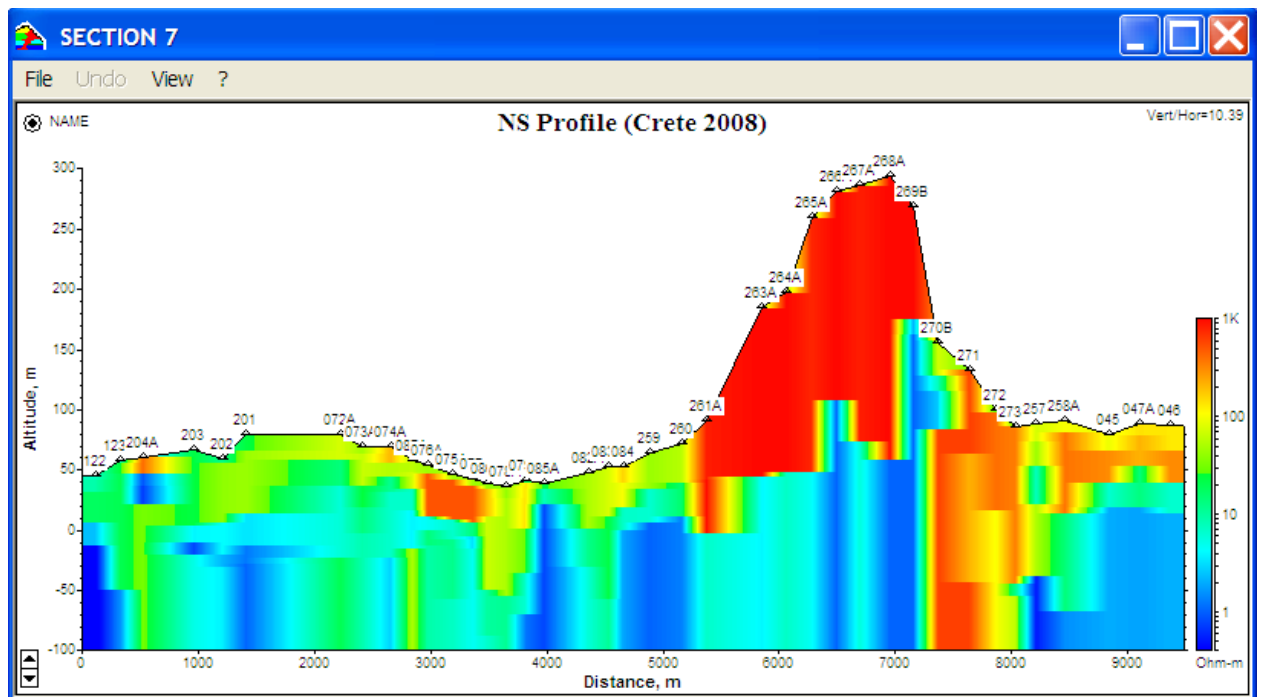


# TEM-RESEARCHER

(version 8a)

## manual



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## INTRODUCTION

TEM-RESEARCHER (TEM-RES) program is intended for modeling and inversion of soundings by determination of field (transient) data, obtained with usage of the ungrounded horizontal magnetic antennas (loops) in two configurations:

- single loop configuration - one loop combines functions of the transmitter and receiver,
- two-loop configuration - transmitting and receiving loops are coaxial.

TEM-RES v.8 supports TEM-data formats acquired with the following tools:

- TEM-FAST PROSYSTEM
- TEM-FAST 32
- TEM-FAST 48
- TEM-FAST 48 HPC

TEM-RESEARCHER program distinguishes with a number of the possibilities ensured with a friendly interface:

- 1) the editor of the initial data which allows to estimate quality of the field measurements and to correct the poor-quality data or to exclude them from the further processing and interpretation;
- 2) modern set of applied tools which gives the possibility to choose the optimal number of layers in a section and to determine their parameters;
- 3) possibility of including some non-conventional parameters to the model, such as frequency dispersion of conductivity and dielectric permittivity, induced polarization (IP-effect) and superparamagnetic (SPM) effect;
- 4) opportunity to adjust the inversion procedure on the basis of an a priori information on a geoelectric section by limiting an allowable range of changing of such parameters of section as thickness, resistivity or IP parameters;
- 5) multipurpose and effective tools for drawing the geoelectric section on a basis of array or profile TEM-information;
- 6) opportunity to transfer the graphic information to any MS Office program and other programs as standard EMF files (Windows Enhanced MetaFile);
- 7) possibilities for completely automatic (or semi-automatic) processing of large arrays of data (hundreds and thousands).

## INSTALLATION OF THE PROGRAM

The program is designed for a Windows 95/98/ME/NT/2000/XP/WIN 7 and is delivered as a unit of executed TEM-RES.exe code, the package of drivers and the electronic USB-key which protects the user from viruses and unauthorized distribution of the program.

Installation of the program is reduced to opening of a new folder (for example, TEM-RESEARCHER) to copy TEM-RES.exe file and dynamic Novex32.dll library in this folder. Further it is necessary to install the driver which supports the operation of a USB-key (DRIVERS\instdrv.exe on your CD). If the driver is installed correctly, the green light on the end of an electronic USB-key flashes. The program is ready to operation.

The serial number of the product is indicated in exposition, and also in the window **? → About TEM-RES** of the main menu.

## THE MAIN MENU

Double-click by the left-hand mouse button on TEM-RES icon to call the main menu. The TEM-RESEARCHER window will appear on the screen:

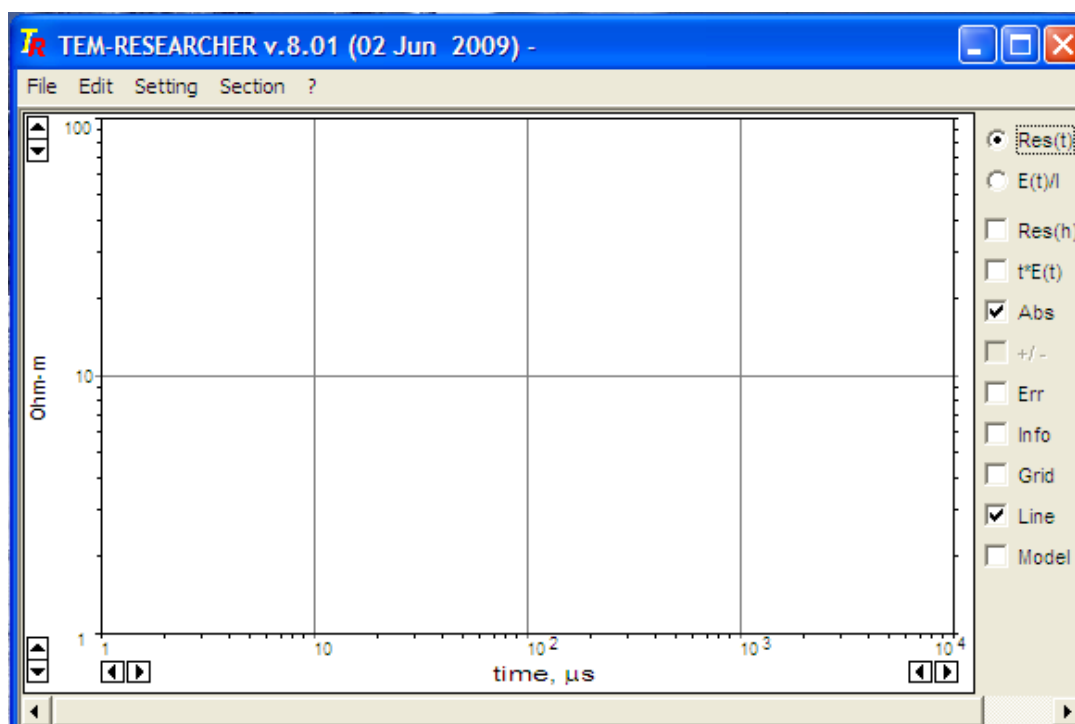



Fig. 1

It is possible to minimize the window in an icon or to maximize at the all screen to make it more convenient, or to delete it using the reference resources of Windows  located in the right upper corner of the main window.

## DATA INPUT

Click once by the left-hand mouse button on **File** in the left-hand upper corner of the main menu. You also can use Alt+F buttons instead of the mouse.

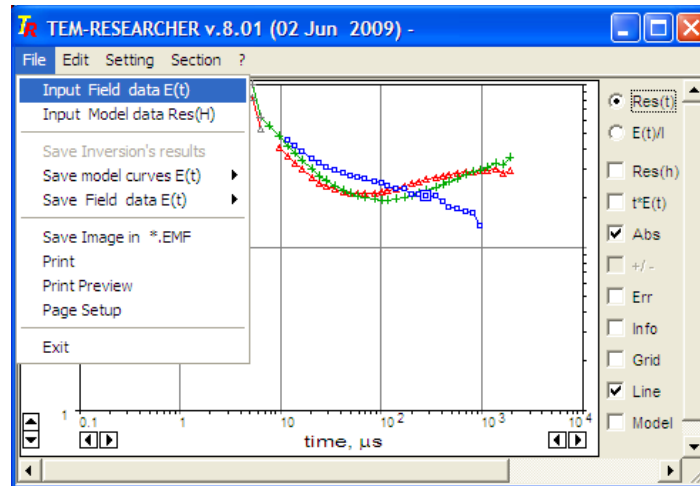


Fig. 2

From the appeared menu select data input (**Input Field data E (t)**) and press the left-hand button of a mouse. Standard Windows file dialogue will appear on the screen. In this window you may choose the necessary file in a TEM-format containing the data of soundings.

The program supports the following types of files containing the initial tem-information:

- Text tem-file (1996, 2002 formats)
- Binary tem-file (copied, but not converted from Handheld PC)
- **Int**-file containing 1D inverse data (1996, 2002 and 2008 formats)
- **Psc**-file containing data of conversion (1996, 2002 and 2008 formats)
- **Sec**- file containing 1D inverse and conversion data (2008 format)

Further the TEM-data of a single sounding we shall name “set”.

After the file is opened, the window in which you can view the information about the file and select data for the subsequent analysis will appear. There is a copy of an information window in the left bottom corner. The loaded earlier sets have square marks (set 020A).

TEM-File contents: All\_11 (22-Sep 2008)

#	Name	Tr	Rec	Time	Sto	HVP	I(A)	F(Hz)	Ampl	Remark
1	001A	50	50	6	5	6	3.7	50		OFFNEXT TO NATIONA
2	002	50	50	6	5	6	3.7	50		OFFPISW APOVILLA
3	003	50	50	5	5	6	3.7	50		OFFCLOSEFITORIA
4	004	50	50	5	5	6	3.7	50		OFFANAMESA 002 KAI 003 METRIS
5	005A	50	50	6	5	6	3.8	60		OFFANAMESA 003 KAI 004 METRIS
6	006	50	50	5	5	6	3.7	50		OFFMETA TIN 003
7	007A	50	50	6	5	6	3.7	50		OFFPISW-MIKRI EKKLISI
8	008	50	50	5	5	6	3.7	50		OFFPORTOKALIES
9	009A	50	50	6	5	6	3.7	50		OFFPORTOKALIES
10	010	50	50	5	5	6	3.7	50		OFFPROS DRAKIANA TA
11	011A	50	50	6	5	6	3.7	50		OFFDRAKIANA PLACE
12	012A	50	50	6	5	6	3.7	50		OFFBIG KARIDIA K PORTOKALIES
13	013A	50	50	6	5	6	3.7	50		OFFKSERES-AKALLIERGITO
14	014A	50	50	5	5	6	3.7	50		OFFPORTOKALIES
15	015	50	50	5	5	6	3.7	50		OFFPORTOKALIES
16	016	50	50	5	5	6	3.7	50		OFFNO SPACE-ALLI PLEYRA
17	017	50	50	5	5	6	3.7	50		OFFNO SPACE-ALLI PLEYRA

☒ 020A  
☒ 012A  
☒ 009A

Auto Transformation    Auto Inversion    Total sets 235

☒ Use "current cut-off Delay"    ☐ Map    XYZ    Sort: Default    Unselect    Input

Fig. 3

To delete set double click on its name. In total you can select up to six sets of soundings which will be shown by different colors in a frame in the left bottom corner.

The information on coordinates of sounding points is displayed at pressing **XYZ** button in column **Remark**. Activation of **Map window** (Fig. 3) visualizes layout of soundings points on a topographical map (Fig. 4a).

**Style window** allows changing a coordinate system:

**Math** (mathematical) - the X-axis increases from left to right, the Y-axis increases from below up.

**Geo** (geographical) - the X-axis increases from below up, the Y-axis increases from left to right.

**Grid** - setting of a grid according to the selected step.

**Label** - setting of a number for a point corresponding to the first column on Fig. 3.

**Altitude** - setting of Z values (elevation).

**Name** - setting of a name for a field point (Set Name)

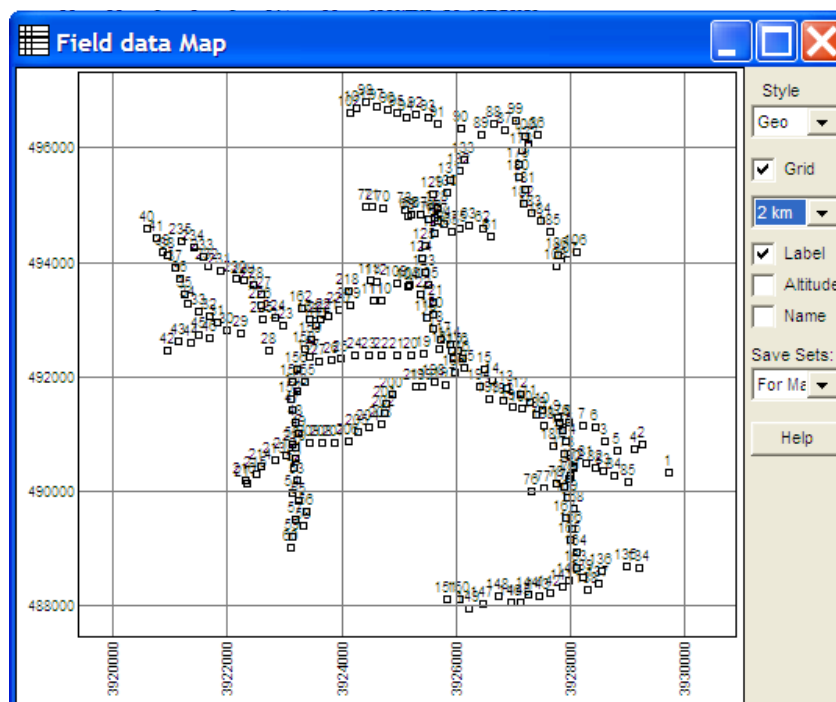


Fig.4a

If the input data contain points with equal coordinates X and Y (repeated, check measuring or wrongly entered coordinates), they are meant as the imposed quadrates on a map.

Zooming: holding the left-hand mouse button, draw a rectangle, after pressing the right button the selected fragment of a map will be enlarged (Fig 4b). Sets outside a selected rectangle become "inactive" and grey.

