter minimum limit.

Option **Max** sets color of parameter maximum limit.

Option **Active** sets frame color of active cell.

Option **Font** sets cell font.

Option **Cell height** sets cell height.

Section

Current object visualizes geoelectrical section variations along profile. Graph is created in profile coordinate versus depth axes. Color bar represents correlation between displayed parameter value and color (fig. 32).

If mouse cursor is located within geological section then use slider to select and highlight layer which is located below it. Cursor shape changes when it is reaching boundary of layers which can be edited then. To do that drag selected boundary with left button pressed. If right button is pressed then selected boundary along with underlying boundaries are dragged. Double click on layer to run its parameter setup window.

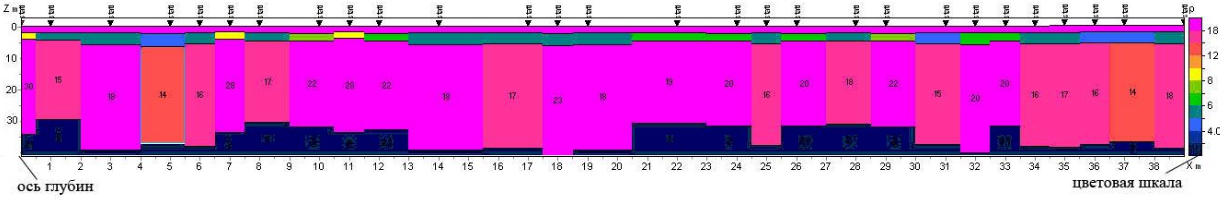
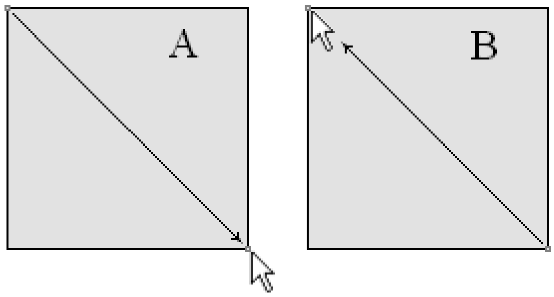


Fig. 32 Geoelectrical section window

Zooming in or dragging some part is performed with pressed button ("rubber rectangular" tool). To zoom in a segment move mouse cursor down and to the right with left button pressed (A). To return to primary zoom do the same but with mouse cursor moving up and to the left (B).



Double click in the object area runs context menu with the following options:

Log data scale	Use logarithmic scale in color bar.
Display labels	Display labels (parameter values) on axes.
Display ColorBar	Display color bar.
Refresh section	Regenerate section.
Setup	Run object setup dialog.
Print preview	Print section.
Save picture	Save section as graphics file.
Output settings	Run output graphics scale parameters setup dialog.
Layered section	Display section as layers.
Layered section [topo]	Display section as layers with topography.
Contour section	Display section as contours.
Smooth section	Display smooth section.

Add background	Add background image.
Remove background	Delete background image.
Increase bottom	Increase maximum vertical axis value.
Decrease bottom	Decrease maximum vertical axis value.
Set bottom	Set maximum vertical axis value manually.
Model interpolation	Interpolate all models (with large inversion misfit) between two selected sounding stations.
Bad data interpolation	Interpolate models (with large fitting error) between two selected sounding stations.

Figure 33 shows four versions of geoelectrical section visualization.

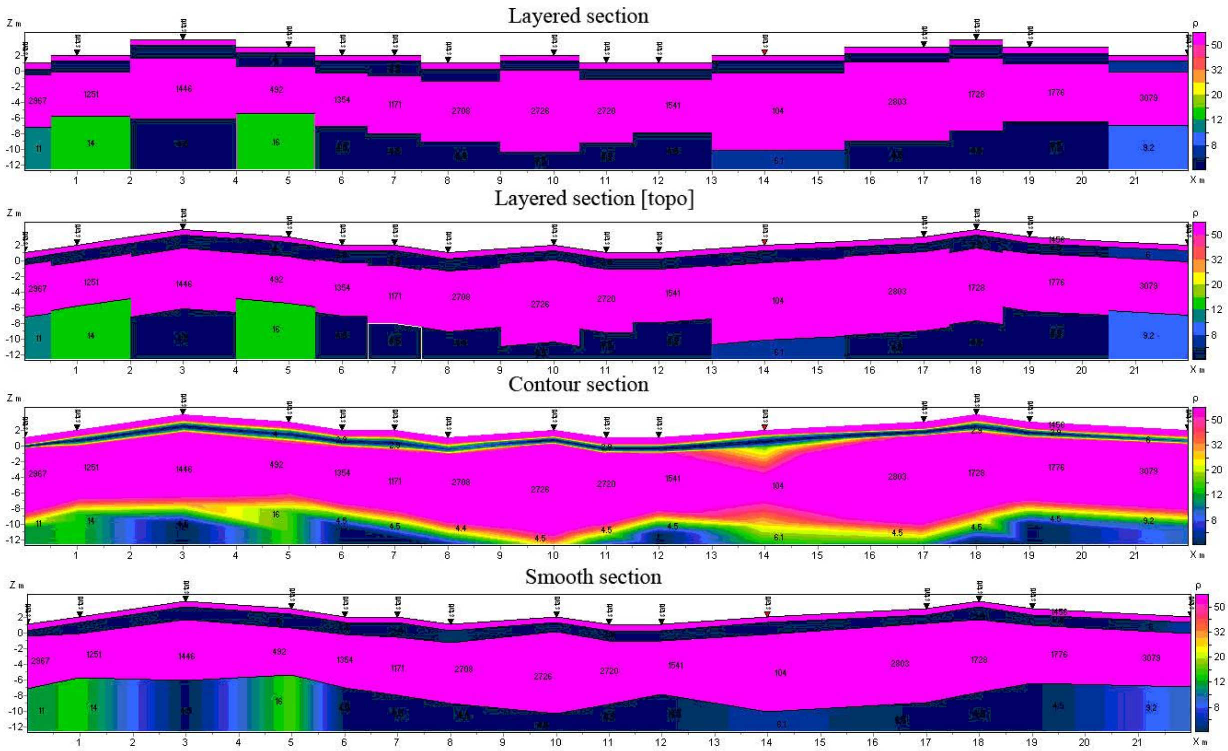


Fig. 33 Options of geoelectrical section visualization

Option **Setup** runs section parameter setup dialog (fig. 34).

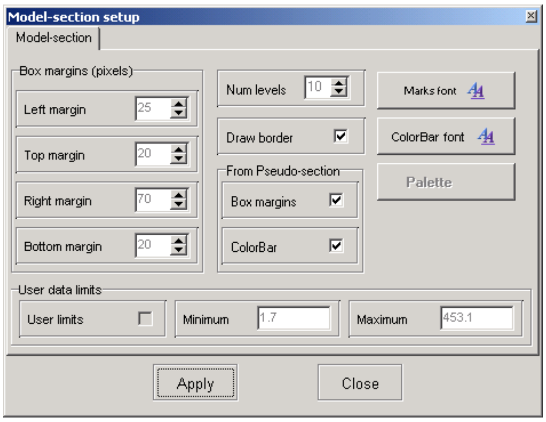


Fig. 34 Geoelectrical section parameters setup dialog

Field **Box margins**

Field *Left margin* sets image indent (in pixels) from window left edge.

Field *Right margin* sets image indent (in pixels) from window right edge.

Field *Top margin* sets image indent (in pixels) from window top edge.

Field *Bottom margin* sets image indent (in pixels) from window bottom edge.

Field *Num levels* sets number of colors. Levels are set using uniform linear or logarithmic step depending on data type.

Button **Palette** runs section layers color setup dialog (more).

Button **ColorBar font** runs color bar font setup dialog.

Button **Marks font** runs layer marks font setup dialog.

Field **User data limits**:

Option *User limits* specifies whether to use minimum and maximum data values or specified in [*Minimum*] and [*Maximum*] fields values for color bar definition.

Field *Minimum* sets minimum value for color bar definition.

Field *Maximum* sets maximum value for color bar definition.

Field **From pseudosection**:

Option *Box margins* specifies to use *Box margins* field values which correspond to pseudosection.

Option *ColorBar* specifies to use corresponding to pseudosection color bar.

Dialog **Output settings** allows specifying vertical scale, horizontal scale, print resolution in dpi and font size if *Automatic* box is not ticked (fig. 35).

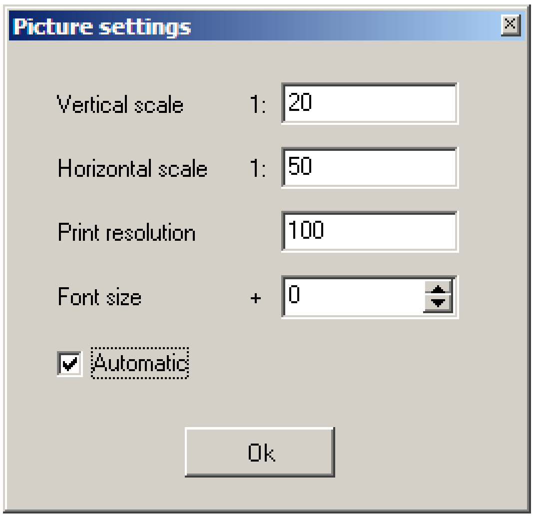


Fig. 35 Output picture settings window

Option **Add background** is used to insert background in model. This function can be useful if a prior information (geological section along profile) or data obtained by other methods are present or to compare inversion results at different stages. Background picture file must be in bmp format. When this option is selected, window appears to specify position of output file. Background is displayed above model and background layer is transparent (fig. 36, 37).

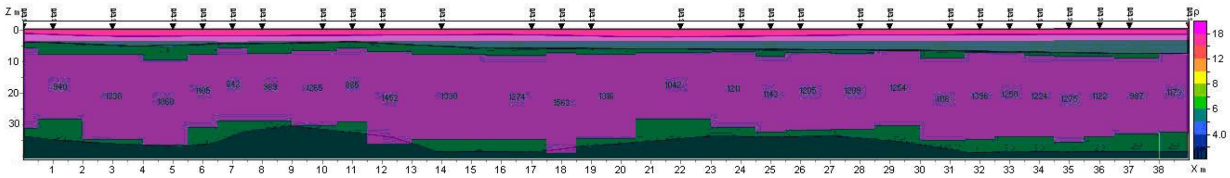


Fig. 36 Example of geological section background

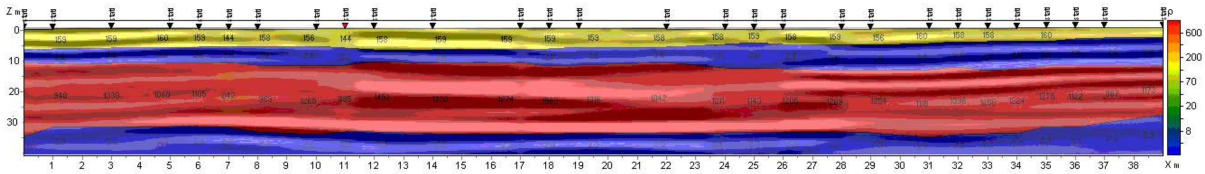


Fig. 37 Example of seismic section background

Pseudosection

Current object visualizes variations of observed values along profile as contour map (fig. 38).

