Program for two-dimensional interpretation of electromagnetic sounding data in time and frequency domain.

(land and airborne version)

ZONDTEM2D

Program purpose and capabilities

«ZONDTEM1D» is intended for 2D interpretation of profile data obtained by electromagnetic soundings in time and frequency domain. Friendly interface and powerful capabilities of data presentation allows solving assigned geological problem to maximum effect.

«ZONDTEM1D» is a convenient instrument for automatic and semi-automatic (interactive) profile data interpretation and can be used on PC-compatible IBM with Windows system.

Electrical resistivity (measured in ohm*meter (Ohm*m)) specifies rock capability to maintain resistance to current flow and it is considered to be the most universal electromagnetic property. In rocks and ores it varies within very wide limits: from 10^{-3} to 10^{15} Ohm*m. For the most widespread sedimentary, volcanic, and metamorphic rocks electrical resistivity depends on mineral composition, physical, mechanical and water properties, salt concentration in groundwater, and to a less extent on their chemical composition, and on other factors (temperature, stratification depth, metamorphism degree, etc.) [Hmelevskoj, 1997].

Electrical resistivity of minerals depends on their crystal bonds. Dielectric minerals (quartz, micas, feldspars, etc.) with mainly covalent forces are characterized by very high resistivity (10^{12} - 10^{15} Om*m). Semiconductor minerals (carbonates, sulfates, haloids, etc.) with mainly 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) are distinguished by electronic conduction and conduct current very well. First two groups of minerals create “rigid” matrix of the majority of rocks. Clay minerals create “plastic” matrix that can adsorb bound water, whereas rocks with “rigid” minerals can adsorb only solutions and free water, i.e. 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 mineralization. Chemical composition of dissolved salts does not really matter that is why only total salt content can be inferred by electrical exploration. Electrical resistivity of bound water adsorbed by solid particles of rocks is

very low and does not change much (from 1 to 100 Om*m). It can be explained by its constant mineralization (3-1 g/l). Average mineralization of ocean water is 36 g/l.

As pore water (bound and free) is distinguished by 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 electrical conductivity 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 abruptly when freezing as free water becomes almost dielectric and electrical conductivity is determined only by bound water that freezes at very low temperatures (below -50^0 C). Increase of resistivity of various rocks while freezing is diverse: several times for clays, up to 10 times for hard rocks, up to 100 times for clay and sandy loams, and up to 1000 times and more for sands and coarse rocks.

Despite the fact that resistivity depends on numerous factors and varies within wide limits in different rocks, main laws of electrical resistivity 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 characterize salts, gypsums, limestones, sandstones, and some other rocks. As a rule, in detrital sedimentary rocks the more grain size, the higher rock resistivity, i.e. electrical resistivity mainly depends on clayiness. 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].

Time-domain electromagnetic sounding is one of pulse methods which is based on examination of attenuation of eddy current field (transient processes) arising in conductive mediums when the constant primary field is suddenly switched off. The primary field is produced by passage through closed ungrounded loop or grounded line of square current pulses with duration sufficient for constant field settling. When the current is suddenly switched off, measured voltage in receiver array does not drop to 0 immediately, it gradually disappears changing in a quite complex way. This is due to the fact that at the moment of current switching off in conductive areas of the section secondary currents are induced and they divide in subsurface layers and then start to penetrate into deeper laying layers attenuating moving away

from the source. This process is called transient phenomenon and relationship between measured voltage in the receiver array and time passed since the moment current was switched is a transient curve. Physical base for pulse electromagnetic methods application is a difference between rock and ore electrical conductivity and polarizability in natural occurrence. The depth of non-stationary electromagnetic field penetration into the Earth is determined by time and this property cause capacity to conduct sounding examining field components-time relationship. Transient phenomenon is examined at the moment of field absence in the loop using inductive field receivers, usually in a form of loop with a size of tens and hundreds of meters or small-scale multiturn frames.

ZondTEM2D program allows performing two-dimensional interpretation of transient electromagnetic method data (TEM) obtained by using various observation systems, both ground and airborne modifications. The program supports the following arrays: coincident loops, in-loop, dipole-dipole.

To solve the inverse problem (inversion), the least square method with regularization is used. Regularization increases the solution stability and allows obtaining smoother distribution of resistivity in the medium [Constable, 1987].

$$\left(A^T W^T W A + \mu C^T C\right)\Delta m = A^T W^T \Delta f - \mu C^T C m$$

where A – matrix of partial derivative of measured values to section parameters (Jacobian), C – smoothing operator, W – matrix of relative measurements error, m – section parameters vector, μ – regularizing parameter, Δf – misfit vector between observed and calculated values.

Program installation and removal

«ZONDTEM2D» program is supplied on the Internet. This manual is included in the delivery set. Latest updates of the program can be downloaded on the website: www.zond-geo.com

To install the program copy it 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 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 remove the program delete work directory of the program.

System requirements

«ZONDTEM2D» 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 is actively using 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.

Start working with the program, main options

To start up «ZONDTRM2D» it is necessary to create data file of certain format which contains information about station coordinates, topography and measuring results.

Usually one file contains data for one measurement profile. Text data files organized in the format of «ZONDTEM2D» software have *.T2D extention.

Zond data file [*.T2D]	Open data or project file in Zond format.

Main data file format

Program presents universal data format which includes information of station coordinates, relative relief elevations and measured values itself. File of this format can be exported from ZondTEM1D.

Data format *ZONDTEM2D data files* has *.T2D extention.

Files of *.T2D format can have different structure – they can be either data files (structure of these files is described below), or project files (they are created by the program during saving of operating results). Project file is binary, it can be read only by ZONDTEM2D. It contains all the information which is used to work with the project – observed data, calculated data, models, input prior information, settings etc.)

First line contains control key showing the program measurement type.

Possible values:

0: two vertical magnetic dipoles oriented along profile.

1: two vertical magnetic dipoles oriented normal to profile.

2: two horizontal Y-Y magnetic dipoles oriented along profile.

3: two horizontal Y-Y magnetic dipoles oriented normal to profile.

4: coincident loops array.

5: Central loop array.

6: In loop array dB/dz component. Sounding in large rectangular loop.

7: In loop array dB/dz component. Sounding in large circle loop.

Types (0,1,2,3) suppose measurement in frequency domain, (4,5,6,7) – in time domain.

Second line contains distance between dipoles for arrays (0,1,2,3) or effective loop diameter (4,5,7). If measurements were performed with square loop, diameter is calculated on the assumption of equal areas of round and square loops. For (6) line contains 3 values: length of loop side along X (correspond to receivers line direction), length of loop side along Y, Y offset of receivers line. For (7) line contains 2 values: diameter of circle loop, Y offset of receivers line. For (6,7) origin of coordinates in the center of transmitter loop, so receiver X positions should be assigned in this way.

For types (0,1,2,3,5) the following line contains value of the array height above topography (positive number).

Third line contains list of frequencies for (0,1,2,3) or list of times (in seconds) for (4,5,6,7).

For types (4,5,6,7) the following line contains value of pulse length (in seconds).

The further block contains description of electromagnetic soundings. Every new station starts with lines containing “pos ” values which are followed by station coordinates. In the following 1-4 lines there are data and measurement weights.

The following keys for data lines designation are available in the program:

Mod – values of modules of measured complex signal which is normalized to the field in the air (in unit fraction). Arrays (0,1).

Mod_w – line of weights of measured complex signal modules. Set within limits 0-1. Arrays (0,1).

Pha – measured complex signal phase values normalized to the field in the air (in degrees). Array (0,1).

Pha_w – phase weights line. Set within limits 0-1. Arrays (0,1).

dbdt – measured EMF values ($x10^6$). Arrays (4,5).

Dbdt_w – EMF measurement weights lines. Set within limits 0-1. Arrays (4,5).

Lines with measurement weights can be missing.

Here is an example of file for array of 0 type. N) is for line number.

1) 0

2) 50

3) 1.2

4) 1.40800000000000E+0004 7.11100000000000E+0003 3.55500000000000E+0003 1.77700000000000E+0003 8.88000000000000E+0002 4.44000000000000E+0002 2.22000000000000E+0002 1.11000000000000E+0002

5) pos 0.00000000000000E+0000 0.00000000000000E+0000

6) mod 0.4625 0.3690 0.2579 0.1838 0.1085 0.06053 0.03200 0.01759

7) pha -41.2220 -3.2470 31.4096 54.2340 62.8443 69.4993 68.1653 61.1036

8) pos 2.50000000000000E+0001 0.00000000000000E+0000

9) mod 0.3995 0.3090 0.2234 0.1600 0.09624 0.04906 0.02775 0.01070

An example of file for array of 0 type.