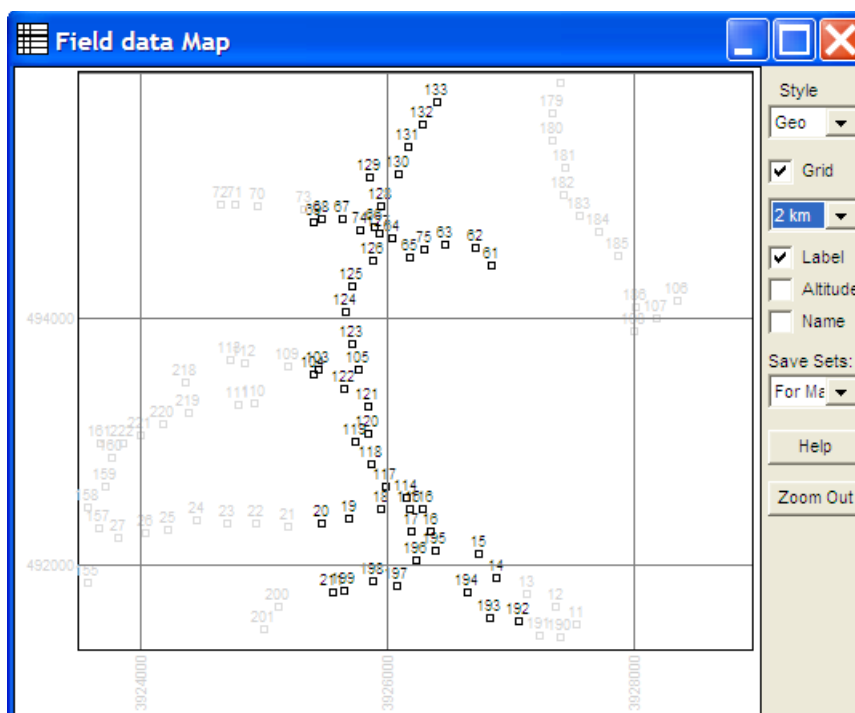


Fig.4b

**Zoom out button** is intended for return to an initial state.

Opening **Save Sets menu** allows to convert and save data from open TEM/INT/PSC/SEC file to: (see section « Conversion of data »)

- tem-file
- int file
- psc file
- sec file
- MAP\_E - (for Map) file has table form: in columns - values  $E(t)/I$  for each time  $t$ , in lines - points of soundings (see formats of files).

Only active sets of soundings colored with black, will be recorded to the new file (Fig. 4b).

Clicking with the right mouse button on any set, it is possible to make it active (black color) or inactive (grey).

Double-clicking with the left mouse button to any set allows to receive the complete information on sounding and to edit some parameters (Fig. 4c). Controlling buttons "+" "-" "<" ">" allow to change smoothly location of sets on the map.

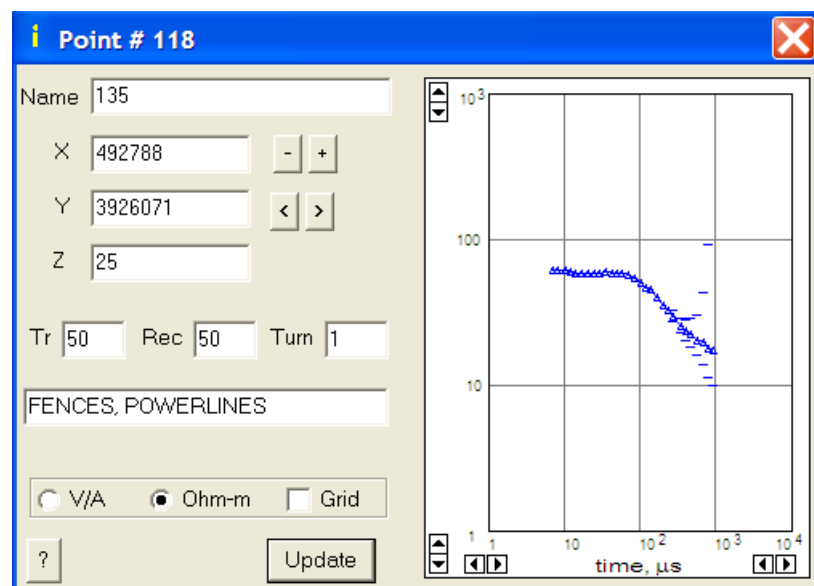


Fig. 4c

Let's return to the Fig 3.

**Sort** menu allows to sort data by: default, time of making, name, X coordinate, Y coordinate, Z coordinate.

The window "**Use current cut-off Delay**" is intended for auto correction of field measuring data taking into account a real front of a current turn off in a generating contour.



**Auto Inversion button** is intended to launch the system of auto 1D inverse of all sets in an active file (*it is active only in special versions of the program*).

**Auto Transformation button** intended to launch the system of auto construction of pseudo -sections (see the section “smoothing the data”). Before the beginning of this procedure it is necessary to set a number of parameters (Fig. 5)

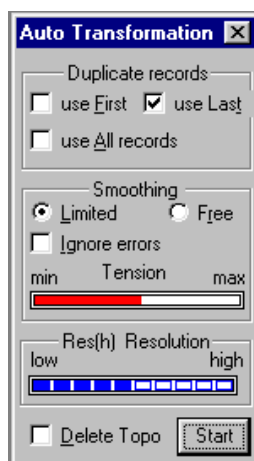


Fig. 5

If there are some points with equal coordinates in a data file, then:

**use First** - only the first point under the order of recording in the file is used;

**use Last** - only the last point under the order of recording in the file is used;

**use All records - all points in the TEM-file are used.**

Parameters **Smoothing** and **Res (h) Resolution** are described further in appropriate sections.

**Delete Topo** - the user can delete a contour of a surface, having assigned for all points  $Z=0$ . By default pseudo-sections for each point are created taking into account an elevation, given in initial data.

The automatic mode construction of pseudo-sections is used at a large volume of homogeneous initial data.

If there is a data file obtained at array researches (several hundred or thousand points), we recommend:

- to test attentively a regularity of the points coordinates definition and if necessary to correct data;
- to select suitable and to delete unnecessary (iterating) sets;
- to load dozen curves of soundings from different parts of the area and to select common modes of smoothing (**Smoothing**) and permissions (**Res (h) Resolution**) for them;
- to start the mode of automatic construction of pseudo-sections.

If the data containing the information on soundings are loaded from the INT-file (2008

format), as a result of automatic conversion it will be the SEC file containing 1D model of the environment, and conversion (see the format of files)

After choosing the necessary sets of soundings (Fig. 3) and pressing the **Input** button, a pattern shown on Fig. 6 appears on the screen.

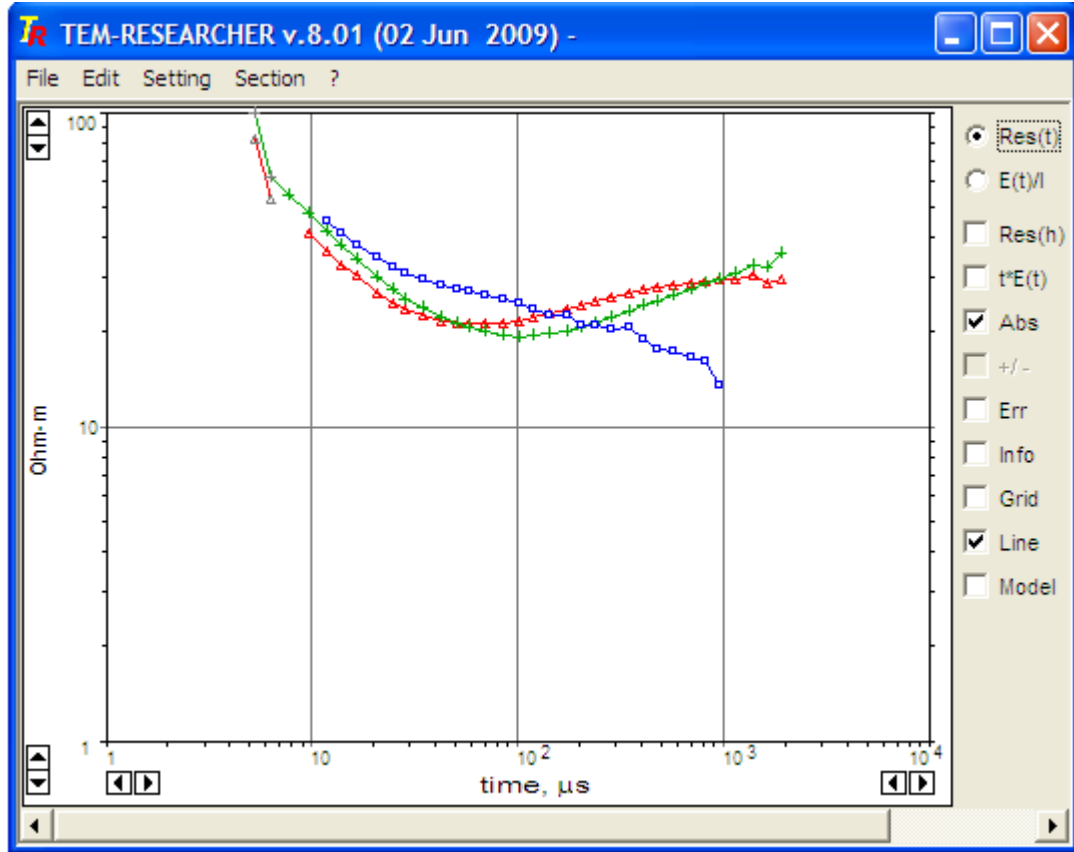



Fig.6


In a right part of the screen the different forms of representation in which it is possible to represent selected data are shown. Here **Res(t)** is apparent specific resistivity  $\rho_a(t)$ , **E(t)/I** is EMF in a receiving antenna or **t\*E(t)** is a signal or a resistivity multiplied to time. Physical dimension of data on diagrams is shown on the left vertical axis.

Having pressed **Err button**, it is possible to display the information on errors of definition **Res(t)** or **E(t)/I** as confidence intervals ( $\pm 3 \cdot \text{STD}$  - standard deviations).

**Line function** allows to present experimental data as points or interpolate them as piece-linear curves. At wish, it is possible to plot more detailed grid to the figure, for this purpose it is enough to press **Grid**.

The buttons  located in the beginning and in the end of coordinate axes allows changing scales and layout of diagrams on the screen to make them more convenient.

Some points on experimental curves can have sometimes the negative sign (for example, at IP-effect). In this case such points are not displayed on diagrams; however they can be seen with the help of **Abs function**.

The button **+/-** allows to display transient process  $E(t)/I$  in a special scale with two logarithmic axes for the positive and negative part of the process. Position of a zero level "0" can be adjusted with the  buttons located near the right boundary of diagram (appears at activation **+/-**, see Fig. 6 a).

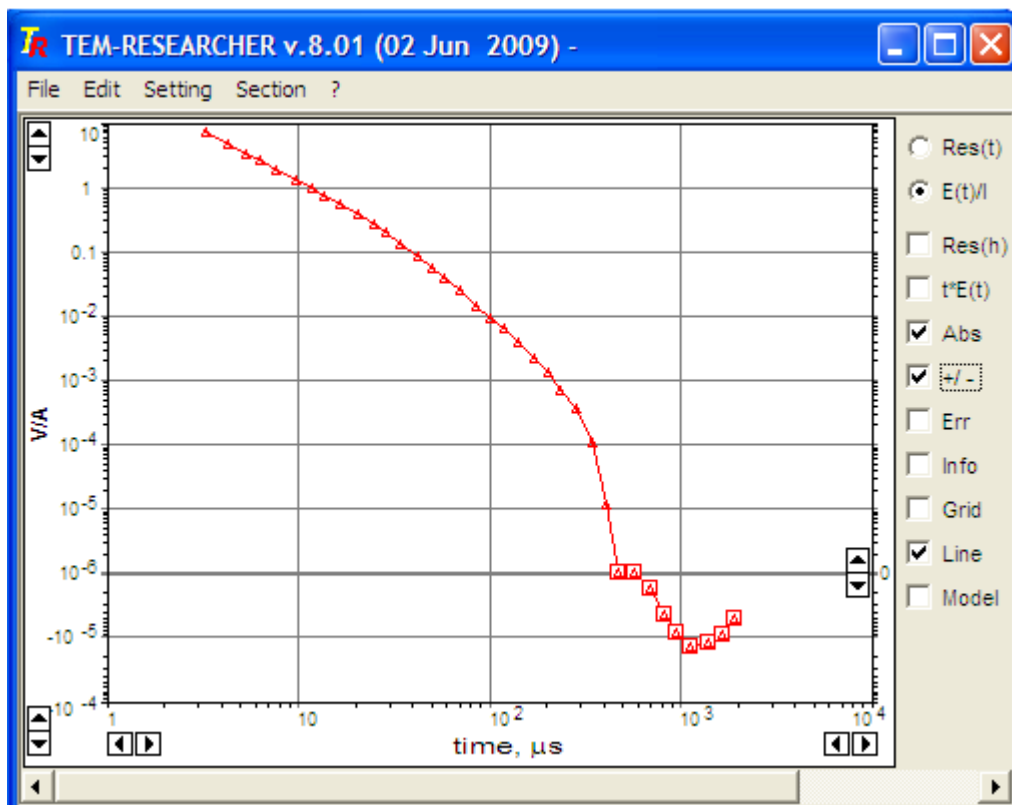


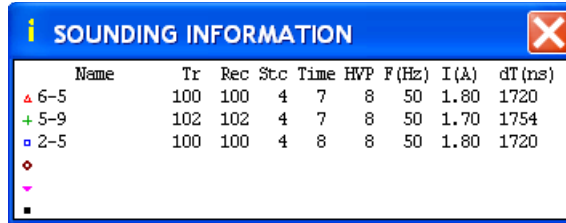
Fig. 6a

#### ATTENTION:

If it is necessary to copy the screen, it is convenient to press **ALT+T-** before this procedure,

all control elements disappear from the graphics. Repeated **ALT+T** restores control elements.

For convenience of the further processing and analysis the interpretive program one can select one or several curves from a data set, and delete data which block up the screen. For this purpose it is necessary to call **Info** function:



Name	Tr	Rec	Stc	Time	HVP	F(Hz)	I(A)	dT(ns)
△ 6-5	100	100	4	7	8	50	1.80	1720
+ 5-9	102	102	4	7	8	50	1.70	1754
□ 2-5	100	100	4	8	8	50	1.80	1720
◇								
▽								
■								

Fig. 7

The **SOUNDING INFORMATION** window (Fig. 7) with titles of selected files and the information about soundings will appear:

**Tr, Rec** - size of transmitting and receiving antennas

**Stc** - the parameter of accumulation ("stack")

**Time** - time range of measurements

**HVP** - adjustment of the HVP-system (in microseconds)

**F (Hz)** - industrial noise filter

**I (A)** - current in the transmitting loop in amperes

**dT (ns)** - correction parameter of current turn off front in the generator loop (delay of a current impulse turn off front in nanoseconds)

Double-click the left-hand mouse button the set which you want to delete to the buffer, and it will disappear from the screen. The repeated operation will return the file from the buffer to the screen.

This operation can be realized with the help of [Alt+1](#), [Alt+2...](#) on a keyboard.

Make active **Sounding Info** window (click the left-hand mouse button in any place of the window). Pressing [Alt+A](#) deletes all (All) sets of field data from the screen.

## SETTING OF THE SECTION MODEL PARAMETERS

Having pressed to **Model** function, an interpreter can go to the window of models **MODEL** which allows controlling the main process of direct and inverse problems solution. By the first call the window always appears in the right bottom corner. Press "?" to get manual for operation with the window - Fig. 8.

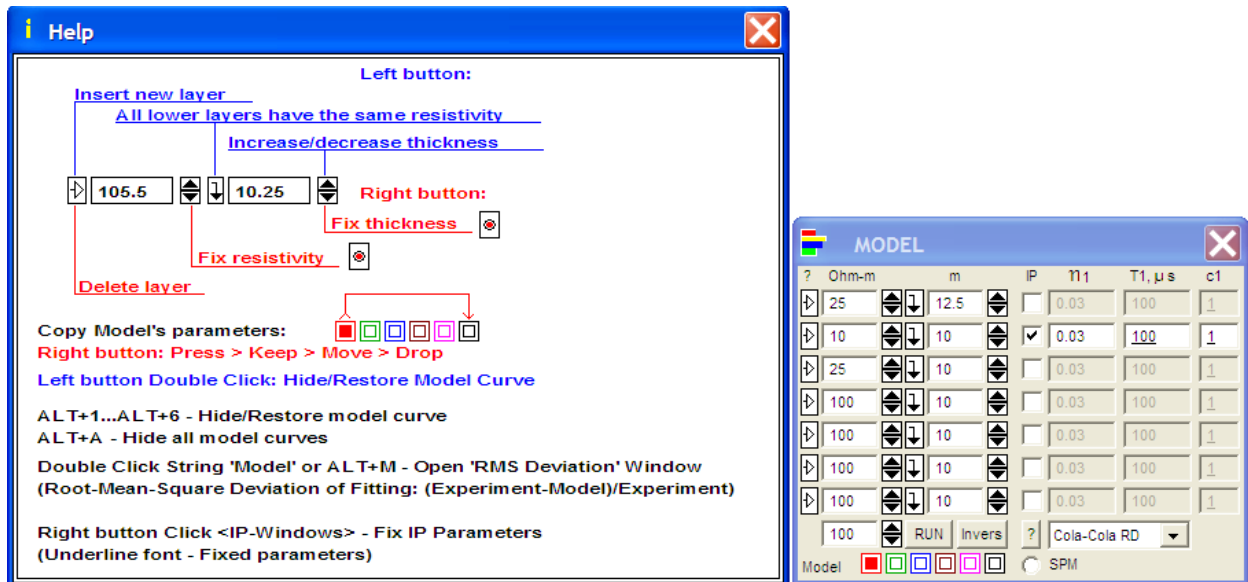


Fig. 8

Let's consider in detail the operation with this window.