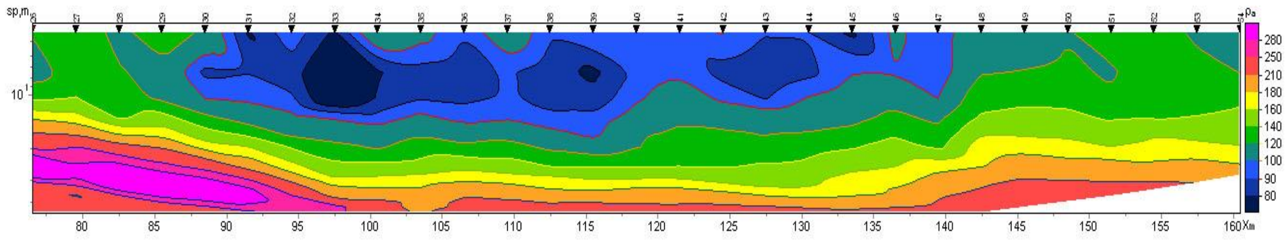
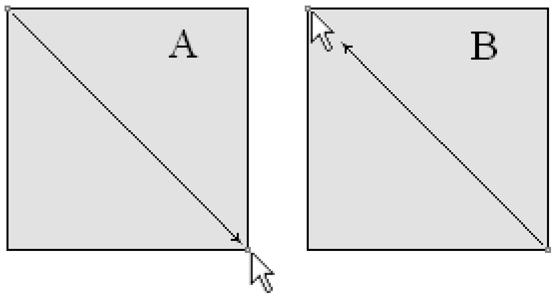


Fig. 38 Example of apparent resistivity pseudosection

Graph is created in profile coordinate versus separation axes. Color bar represents correlation between values of displayed parameter and color.

Zooming in or dragging some part is performed with pressed button (“rubber rectangular” tool). To zoom in a segment move mouse cursor down and to the right with left button pressed (A). To return to primary zoom do the same but with mouse cursor moving up and to the left (B).



Double click in object area runs context menu with the following options:

Setup	Run object parameters setup dialog.
Print preview	Print preview dialog (more).
Smooth image	Smooth pseudosection.
Log data scale	Use logarithmic scale in color bar.
Display labels	Display labels of measurement points.
Display ColorBar	Display color bar.
Save XYZ file	Save pseudosection as Surfer file.
Save picture	Save pseudosection as graphics file.

Tab **Setup** is used to adjust pseudosection parameters (fig. 39).

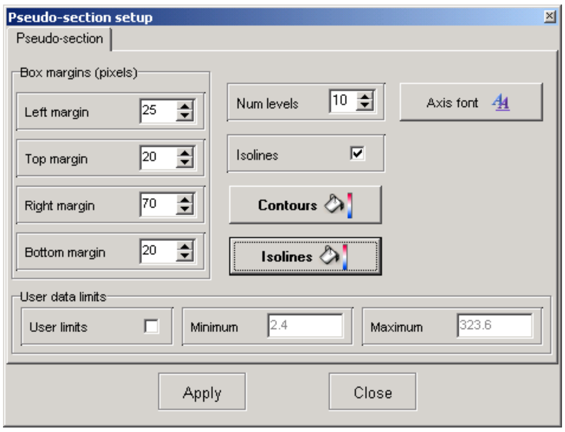


Fig. 39 Window of pseudosection parameters setup

Field **Box margins**:

Field *Left margin* sets image indent (in pixels) from window left edge.

Field *Right margin* sets image indent (in pixels) from window right edge.

Field *Top margin* sets image indent (in pixels) from window top edge.

Field *Bottom margin* sets image indent (in pixels) from window bottom edge.

Field **Num levels** sets number of contour intervals. Contour intervals are set using uniform linear or logarithmic step depending on data type.

Option **Isolines** specifies whether isolines are created or not.

Button **Contours** runs contour filling color setup dialog (more).

Button **Isolines** runs isoline colors setup dialog.

Button **Axis font** runs color bar font setup dialog.

Field **User data limits**:

Option **User limits** – specifies whether to use minimum and maximum data values or specified in *Minimum* and *Maximum* fields values for contour intervals definition.

Field *Minimum* – sets minimum value for contour intervals definition.

Field *Maximum* – sets maximum value for contour intervals definition.

Profile plot

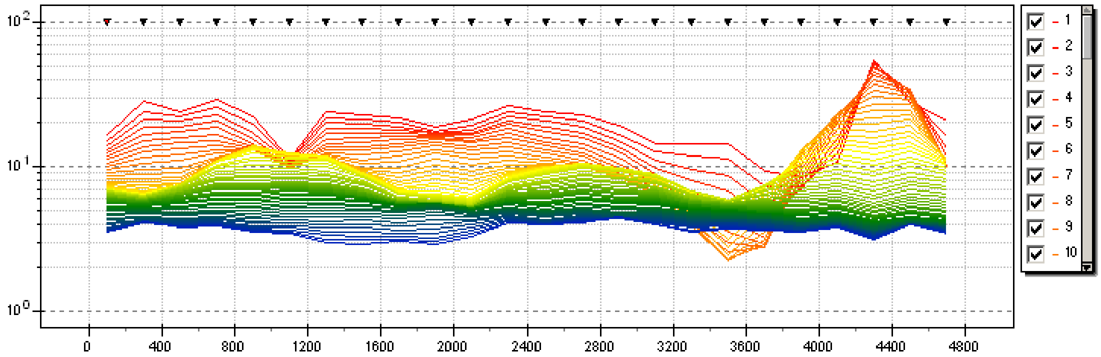
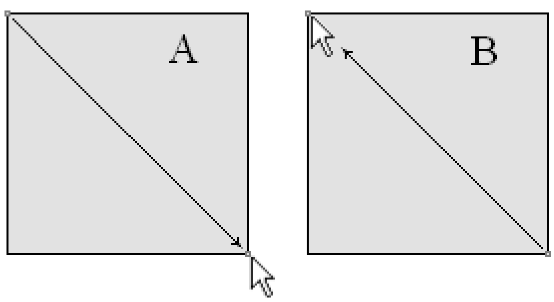


Fig. 40 Profile plot window

Current object visualizes profile graphs (theoretical and experimental) for different separations (available for **Profile** and **Interpretation** styles). Curve color corresponds to certain separation.

This tool is useful for analyzing raw data and for profile graphics visualization on a single spacing, which will correspond to a single investigation depth. Figure 40 shows that between PC 800 and 1200 there is graphs inconsistency for high (red lines) and low periods (blue lines). It indicates the presence of local relatively more conductive object (heterogeneity) in the upper section. It should also be noted that, in general, graphic profiling should contain no outliers among individual points. If there is one outlier on a graph, which is not present in the graphs on other periods, most likely this point should be removed.

Zooming in or dragging some part is performed with pressed button (“rubber rectangular” tool). To zoom in a segment move mouse cursor down and to the right with left button pressed (A). To return to primary zoom do the same but with mouse cursor moving up and to the left (B).



Move mouse with right button pressed to drag plots vertically.

Marks on experimental curves indicate separation numbers which they are created for. When you left click on curve, curves for other periods disappear until you release the button. Plots can be shifted vertically by mouse dragging with right button pressed. Left click on curves list with [SHIFT] button pressed to display one curve only. Use scroll wheel to proceed to the next plots. Use again left click on curves list with [SHIFT] button pressed to display all curves.

Right and left click with [ALT] button pressed to increase or decrease point weights respectively.

Use scroll wheel with [ALT] button pressed to delete points.

Double click in object area runs context menu with the following options:

Setup	Run object parameters setup dialog.
Print preview	Print graphics plan.
Display calculated	Display theoretical curves.
Delete invisible	Delete invisible graphs.

Option **Setup** is used for profile plot setup (fig. 41).

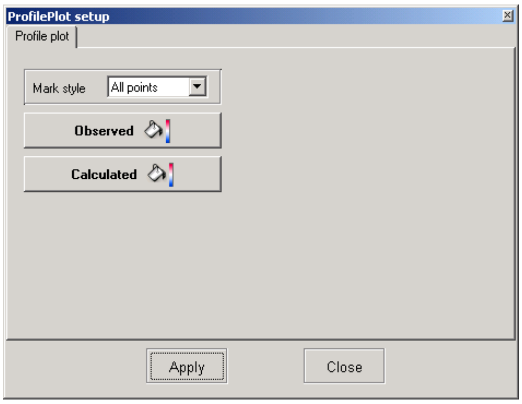


Fig. 41 Profile plot parameters setup dialog

Option **Marks style** specifies marks style.

Value *Left points* – to the left of the plot.

Value *All points* – from point to point.

Value *Right points* – to the right of the plot.

Buttons **Observed** and **Calculated** – runs graphics parameters setup dialog for observed and calculated curves.

Axis parameters can be specified in axes editor (right clock+[SHIFT] on axis).

Areal data and 3D visualization

Select **Options/Set lines/coordinates** in the main menu to set a number of profile lines. **Line settings** window appears then (fig. 42). It displays areal positions of sounding stations.