1) 4

2) 56

3) 0.00003200 0.00003400 0.00003700 0.00003900 0.00004200 0.00004500 0.00004900 0.00004900 0.00005200 0.00005600 0.00006000 0.00006000 0.00006400 0.00006900 0.00007400 0.00008000 0.00008000 0.00008000 0.00008500 0.00008500 0.00009200 0.00009800 0.00009800 0.0001050 0.0001130 0.0001210 0.0001300 0.0001390 0.0001500 0.0001600 0.0001720 0.0001850 0.0001980 0.0002120 0.0002280 0.0002440 0.0002620 0.0002810 0.0002810 0.0003010 0.0003230 0.0003470 0.0003720 0.0003720 0.0003990 0.0004280 0.0004590 0.0004920 0.0005280 0.0005660 0.0006080 0.0006080 0.0006520 0.0006990 0.0007500 0.0008040 0.0008040 0.0008630 0.0009250 0.0009250 0.0009920 0.001064 0.001142 0.001225 0.001313 0.001409 0.001511 0.001621 0.001738 0.001865 0.002000

4) 0.004

5) pos 2.50000000000000E+0001 1.45200000000000E+0003

6) dbdt 244860 213600 185480 160400 138220 118780 101870 * 87267 74727 64011 * 54883 47119 40514 34884 * * 30068 * 25932 22361 * 19266 16574 14226 12179 10394 8843.5996 7501 6343.7998 5351.3999 4504.5000 3784.8999 3175.8000 2661.6001 2228.2000 1863.3001 * 1556.1999 1297.6999 1080.1999 897.4500 * 744.1400 615.8800 508.9500

420.1600 346.6900 286.1000 236.1900 * 195.0900 161.1500 133.0200 109.5900 * 89.9760 73.5010 * 59.6560 48.0590 38.4150 30.4870 24.0670 18.9610 14.9770 11.9290 9.6318 7.9158 6.6278

7) dbdt_w 1.0000 1.0000 1.0000 0.9999 0.9999 0.9999 0.9999 1 0.9999 0.9999 0.9998 1 0.9998 0.9998 0.9998 0.9997 1 1 0.9997 1 0.9996 0.9996 1 0.9995 0.9994 0.9993 0.9992 0.9990 0.9989 0.9987 0.9984 0.9981 0.9978 0.9974 0.9969 0.9962 0.9955 0.9946 1 0.9936 0.9923 0.9907 0.9889 1 0.9866 0.9838 0.9804 0.9762 0.9712 0.9650 0.9577 1 0.9487 0.9379 0.9248 0.9087 1 0.9000 0.9000 1 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000 0.9000

8) pos 7.50000000000000E+0001 1.45700000000000E+0003

9) dbdt 312770 276600 243650 213870 187130 163260 142090 * 123390 106960 92545 * 79941 68935 59330 50952 * * 43645 * 37275 31728 * 26906 22726 19117 16016 13368 11122 9229.9004 7647.6001 6333.1001 5247.3999 4354.5000 3621.8000 3020.8000 2526.7000 2118.7000 * 1779.8001 1496.5000 1258.1999 1056.6999 * 885.8100 740.8100 617.9100 514.0600 426.6600 353.4200 292.2700 * 241.3800 199.0600 163.8600 134.5500 * 110.0900 89.6640 * 72.6160 58.4380 46.7270 37.1560 29.4410 23.3240 18.5620 14.9200 12.1750 10.1200 8.5743

With no measurement its value is replaced with symbol “*”.

Program main window toolbar

The toolbar is intended for fast call of the most frequently used functions. It contains the following functional buttons (from left to right):

	Open data file.
	Run data saving dialog.
	Run inversion parameters setting dialog.
	Start or stop (on second press) inversion procedure.

Main window functions menu

Menu items and its assignment are listed below:

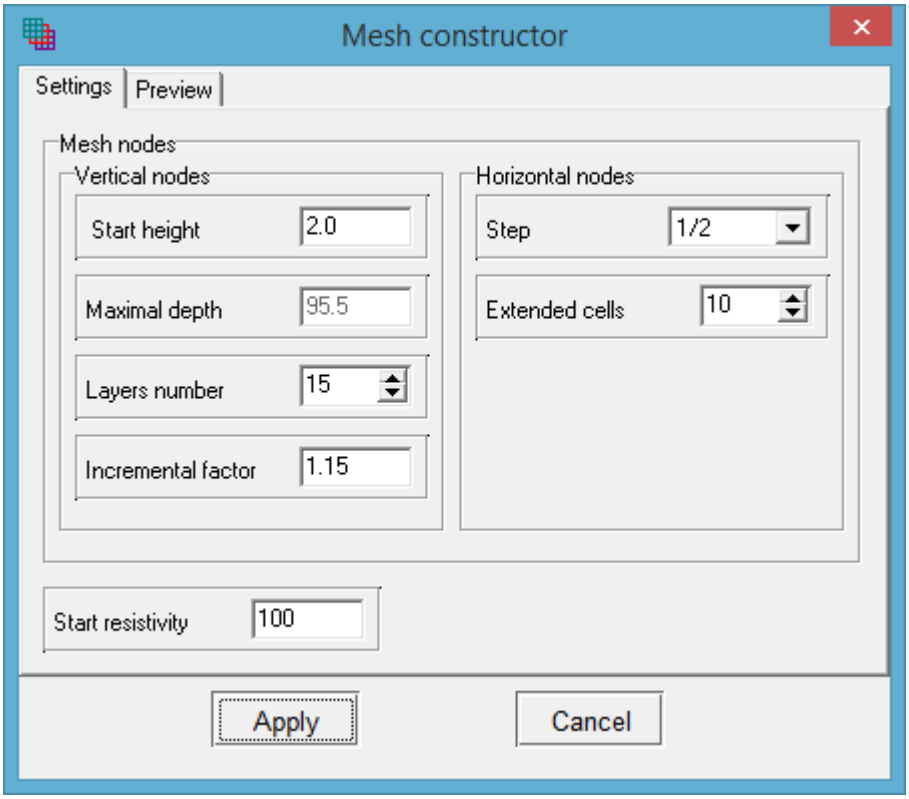
File/Open file	Open data file.
File/Save file	Run saving dialog.
File/Edit file	Open file used by the program in Notepad editor.
File/Print preview	Run program main window printing dialog.
File/Recent	Recently used files.
File/Exit	Exit the program.
Options/Project information	Show the information about loaded project.
Options/Mesh constructor	Run starting model setting dialog.
Options/Program setup	Run inversion parameter setting dialog.
Options/Geological editor	Run window of geological interpretation of geoelectric section.
Options/***Data***/dBdt10^6	Show EMF graphs.
Options/*Data*/Magnitude	Show complex signal modulus graphs.
Options/*Data*/Phase(deg)	Show complex signal phase graphs.
Options/*Data*/Graphics settigs	Show setting dialog for measured data graph parameters.
Options/***Inversion***/Set boundaries	Run setting dialog for boarders which the program will take into account while performing inversion.
Options/*Inversion*/Resolution	Allows zooming in inversion resolution with depth. The greater this parameter value, the stronger the influence of deep objects.
Options/*Inversion*/Invert phases	In frequency domain data interpretation mode this option shows the program weather it is required to invert phases.
Options/Inversion/Invert only visible graphs	Only displayed on the screen data (in graphs mode) are considered for inversion. Data which should not be used are turned off in legend.
Options/ Inversion/LinLog barrier	Sets linear-logarithmic barrier for data in time domain. Since data can be alternating, logarithmic scale usage is impossible. The value close to data noise level should be input. If the "*" value is input, linear-logarithmic barrier is calculated

	automatically.
Options/ Inversion/Preconditioned	Gives more smooth solution.
Options/ Inversion/DF optimization	Turn on optimization of inversion during every iteration.
Options/***Borehole***/Create/Edit borehole data	Add (edit) well data (lithology columns). Runs borehole information creating dialog.
Options/Borehole/Load borehole data	Open and show file with logging data and lithology columns and also files of mod1d format (1D interpretation files).
Options/Borehole/Remove boreholes	Remove logging data and lithology columns from the project.
Options/Borehole/Set column width	Set lithology column width for displaying in the section.
Options/Import/Export/ Background image	Background import – graphic file of bmp format or file of SectionCor (*.sec) program format.
Options/Import/Export/ Remove background	Remove background.
Options/Import/Export/ Change sizes	Change size and position of background.
Options/Import/Export/ Save background	Save background image into file.
Options/Import/Export/ Load 1D model	Load 1D interpretation model from Zond1D file.
Options/Import/Export/ Load MOD2D model	Load geoelectric model of ZOND MOD2D into section.
Options/Import/Export/ Save MOD1D file	Save current model into Zond MOD1D format.
Options/Import/Export/ Save MOD2D file	Save current model into Zond MOD2D format.
Options/Import/Export/ Export model to geosoft	Export current model into GeoSoft format.
Options/Import/Export/	Export current model into seg-y format.

Export model to seg-y	
Options/***Extra***/ X=Z scale	Set equal scales for vertical and horizontal axes of model.
Options/Extra/ Bitmap output settings	Run setting dialog for graphic image parameters for export.
Buffer/Model	Load model in buffer or load from buffer.
Buffer/Model	All buffer models displaying in one window.

Starting model setting dialog

After creating «*.T2D» data file or another supported format file, you should load it using the button or corresponding menu item. On successful file loading starting model setting dialog appears where it is suggested to choose mesh parameters and resistivity of the host medium. This model is starting for data inversion as well. You can also run mesh parameters choosing dialog in main menu **Options/Mesh Constructor**.



Vertical nodes section contains options allowing setting model mesh parameters in vertical direction.

Start height – sets thickness of first layer. This value must approximately correspond to cell length and be appropriate for necessary resolution.

Maximal depth – sets depth of the lower layer. It should be kept in mind that the maximum depth must not be too large since geoelectric section parameters influence decreases with depth.

Layers number – sets number of layers. Usually 12-20 layers are enough to describe the model. It is undesirable to set large values of this parameter since it will significantly slow down calculation rate.