The window is constructed as the table. In the first column the value of resistivity for 8 layers of a model in Ohm-m, in the second one - thickness of these layers in meters is represented. Color rectangles with small squares inside correspond to model which is active at present, and can be activated by left button click. Change of a small square gives in replacement of current model by activated one (on Fig. 8 the first model highlighted by red color is active). Control elements of the window are as follows:



- this control element is used for:


- inserting a new layer to the model (left mouse button),
- deleting a layer from the model (the right mouse button);

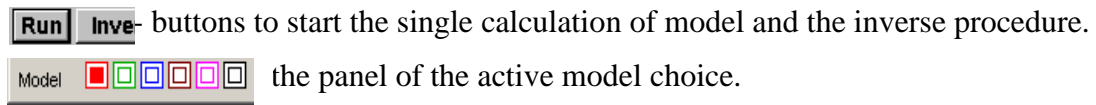


- this control element is used for increase (upwards) or decrease (downwards) values of the model parameters with step  $\Delta\rho$  or  $\Delta h$  (steps are determined in window **Setting** → **Modeling**);



- this control element is used for alignment of model resistivity, starting from the chosen layer.

The results of activation of this element on layer N3 are shown in the figure. In other words, the function  allows to combine all underlying layers in homogeneous half-space and to consider them during further processing as the homogeneous basement of a section.



After **RUN** or **Inverse** appropriate operations for selected model are fulfilled.

**Operations:** Pressing → keeping → moving → releasing of the right mouse button gives in copying of all parameters from start (at pressing the button) models in target (release of the button) model.

#### ATTENTION!

1. MODEL window appears on the screen in shorthand form (6 left columns). Standard for WINDOWS procedure of "spinning out" by the mouse allows receiving the extended alternative of the window. Besides the user can reduce a vertical dimension of the window, but with loss of some layers. The function of the right (hidden at initial loading) part of the window we shall consider later.

2. The amount of model layers is calculated starting from the bottom layer. The calculation starts from the moment of when the difference in resistivity of  $i$  and  $(i-1)$  layer exceeds 1%, i.e.  $(\rho_i - \rho_{i-1}) / \rho_i > 0.01$ . For example, model with resistances (starting from surface): **10, 20, 20, 1000**, 1001, 1005, 999.9, 1000, will be considered four-layer, the last four layers are skipped. At the same time intermediate layers with equal resistances 20 Ohm-m are not combined but calculated separately, as two separate layers.

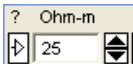
3. During the inversion, situation when visibility of layers is less than 1 % can take place, however the program does not reduce a number of layers automatically.
4. At start **Inverse** the inversion procedure starts calculations for model, prescribed in MODEL window, the number of layers during calculations does not change.
5. The user can delete a graphics, appropriate to model calculations, pressing the keys **"Alt+1"**, **"Alt+2"**, ... **"Alt+6"** if **Model** window is active (is positioned in focal point). Pressing **Alt+A** gives in deleting all models.

## MODELING

Before the beginning of modeling, it is necessary to set receiving/transmitting antennas: size of loops, number of turns. These parameters are set in **Setting** → **Modeling** window of the main menu.


Fig. 9

The window for setting the modeling parameters determines:

- activity/passivity of models (in this case models No 1-3 are active, and 2,4,5,6 are passive). The user can deactivate model with click to an appropriate quadrate in the left column of the window. At the same time « model curves » will disappear from all diagrams.;
- name of the model;
- size of transmitting and receiving antennas and number of turns;
- **Resistivity step (r.un.)**  $\Delta\rho$  is step of the resistivity changing in the **MODEL** window at activation of the control element .

Resistivity of the layers change according to the formulas:

$$\rho = \rho * \Delta\rho \text{ или } \rho = \rho / \Delta\rho, \Delta\rho = 1.01 \text{ (by default).}$$

- **Thickness step (m)**  is  $\Delta h$  step of the layers' thickness changing at activation of the control elements.

The thickness is changing as  **$h=h+\Delta h$  or  $h=h-\Delta h$ ,  $\Delta h=0.5$**  (by default).

- **Width of pen (pixel)** is a thickness of the lines on diagrams in pixels of the screen.

ATTENTION:

If there are field data on the screen, the program automatically installs **Name, Tr, Rec, Turn** according to parameters of field data sets.

Change, if it is necessary, **parameters Name, Tr, Rec, Turn** and start modeling.

For direct problem solution it is enough to install parameters of section in **MODEL** window and to click in the same window button **RUN**. In the main window the colored curve, appropriate to color of the activated small square **Model** located in a bottom line of **MODEL** window will appear.

ATTENTION:

Unnecessary at present graphics of model curves can be deleted from the screen, if

- MODEL window is active (the top stripe at the window is dark blue or blue)
- Pressing **ALT+1, ALT+2 ... ALT+6** - appropriate graphics will disappear
- ALT+A-all graphics will disappear.



## EDITING OF EXPERIMENTAL DATA

Let's consider now the procedure for the analysis and edition of experimental data. Let's select for instance a curve of the apparent resistance complicated with an error.

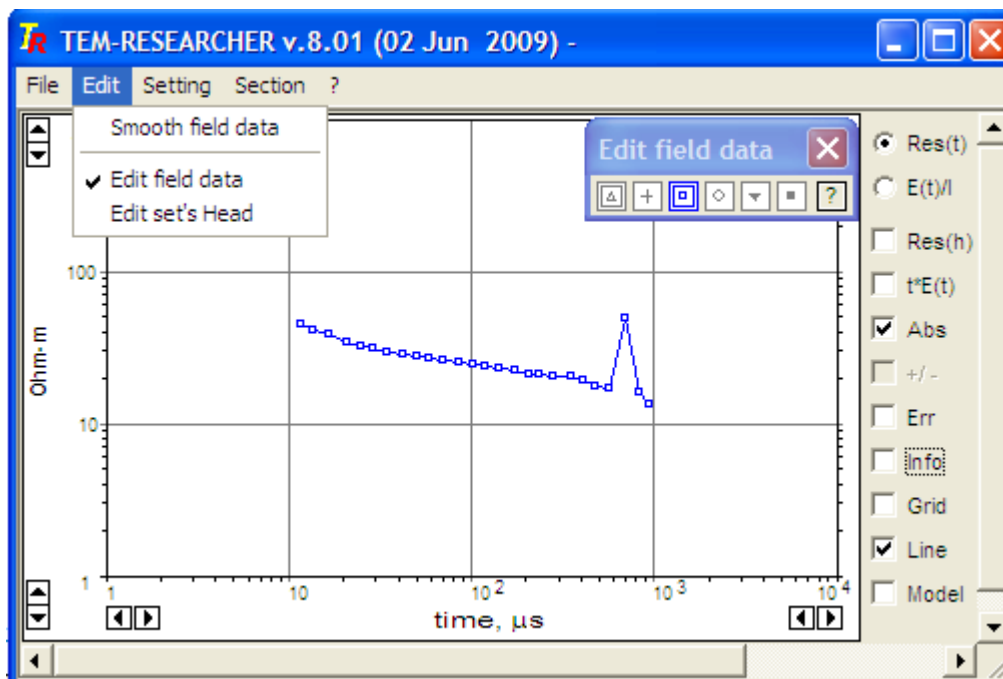


Fig.10

For correction of outliers on a curve (Fig. 10) it is necessary to use sequentially the **Edit** → **Edit field data** functions. In the appeared window mark a curve which should be corrected (in this case the dark blue curve is activated).

- For excluding a point it is necessary to choose it by cursor of a mouse, simultaneously press the key **Ctrl** and the left mouse button (color of a point becomes grey).
- To change a sign of a point (at active **Abs** option) it is necessary to choose it by the mouse cursor, simultaneously pressing the key **Ctrl** and the left mouse button.
- To change position of a point it is necessary to choose it by the mouse cursor, press the left button of the mouse and to move it (upwards - downwards), not releasing the button. After releasing the button, the point will change its vertical coordinate.

After correction of points **Edit field data**, window can be deleted from the main menu.

To correct the errors contained in the " head " of field data (Name, Tr, Rec, X, Y, Z) it is necessary to call editor **Edit** → **Edit set's Head** (Fig. 10).

## INVERSION OF EXPERIMENTAL DATA

Two ways of a section construction on experimental data are included in the given package: transformation and inversion. Let's consider both ways.

### *TRANSFORMATION OF THE CURVES $E(t)$ IN PSEUDOSECTION $\rho(h)$ .*

To begin with transformation, the initial data  $E(t)$  should be smoothed. The data smoothing is made by using the method of exponential spectrums [1], namely the nonlinear task of minimization of functional  $\Theta$  is solved:

$$\Theta = \|E(t) - E_s(t)\|, \quad E_s(t) = \sum_{i=1}^N A_i \exp(-t/\tau_i),$$

i.e. initial  $E(t)$  process is approximated by "synthetic"  $E_s(t)$  function which represents a superposition of exponential components with different initial amplitudes  $A_i$  and time constants  $\tau_i$ . Norm  $\|\cdot\|$  in (1) is determined as average quadrate of deviations of processes on all time interval of measuring. After minimum  $\Theta$  is found, i.e. parameters  $A_i$  and  $\tau_i$  are defined, initial data  $E(t)$  "are replaced" by analytically given, smooth  $E_s(t)$  function which can be multiply differentiated easily.

Further  $E_s(t)$  function is transformed to dependence of apparent resistivity on time  $E_s(t) \rightarrow \rho(t)$ . For late times where the requirement of a near zone  $\frac{t}{\mu\sigma L^2} \gg 1$  (here  $\mu$  is magnetic permeability,  $\sigma$  is conductivity of medium,  $L$  is a size of one-loop transmitting-receiving antenna) is fulfilled, transformation is described by the formula:

$$\rho_k(t) = \left[ \frac{\sqrt{\pi}}{20} \frac{\mu^{5/2} R^4}{t^{5/2} E(t)/I} \right]^{2/3} \quad R = \frac{L}{\sqrt{\pi}},$$

where  $I$  is amplitude of the current impulse.

However application of this formula imports essential distortions on small and average times where requirements of a short-range band are not observed. Transformation  $E_s(t) \rightarrow \rho(t)$  correct for any times of measuring can be implemented on the basis of the complete formula for transient processes for EMF at one-loop configuration on a surface of the homogeneous half-space with resistivity  $\rho$ :

The apparent resistivity  $\rho_a$  can be found for each fixed time  $t$  by solving the above-stated

$$\frac{E_0(t)}{I} = \mu\pi R^2 \int_0^\infty \frac{e^{-t/\tau}}{\tau} \left[ \frac{1}{\sqrt{\pi t/\tau}} - e^{t/\tau} \operatorname{erfc}(\sqrt{t/\tau}) \right] J_1^2(\lambda R) d\lambda, \quad \tau = \frac{1}{\rho} \frac{\mu}{\lambda^2}$$

equation with right member  $E_s(t)=E_0(t)$  for each fixed time  $t$ . In result it is possible to receive dependence of resistivity  $\rho_f(t)$  which coincides on late times with  $\rho_a(t)$ . On early times resistivity  $\rho_f(t)$ , calculated on the complete formula (the index *f-full*), adequately reflects the true resistance of the medium (the same as for soundings in direct current methods).

For implementation of  $E(t) \rightarrow \rho(h)$  conversion it is necessary to calculate correcting non-dimensional coefficient  $k(t)$ , depending from logarithmic velocity  $\nu$  of apparent resistivity change:

$$k(t) = \frac{1}{(1-\nu)^{3/2}}, \quad \nu = \frac{t}{\rho_f(t)} \frac{d\rho_f(t)}{dt} = \frac{d \ln \rho_f(t)}{\ln t} \quad |\nu| < 1$$

and after that to calculate resistivity  $\rho(h)$ , as function of sounding depth  $h$ :

$$\rho(h) = k(t) \rho_f(t), \quad h = \sqrt{k(t) \frac{t \rho_f(t)}{\mu}}$$

The formula for calculation of effective depth  $h$  can be modified to

$$h = \sqrt{\frac{t \beta(res)}{\mu}}.$$

The function  $\beta(res)$  has dimension  $[\Omega m]$  and can vary from  $\rho_f$  value - a "not transformed" resistivity to  $\rho = k(t) \cdot \rho_f(t)$  value.

Change of values  $\beta(res)$  essentially change form of  $\rho(h)$  curve and correspondingly resolution of transformation. For a weak contrasting medium  $\beta \rightarrow \rho$ , and for contrasting one  $\beta \rightarrow \rho_f$ ; for the media with an average contrast level  $\beta = (\rho_h \rho_m)^{1/2}$ .

$\beta(res)$  function is regulated by special parameter **resolution (res)** - « resolution of conversion »

$$\ln(\beta(res)) = \ln(\rho_m) + res \frac{\ln(\rho_h) - \ln(\rho_m)}{10} \quad 0 \leq res \leq 10$$

The algorithm of conversion and instances of application explicitly are described in references [2, 3, 4, 5].

## WINDOW FOR SMOOTHING OF EXPERIMENTAL DATA

The smoothing procedure becomes active in window **Smoothing** - Fig. 11.

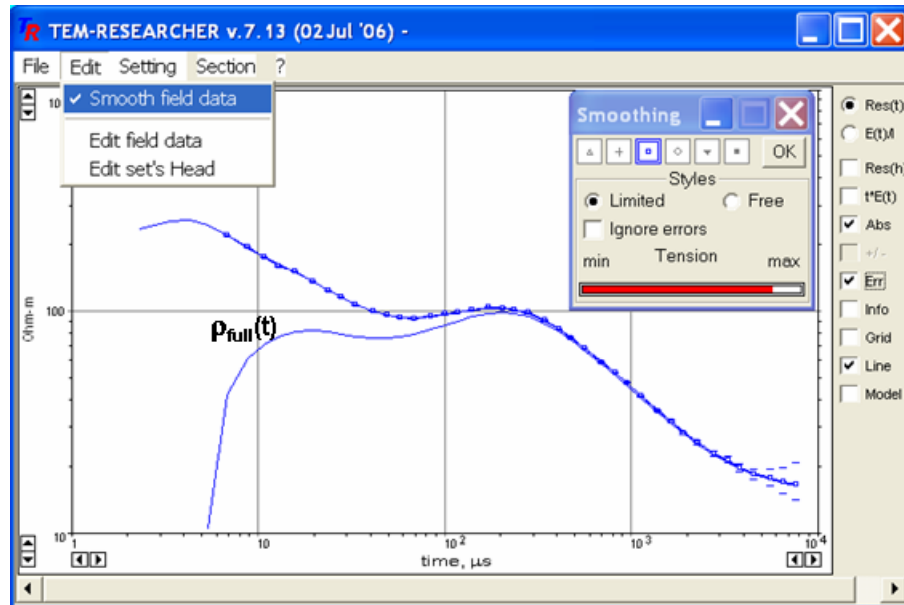


Fig. 11

### The Note:

It is recommended to use the command **Alt+A** (smoothes all curves on the screen) after data editing.

### Control elements:

**Limited** - the exponential spectrum is positive  $E(s) > 0$

**Free** - the sign of exponential spectrum  $E(s)$  is unlimited

**Ignore errors** - the procedure of smoothing does not take into account the weight coefficients defined by lapses of measuring

**Tension** - "strength" of smoothing: the more is **Tension parameter**, the more detailed is approximated initial dependence  $E(t)$ .

Let's mark, that limitation  $E(s) > 0$  is valid only under condition of the joint receiving and transmitting antennas at absence of the frequency dispersion of conductivity and permittivity of the researched medium.