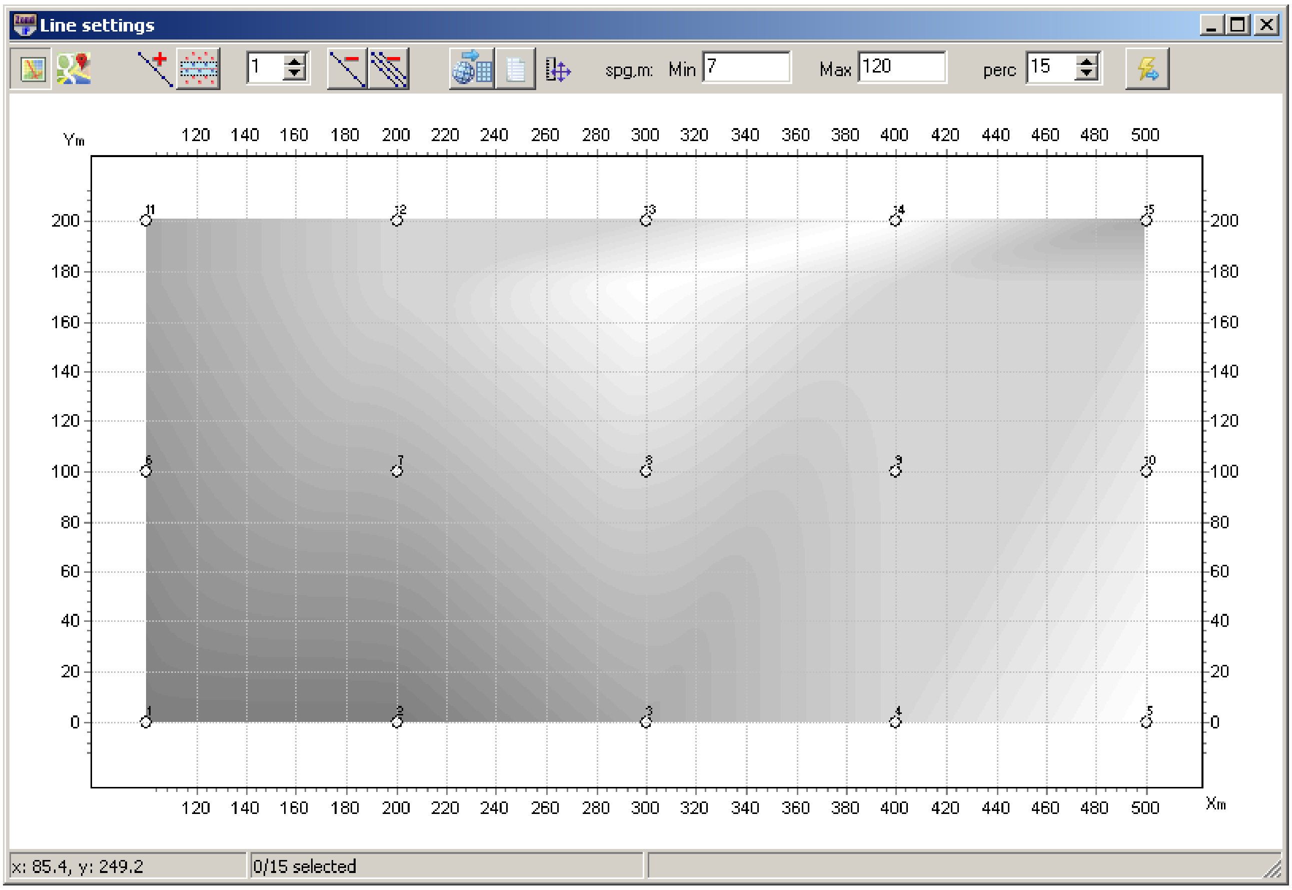
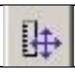
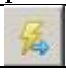


Fig. 42 **Line settings** dialog window for areal data

The main toolbar contains the following functions:

	Load raster file of map (Load map) or create relief isolines (Draw topography).
	Load Google map
	Add profile line. Left click to set profile points, right click to specify the last point.
1	Set a number of the active profile.
	Delete all profiles.
	Include sounding stations (located within rectangular area around selected line in profile automatically.
	Delete current profile.
	Recalculate geographical coordinates to rectangular. When EDI files are loaded they

	are recalculated automatically. If beforehand file is known to contain geographical coordinates (latitude and longitude) then prior to interpretation they must be recalculated to rectangular coordinates using this button.
	Open and edit table of coordinates (Station locations dialog)
Spsg,m: Min-Max	Set minimum and maximum separations respectively. Out-of-range measurements are not loaded to the program.
	Select image scale: equiaxial or maximum window filling.
perc	Set size of sounding station automatic selection domain for profile.
	Start data inversion for selected profile set.

A few profile lines can be specified in the program simultaneously. When profile and all points around it are set, all included in profile points are displayed in blue. Left click to include/exclude profile point. If profile line does not cross points then position of sounding station projection is displayed in green.

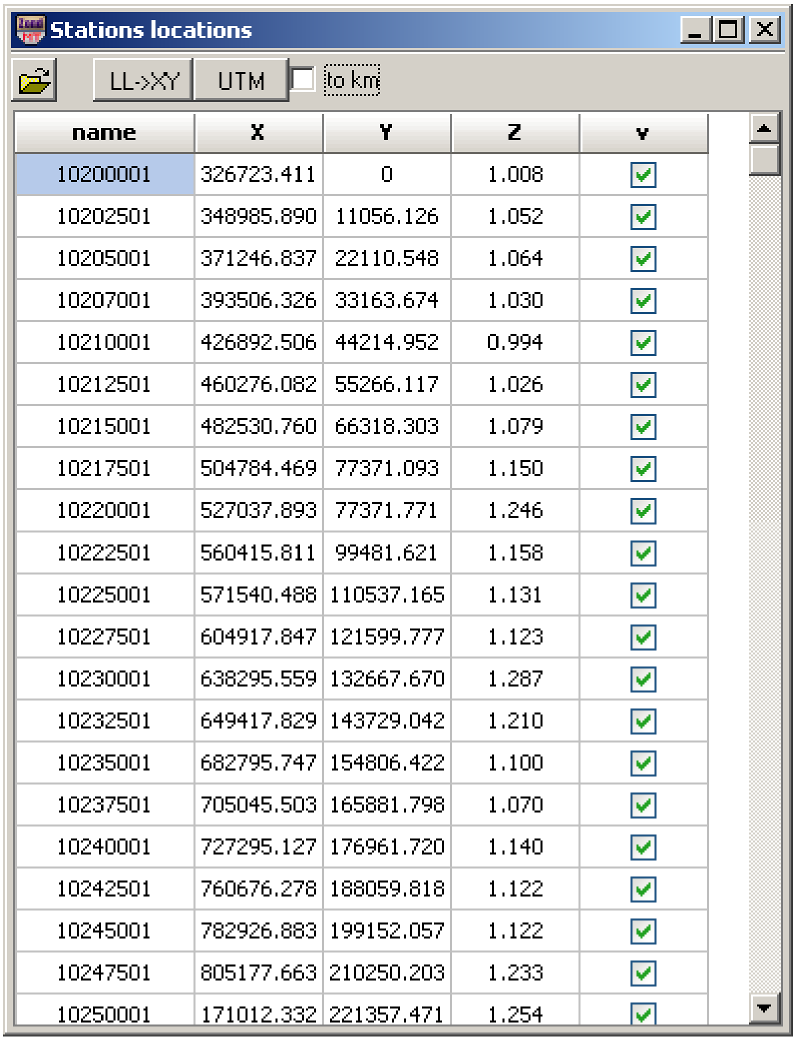
To display and edit points coordinates, use Stations locations dialog (fig. 43), in which user can specify coordinates manually, copy from Excel or load text file with coordinates using the button .

Toolbar buttons allow performing the following coordinate transformations:

- convert the geographical coordinates in rectangular

- convert geographic coordinates to UTM system

- specify the units. By default, the coordinates and height are given in meters, when choosing the option - in kilometers.



name	X	Y	Z	v
10200001	326723.411	0	1.008	☑
10202501	348985.890	11056.126	1.052	☑
10205001	371246.837	22110.548	1.064	☑
10207001	393506.326	33163.674	1.030	☑
10210001	426892.506	44214.952	0.994	☑
10212501	460276.082	55266.117	1.026	☑
10215001	482530.760	66318.303	1.079	☑
10217501	504784.469	77371.093	1.150	☑
10220001	527037.893	77371.771	1.246	☑
10222501	560415.811	99481.621	1.158	☑
10225001	571540.488	110537.165	1.131	☑
10227501	604917.847	121599.777	1.123	☑
10230001	638295.559	132667.670	1.287	☑
10232501	649417.829	143729.042	1.210	☑
10235001	682795.747	154806.422	1.100	☑
10237501	705045.503	165881.798	1.070	☑
10240001	727295.127	176961.720	1.140	☑
10242501	760676.278	188059.818	1.122	☑
10245001	782926.883	199152.057	1.122	☑
10247501	805177.663	210250.203	1.233	☑
10250001	171012.332	221357.471	1.254	☑

Fig. 43 Stations locations window. Definition of sounding station coordinates

Sounding points table contains the following columns: Name - the name of the source file, X, Y, Z - coordinates and elevation of the point, v - t include or exclude point.

Right click on necessary point to view and edit sounding station coordinates. Coordinates which can be edited are displayed in opening window.

Press  button to start data interpretation when profile is set. Main window of the program appears then. Use 

window in the main window toolbar to switch profiles.

Option **Plane data (Options/Plane data)** is used to create areal distribution maps of selected parameter (resistivity, apparent resistivity, elevations, etc.) depending on depth or time. Figure 44 shows example of apparent resistivity areal distribution map.

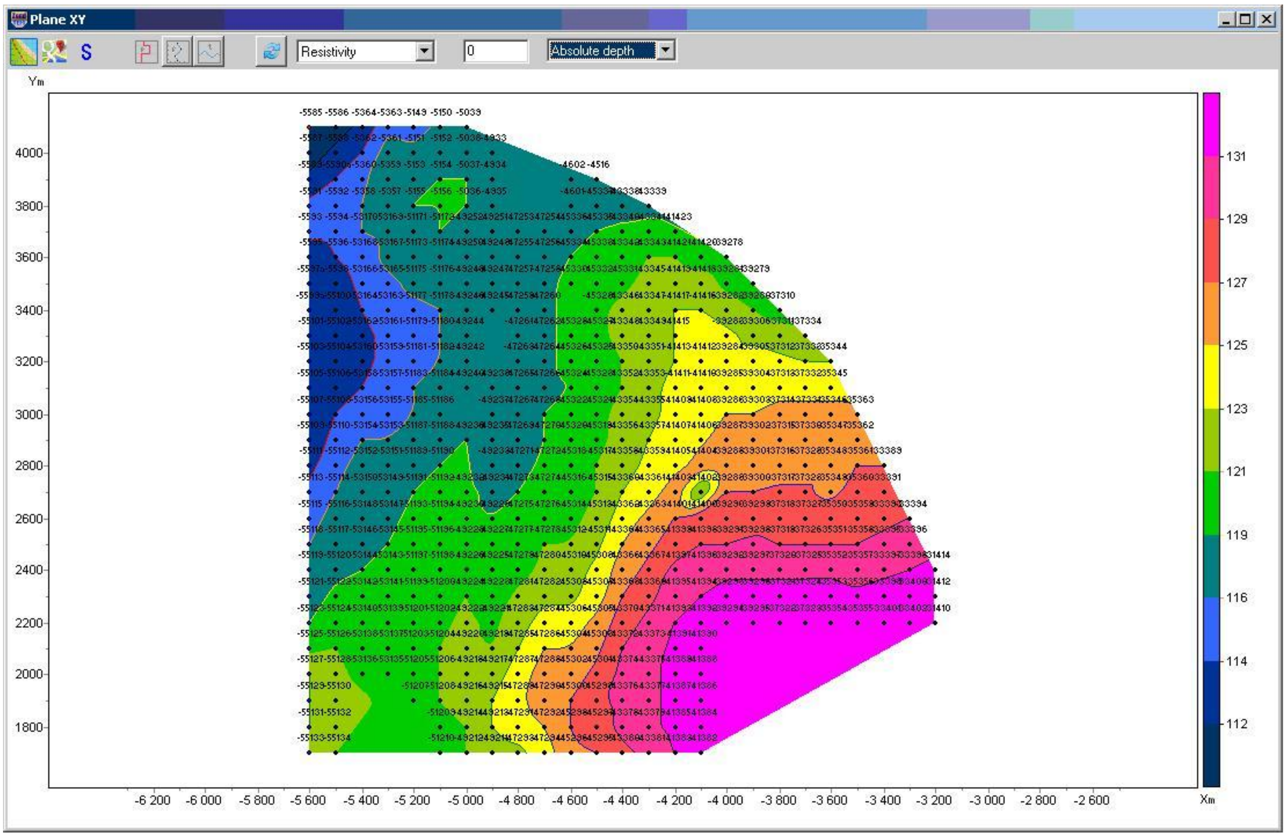
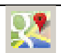
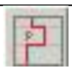
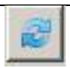