Incremental number – sets relationship between adjoined layers' thickness. This parameter values are usually set between 1 and 2.

Horizontal nodes section contains options allowing setting horizontal model mesh parameters.

Step – sets mesh step width in units of distance between adjoined stations.

Extended cells – specifies a number of additional columns of cells to the left and to the right from model.

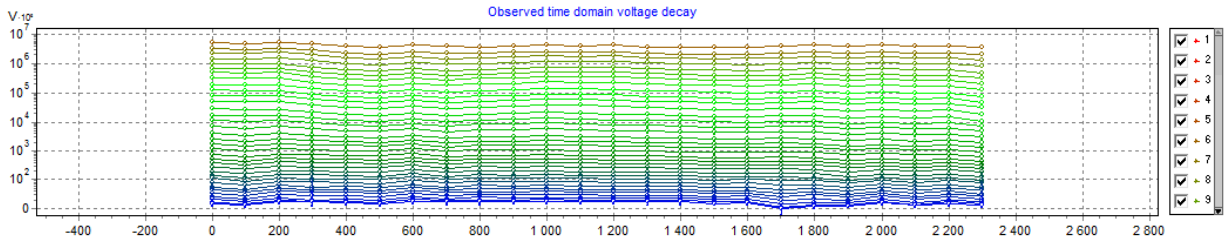
Start resistivity – sets resistivity of starting model.

Preview tab allows preview of set mesh image.

Graphs plan

Graph plan is intended to display measurements along the profile in a form of graphs at certain frequency or time.

In program main menu you can choose data type for displaying.



Operating with graphs plan is performed using mouse.

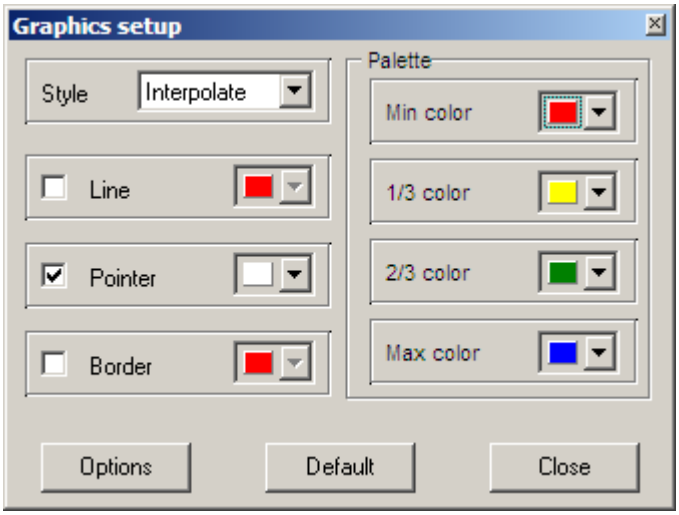
Zooming in or dragging some part is performed with pressed button ("rubber rectangular" tool). To zoom in a segment, move mouse cursor down and to the right with left button pressed. To return to primary zoom do the same but with mouse cursor moving up and to the left. Moving (scrolling) of the graph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

By pressing left mouse button on graphic point all the other graphs become hidden until the mouse button is released. To remove a certain point from inversion, you should click right mouse button on it and then it will be displayed in a form of diagonal cross.

Graphs plan setting dialog is run from main window **Options/Extra/ graphics settings**.

Selecting one and accordingly removing other graphs is performed by mouse button on the legend with SHIFT key pressed. On second press the reverse operation is performed.

Graphs set editor



Graphics set editor serves for setting color sequence of graphs set.

Option **Style** defines an algorithm of graph color palette setting.

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 the graphs. Value **random** assigns random colors for all graphs.

Option **Line** sets color for graphs connecting lines. If this function is not active, palette color is used, otherwise color specified in **Line** field is used.

Option **Pointer** sets color for graph pointer color fill. If this function is not active, palette color is used, otherwise color specified in **Pointer** field is used.

Option **Border** sets graph pointer outline color. If this function is not active, palette color is used, otherwise color specified in **Border** field is used.

Button **Options** runs graph setting dialog.

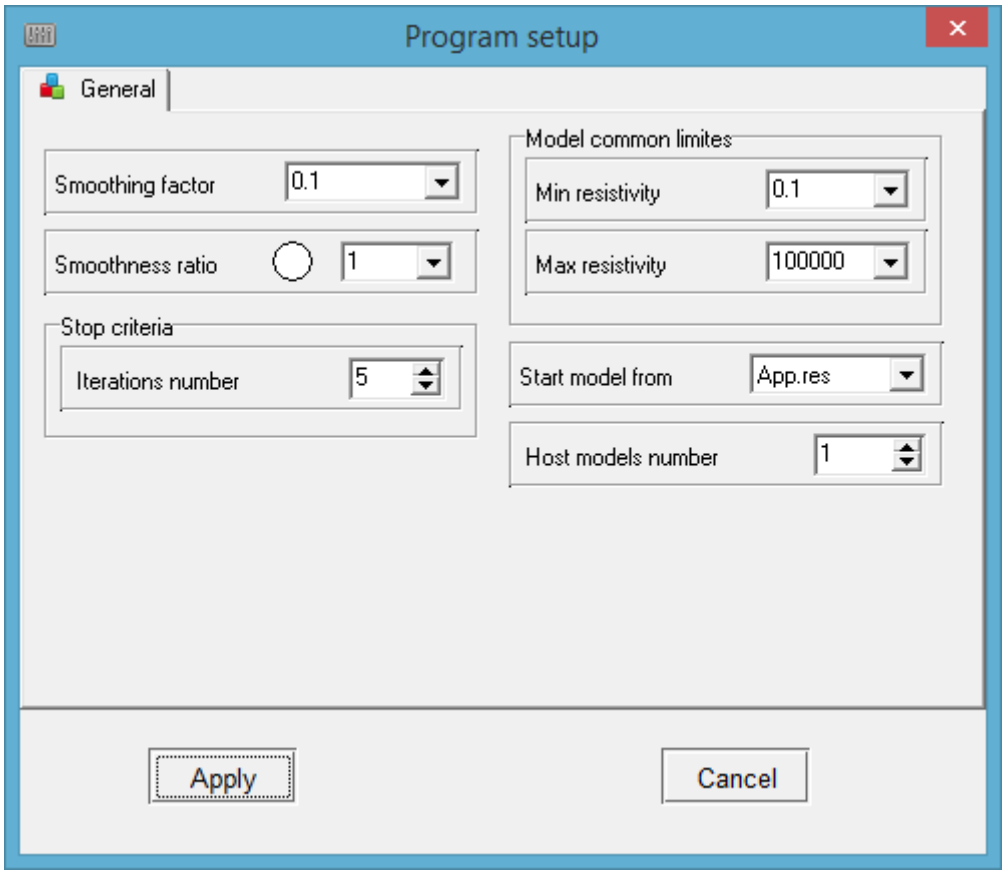
Button **Default** sets graph settings equal to default settings.

Data inversion

After loading data file and setting the starting model, next step is to choose inversion type and set parameters. Inversion parameter setting dialog can be run using the button or menu item **Option/Program setup**.

Inversion parameter setting dialog

The dialog is intended to set parameters connected with the reverse problem solution.



The **Inversion** option determines an algorithm by which the reverse problem will be solved.

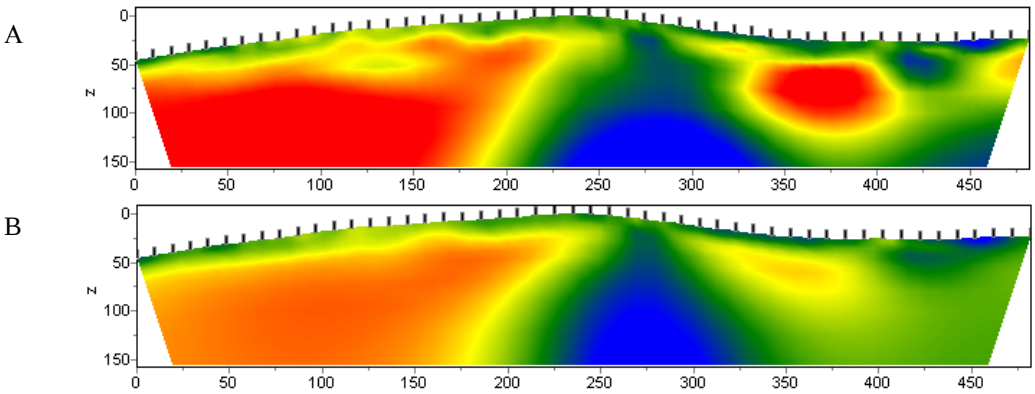
The **Stop criteria** section contains criteria of the inversion stop.

Iterations number – the process stops on reaching the set iteration number.

The **Model common limits Min resistivity, Max resistivity** section sets the change range for model parameters for inversion.