If antennas are not joint or IP-effect\_occurs, the procedure of smoothing is correct only with option **Free**.

The instance of smoothing of experimental data is shown in Fig. 11.

Upper blue curve approximates the initial data – this is smoothed  $\rho(t)$ ,

and lower blue curve is calculated dependence  $\rho_f(t)$  [ $\rho_{full}(t)$ ].

In a column of data sets choice one can make active simultaneously all disposable sets (Alt+A). After **OK** the data will be smoothed and transformation  $\rho(h)$  and  $S(h)$  - distribution of a specific resistivity and longitudinal conductance versus apparent depths will be scaled. The graphic of  $\rho(h)$  and  $S(h)$  function can be seen after activation of option  $\rho(h)$  of the main window (Fig. 12).

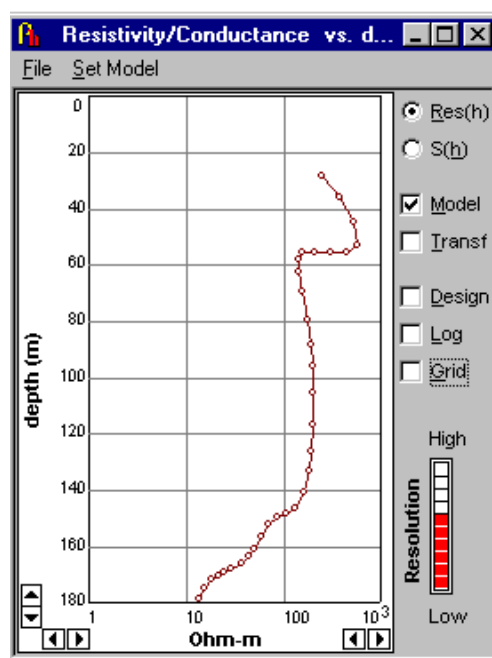


Fig. 12

Control elements:

**Res (h)** - to show apparent resistivity  $\rho(h)$

**S (h)** - to show apparent longitudinal conductivity  $S(h)$

**Model** - to show the piece - uniform model of the medium (if it is calculated)

**Transf** - to show transformation  $\rho(h)$  or  $S(h)$  for preset and calculated the piece - uniform

model of the medium (**Model** window)

**Design** - makes active mode of construction of new piece-uniform model

**Log** - to change a vertical scale to logarithmic one

**Grid** - to show detailed grid of depths and resistivity

**Resolution** - to change the resolution of transformation: the higher is this parameter - the more detailed are curves  $\rho(h)$  or  $S(h)$ .

**ATTENTION!**

**Transformations  $E(t) \rightarrow \rho_f(t) \rightarrow \rho(h)$  for remoted loops are correct only in near zone**  
 **$t/(\mu_0 R^2 / \rho_a(t)) \gg 1$**

Control elements **Model** and **Transf** are intended for the resolution of transformation  $\rho(h)$  analysis.

In particular, change of resolution of transformations at change of distance between two thin well conductive clay layers ( $\rho = 3 \text{ Ohm-m}$ ), deposited within rather high-resistive rocks ( $\rho \sim 70 \text{ Ohm-m}$ ) is shown in the Fig. 13. The piece - uniform diagram concern to model, and smooth curve - to transformation  $\rho(h)$ .

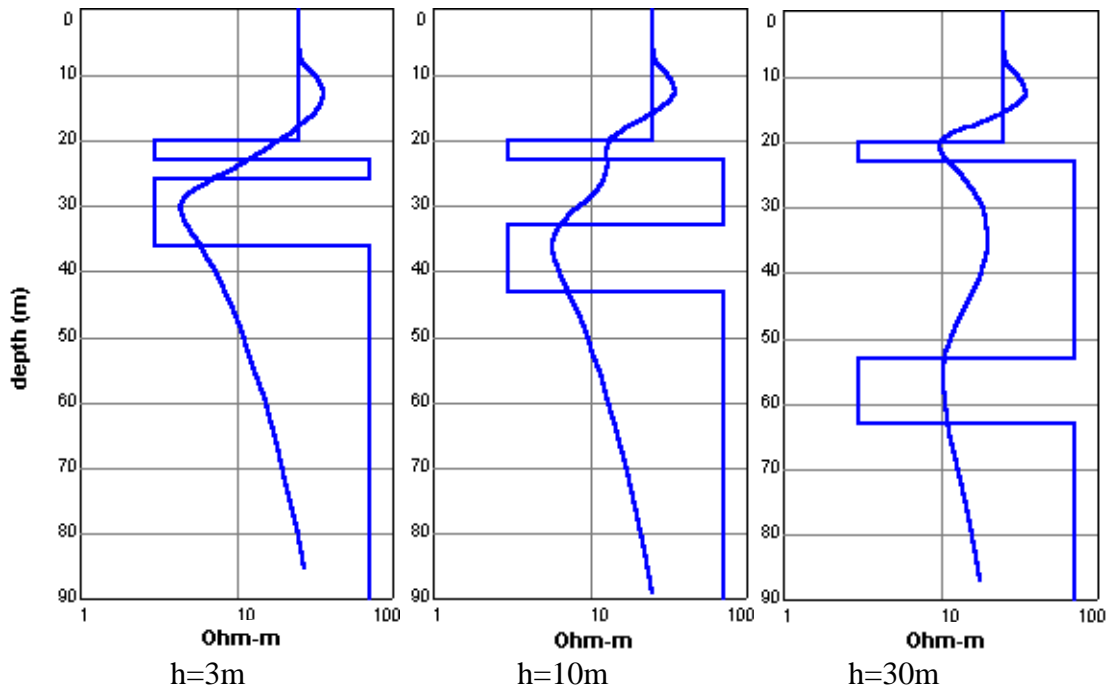


Fig. 13

At distance  $h=3 \text{ m}$  the layers are indiscernible, and with increasing of distance between layers the resolution is increased. These functions are very useful at planning researches in any region in a case when there is preliminary information on structure.

## SAVING OF DIAGRAMS

The diagrams may be printed, saved in the EMF-file or saved in the PSC file (Pseudosection) which is used for construction of pseudo-section at array or profile research. There is function **File-> Save Image in MetaFile** in the menu, which is intended for record of diagrams Res(h) or S (h) in the standard OS Windows file (\*.EMF is Enhanced MetaFile). Having kept the image in this file, the user has an opportunity to insert and edit a figure in any text in the form convenient for him. For example, in the MS-programs Word/Excel/PowerPoint this procedure looks like:

**Insert -> Image -> from File.**

The program requests size of the figure and a color mode (black- and-white or color image) at saving the data in EMF file. Saving the data in PSC file and printing the diagrams is carried out by standard for Windows way.

### ATTENTION!

The legend to figures (only names of field sets) is kept in the case if the switch **Info** in the main window of the program is activated.

The legend to the figure may be located:

- in the left top corner,
- in the left bottom corner,
- in the right top corner,
- in the right bottom corner.

Location of the legend coincides with the location of window **Info** respectively to corners of the main window of the program.

## DESIGN OF INITIAL MODEL

The initial model can be constructed by two ways:

1) on the basis of apparent resistivity  $\rho(h)$  function,

2) on the basis of apparent conductance  $S(h)$  of function  $S(h) = \int_0^h \rho^{-1} dh$ .

In first way it is necessary to activate the function **Design**. After that construct a section on the graph of  $\rho(h)$  curve using the left button of the mouse by marking nodes as it is shown in Fig. 14.

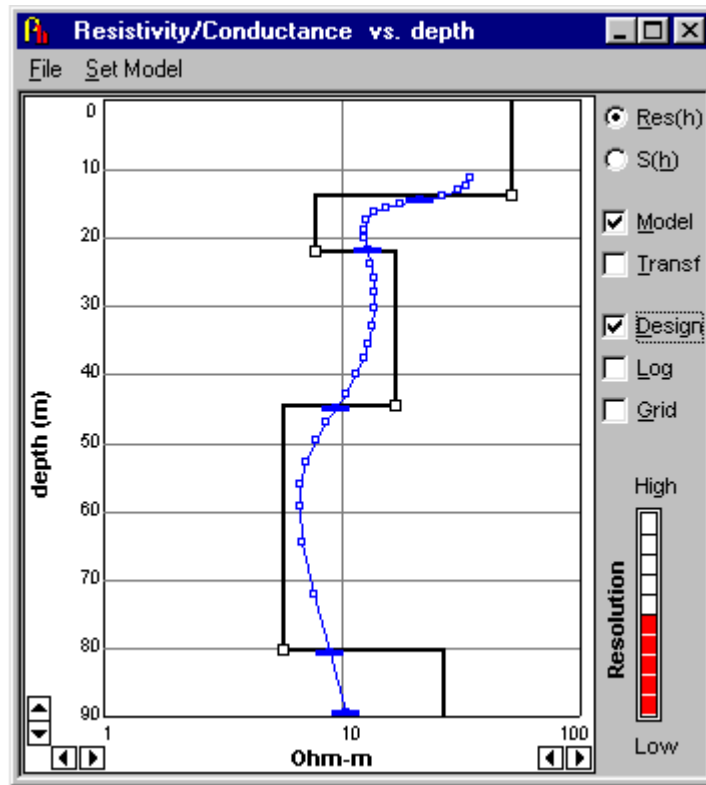


Fig. 14

At some experience this way provides good approximation of the initial model to a start model. As a basis for doing that the recommended boundaries of the layers determined according to the extremums of the  $d^2\rho(h)/dh^2$  derivative are marked after activation of the **Design** command. In this way the user can more or less correctly to draw resistance of the layers. During this procedure we recommend to use the rule demonstrated by the example shown in Fig. 14:

- the higher resistivity of the layers the function  $\rho(h)$  a few decreases,
- the lower resistivity of the layers the function  $\rho(h)$  a few increases.



In the second way user first has to enable the options **Log** and **S(h)**. After that it is necessary to make approximation of the  $S(h)$  with the piece-linear function using left mouse button -Fig. 15.

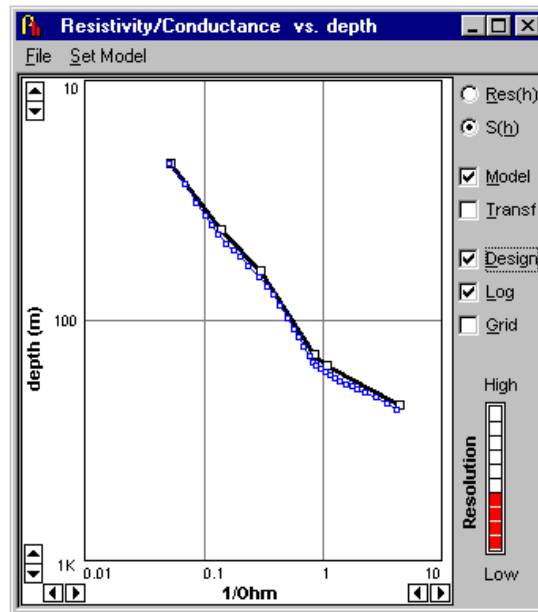




Fig. 15

For convenience of the editing, the opportunity of correction of the approximation is stipulated in the program. For this purpose click with the left mouse button on the unit created by you designated by a black square, and pull it in any side, keeping the button. After releasing the button, the node changes its coordinate ( $S$  and  $h$ ). In addition, at construction (marking) the nodes, pressing the right mouse button delete the last created node.

To each piece of the line corresponds a layer in the horizontally - layered model. Thickness of a layer is equal to a difference of the ordinates appropriate to two next units, and resistivity of this layer:  $\rho = h/\Delta S$ , where  $\Delta S$  is the value of conductance between these units. First layer laying just under the earth surface is added to the layers shown on the diagram automatically. For more precise design of the preliminary section it is possible to stretch or compress the diagram  $S(h)$  using the   manipulators.

Sometimes it is convenient to use both scales at construction of a broken line: linear in the beginning of a curve (near to the earth surface) and logarithmic on the late times. After termination of the preliminary section design procedure, click the commands **Set model -> OK** to receive a starting layered model (in the table form it will be shown on the screen before loading (Fig. 16). After that it will be automatically loaded into window MODEL of the basic menu.

### ATTENTION!

Do not forget to mark an appropriate model for loading the created section (color square - from red to black, Fig. 16):

Resistivity Ohm-m	Thickness m	Depth m
3.781	10	10
4.686	30	40
54.07	20	60
73.01	20	80
12.04	5	85
12.04	100	185
12.04	10	195
12.04		

Color selection: ☒ ☐ ☐ ☐ ☐ ☐

OK

Fig. 16

It should be noted that the procedure of the second derivative  $d^2\rho(h)/dh^2$  calculation is unstable with respect to errors of the initial data. At small changes  $\rho(h)$  (poor contrasting section) for correct marking of the borders of layers it is necessary to have small ( $< 5\%$ ) errors of the measurements. If the errors are large, numerous thin layers can appear on a curve  $\rho(h)$ , and at changing the **Tension** parameter of the smoothing intensity (Fig. 11), the picture sharply varies: the part of layers vanish, some change their position etc. It testifies to instability of the procedure of the second derivative calculation. In this case it is recommended to reduce gradually parameter **Tension** before occurrence of steady results of level-by-level splitting.

### INVERSION

First of all it is necessary to set parameters of the inversion process. For this purpose the program provides 4 special windows.

The tuning window of adjustment - “**Attach field data to models**”. It is intended for setting of conformity between sets of experimental data (field data) and models which will pay off in the window “**MODEL**” at start of the inversion procedure (**Invers**s). This setting informs the program for which set of the field data the inversion is made at activating of any model.

The window is caused by **Setting->Inversion->Attach Field sets to Model** (look Fig. 19).

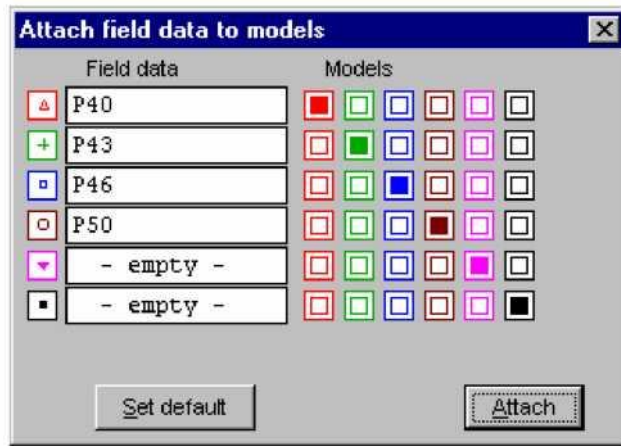


Fig. 17

In this case the standard mode (Fig. 17) is activated. In standard mode, the color and number of a model corresponds to color and numbers of the field data sets. For example, at start of **Invers** with the active model N 4 (brown color) the procedure of inversion is carried out for the appropriate set N 4.

However there is an opportunity to configure the model with another way as it is shown, for example, in Fig. 18:

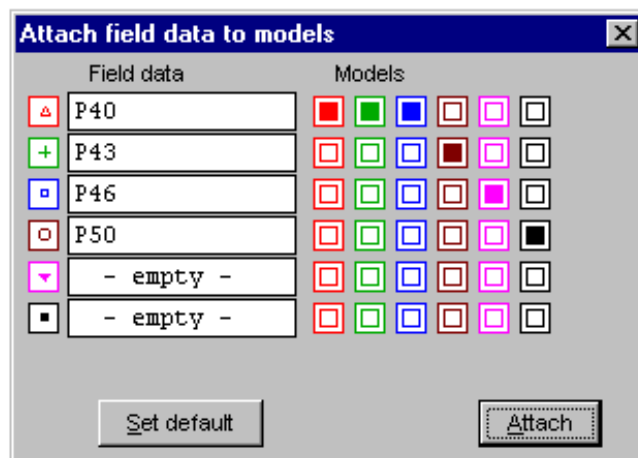


Fig. 18

In the shown example the inversion procedure is carried out for the field data set N 1 (red color) at activation of the models N 1-3, while at activation of the models N 4,5 and 6 - for the sets N 2,3 and 4 respectively. Non-standard setting in this window is useful in the cases when the user wants to compare the results of inversion of the same field data at various initial conditions (parameters of starting model). In usual cases it is recommended to use the mode “**Set default**”.