Fig. 44 Window **PlaneXY**. Resistivity contour map

Window toolbar contains the following buttons:

	Load map raster file as background.
	Load Google map
	Export areal scheme of parameter distribution in Golden Software Surfer and run the program.
	Create contours for model parameters (resistivity, conductivity or thickness).
	Create contours for measured parameters (apparent resistivity or apparent polarizability).
	Create contours for elevations.
	Redraw current plan.

When plotting model parameters there are two windows in the toolbar which are used to select one of parameters and specify depth to display it at. Depth counting method is specified in the right window: *Depth from topo* – depth values are counted off the ground, *Absolute depth* – absolute depth values are used, *Layer index* – contour map is generated for specified layer.

When plotting contours of measured parameters, layer number corresponds to initial data time grid.

Option **3D sections (Options/3D sections)**

Current option is meant for 3D visualization of profile interpretation results. If this option is selected **3D sections viewer** window appears. Window toolbar contains the following buttons:

	Print preview.
	Rotate 3D model.
	Display horizontal map. Plan depth from the surface is set in kilometers in the window to the right .
	Press this button to set equal scale for all axes. Window to the right appears then. It allows specifying scale ratio for each axis.
	Vertical axis Z setup.

Window **3D section viewer** contains three tabs:

Tab ***Lines*** (fig. 45) is used to edit coordinates of profile beginning and end and to set profile for 3D visualization. There is a table to the left which contains profile names and coordinates of profile beginning and end. Tick box in the last column (V – visible) to display profile in 3D. Profile plan is displayed in the right window. Active profile is highlighted in red. Axes properties can be edited by right click with [Shift] button pressed. See Axes editor for details on axes parameters setup.

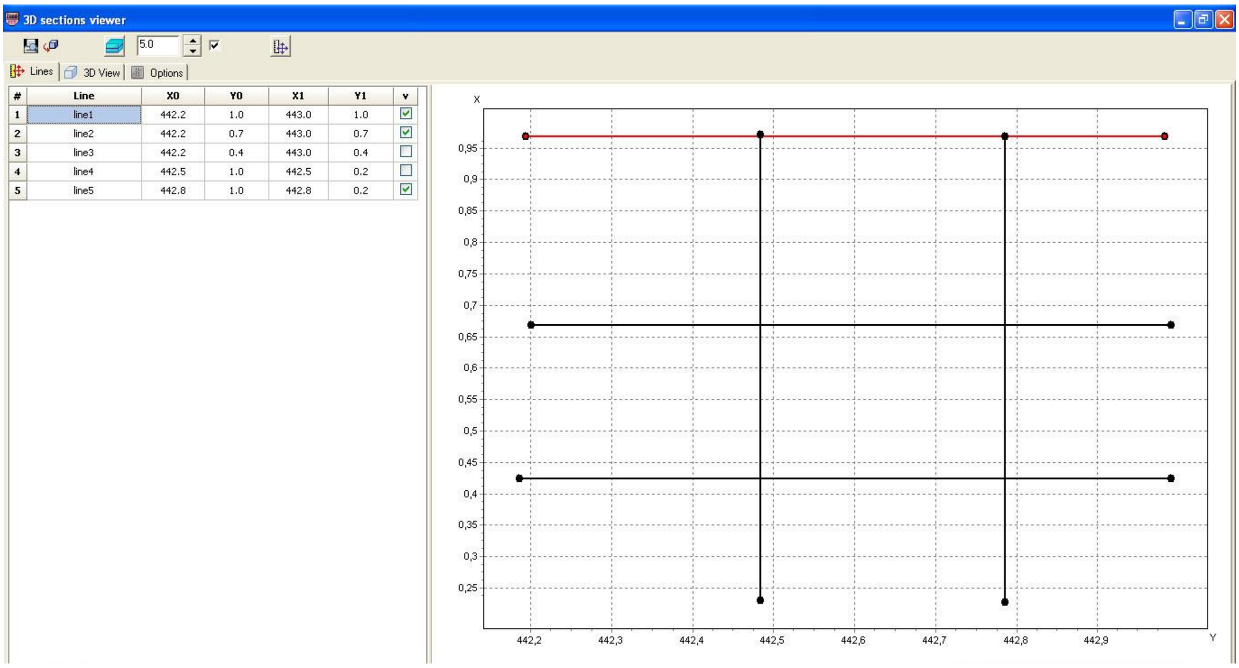


Fig. 45 Window **3D section viewer**, tab **Lines**

Tab ***3D view*** (fig. 46) is used to view 3D model.

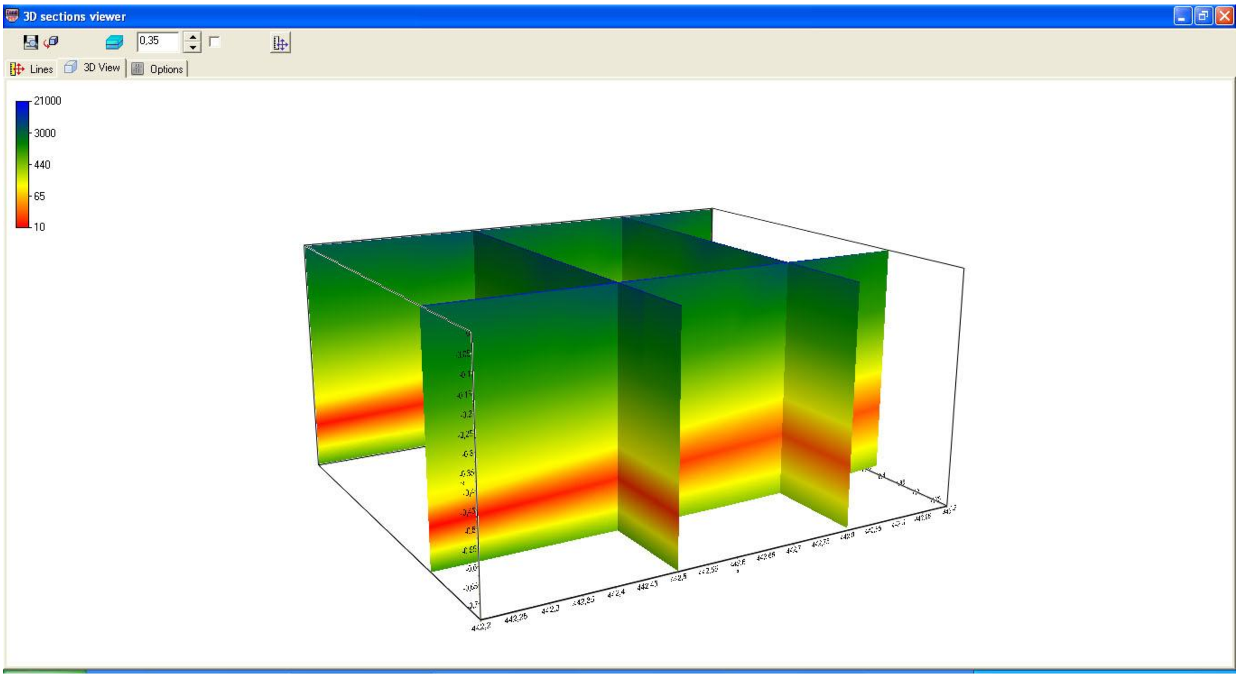


Fig. 46 Window **3D section viewer**, tab **3D view**

Tab **Options** (fig. 47) is meant for image parameters setup.

Field *Color scale* allows specifying filling parameters. **Palette** button runs filling setup dialog (more). Field *Color scale limits* is used to specify color bar minimum and maximum values manually or select automatic mode of range definition by ticking certain box.