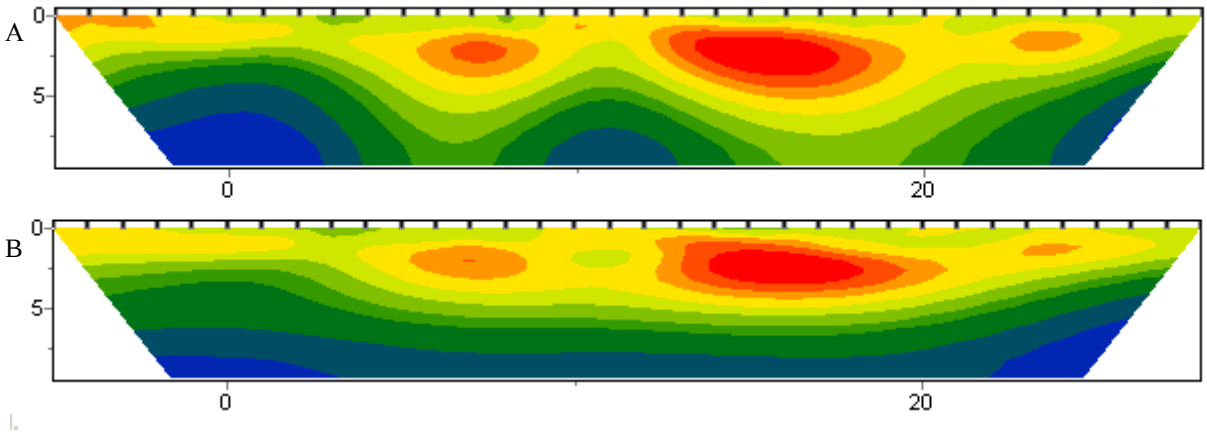
Smoothing factor – sets the relationship between minimization of measurement misfit and model misfit (for instance, smoothing). For the data with high noise level or to get smoother

and more stable distribution of parameters, it is better to set relatively large values of smoothing parameter: 0.5 – 2; for high quality measurements 0.005 – 0.01 values are used. For large values of smoothing parameter large values of data misfit are typically obtained.



Geoelectric models as a result of ***Occam*** inversion with **smoothing factor** 0.01 (A) и 1.0 (B).

Smoothness ratio – determines the relationship between smoothing in horizontal and vertical directions. For horizontally layered structures use this parameter values <1, for vertically layered >1. Usually for this parameter values from 0.2 to 1 are used.



Geoelectric models as a result of "smooth" inversion with **Smoothness ratio**: 1 (A) и 0.3 (B).

The **Start model from** option serves to build starting geoelectric model. App.res – average apparent resistivity calculated from data is used as initial resistivity. 1D inversion – initial model is set according to 1D inversion results from all soundings average value, current – current model shown on the screen is used.

Host models number – sets a number of base 1D models on profile. Base models evenly divide the profile lengthwise, cell resistivity between base models are calculated as a result of

linear interpolation. It is recommended to set values greater than 1 for very long profiles or when geoelectric section changes a lot along the profile.

Before performing inversion, it can be necessary to input existing prior information. It can be starting model built from geological data, other geophysical methods or previous inversion results.

A large number of inversion parameters gives an opportunity to obtain a variety of equal models. For interpretation they must be compared, at least to choose the most probable one from the geological point of view.

A convenient tool for operating with several models in one project is the **Buffer** function in the program main window. It gives an access to buffer of models where you can insert or load the created model. The **Buffer/Open** button allows seeing all the created models in one window that is convenient for their comparison.

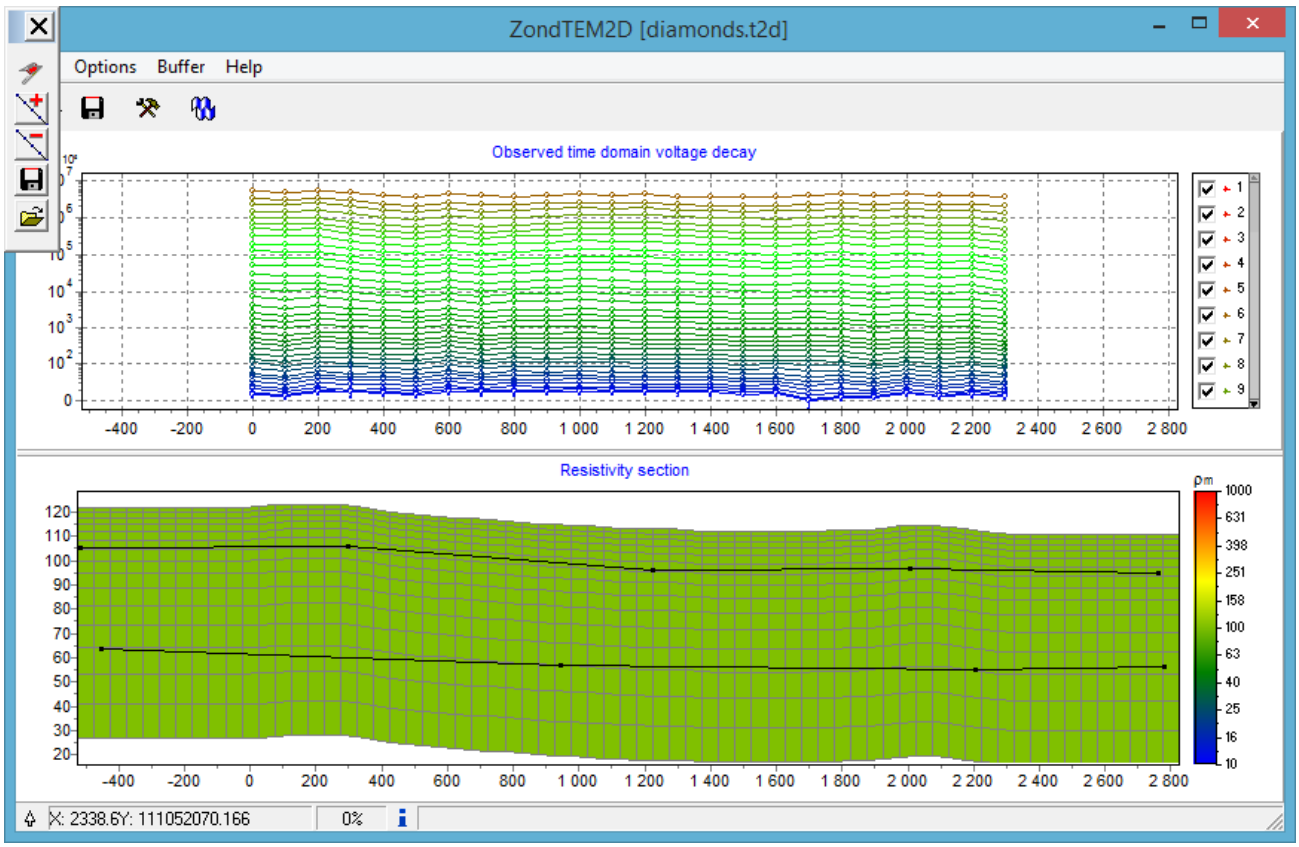
Prior information accounting during inversion

Inversion can be performed without accounting for prior information (clear transformation) and with accounting for prior information (in this case an element for interpretation is added to transformation). There are usually two ways to account for prior information: to set starting model (presumable distribution of resistivity in a section) or contrast borders.

The current model displayed in model editor is used as a default starting model for inversion in ZONDTEM2D. Program will change it during the inversion. Resulting model depends on this model to a large extend.

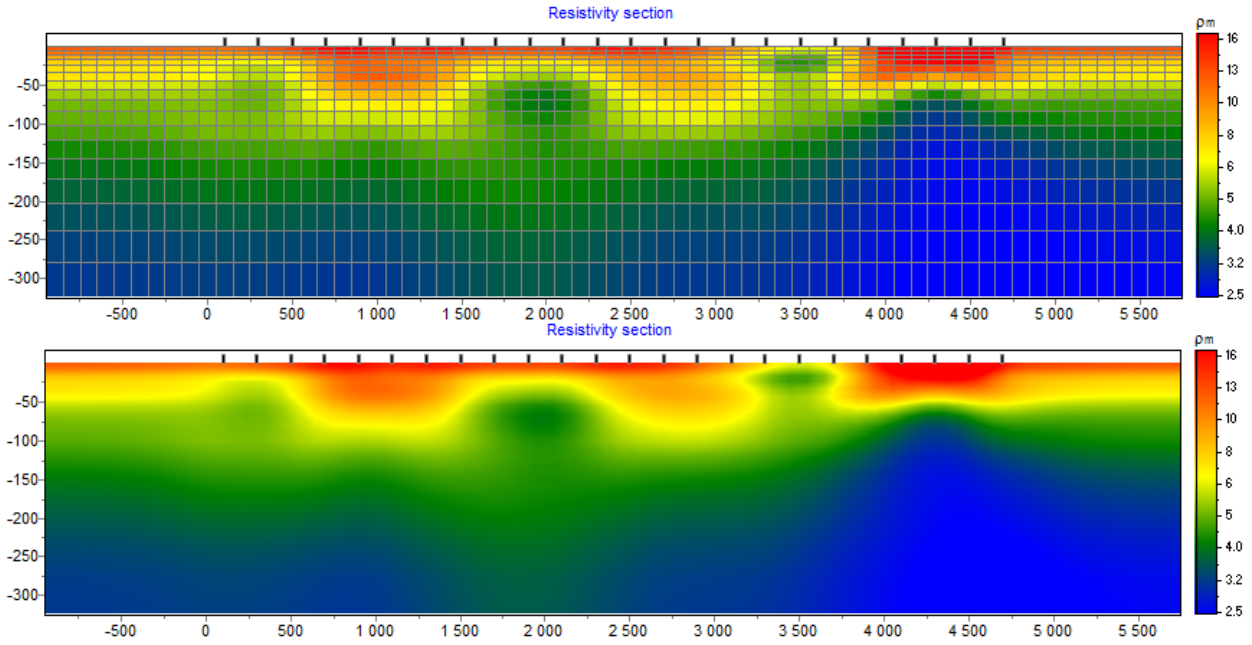
Geoelectric model (MOD1D) obtained during one-dimensional data interpretation (for example in ZONDTEM1D program) can be used as priory information

Contrast borders position known from well or other geophysical methods data is set using the tool bar run by menu item **Options/Inversion/Set boundaries**. Borders position editing and borders accounting during inversion occurs when the  button is pressed. Adding border points can be done using the left mouse button when the  button is pressed. Adding border point can be finished with the right mouse button and then you can move to adding the next border or to inversion. When setting borders, it is desired that they do not cross borders of cells if it is possible. You can remove border with the right mouse button when the  button is pressed. Borders can be saved and loaded.