### Window MAIN SETTING (Inversion)

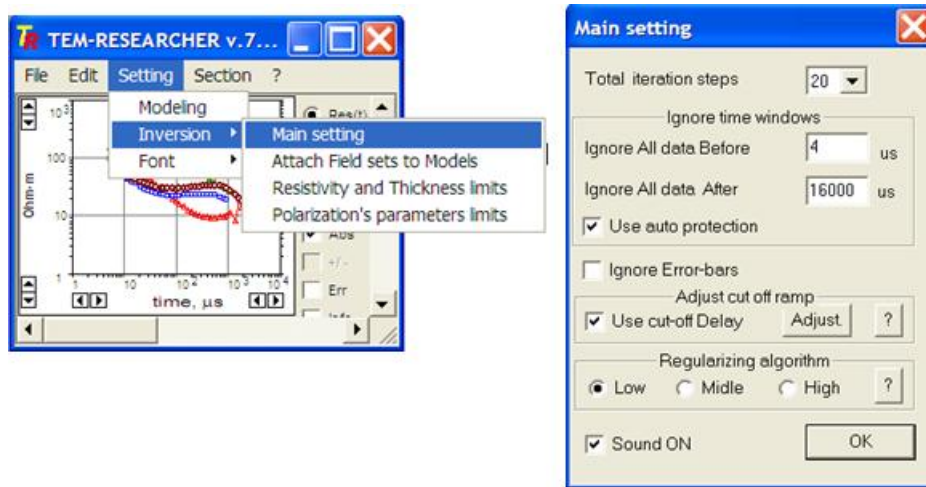


Fig. 19

**Total iteration Steps** means amount of iterations of inversion procedures after which the result is displayed. Experience shows that usually 10-15 iterations are enough for receiving of the acceptable solution. If necessary, one can repeat the process of iterations.

**Ignore All data Before** gives possibility to ignore all points of the curve corresponding to times less than the noted (in the real case less than 4 microseconds).

**Ignore All data After** gives possibility to ignore all points of the curve corresponding to times more than the noted (in the real case more than 16 microseconds).

**Use auto protection** – provides the ignoring mode of the points on the curve belonging to early time corresponding to work of HVP system.

At activation of the **Ignore Error-bars** command, the procedure of inversion carries out fitting of the model data to the experimental ones without taking into account errors of measurements; otherwise the readouts with great errors are used with smaller weight in misfit functional, than readouts with a small errors [2].

**Use cut-off Delay** permits to use the procedure for correction of the field data according to real switching-off front of the current in the generating loop. In the window **Adjust** the fine tuning of correction parameters is stipulated.

**Regularizing Algorithm** is the algorithm preventing the appearance of the thin resistive layers in the fitting models. “**Low**” – the total conductivity of the layer  $S = h/\rho$  [Siemens] is not limited, “**Middle**”  $S > 0.1$  S, «**High**” -  $S > 0.25$  S.

## ATTENTION!

The window “**Adjust**” is intended only for experienced users! The parameters of switching-off current delay are determined experimentally according numerous field measurements with different types of cables and size of antennas. These parameters corrects the field data with the best way at condition that the transmitting antenna (independently on its size) has resistance of 3-8 Ohm and the current in antenna is less than 1.25 A.

### Setting of resistivity and thickness for the Models in the inversion procedure

The window is caused by **Setting-Inversion-Resistivity-Thickness Limits** (Fig. 20)

Resistivity (Ohm-m)				Thickness (m)			
Fix	Min	+	Max	Fix	Min	+	Max
<input checked="" type="checkbox"/>	0.1	+	20	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	100	+	150	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000
<input type="checkbox"/>	0.1	+	2000	<input type="checkbox"/>	0.25	+	1000

Model: ■ ■ ■ ■ ■

Buttons: Set Default, Set into All Models, Apply

Fig. 20

**Fix** columns determine fixing parameters of the model. These parameters are fixed and do not vary when inversion the procedure works. In the given example, resistivity of the first layer in the model N 1 (red color) is fixed. The value of the resistivity can be seen from the parameter in the Model window.

Columns **Min** and **Max** show the minimal and maximal values for the resistivity and thickness parameters of the model actual during the work of the inversion procedure. In Fig. 20 resistivity of the second layer may change within the limits from 100 to 150 Ohm-m.

«+» provides possibility to control the limits for resistivity and thickness of the layers lying below.

**ATTENTION:** if the model's parameters are fixed, the following indicators are appeared in the window **MODEL**.

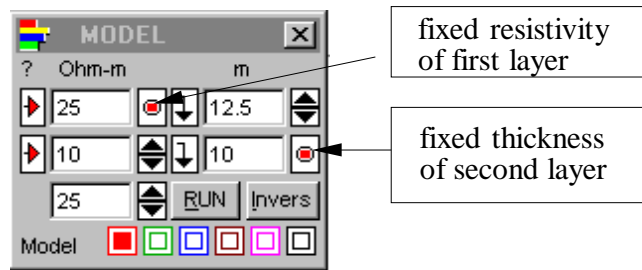


Fig. 20a

The button  fixes parameters and  cancels them.

### Window for setting of polarization parameters

The window is caused by [Setting->Inversion->Polarization's parameters limits](#) (Fig. 21)

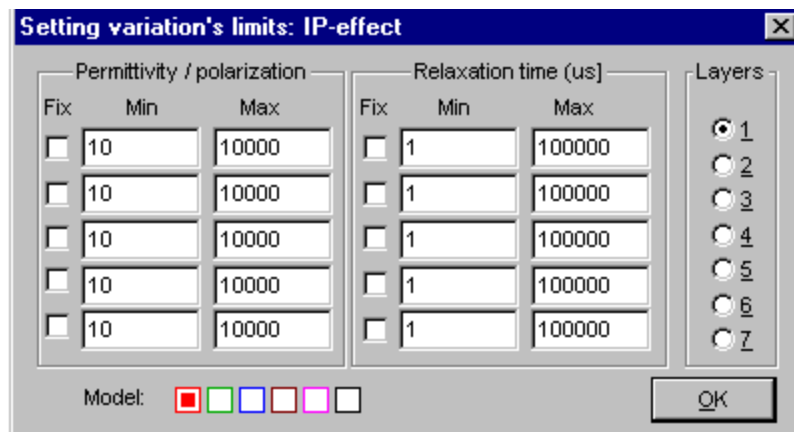


Fig. 21

Here, as well as in the previous case, it is possible to fix or to limit changing of the polarization parameters and the constants of a relaxation time.

It is possible to fix or to release the parameters of dispersion directly in the window **Model** (Fig. 21a) by click by right mouse button onto red painted margin.

All possible operations are shown in subsidiary **Help** window (Fig. 8). Fixation of the layers' parameters is reflected in the panel **Model** as circles with the color corresponding to a chosen model. For example, in shown below case (Fig. 21a), the resistivity of second layer (10 Ohm-m) and thickness of the first layer (12.5 m) in the model 3 (blue square) are fixed.

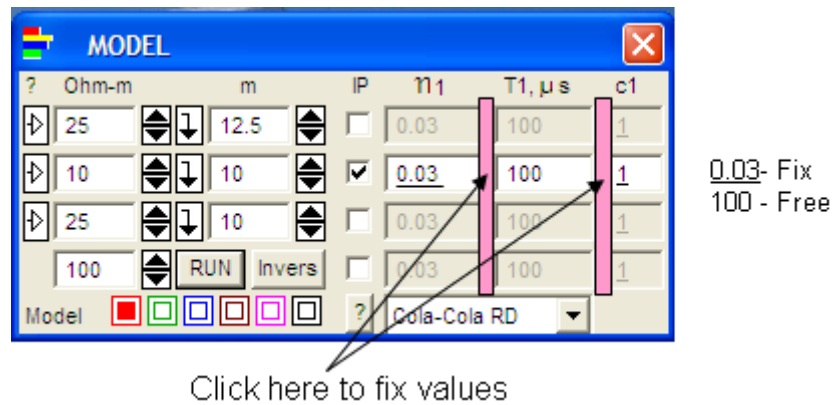


Fig. 21a

Underlined numbers indicate that the polarization parameters are fixed.


#### ATTENTION:

1. Setting of limitations on resistivity or thickness of the layers is not indicated in the **MODEL** window.
2. All possible operations can be seen in the **Help (?)** window (Fig. 21a, left upper corner of the **MODEL** window).

### Invers FUNCTION

After definition of a start model and setting of all parameters of iterative inversion process, it is necessary to click **Invers** in order to start process of inverse problem solution. Sometimes as a first step it is useful to start up **RUN** to see how well (or bad) is the initial section. If the quality of the initial section does not satisfy you, it is possible to return to the window **Res(h)** and either design new section or to correct parameters of the existing section manually having changed number of layers or parameters of some layers, or having inserted

or having removed some layers. Sometimes it is useful to fix or put restrictions on that part of the section which is fitted well and satisfies you.

In order to make interpretation of the profile data, it is expediently to do sequential analysis of adjacent sites, accepting for the starting model the section, which has been fitted in the previous site. For this purpose the panel Model  is used for choice of the active model. The left button of the mouse makes active the chosen model. After **RUN** or **Invers** the appropriate actions for the chosen model are carried out.

**Actions:** Pressing -> keeping -> moving -> releasing the right mouse button results in copying all parameters from starting (at pressing the button) models to the target (releasing the button) model.

The result of the **Invers** procedure is described in the left screen's corner in form of mean square deviation of the experimental and model curves of sounding (rms, %).

Let's consider now the additional opportunities of the **MODEL** window - Fig. 22.

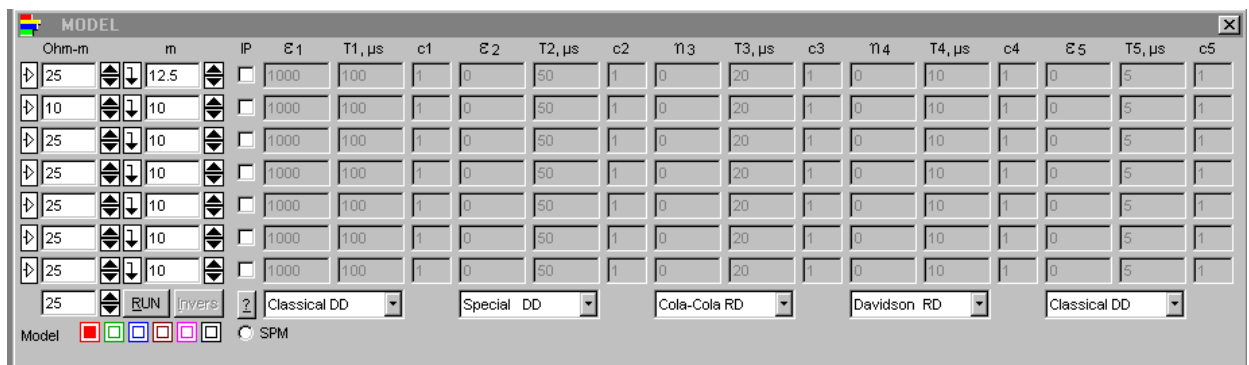


Fig. 22



This window has the contraction and expanded form. In contraction form (default) only 7 left columns are shown on the screen. This mode is used for modeling in case of frequency - independent resistivity of media, without taking into account IP - effect.

The standard for WINDOWS “stretch” procedure gives possibility to expand the window with the mouse. Besides, the user can exclude some last (deep) layers by reducing the vertical size of the window.

## IP - EFFECT

The expanded part of the window is intended for modeling of effects of induced polarization **IP** (sometimes this effect is called as frequency dispersion). The column of IP switches mark the layers selected for calculations with the induced polarization effect.



The model of frequency dispersion is selected in the window  and can be seen having pressed on the button .

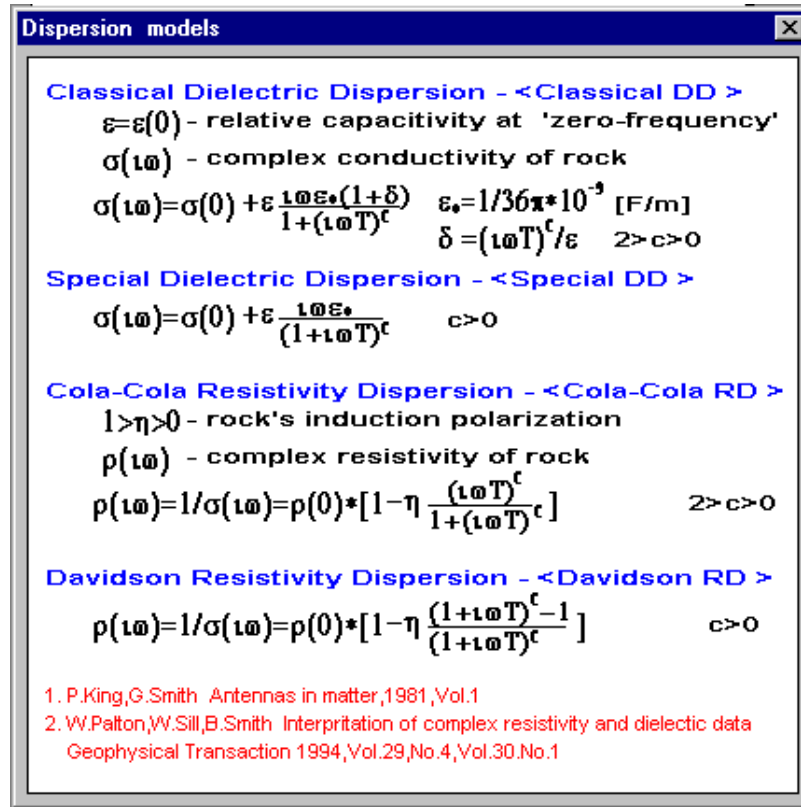


Fig. 23

In each layer the user can set “five-component” polarizing model with the different  $\epsilon$  or  $\eta$ , time constant  $\tau$  and logarithmic speeds of relaxation  $c$ . At that, in the same layer it is possible to model jointly the effect of frequency dispersions of resistivity and dielectric permeability.

#### ATTENTION!

The inversion procedure determines only two parameters of IP-effect:  $\epsilon$  (or  $\eta$ ) and the relaxation constant  $\tau$ . The parameter  $c$  is considered fixed (Fig. 23). However, in case of complicated model of polarization (for example two or three-component IP-effect in one or several layers), the inversion procedure becomes inefficient because of large in number of variables. So, one should remember, that polarizing effects essentially extends equivalence area of geoelectric section: *to a set of experimental data (even in case of laterally layered media and small error of measurements) multiple sets of rather various electric parameters  $\rho$ ,  $\epsilon$  and  $\tau$  can correspond*. Therefore we recommend to limit oneself by one-component IP-effect and whenever it is possible to fix a part of parameters.

## SPM - SEFFECT

The inversion procedure does not determine parameters of SPM-effect, they are considered fixed. Setting of SPM parameters [6,7,8] is carried out in the window **SPM** – Fig 24.

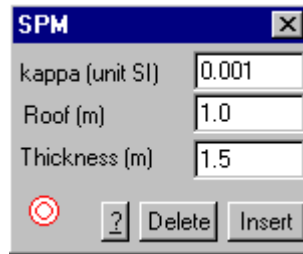



Fig. 24

Here:

**Roof (m)** is the bedding depth of a superparamagnetic layer (distance from the earth surface,  $\text{Roof} > 0.01 \text{ m}$ );

**Thickness (m)** is thickness of the layer;

**kappa (unit SI)** is superparamagnetic susceptibility of the layer;

Change of a symbol's form in the line **Model** (see Fig. 22) indicates existence of SPM effect in the media. Here in the example case:  the model 1 and 3 contain SPM-effect. The button **Delete** deletes SPM-effect from the model, **Insert** - establishes it.

## SAVING OF THE INVERSION RESULTS

After completion of the inversion process, it is necessary to save the received results in a file. For that, you can select the **File->Save Inversion's results**, correct the names and coordinates, then these data are saved into INT-file – Fig. 25.

If you need to read the information from INT-file and to set parameters in the window **Model**, use **File->Input Model data Res(h)** function which opens INT-file. Select the model you need (Fig. 26) and using **Install** button insert the needed parameters in one of six modeling cells.