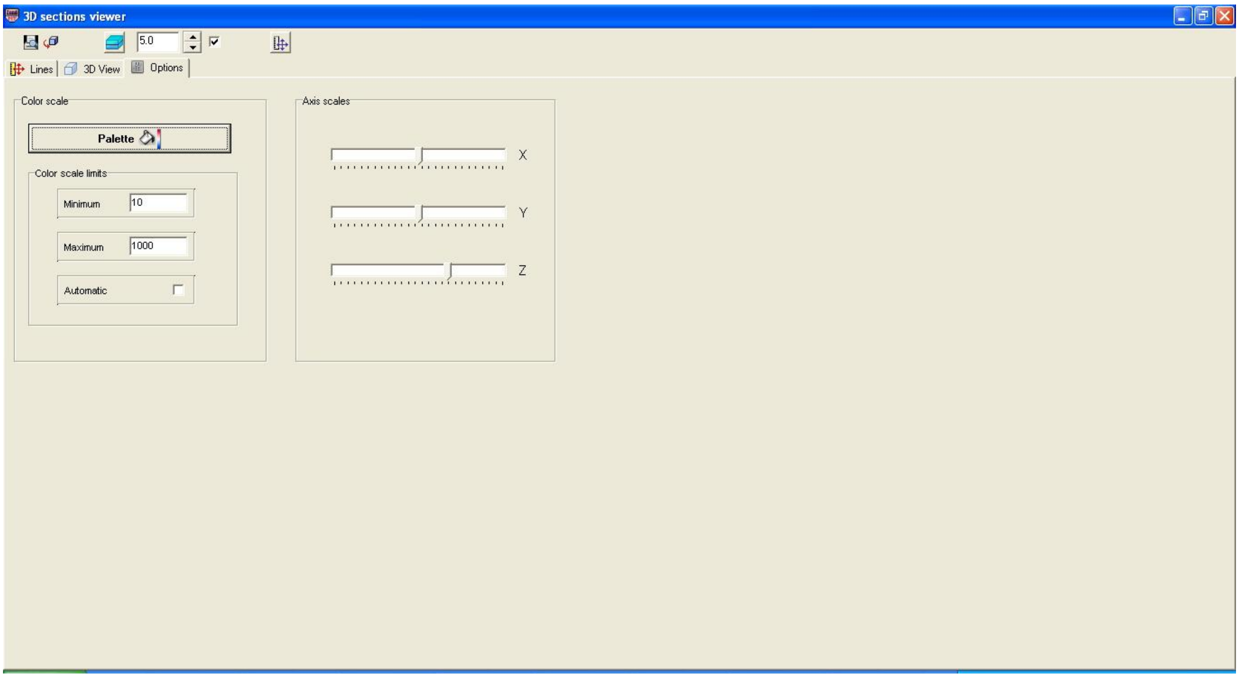


Fig. 47 Window **3D section viewer**, tab **Options**

Field **Axis scales** is meant for axes scale definition. Scales can only be set with pressed button  in window toolbar.

A prior data input

A prior data (borehole data) availability helps to increase reliability of received geoelectrical sections significantly. «ZOND-IP» program has integral module which is used to visualize a prior data graphically in sections.

Lithology and logging data creation and input

Choose **Options/Create/Edit borehole data** option in the main menu to create stratigraphy file. Dialog window of the module **Add borehole data** (fig. 48) appears.

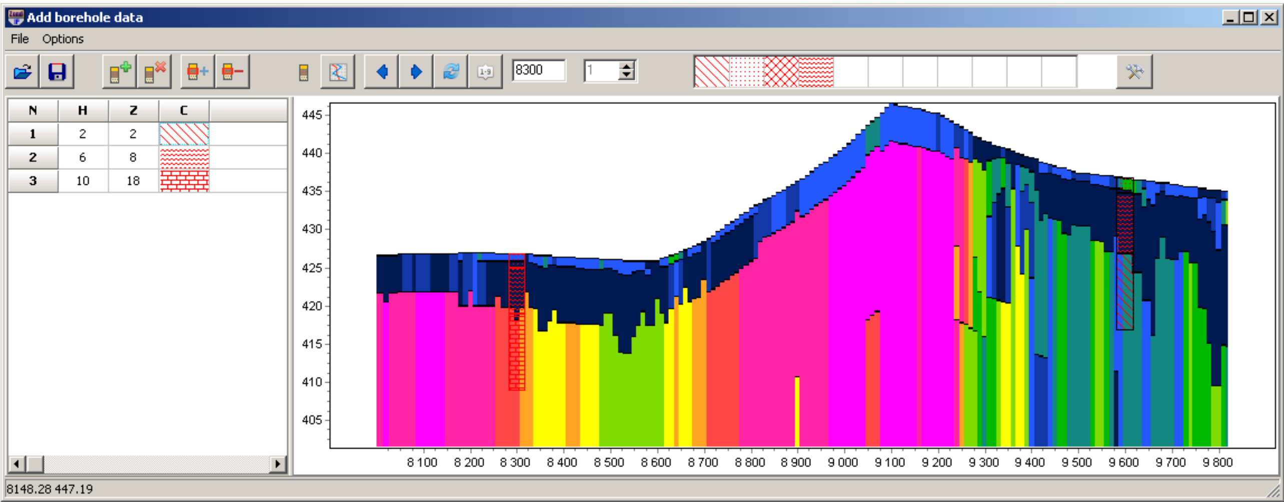
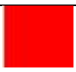


Fig. 48 Dialog window of lithology file creation **Add borehole data**

Dialog window toolbar contains the following buttons:

	Open lithology file.
	Save lithology file.
	Create new borehole.
	Delete borehole.

	Add new layer to borehole.
	Delete layer from borehole.
	Load logging data.
	Return to previous borehole.
	Proceed to next borehole.
	Refresh window.
	Sort out boreholes by coordinate.
	Select fill color of borehole display window (red in example).
	Advanced options.

The main toolbar also contains fields used to specify horizontal coordinate of borehole (offset from profile beginning) - **horizontal position** and elevation - **Position from surface**. Vertical and horizontal coordinates are set in kilometers. Empty square windows are used to create set of filling patterns.

The module consists of two windows. **Data window** is located on the left. It contains table with the following columns: **N** – number of layer, **H** – layer thickness in meters**,** **Z** – layer bottom depth in meters, **C** – type of pattern. Borehole data is displayed graphically in the right window.

Press  button in the toolbar to start creating lithology file. New table appears in **Data window**. Use  button to set number of layers, then edit table by specifying thickness and layer bottom depth and select pattern type according to lithology. Double left click on *C* column to run pattern setup dialog **Pattern Color Editor** (fig. 49). There is a wide range of lithology pattern in the program. Use option **Color** to select pattern color.

Fig. 49 Pattern Color Editor window

When borehole data is entered, press  button to display borehole graphically. Then specify horizontal and vertical coordinate of borehole in kilometers in the toolbar and after that borehole is displayed according to its coordinates. Active borehole is displayed in red in graphics window.

Palette can be saved to make work with large number of boreholes more convenient. In order to create palette select pattern in pattern column of **Data window**, then right click on pattern domain in the main toolbar. Set of patterns can be created in this way. To save it press  button and select **Save default palette.** Saved set of patterns can be used while creating new lithology and logging data file (- **Load default palette**).

Function **Set percent,** run via button , serves to change scale of borehole data graphical representation.

When data file is saved a few files are created: ***.crt** – module project that can be loaded in «ZONDMT1D» program and ***.txt** – file for each borehole, file names correspond to horizontal and vertical coordinate. See Appendix 1 for details on lithology data file format.

Use **Options/Load borehole data** function to add borehole data. Borehole data is displayed in geoelectrical section and in model editor window (fig. 50).

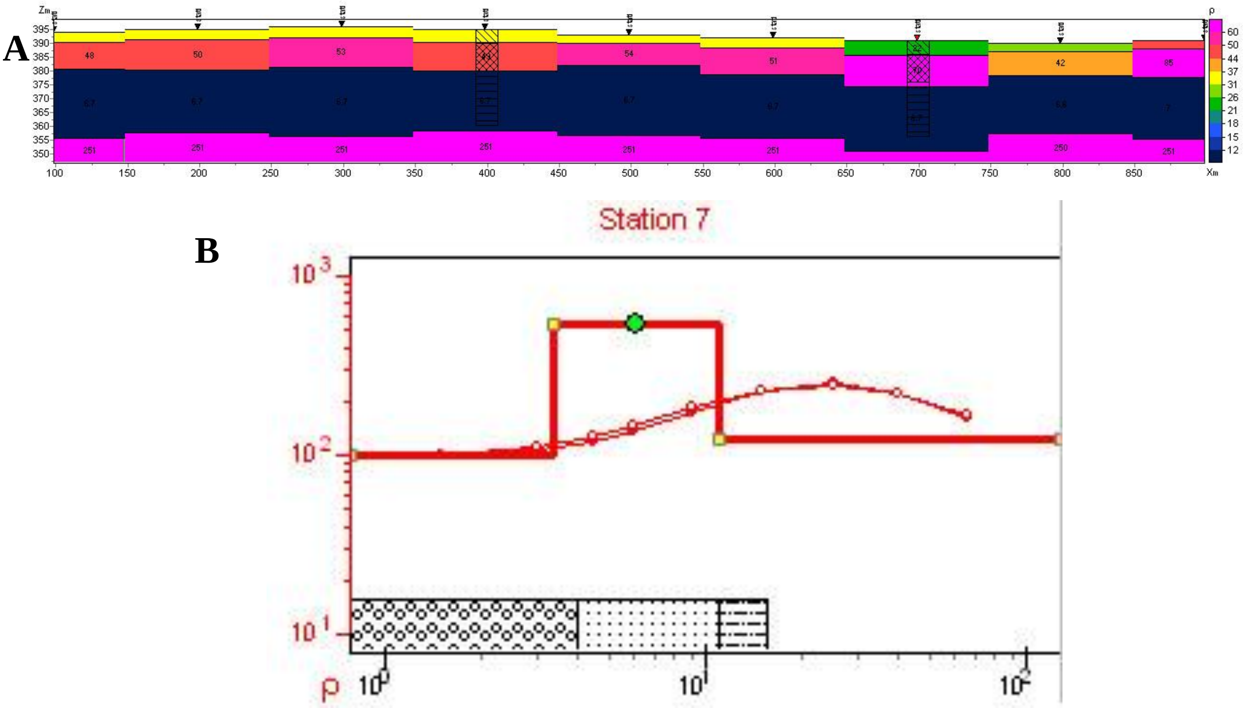
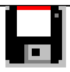


Fig. 50 Display of lithology data in geoelectrical section (A) and in model editor (B)

Logging data can also be added. Click button  in **Add borehole data** window to do it. Select a corresponding *.crt file. Logging data can be added to the existing lithological column.

Set boundaries dialog

Use **Options** menu to run boundaries setup dialog **Set boundaries**. It allows taking into account a prior geological information. Menu with the following buttons appear when this tab is selected:

	Enable/Disable editing boundaries mode	Enable/Disable editing boundaries mode.
	Add new boundary	Add new boundary.
	Delete boundary	Delete all boundaries.
	Save boundaries to file	Save boundaries to file.
	Load boundaries from file	Load boundaries from file.

A prior data entry to inverse problem is extremely important to increase interpretation quality. On one hand it increases problem stability and on the other – decreases equivalence field and allows receiving more consistent structure. This is almost the only way to receive acceptable result in models with low-sensitive parameters.

Prior to setting boundaries it is recommended to perform **Smooth** inversion (selecting type of inversion **(Style)** in **Inversion** tab of program setup window) with enabled depth fitting (tick **Thick/depth**). See Program setup dialog for details on inversion parameters.

Boundaries must be plotted in the geoelectrical section according to borehole data or on the assumption of a priori conception of geological structure. Use left mouse button with enabled boundaries editing mode to set boundaries. Right click to close boundary. It is not recommended to use many nodes in boundaries. It is preferable to have as smooth boundaries as possible.

When boundaries are set run inversion again. It will take specified boundaries into account (fig. 51B).