Model visualization modes and parameters

Model can be displayed in a form of **Smooth image** in gradient palette.



When clicking on the right mouse button in different sections of model editor, context menus with the following options appear.

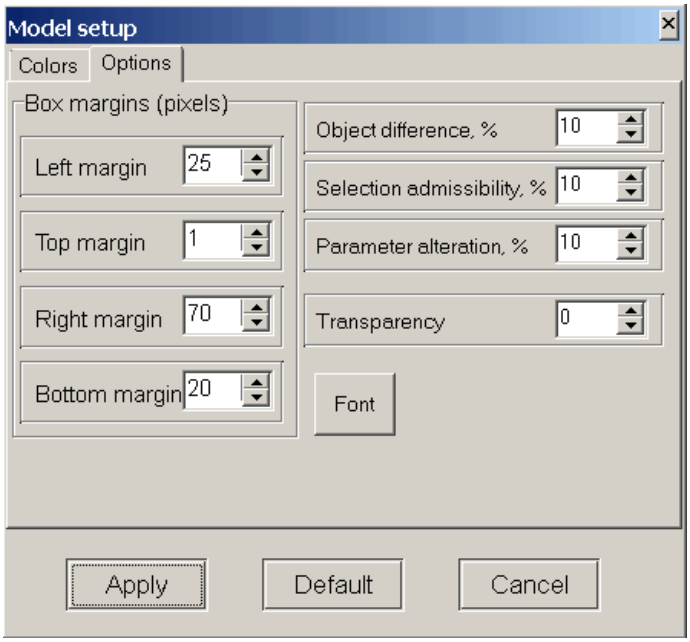
Top section, next to «Resistivity section»	Display model mesh	Specifies whether to display mesh.
	Display objects border	Specifies whether to display object border.
	Display color bar	Specifies whether to display color bar.
	Setup	Runs model parameter setting dialog.
	Zoom&Scroll	Turn on zooming and scrolling mode.
	Print preview	Print model.
Colorbar	Set minimum	Set color scale minimum value.
	Set maximum	Set color scale maximum value.
	Set incremental factor	Determine color scale minimum and maximum in relation to host medium value.
	Automatic	Determine color scale minimum and maximum automatically.
	Log scale	Set logarithmic scale for color scale.
	Set halfspace value	Determine host medium parameter value.
	Colors as histogram	Set colors based on model cell resistivity distribution.
	Smooth image	Mode of model displaying in continuous gradient palette.

When moving mouse cursor over windows created during operating with the program, coordinates corresponding to proper axes of this window are displayed in the left section of status panel

Setting dialog for model displaying parameters

Setting dialog for model displaying parameters is run when you select the **Setup** item on the right mouse button click in the top part of model window next to «Resistivity section» inscription.

Tab **Options**



Section **Box margins**

Left – – sets image indent (in pixels) from window left edge.

Right – sets image indent (in pixels) from window right edge.

Top – sets image indent (in pixels) from window top edge.

Bottom – sets image indent (in pixels) from window bottom edge.

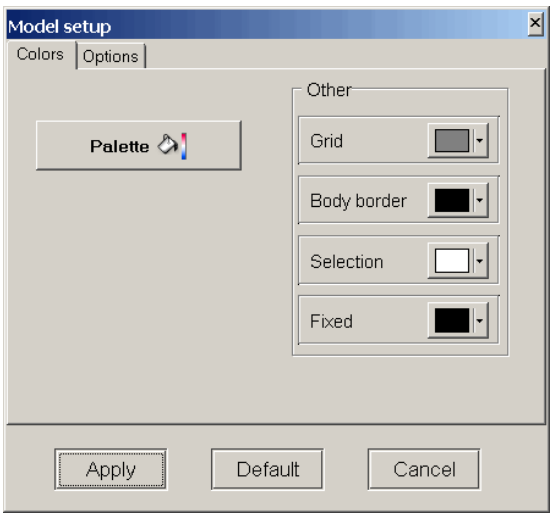
Object difference – sets the maximum value of parameters of adjoining cells ratio exceeding which a border is drawn between them.

Selection admissibility – sets the admissible level of difference between parameters of adjoining cells for which cells are considered as a unit object and are selected jointly (in Magic Wand selecting mode).

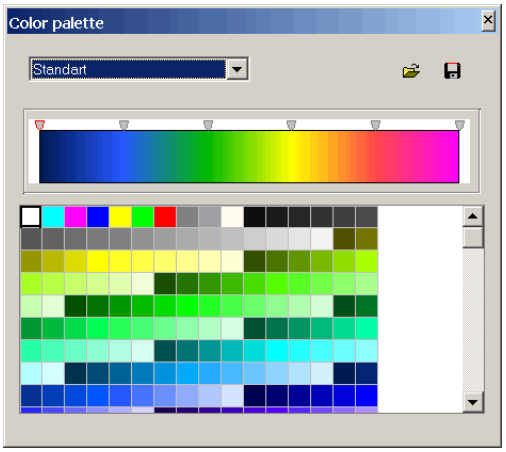
Parameter alteration – determines value of increment to parameters of selected cells (in presents relatively to parameter value) when working in **Edit** mode with the Shift button pressed.

The **Font** button runs font setting dialog.

Tab **Colors**



Palette – sets color palette:



Palette can be changed, edited, loaded from file and saved into file of Surfer program *.clr format.

A convenient tool for choosing maximum and minimum resistivity values is its setting using vertical lines positions on a resistivity distribution histogram (**Options/Extra/Model&Data histograms**).

Section **Other**

Body border – allows setting color of a border between adjoining cells if measure of discrepancy between them is greater than value set in **Parameter alteration** section.

Grid – sets mesh color.

Selection – sets color of selected cell mark.

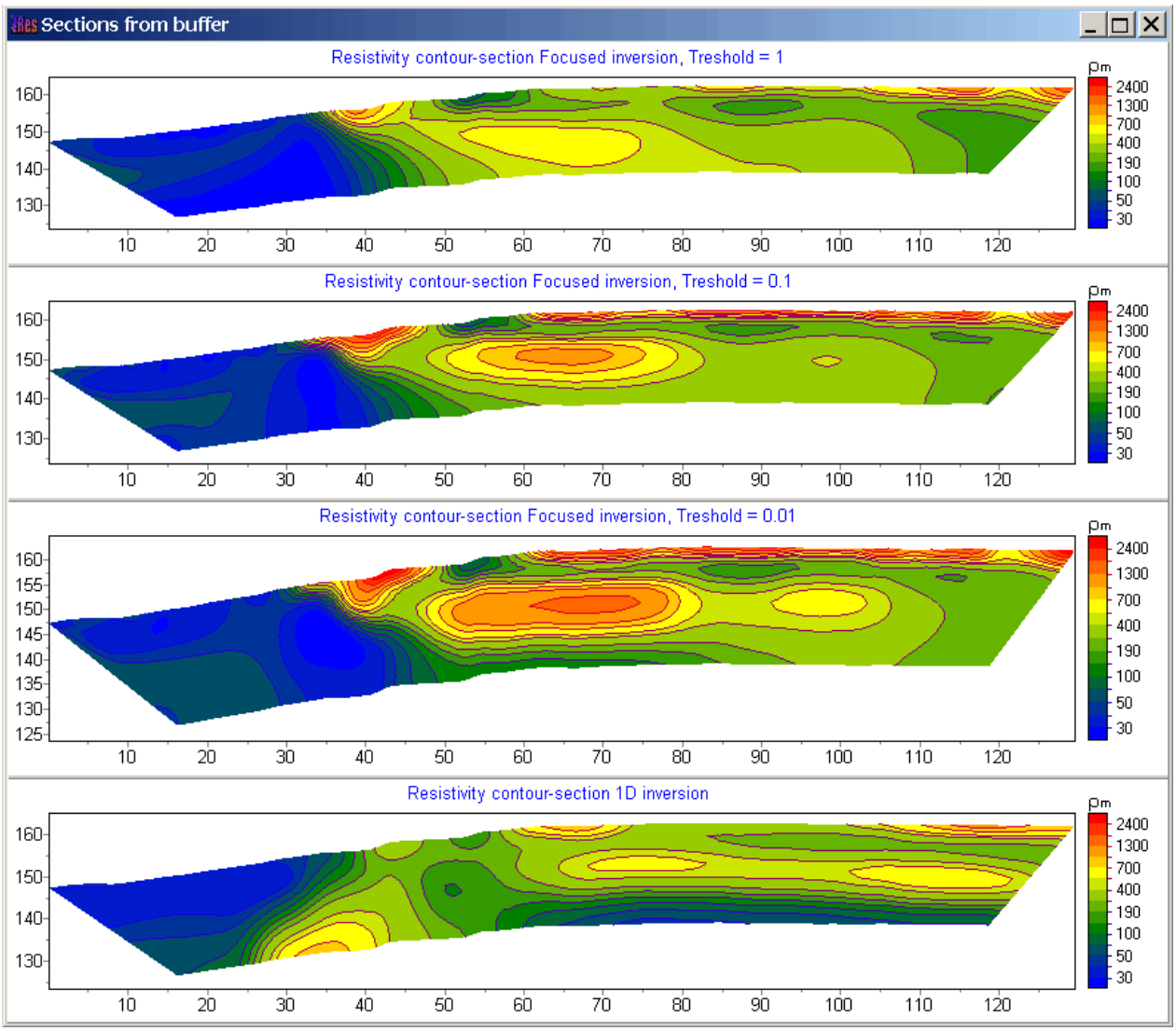
Fixed - sets color of fixed cell mark.