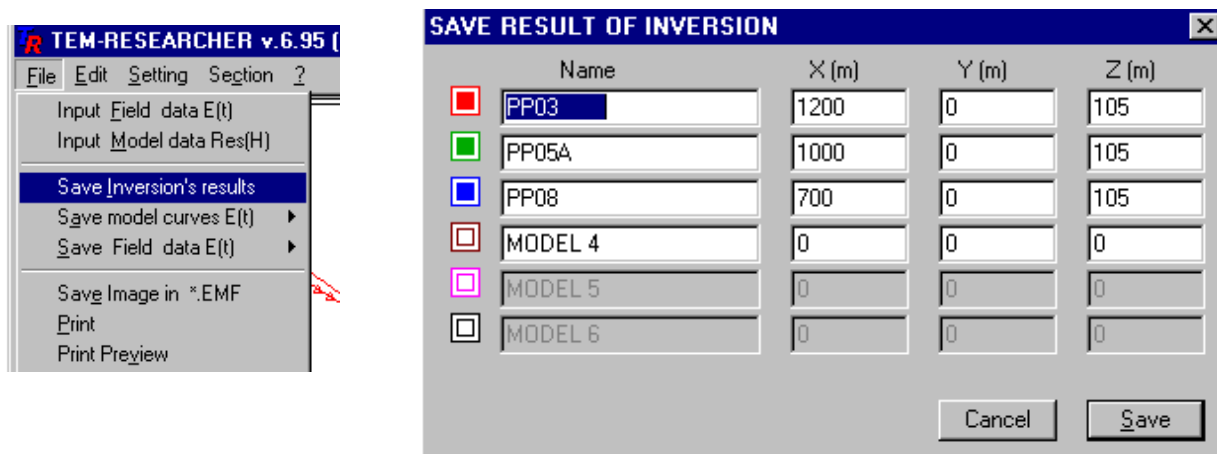


Fig. 25

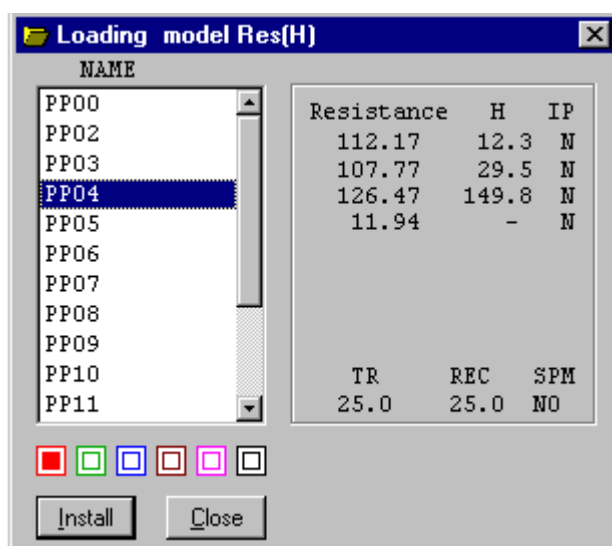


Fig. 26

## ADDITIONAL FUNCTIONS FOR DATA SAVING

### 1. Saving $\rho(t)$ and $E(t)$ calculated on the basis of layered model.

After calculation of  $\rho(t)$  and  $E(t)$  (Fig. 27), it is possible to save the data in Tem-format (as for the field data) or in free format (ASCII) for further use in any electronic table (for example, MS Excel) using the function **File->Save model curves E(t)->TEM-FAST format** (or **General-purpose style**).

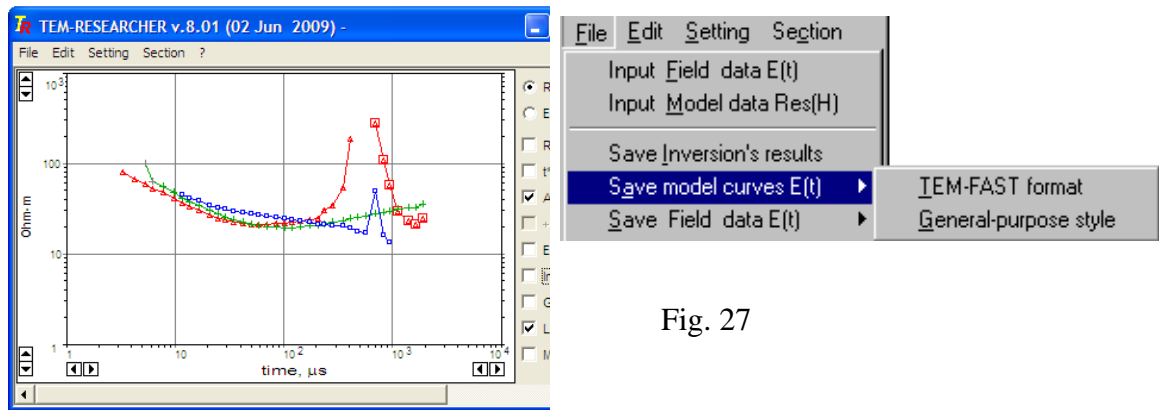


Fig. 27

## 2. Editing and saving of the field data

After redaction and smoothing of field data, one can change the names, coordinates, or antenna's size and save them to TEM-file using the scheme shown in Fig. 28:

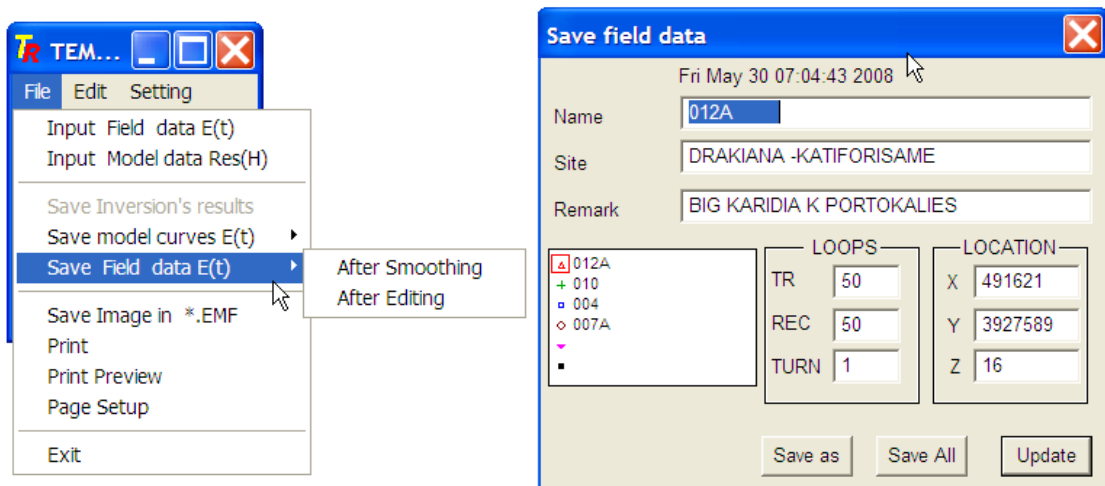


Fig. 28

## PRINTING AND COPYING OF THE GRAPHIC DATA

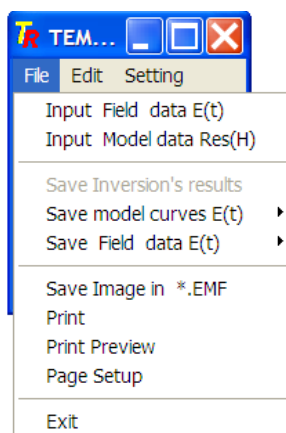


Fig. 29

All main windows of the program have a menu's section (Fig. 29) intended for operation with graphic information: printing of graphics and copying.

The function **Save Image in \*EMF** is intended for inserting in a standard OS Windows file (\*.EMF – Enhanced MetaFile). Having save the graph in the file, a user has possibility to insert the picture in any document in workable form. In MS Word this procedure is:

**Insert -> Image -> from File.**

At saving graphs in EMF format the program inquires the size and color (black-white or color image).

**Print, Print Preview, Page Setup** commands are standard Windows functions, providing capable setting of the printing parameters: page size, preliminary view etc.

## CONSTRUCTION OF GEOELECTRIC SECTIONS

For construction of geoelectric (a horizontally-uniform layered medium) or pseudo-section (gradient resistivity section), it is necessary to have:

- the data received at profile or array measurements (TEM-file);
- the inversion's data received in result of inversion procedure and saved in **INT**-file (for geoelectric sections);
- the results of transformations  $\rho(t) \rightarrow \rho(h)$ , received in window **Res(h)** and written in **PSC**- file (for pseudo-sections)

### ATTENTION!

1. At the first stage of array and profile data interpretation, check up and modify coordinates X,Y,Z of sounding sites!
2. TEM-RES v.8 supports formats of **INT**-files TEM-RES v. 4 (DOS), however inquires a size of the transmitter antennas used at measurements.

Command **Section->New** of the main menu causes file dialogue with the help of which it is possible to open either **INT** or **PSC** file containing the results of inversion or transformation along of **all sites of the profile or area.**

The window containing the INT-file's information on coordinates of the field sites, existence or absence of **IP** and **SPM** effects is represented in Fig. 30.

In column = the sets with identical coordinates (**X** and **Y**) are marked. If those are present, it is necessary to choose a unique set convenient to your requirement (the program of section's construction does not suppose duplicate sets of the data).

File: D:\Works\Crete-Greece 2008\Area Asimin...

Save as

#	Name	X (m)	Y (m)	Z (m)	IP	SPM	ms	%
1	001A	490245.0	3930191.0	2.0	No	No	2.29	
2	002	490749.0	3929718.0	10.0	No	No	1.78	
3	003	490802.0	3929077.0	2.0	No	No	0.95	
4	004	490667.0	3929578.0	11.0	No	No	1.18	
5	005A	490636.0	3929271.0	2.0	No	No	3.43	
6	006	491048.0	3928914.0	14.0	No	No	1.00	
7	007A	491071.0	3928688.0	9.0	No	No	1.52	
8	008	491121.0	3928439.0	6.0	No	No	0.29	
9	009A	491212.0	3928236.0	8.0	No	No	2.83	
10	010	491328.0	3927967.0	8.0	No	No	1.39	

☐ Map   Sort: default   Unselect   ?   Select All

Fig. 30

Double click by the left button on any data set, and detailed information on a sounding site (Fig. 31) which can be edited will result.

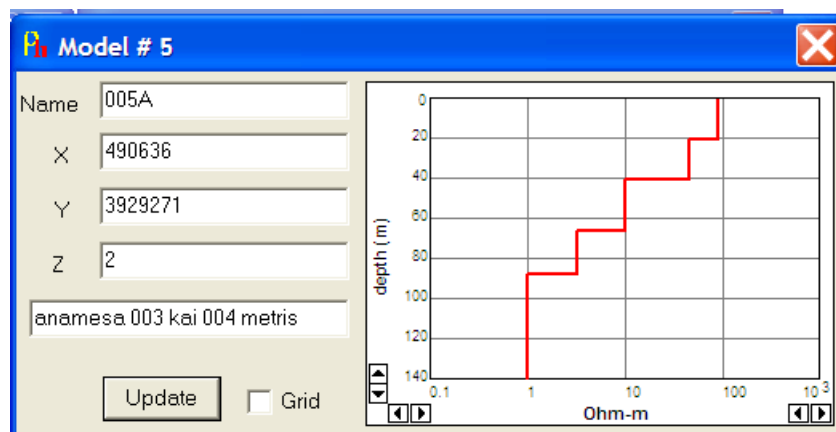


Fig. 31

Click the **Select All** command (Fig. 30) and mark the window **Map**. You will see the location of points of soundings on a topographic map (Fig. 32).

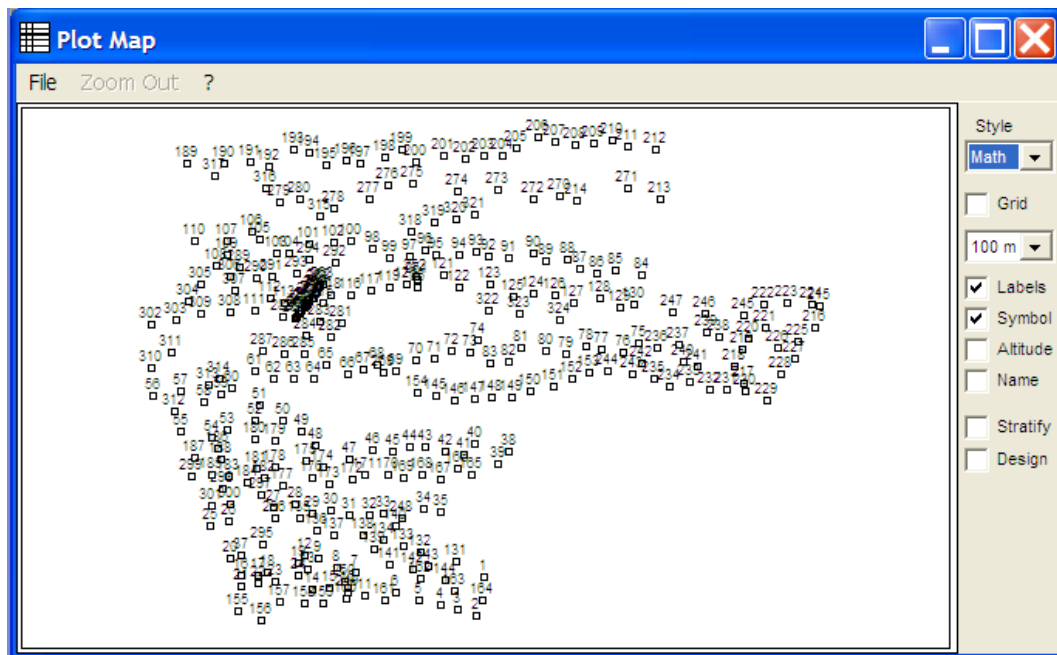


Fig. 32

Here the following denotes are used:

**Style** – changes the style of the map

**Math** - X-coordinate increases from the left to the right,  
Y-coordinate increases from the bottom to the top;

**Geo** - X-coordinate increases from the bottom to the top,  
Y-coordinate increases from the left to the right;

**Grid** - sets the grid with different mesh sizes;

**Labels** - displays the serial number of the point of sounding as it is shown in Fig. 30;

**Symbol** - indicates the point of sounding in a square form;

**Altitude** - Altitude shows Z coordinate of sounding location;

**Name** - displays the the name of the point of sounding (Set Name);

**Stratify** - activates the procedure for constructing fiber wise horizontal slices resistance;

**Design** mode includes the construction of the profile, along which you want to build a vertical cross-section resistances;

Click the left mouse button on the points that you want to be included in the profile, for example, as shown in the left panel of Fig. 33.

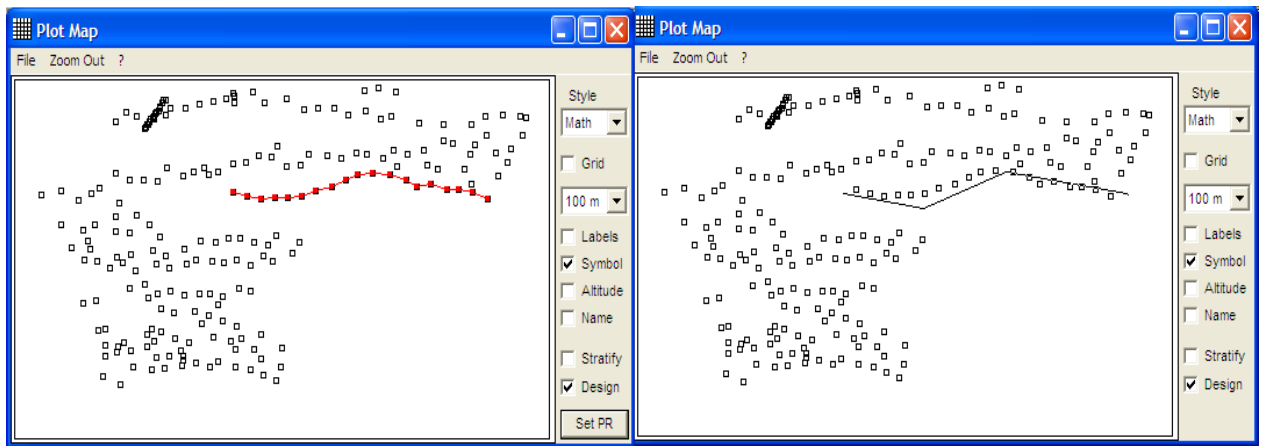


Fig. 33

If you made a mistake and didn't not include the point that you need, press the right button and your last action is canceled.