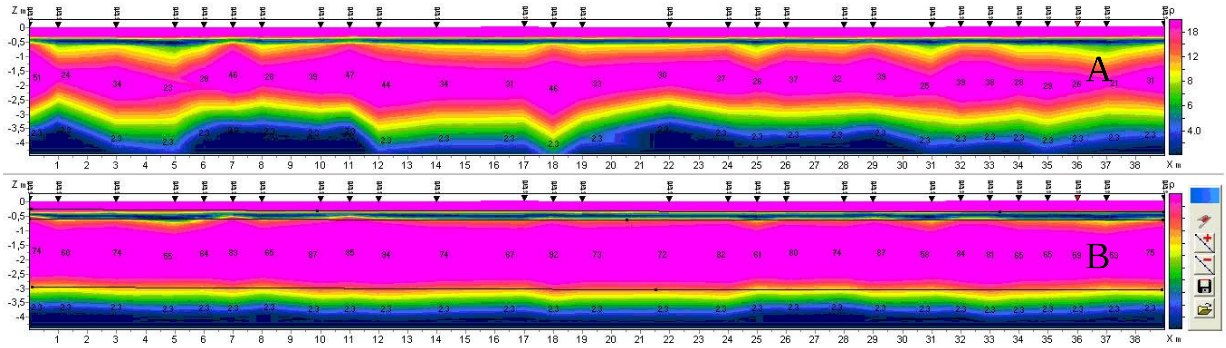


Fig. 51 Example of geoelectrical section after inversion without (A) and with (B) regard to geological boundaries

Module of joint interpretation of VES and MT (AMT, RMT) data

This module is intended for joint interpretation of VES and modifications such as AMT (MT, RMT, CSAMT, CSRMT) data. All of these modifications different in frequency band and, correspondingly, in depth. Only MT sounding (abbreviation of the deepest modification) is used below.

The module can be called from the **Options/MT Data** menu. The following options are available in the menu:

Load MT data	Load MT data from TXT file (file format is described below).
Load MDF data	Load MDF data created by ZondMT1D or ZondMT2D program
Remove MT data	Remove MT data

Joint inversion	Joint inversion of VES and MT data
Display MT plot	Plot MT curves.

Text file of MT data must contain the following values (are recorded in lines):

per – set of periods

app.res – corresponding values of apparent resistivity

pha – corresponding values of impedance phase

The apparent resistivity and impedance phase curves are displayed in window MT Plot (Fig. 52). Curves with circle shows measured parameters, solid lines – selected by joint inversion. It is possible to edit axes properties. To run the editor, right-click with pressed Shift button. For details of setting axis parameters, see Axes editor.

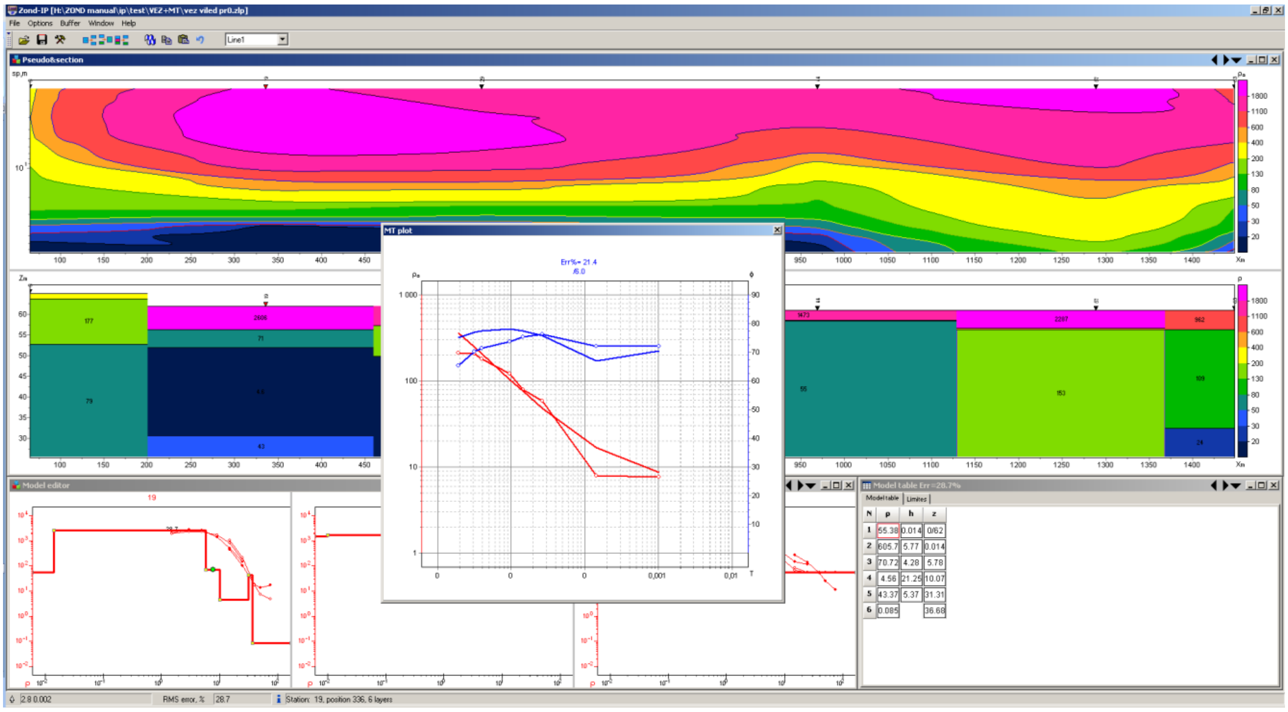


Fig. 52 Displaying of MT curves. The joint inversion results of VES and CSRMT data

Menu Buffer for comparison of inversion results

Menu **Buffer** of the main window allows comparing inversion results using different parameters. After calculating the first model, go to the menu **Buffer** and select **Model 1**. In the appeared dialog, it is possible to specify model name, reflecting, for example, used parameters in the inversion. In this way, 1 to 5 models can be saved.

A tick will appear in front of a saved model. When clicking on the saved model, shown dialog allows loading selected model as a current (button **From Buffer**), or saving the current model as selected (Button **To Buffer**).

The option Open from the Buffer menu opens all saved models for the current measurement point in one window (fig. 53).

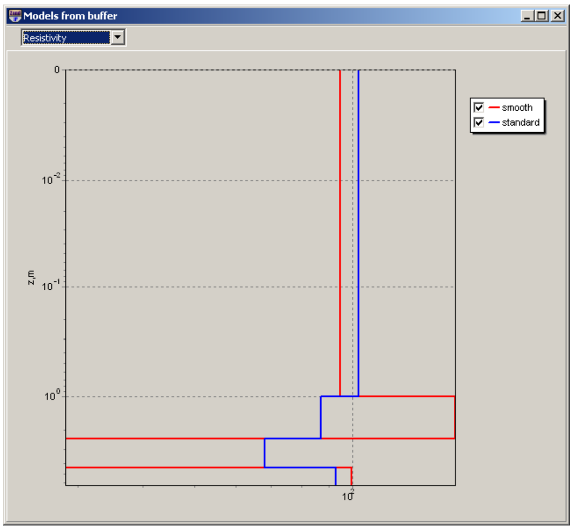
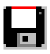


Fig. 53 Two models opened in the same window for one measurement point

.

Settings of graphic objects

Color palette setup dialog

The dialog is meant for object palette setup and can be run using **Palette** button (fig. 54). The dialog allows choosing one of default palettes (forward and inverse rainbow, grey scale, etc.) or creating own one. Right click with Ctrl button pressed to add slider to the scale. Use Delete button to remove slider. Use  button to save scale or load already existent scale using  button.

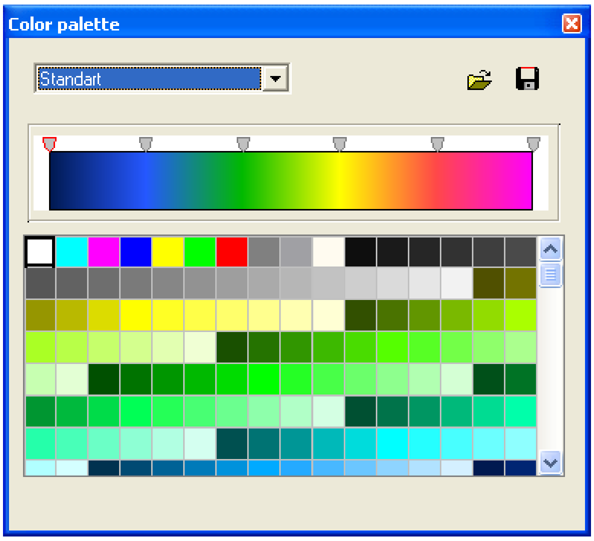


Fig. 54 Color palette parameters setup dialog

Axes editor

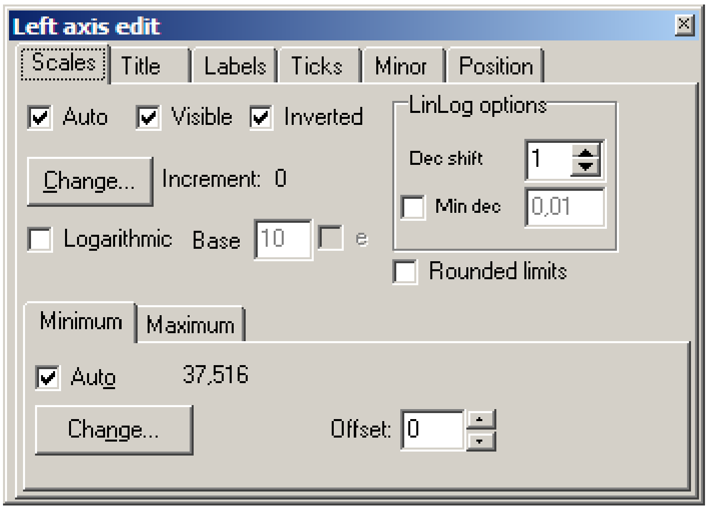


Fig. 55 Axes editor window

Axes editor is used to set graphic and scale axes parameters. Right click on necessary axis with SHIFT button pressed to run it. Pop-up menu with two fields (**options** and **default**) appears. The first one runs dialog, the second sets values on default.

First tab of **Scales** dialog contains options for axes scale parameters setup.

Option **Auto** defines how minimum and maximum axis values are chosen. If this option is ON axis limits are set automatically otherwise values from Minimum and Maximum filed specified by user are selected.

Option **Visible** shows/hides selected axis.

Option **Inverted** defines axis orientation.