Operating with several models in one project

It can often be necessary to keep several models in one project and simultaneously visualize them for comparison. For instance, to determine optimal inversion parameters, it is not convenient to create separate project for every set of parameters, would be better to keep all the inversion models in one project and have an opportunity to compare them in one window. In modeling mode at the time of reverse problem calculating from several connected models it is also more convenient to keep them in one project.

In ZONDTEM2D described functions are realized using the **Buffer** function of the program main menu. The buttons **Model 1 – Model 5** correspond to five buffer models which can be kept in the frame of one project.

To write the current model into buffer, click one of the buttons corresponding to buffer models. If chosen buffer model is empty, the current model will be written there. Dialog which appears after this allows you to input title of the buffer model which then will be displayed on a corresponding button in **Buffer** list and as a title when the model is being displayed.



Once the first buffer model is set, you can clear the current model in the model editor and create next one by writing it into next buffer model.

If chosen buffer model is not empty, program will ask whether we want to open this buffer model (**From Buffer**) or write the current instead (**To Buffer**). When choosing **From Buffer** the buffer model will be placed on the current active model's place in the section editor.

The **Buffer/Open** button allows preview of all the created models in one window, that is useful for comparison.

Saving the results of interpretation

An interpretation result of data profile is kept in a binary «ZONDTEM2D» file (*.T2D extension). In this file there are field data, values of relative measurement weights, the current model of medium and some more information. Next time you load it, the data from the file will be used to create a model of medium.

You can save the interpretation result by pressing the  button of the tool bar or the corresponding menu item **File/Save file**. In the appearing dialog you can choose the type of the data you are saving: project file **Project data**, image file (**Model**, **WorkSheet)** in *.BMP format in needed scale. Image scale can be set using **Picture settings** dialog in **Options/Extra/Bitmap output settings** menu.

Zond project data	Save measured values and current medium model.
Worksheet	Save three graphic window section in BMP.
Model	Save lower graphic window section in BMP. To set image scale use **Picture settings** dialog.
Grid file	Save model data for Surfer: values in text file *.dat.
Section file	Save current model as a picture in Sec format (with coordinates).

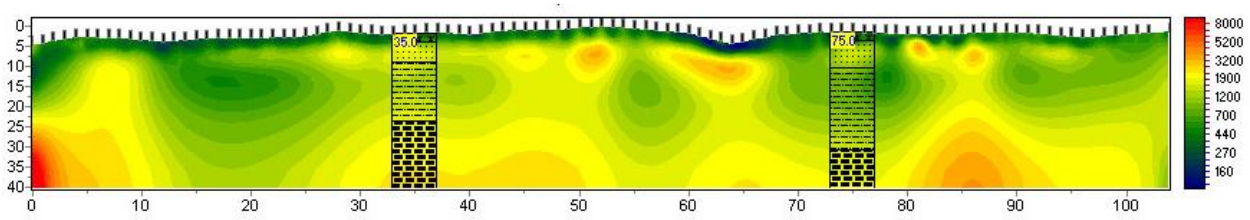
Data import and export

The most effective method to increase data interpretation quality is integration of geophysical exploration methods and accounting for prior information. ZONDTEM2D has developed tools to solve this problem. They are various data visualization in program window: lithology columns, logging data, other methods models obtained in Zond programs and also arbitrary information in a form of raster image of geological or geophysical sections.

Additional information visualization

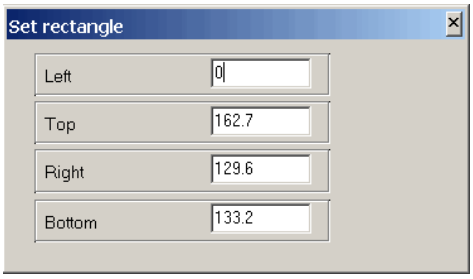
There are several ways of visualization of prior information. Using **Options/Import/Export** you can load or various geological and geophysical information: models from projects of other Zond programs, graphic image as a background under geoelectric section (for example, geological or seismic section).

If there are logging data or lithology columns, they can be load into model window using **Options/Borehole/Load borehole data** option.



If there is priory information, you can use it (as a background under model editor) with option **Options/Import/Export/Background image.** It can be, for instance, geological, electrical or seismic section, section for adjoining profile. There are two background formats in the program – graphic file *.bmp and *.sec file containing graphic information and information about image positioning.

After *.bmp file choosing the setting dialog for image coordinates in which you can specify coordinates of image borders in the section coordinate system.



To make an image transparent, select half-space transparency mode in model setting dialog (the right mouse button click near Resistivity section in model window, Setup option).

*.sec file has the following structure:

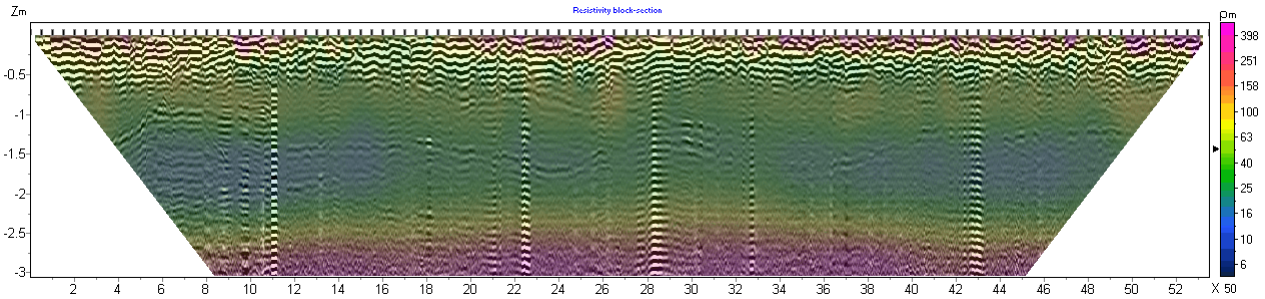
1st line – name of the file with the image;

2nd line – four coordinates through space in sequence of the left top corner and the right bottom corner X1 Y1 X2 Y2;

sect.emf

0 0 152.4 53.3

Using background allows you to account for the results of other profile geophysical methods of exploration (for instance, seismic measurements) and geological sections along profile while performing inversion (setting inversion borders, creating prior models). The following picture shows an example of operating with background radiogram while working with geoelectric.



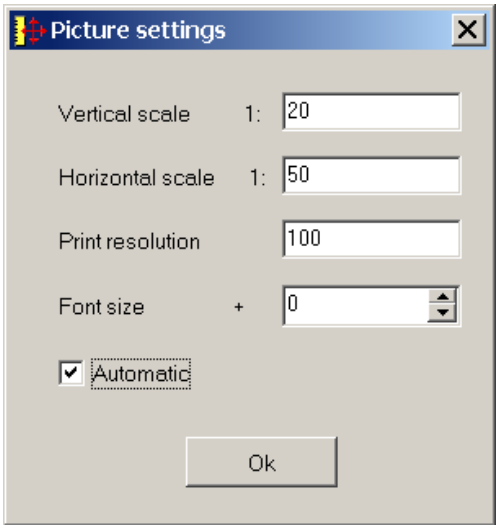
In section «

» various features of export of data as well as resulting model are described. For the following geological interpretation and composing of report graphic there is an opportunity to save current model in dat-file. Model can be saved as a raster image of set resolution and size using **Picture settings** dialog.

Exported image setting dialog

The **Picture settings** dialog allows you to adjust **Vertical scale** (in meters per centimeter), **Horizontal scale** (in meters per centimeter), resolution of the exported image Print resolution (in DPI), and the **Font size**.

These settings are applied to the model saved in the BMP model format (Model) if the Automatic option is disabled. Otherwise, the image is saved in the same form as on the screen.