To construct a profile you can draw a straight line or broken line near the points to be included in the profile (press and hold the left mouse button), as shown in the right pane in Fig. 33.

Once all the necessary points are marked, i.e., profile is created, double click the mouse button to end the process of building the profile. The menu is displayed **Set PR** that means «set profile», and point of the profile will turn red.

If the data is only one coordinate (for example, only **X**, and **Y** at all points of the same profile), the profile is automatically represented on the screen after the activation of **Design**.

Click **Set PR**, and display show the created profile (Fig. 34).

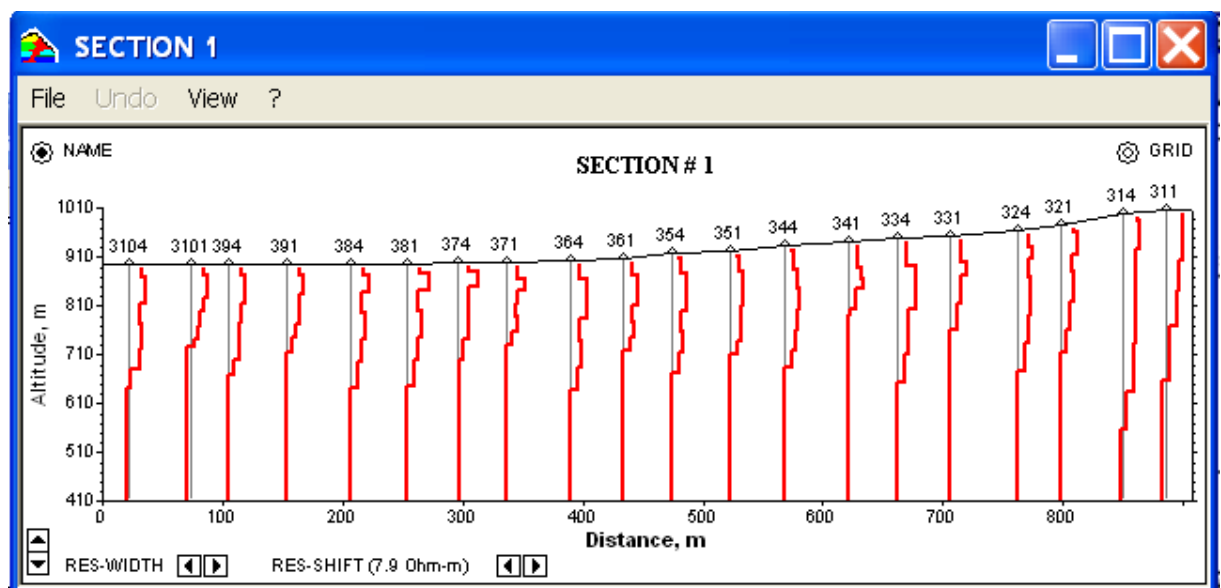






Fig. 34



By default, the profile depicted **as Logging** (logging) style, i.e., as a horizontally-layered medium. The horizontal scale of the resistivity **Res (h)** is logarithmic.

Below there are two control elements: RES-WIDTH   RES-SHIFT (0.6 Ohm-m)  , you can use them to change the position and scale of the **Res(h)** graphs. In parentheses is shown the magnitude of the resistivity corresponding to position of the vertical line marker that is present at each point sensing.

Going into the **View** menu, you can change the style of the image into **as Tomography**, and to see a section in color (Fig. 35).

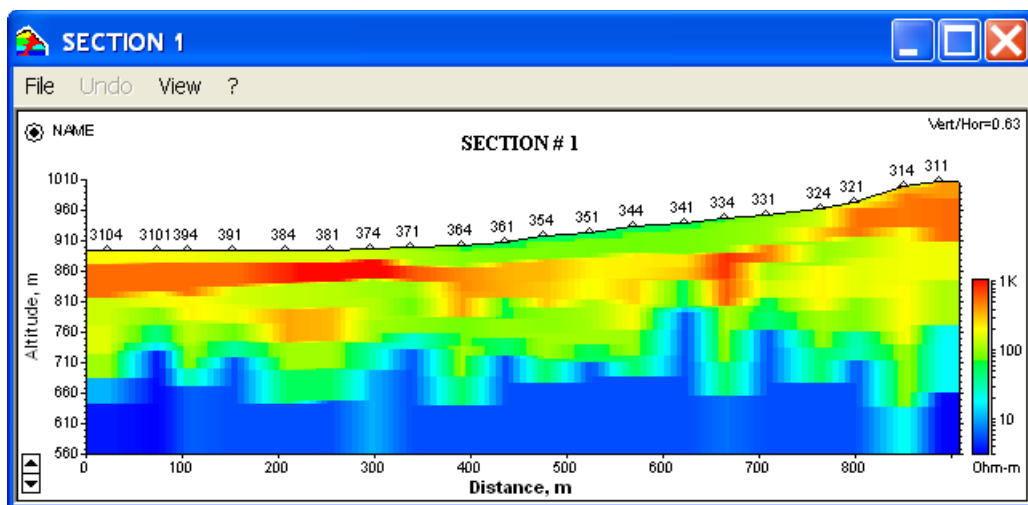
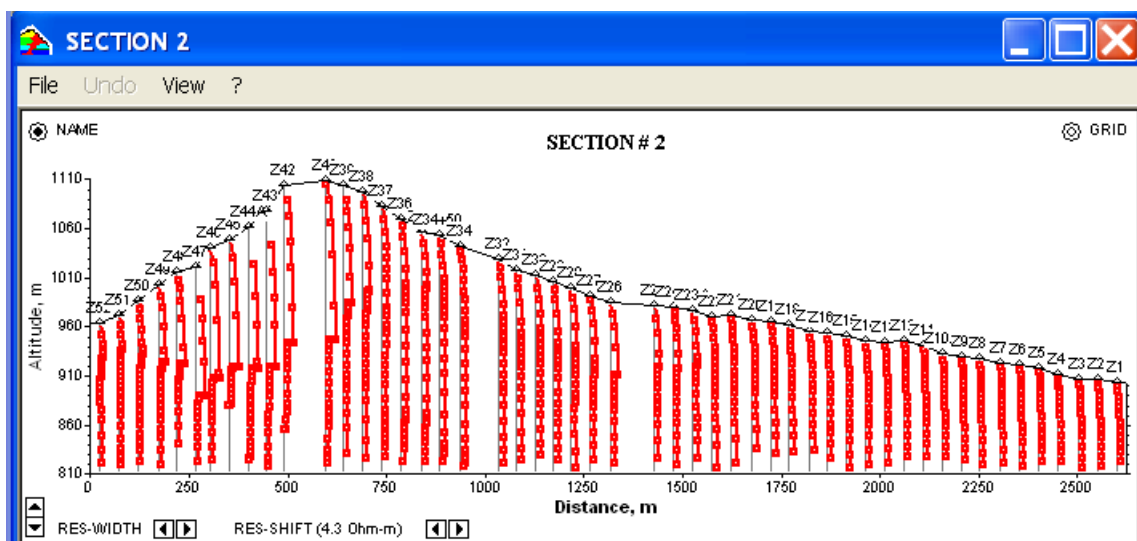


Fig. 35

The similar figures can be obtained by opening the files from the PSC-transformations.



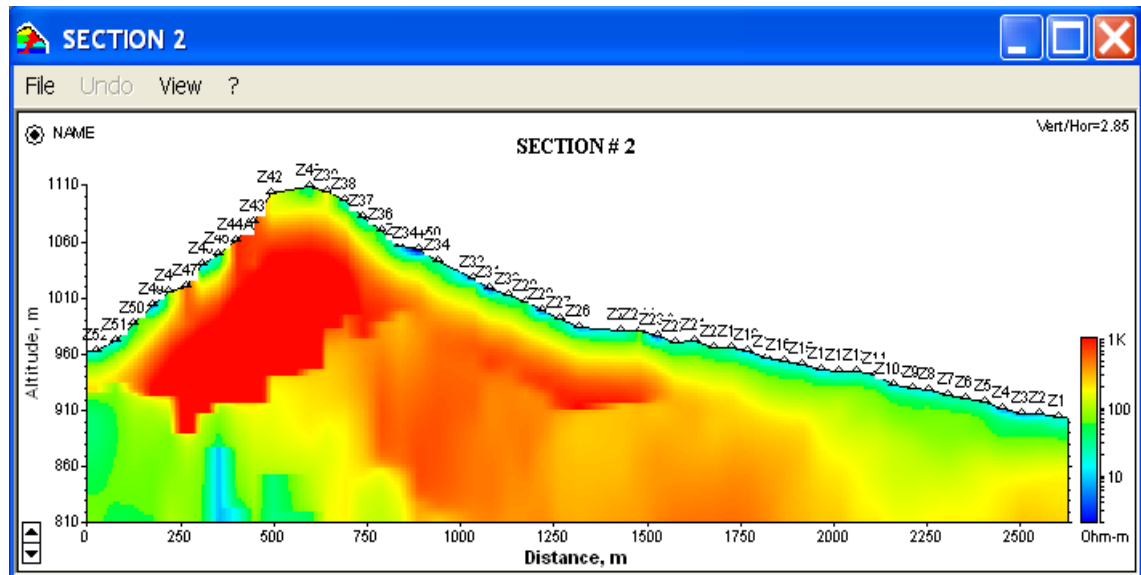


Fig. 36

As a result of loading of a SEC file containing the information on both the 1D inversions and transformations, the menu in the window **Section** expands to six positions and allows you to build six different sections (Fig. 36a):

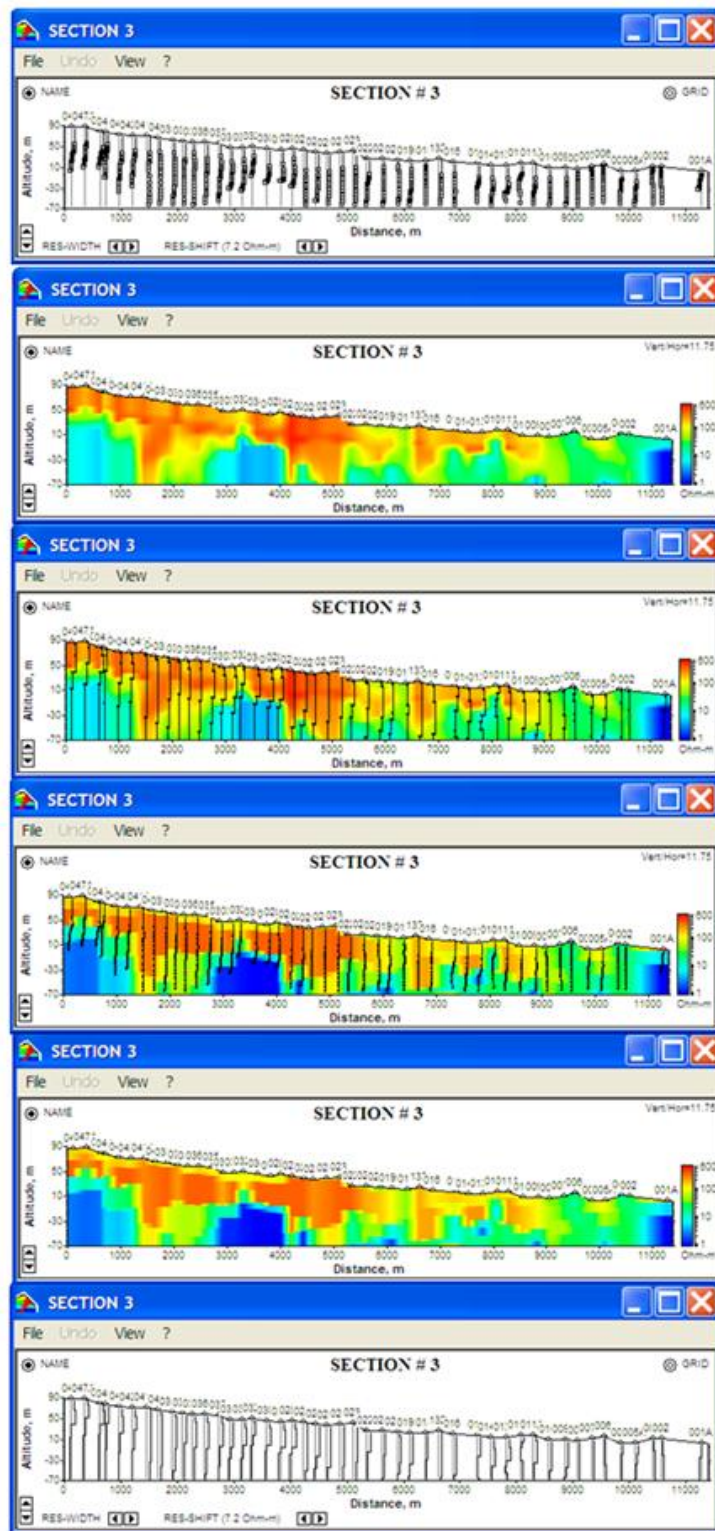


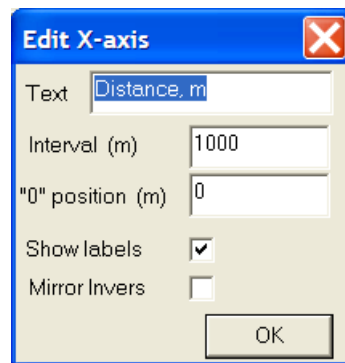
Fig. 36a

- The transformation in the form of curves - Transformation (Logging);
- Transformation in the form of a color palette - Transformation (Tomo);
- Transformation in a color palette form with the 1D inversion data - Transformation & Inversion;

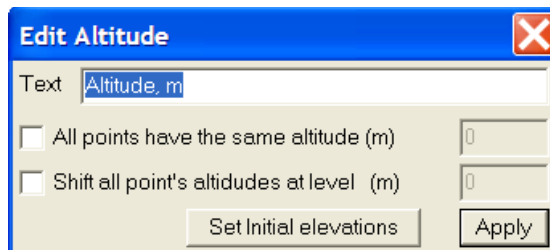
- 1D inversion of a color palette form with the curves of transformation - Inversion & Transformation
- 1D inversion in a color palette form of Inversion (Tomo),
- 1D inversion in the form of a horizontally layered models of Inversion (Logging)

The user can change a title of the section and the font, for that it is necessary to double-click the left mouse button on the title (**SECTION # 2**, for example)

By clicking the left mouse button on "**Distance, m**", the user can change the labeling on the profile distances signatures, remove them or flip the cut (left-right to change).



By clicking with the left mouse button on "**Altitude, m**" you can call the window



Here you can set elevations of all points on the section to a convenient level (i.e., remove the relief) or to move all the points of the profile at the selected value (i.e., add or subtract any level). You can also return to baseline levels of elevations (axis Z).

To correct the color palette of the scale of resistances click twice on the scale ruler on the right side of the figure - Edit dialog appears (Fig. 37).

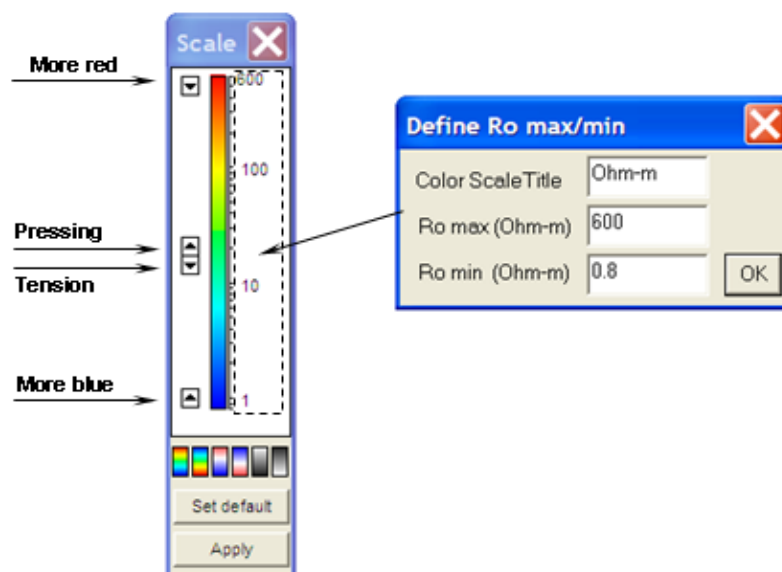


Fig. 37

The control elements to the left of the color scale palette let you edit the resistivity. Possible coloring scales (6 options) are shown at the bottom of the window. Click the left button to select the color option. Scale (maximum and minimum) column of resistivity is selected automatically. However, in some cases the user can set a specific range of resistivity values. Such need arises at the comparative analysis of sections obtained at the same area of research. In this case all sections and the corresponding maps (see the section "CREATING MAPS OF RESISTIVITY AND CONDUCTIVITY") it is conveniently to represent in a single palette. To change the maximum and minimum values of the resistivity double-click in any point to the right of the Color column, and after appearance of the window " **Define Ro max/min**", enter the required parameters. Similarly, you can change the scale of the resistivity maps (Fig. 45).