Button **Increment change** runs dialog for axis label step definition.

Option **Logarithmic** selects logarithmic or linear axis scale. In case of sign-changing scale additionally use options from **LinLog options** field.

Option **Base** sets logarithm base for logarithmic axis.

Field **LinLog options** contains options for linear-logarithmic axis adjustment. Linear-logarithmic scale allows representing sign-changing or zero containing data in logarithmic scale.

Option **Dec Shift** sets indent (in logarithmic decades) relative to maximum axis limit modulo to zero. Minimum decade (prezero) has linear scale, others have logarithmic.

Option **Min dec** sets and fixes minimum (prezero) decade value if option is ON.

Option **Rounded limits** defines whether it is necessary to round minimum and maximum axis values or not.

Fields **Minimum** and **Maximum** contain options for axis limits adjustment.

Option **Auto** defines whether axis limit is selected automatically or using **Change** button.

Option **Offset** sets percentage axis limit shift relative to its actual value.

Tab **Title** contains options for axis header adjustment.

Tab **Style**:

Option **Title** sets axis header text.

Option **Angle** sets header text rotation angle.

Option **Size** sets header text indent. If 0 value is specified it is selected automatically.

Option **Visible** shows/hides axis header.

Tab **Text**:

Button **Font** runs header font setup dialog.

Button **Outline** runs dialog for header letters outline adjustment.

Option **Inter-char spacing** sets letter spacing in axis header.

Button **Gradient** runs gradient fill setup dialog for header text.

Option **Outline gradient** specifies if gradient fill is used in outline or interior of letters.

Button **Shadow** runs axis header shadow setup dialog.

Tab **Labels** contains options for axis label adjustment.

Tab **Style**:

Option **Visible** shows/hides axes labels.

Option **Multiline** is used for setting multiline axes labels.

Option **Round first** rounds first axis label.

Option **Label on axis** hides labels that go beyond axis.

Option **Alternate** arranges labels in two lines.

Option **Size** sets axis label indent. If 0 value is specified it is selected automatically.

Option **Angle** sets label rotation angle.

Option **Min separation %** sets minimum percentage label spacing.

Tab **Text**:

Button **Font** runs label font setup dialog.

Button **Outline** runs dialog for label letters’ outline adjustment.

Option **Inter-char spacing** sets letter spacing in label text.

Button **Gradient** runs label gradient fill setup dialog.

Option **Outline gradient** specifies whether gradient fill is used in outline or interior of letters.

Button **Shadow** runs label shadow setup dialog.

Tab **Ticks** contains options for axis main ticks adjustment.

Button **Axis** runs axis line setup dialog.

Button **Grid** runs line setup dialog for main ticks’ grid.

Button **Ticks** runs external main axis tick setup dialog. Option **Len** sets its length.

Button **Inner** runs internal main axis tick setup dialog. Option **Len** sets its length.

Option **Centered** centers grid of axis ticks.

Option **At labels only** displays main axis ticks only if axis labels are present.

Tab **Minor** contains options for axis intermediate ticks adjustment.

Button **Grid** runs line setup dialog for intermediate ticks grid.

Button **Ticks** runs external intermediate axis tick line setup dialog. Option **Length** sets its length.

Button **Minor** runs internal intermediate axis tick line setup dialog. Option **Len** sets its length

Option **Count** sets number of intermediate ticks between main ones.

Tab **Position** defines axis size and position.

Option **Position %** sets axis indent relative to its standard position on graph (in percent to graph size or in screen units depending on selected option Units).

Option **Start %** sets axis start indent relative to its standard position on graph (in percent to graph size).

Option **End %** sets axis end indent relative to its standard position on graph (in percent to graph size).

Legend editor

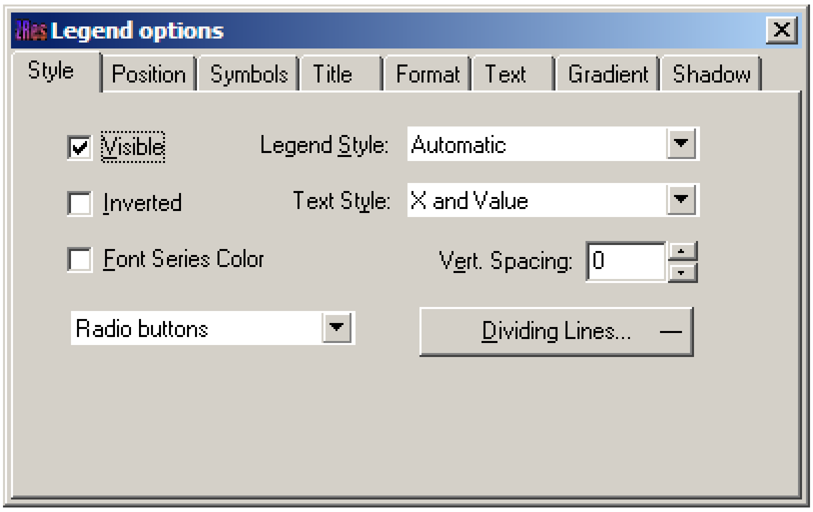


Fig. 56 Legend editor window

Editor allows adjusting graphic and legend interface. Right click with SHIFT button pressed on legend to the right of the graph to run it.

Pop-up window with set of tabs will appear.

Tab **Style** contains settings of legend display, allows choosing data label format and showing boundaries between legend labels and so on.

Tab **Position** serves for choosing legend position relative to graphics plan.

Tab **Symbols** sets legend symbols display parameters.

Tab **Title** specifies legend name and allows adjusting its format.

Tab **Text** serves for adjusting legend label format.

Tabs **Format**, **Gradient** and **Shadow** contain settings of legend window, its gradient fill, and shadow.

Graphics set editor

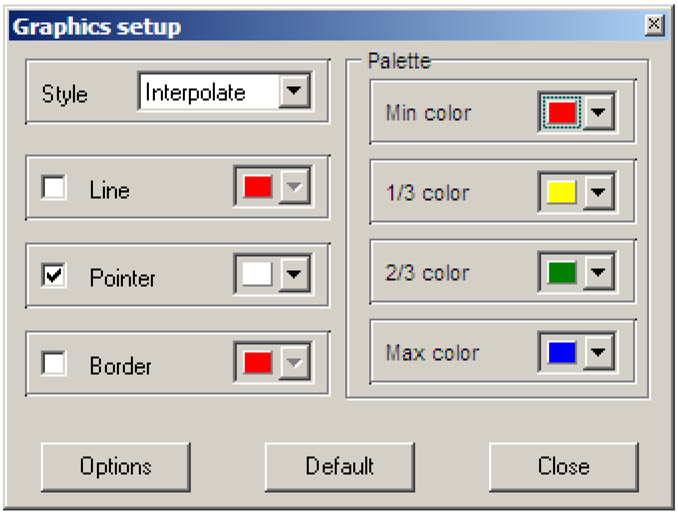


Fig. 57 Graphics set editor window

Graphics set editor serves for color adjustment of graphics set.

Option **Style** defines algorithm of graphic's color palette specification.

Interpolated palette is used if **Interpolate** is selected. It is created using colors specified in fields **min color, 1/3 color, 2/3 color** and **max color**. Value **const** sets the same color (option **color**) for all graphics. Value **random** assigns random colors for all graphics.

Option **Line** sets color for graphic's connecting lines. If this function is OFF palette color is used otherwise specified in **Line** field color is used.

Option **Pointer** sets color for graphic point's color fill. If this function is OFF palette color is used otherwise specified in **Pointer** field color is used.

Option **Border** sets graphic point's outline color. If this function is OFF palette color is used otherwise specified in **Border** field color is used.

Button **Options** runs graphics setup dialog.

Button **Default** returns graphics default settings.

Graphics editor

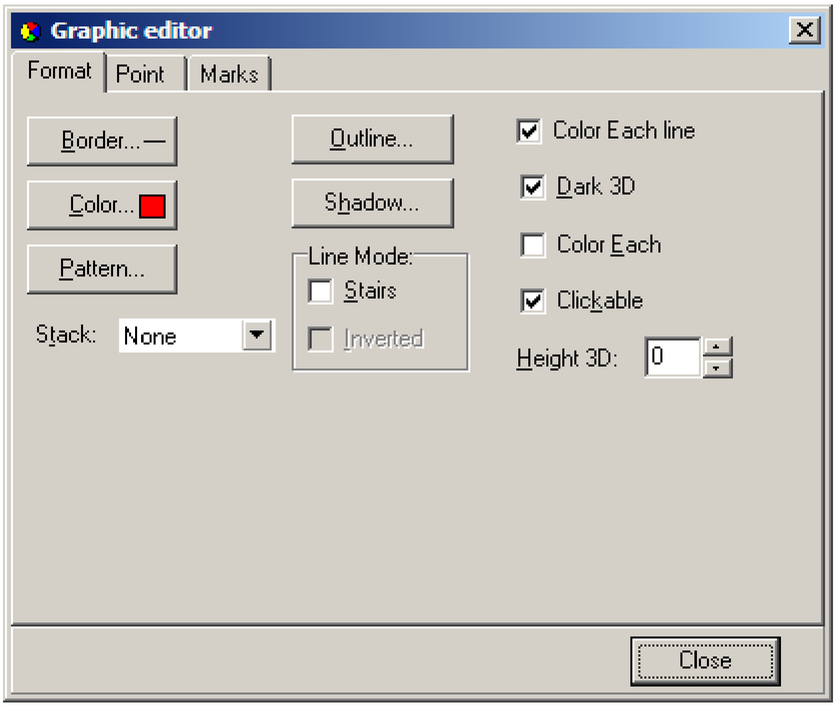


Fig. 58 Graphics editor window

Graphics editor is used for graphic interface setup. Right click with SHIFT button pressed on graphic to run it.

Tab **Format** contains connecting line settings.

Button **Border** runs connecting line parameters setup dialog.

Button **Color** runs color setup dialog.

Button **Pattern** runs filling parameters setup dialog.

Button **Outline** runs graphic's connecting line setup dialog.

Button **Shadow** runs shadows setup dialog.

Tab **Point** contains plot point settings.

Option **Visible** is used to show/hide plot points.

Option **Style** sets point shape.

Option **Width** sets point width in display units.

Option **Height** sets point height in display units.

Option **Inflate margins** defines if image size is zoomed in according to point size or not.

Button **Pattern** runs point's color fill setup dialog.

Button **Border** runs point's outline parameters setup dialog.

Button **Gradient** runs point's gradient color fill setup dialog.

Tab **Marks** contains settings of graphic's point marking.

Tab **Style**

Option **Visible** is used to show/hide plot point marking.

Option **Draw every** allows plotting every second, third and so on marking depending on selected value.