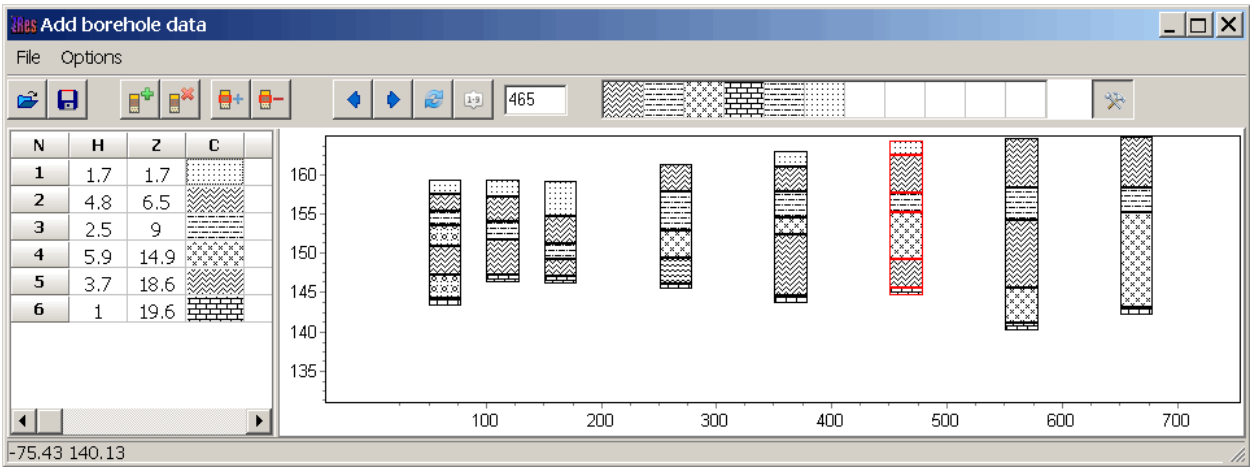


Dialog window **Picture settings**.

Borehole information editor

To create files with logging or lithology data, it is recommended to use the corresponding module, which is called in the main menu item **Options/Borehole/Create/Edit borehole data**. The module allows creating lithological columns for the wells along the observation profile, to save files with the created lithological information, to load and edit previously saved files.

Creating (removing) the wells is performed by the  and  buttons. To the right of the group of buttons on the tool bar there is a text field, which sets the position of the well in the profile coordinates. Moving between wells for their editing is performed using  buttons.



After moving to the edited well (the well whose planned position is set in the field) using the  and  buttons and you can add new layers, or remove them while editing. The thicknesses of the created layers are input in the left column of the table (**H**). In this case, the base of the bottom of the layer from the observation surface at each point is automatically displayed in the right column (**Z**).

Column **C** contains an image of the layer's filling. The selection of a filling is performed in a window run by clicking on the corresponding cell in column **C**.

As a rule, wells along the profile contain common lithological layers. Therefore, for the convenience of specifying layer's filling, in order not to search for the necessary one every time, you can move selected filling to the filling panel at the top of the window (to the right of specifying the position of the well), and then grab the filling for the layer from the toolbar. If you select a cell with the filling in column **C** and click on the cell of the panel with the right button, the filling pattern is copied into the cell of the panel. When you click on the cell of the panel with the left button, the filling from the panel is copied into the cell of the table.

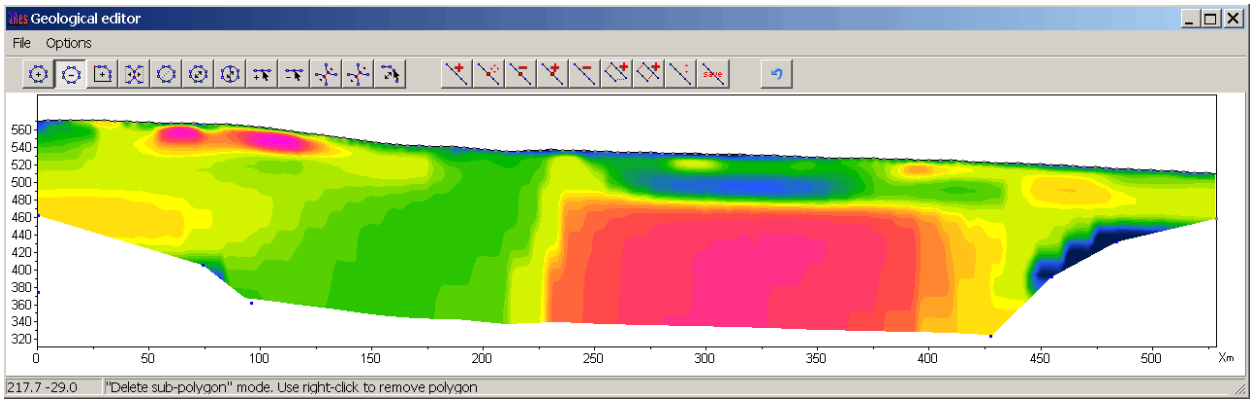
The width of the columns in a percentage of the section length is specified in the Set borehole width menu, which is run by pressing the  button. This function is also available in the main program window (Options/Borehole/Set column width).

The buttons of the lithology data setting module toolbar are duplicated in the **Options** menu. It also contains the **Remove background** function, which allows you to remove the background - the resistivity model when specifying well data.

Geological and geophysical model creating window

To create a geological and geophysical model (performing geological interpretation), use the window of geological model editor - Geological editor – which is run using the **Options/Geological editor** menu. The editor allows you to interactively create a geological model based on the current project model, borehole data, data from other programs of the Zond package and a prior raster information, print the resulting sections at a given scale, save and export the interpretation results.

When you run the geologic model editor window, it displays the current project model. To load a prior information in the form of * .sec files, use the **File/Open section** menu item, to load borehole data - **Options/Load borehole data**.



To perform the geological interpretation, the toolbar provides two sets of buttons: one is intended for creating polygonal bodies (with the possibility of editing the patterns, fills, the style of borders, etc.), the other is intended for drawing individual lines on the section. They can be used to designate some elements of the geological structure (for example, planes of tectonic dislocation) or, in general, increase the demonstrativeness of the interpretation section.

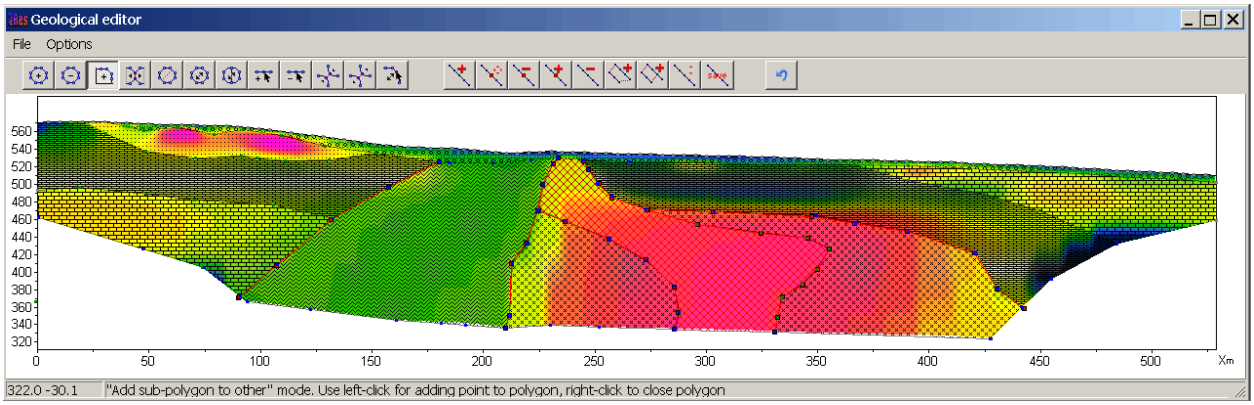
Working with the tools for creating bodies is completely analogous to polygon modeling tools (see the "Polygon modeling" section). Tools for creating lines, in general, are similar in their functions:

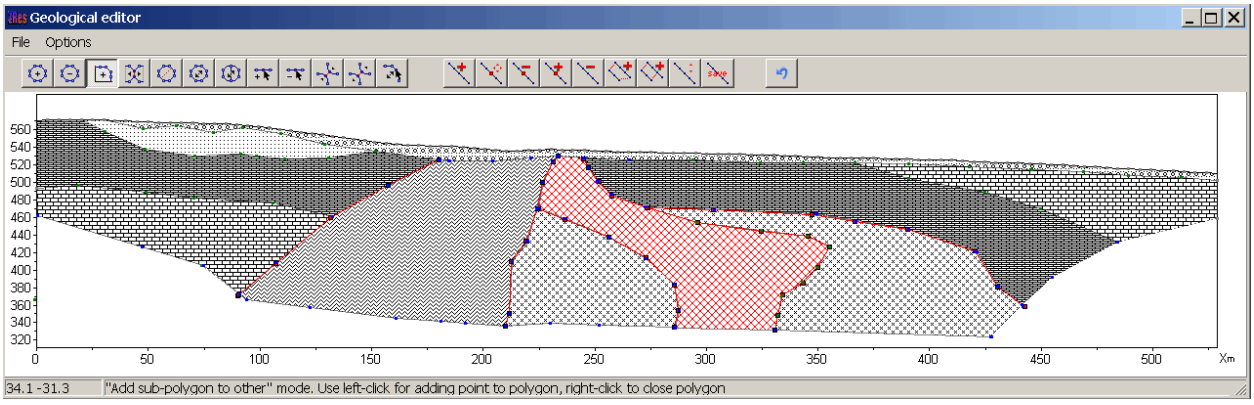
	Create a line		Move a node

	Remove a line		Lock a polyline
	Move a line		Lock a polyline
	Add a node		Save changes
	Remove a node		Undo