Option **Angle** sets point marking rotation angle.

Option **Clipped** defines whether point marking is plotted or not if it is located beyond graphic borders.

Tab **Arrows** allows adjusting arrow from marking to point.

Button **Border** runs arrow line parameters setup dialog.

Button **Pointer** runs arrowhead shape setup dialog (options in tab Point).

Option **Length** sets arrow length.

Option **Distance** sets distance between arrowhead and plot point.

Option **Arrow head** sets type of arrowhead. **None** – arrowhead specified by **Pointer** button is used. **Line** – classic thin arrowhead is used. **Solid** - classic thick arrowhead is used.

Option **Size** sets arrowhead size if classic arrow is used.

Tab **Format** contains graphic settings of marking frame.

Button **Color** runs frame background color selection dialog.

Button **Frame** runs frame line setup dialog.

Button **Pattern** runs background parameters setup dialog.

Option **Bevel** sets frame type: usual, elevated or submerged.

Option **Size** sets elevation or submergence level.

Option **Size** rounds frame corners.

Options **Transparent** and **Transparency** sets frame seamlessness degree.

Tab **Text**:

Button **Font** runs marking font setup dialog.

Button **Outline** runs marking letter outline setup dialog.

Option **Inter-char spacing** sets letter spacing for marking text.

Button **Gradient** runs gradient fill for marking text setup dialog.

Option **Outline gradient** specifies if gradient fill is used in outline or interior of letters.

Button **Shadow** runs marking text shadow setup dialog.

Tab **Gradient** contains gradient fill settings for frame around markings

Tab **Shadow** contains shadow settings of frame around marking.

Print preview dialog

Use **File/Print preview** function of the program main menu to run print preview dialog. Double click on any program object also runs it. Two options are available when running via main menu:

Option **Station** serves to print sounding curves and current station model (fig. 59). Model parameters are displayed as table which contains number, resistivity value and depth of top layer boundary.

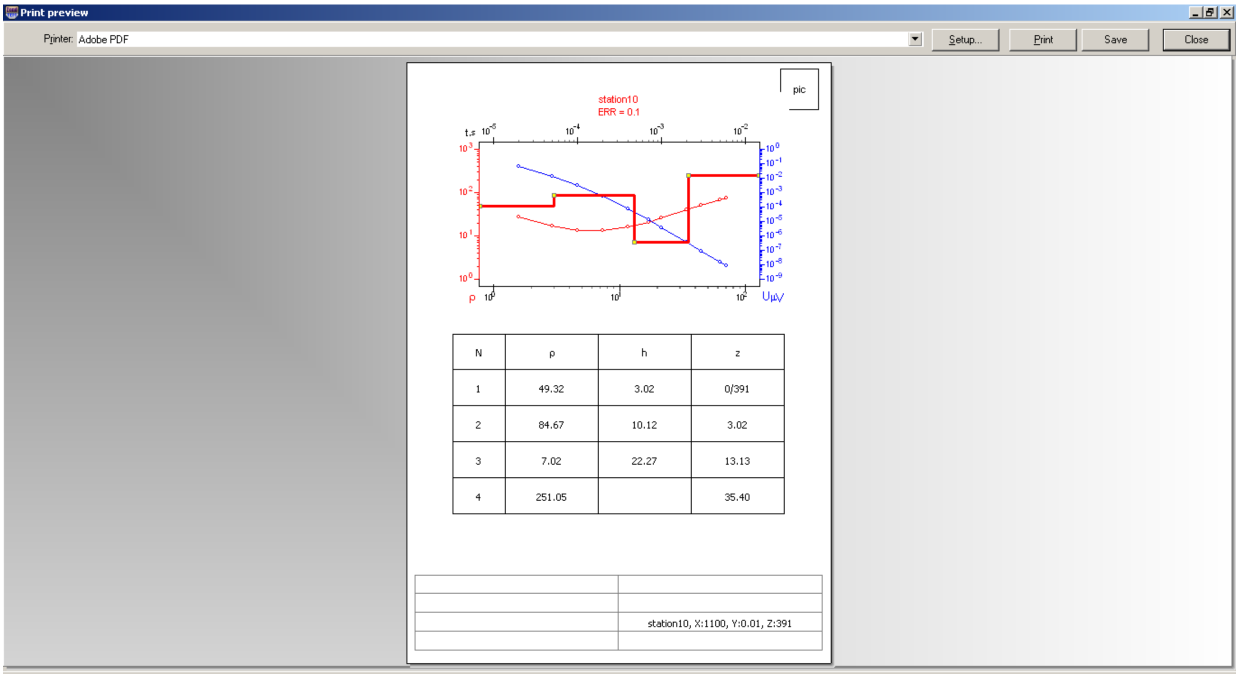


Fig. 59 Window **Print preview/Station**

Option **Section** serves to print geoelectrical section (fig. 60).

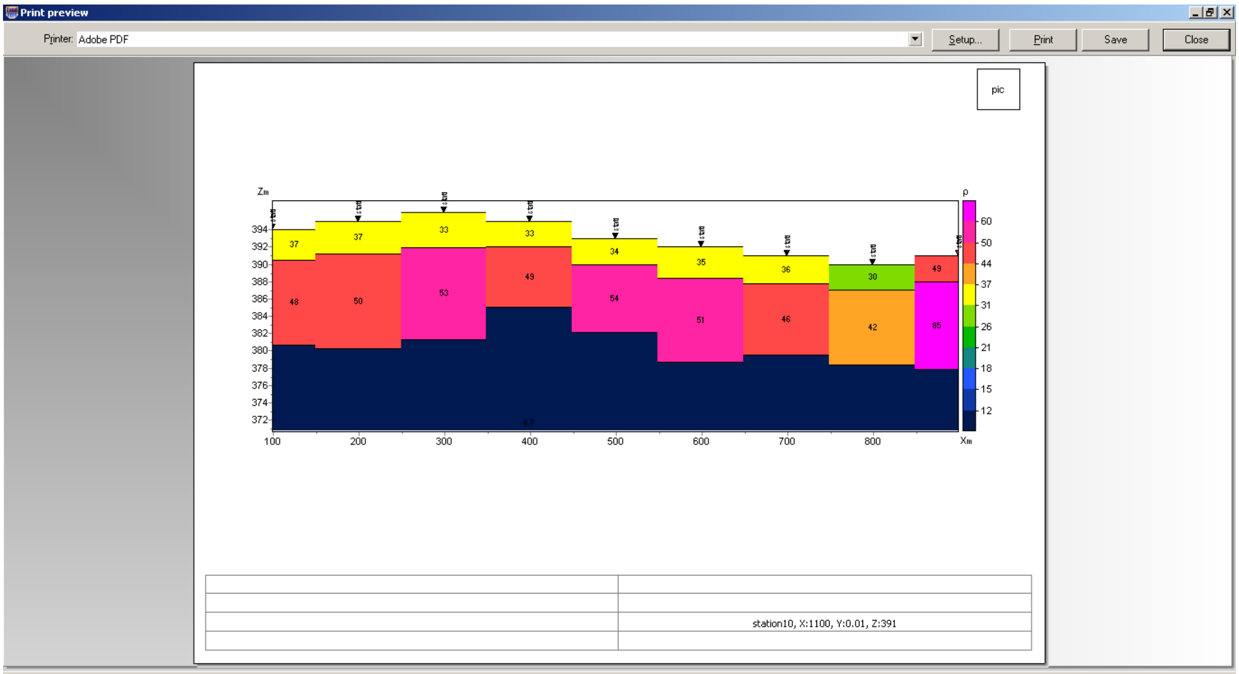


Fig. 60 Window **Print preview/Section**

Use left button to move print object in the page.

Print Preview window of the main menu contain the following buttons:

- select printer. One of adapted printers can be chosen in opening menu.

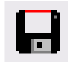
- print setup button. Size and page orientation, print properties, number of pages per sheet and other parameters can be set in opening window.

- press this button to start printing when necessary parameters are specified.

- save in bitmap files

- close **Print preview** window.

Squares in the top part of the page are designed for company seals, stamps and symbols. Right click on the square and choose raster image which you would like to insert in to opening window. Use mouse to change square size.

Editing table is located at the bottom of the page. In order to add text, right click on the table and type in necessary text in opening window. Comments can be also saved in table files using  button or already saved comments can be loaded using  button.

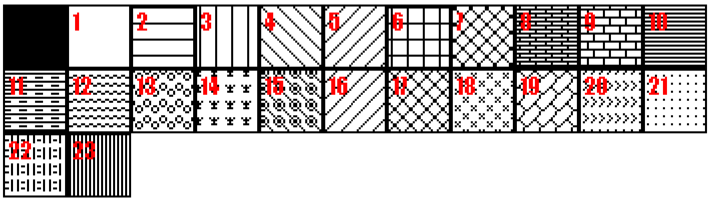
Appendix 1. Lithology data file format

Lithologic columns are hold in certain file formats. First type of files has txt extension.

The following file structure is used to create lithology data file:

First column contains depth (from ground surface) of layer boundary. Second column contains zeros. Third column defines layer color for visualization, forth – type of pattern

Lift of first 23 patterns which can be used for lithologic column creation is given below.



Lithologic data sample-file is given below:

0 1 0 13 Top of layer 1
4 1 0 13 Bottom of layer 1
4 1 0 19 Top of layer 2
11 1 0 19 Bottom of layer 2
11 1 0 27 Top of layer 3
16 1 0 27 Bottom of layer 3

Second type of files has *.crt extension; these are control files which specify type of data and way of visualization. Structure of CRT file for lithology data visualization for any number of boreholes is described below.

2280.txt	First line – logging or lithology data file
brhl2280	Second line – Borehole name (is displayed on borehole)
18 2 2 1 0 1 0 0	Third line contains control parameters.

Data record 18 – borehole coordinate on profile.

2 – image width (in percents to profile length, usually 1 - 20).

2 – type of data visualization 0 - 3.

0 - logging data (as graph)*;*

1 - logging data (interpolated color column), section color scale is used for visualization;

2 - lithologic column;

3 - logging data (color column), colors for data visualization correspond to model color scale, column colors are selected in compliance with model color scale;;

1 - Logging data normalization parameter 0 - 2.

0,1 – the same minimum and maximum is used for all data;

1,2 - subtract average value from every borehole log;

0 - Logging method index (if different logging methods are displayed indices of all methods should be specified) 0 – n-1, where n – number of methods.

1 – Plot color.

0 – Data scale is logarithmic 0 or linear 1.

0 – Vertical borehole shift relative to ground surface.

3246.txt Description of the following borehole on profile

brhl3246

102 2 2 1 0 1 0 0