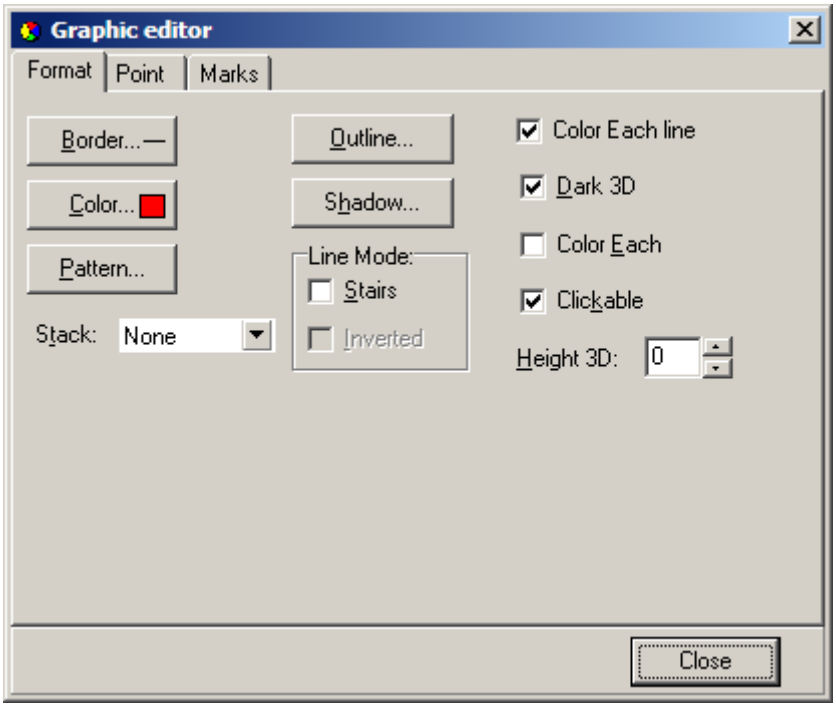
An example of the geological and geoelectric section and the geological model created on its basis is presented in the following picture. The menu item **File/Remove picture** allows you to remove the background - the section of the parameter on which the interpretation is based.

Using the menu item **File/Save section**, you can save the result in * .sec format to work in other programs of the Zond package or as a raster image. The menu item **Options/Output settings** allows you to set the scale of the image for export or printing (**File/Print preview**).





Graph editor



Graphs 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 graph 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.

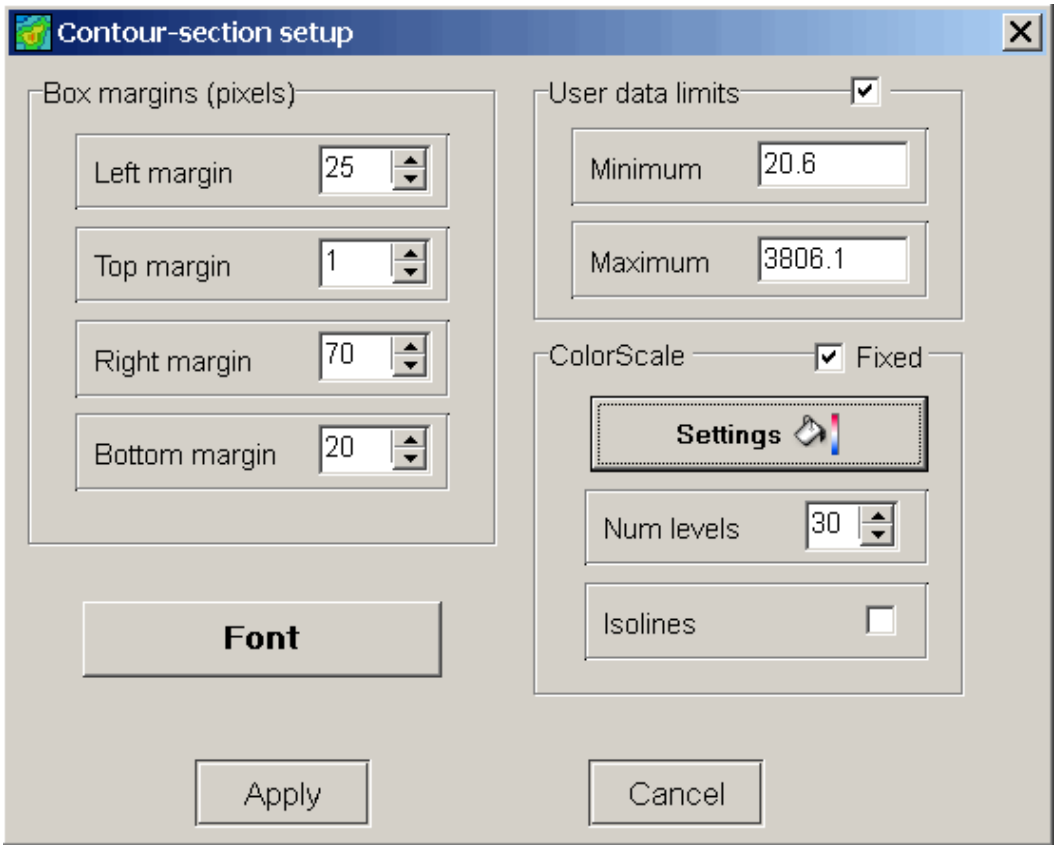
Option **Outline gradient** specifies if gradient fill is used in outline or interior of letters.

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.

Contour section parameter setting dialog



Диалог служит для настройки параметров псевдоразреза.

This dialog serves to set the contour-section parameters.

Field **Box margins**

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

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

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

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

Field **User data limits**

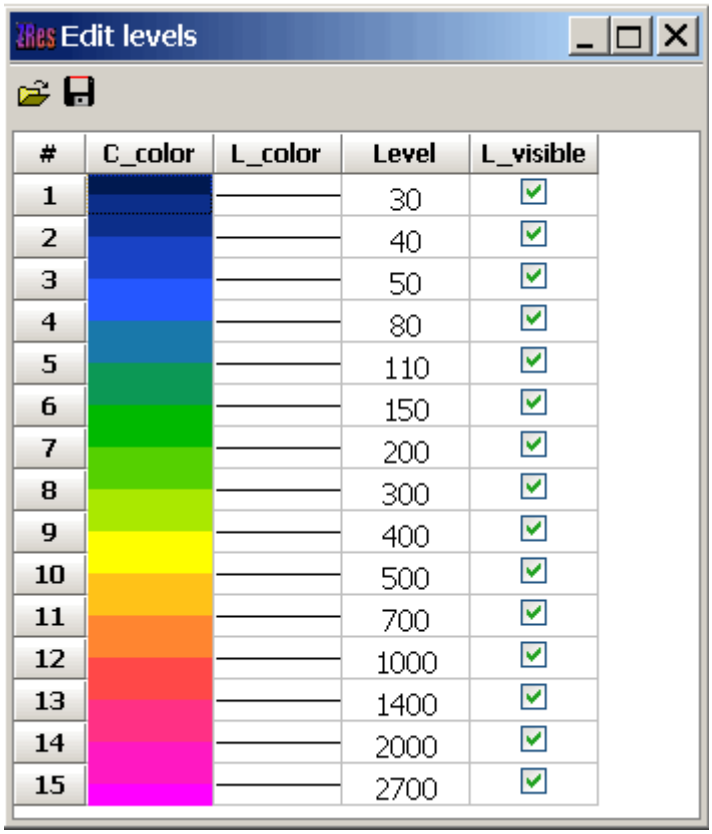
Option **User limits** specifies whether minimum or maximum data values or values from **Minimum** and **Maximum** filed are used for setting isoline sections.

Field **Minimum** sets minimum value to specify isoline sections.

Field **Maximum** sets maximum value to specify isoline sections.

Field **Color scale**

Setings – sets color palette:



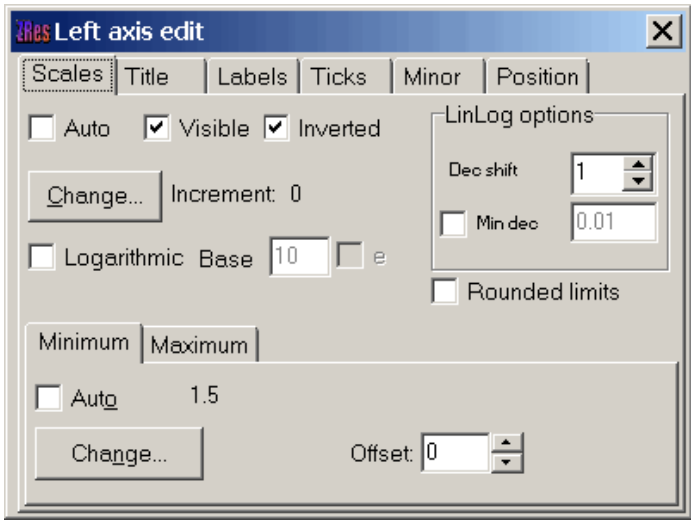
This dialog allows editing colors, isoline parameters, values of parameters, certain color displaying. You can load and save color scales in *.lvl Surfer format.

Num levels section – sets a number of contour intervals. Contour intervals are set with uniform linear or logarithmic spacing depending on the data type.

Isolines option – tell the program whether to draw contours.

Axes editor

Many objects have coordinate axes. Axes editor is used to adjust appearance and scale axes. 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 **Len** 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).