After clicking the **Apply** button, the section will be rebuilt in accordance with the selected palette.

## REINTERPRETATION OF THE DATA

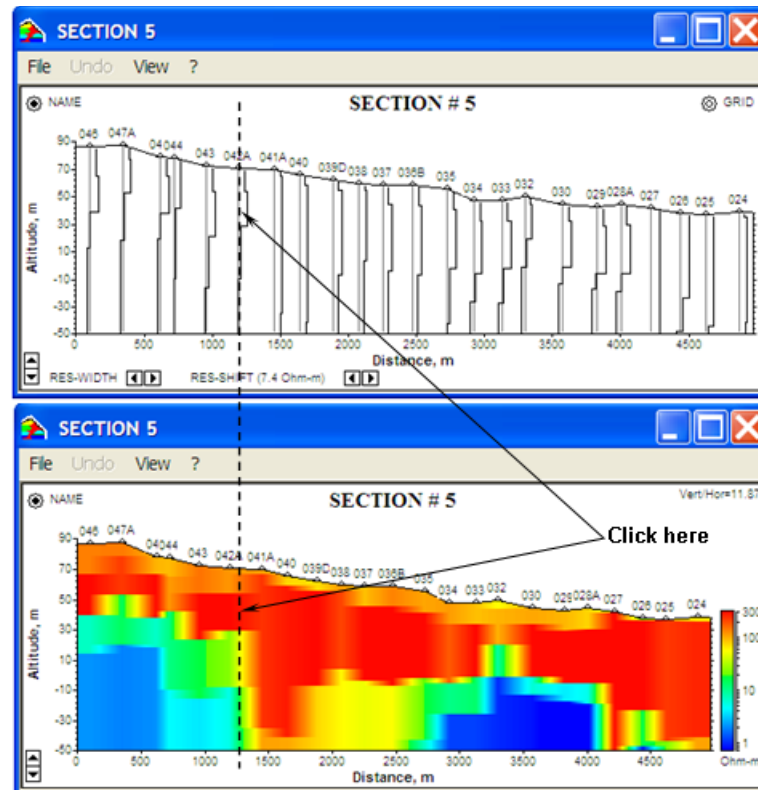


Fig. 38

In some cases, after the construction of the sections is that the results of the inversion or transformation at some points need to be corrected because of errors of interpretation or of poor quality input data. In this case, a procedure for re-correction, data transformation and inversion.

In order to re-edit, to make 1D inversion, or transformation of the data, double-click the left mouse button on one of the vertical lines, as shown in Fig. 38. The data from the section are recompiled to the main window. To edit them it is necessary to open the window **Edit Field Data** and prepare to re-inversion, as shown in Fig. 39



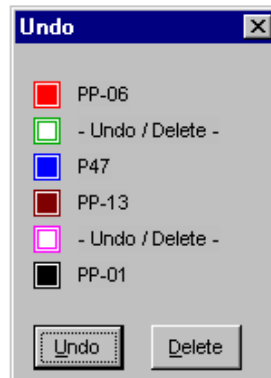


Fig. 40

If the section is constructed using the data from Psc or Sec file, you can edit the tem-data (sounding curves) and restart the procedure for smoothing, and then, opening a window Res(h), repeat the transformation using the old or new settings.

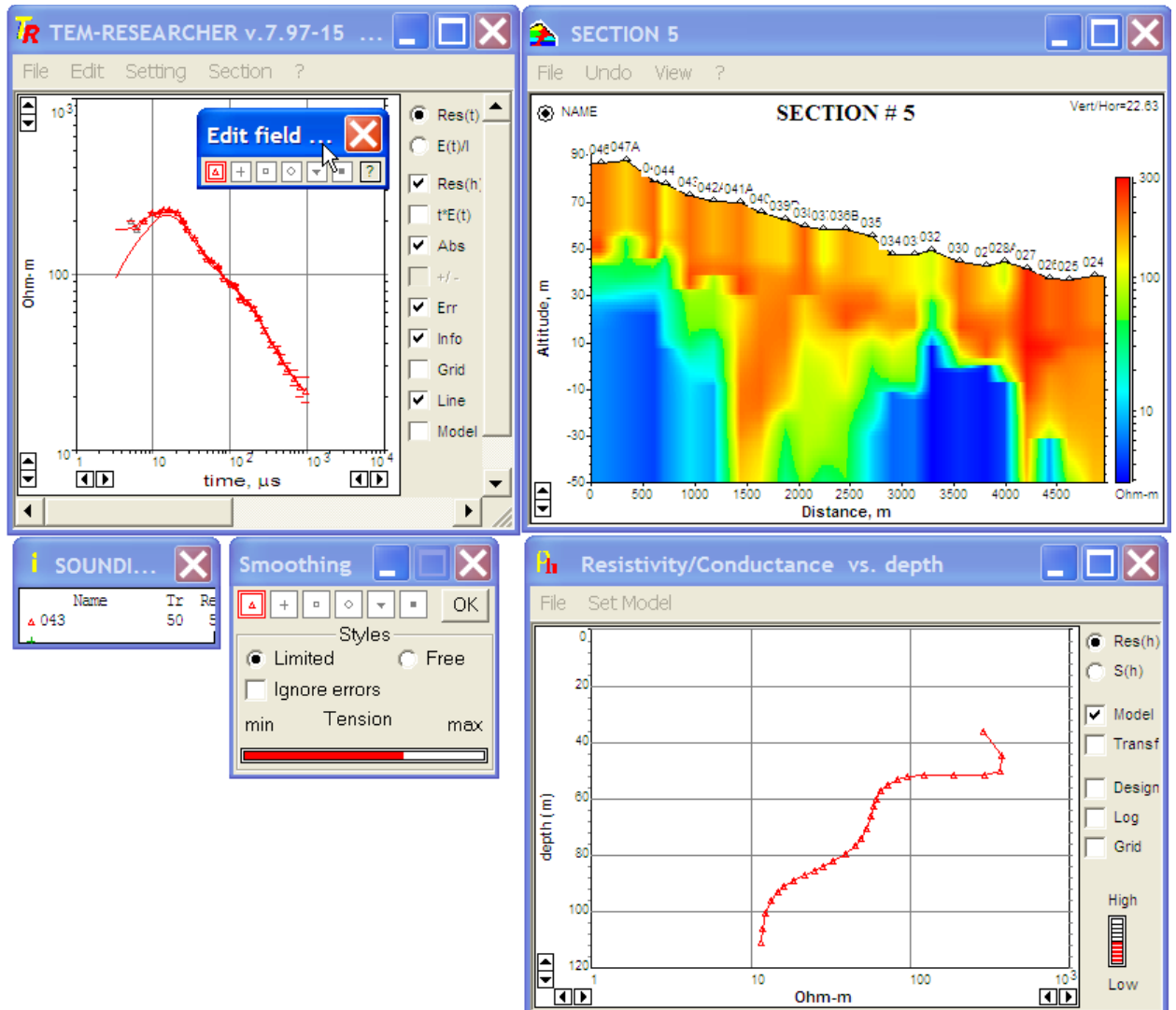


Fig. 41



After correction, the geoelectric section can be:

- Printed on a printer (**Print, Print Preview**)
- Saved as emf-file (**Save Image in \*EMF**)
- Stored as INT or PSC or SEC files (**Save Section**)
- Saved as a text file (**Save as txt-data**) for use by other programs.
- All of these features, see in the menu **File**.

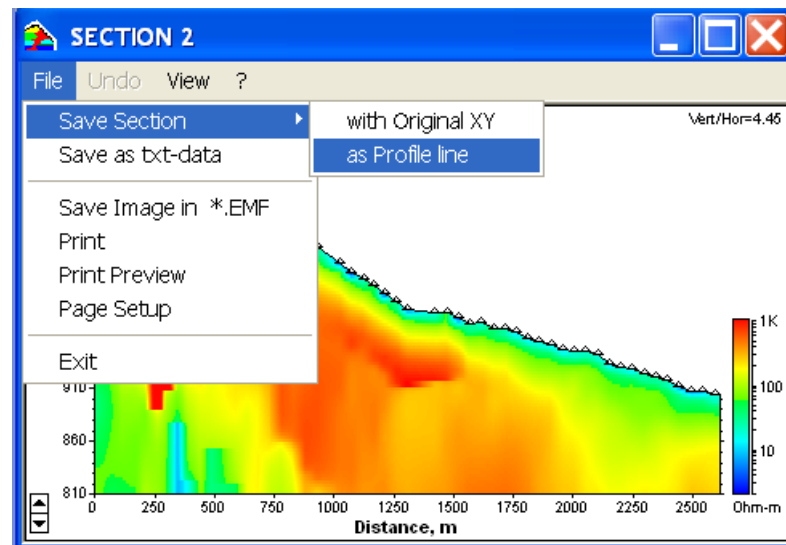



Fig. 42

ATTENTION:

Before using the procedure of copying the screen with a section it is recommended to hide the control elements by pressing **Alt+T**, and then use the **Print Screen**.

Once work with the section is completed, you can either remove the section of the program or leave it in the buffer that would later continue to work with it. Both operations are performed by pressing the **Exit** command or **×**  .

The program asks: "Do you want to remove the section or not?" If you answer "YES" the section is removed from the program. If you answer "NO" the section is placed in the buffer, whose contents can be seen in the main menu (Fig. 43).

To call from the buffer it is enough to click on the desired menu item (in this example, **Section 5, Section 6**), and the section will once again be on the desktop of the program. This operation is almost completely analogous to minimizing of the window. At the same time, the user can create up to 5 different sections.

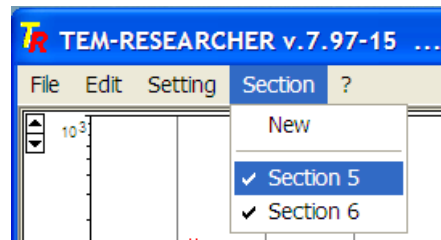


Fig. 43

If the buffer containing the sections is full of cuts, it is necessary to remove an unnecessary incision and in its place a new one. Use the dialog "**Delete Section**" to remove the cuts.

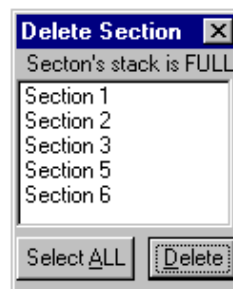


Fig. 44

### ATTENTION!

**Reputed adjustment inversion (reinterpretation) is possible only for data of INT (2002 format) or INT/ PSC/SEC for files recorded in the format of TEM-RES v.7 (2008-09). If you have INT-files in TEM-RESEARCHER-DOS format (written before 2002 year), we recommend you to reformat them into a new format. To do this, download both the corresponding TEM-file with the original data and INT-files with the results of the inversion (input Model data), to establish a correspondence between sets of soundings and the models run Invers and after the inversion to save the results in the INT-file (Save Inversion's results).**

## CREATION OF THE RESISTIVITY AND CONDUCTIVITY MAPS

After opening the **PSC SEC** or **INT** files containing data on array studies (Fig. 30), the user opens the **Map** (Fig. 32), which depicted a map of plotted soundings' points. Click **Stratify** and in the appeared window specify the position of the roof (**Roof**) and bottom (**Floor**) of the layer, the average resistivity of which are of interest for you (in this case - Fig. 45, "cut" is made at depths ranging from 35 to 45 meters **above the ground**). For assistance, see "?". Click the **OK**.

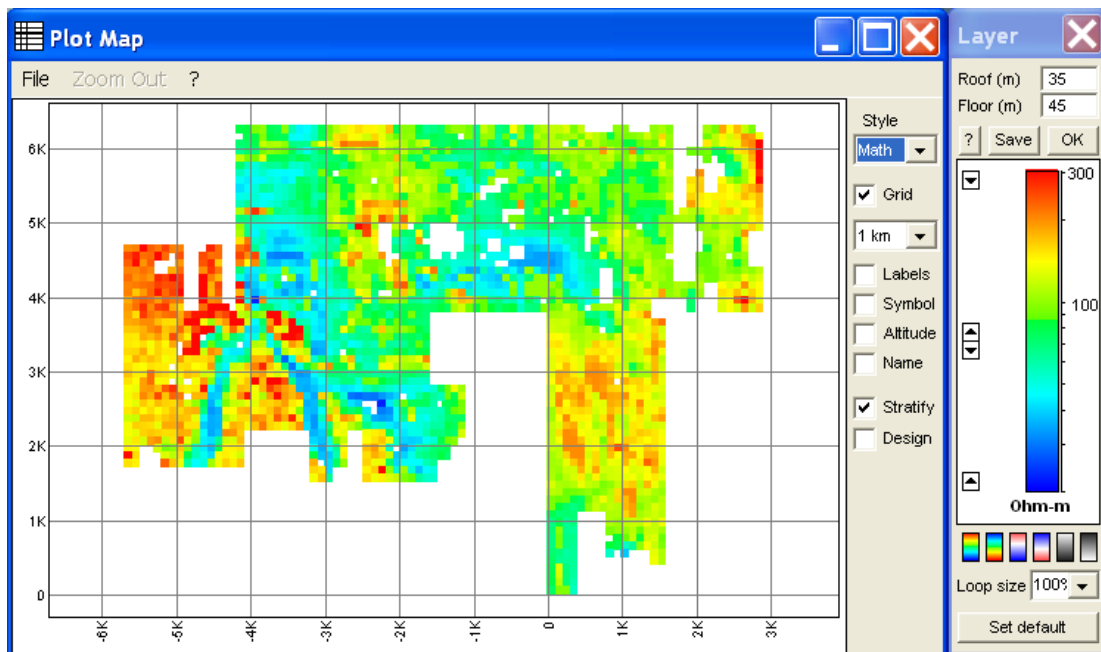


Fig. 45

This example illustrates the "*electromagnetic image*" of a paleovalley. Zones of low resistivity (blue) correspond to the clay and silt deposits and zones of high resistivity (green and red) are localized sands and conglomerates (demo\_map.psc file contains more than 1,500 sounding points and applied as a demonstration). Each shaded square on the map corresponds to the actual size of the used antennas (loops). **Loop size** window is used to display not scaled loop antennas with rare, irregular location of sounding points.

### INCREASING OF THE MAP'S FRAGMENTS

Holding the left mouse button, draw a rectangle; after clicking by the right button the selected fragment of the map will be increased. **Zoom out** command is intended to return it in initial state.

Clicking the **Save** button you can write the characteristics of the layer (resistivity  $\rho$  and the conductance  $S$ ) in the MAP-specific file (the file format is described below).

You can then use these data to construct maps using any special programs, for example, Golden Surfer.

**Map** window allows the user to save a color map of the resistivity in the Windows MetaFile (EMF) and then paste the picture into the document MS Office package. Use the **menu Save Image in \* EMF** and after determining of the image's size and file name save the image. IFig. 46 shows a resistivity map for the layer 0-20 m, created in the window **Map**, stored in

the EMF-file and pasted into MS WORD. THE map corresponds to the example shown in Fig. 45, but for a different cut-off level (file **demo\_map.psc**).

### **WARNING!**

- 1. To change the scales in the color range it is necessary to use the methods of Fig. 37.**
- 2. For full color at the construction and writing maps and sections in the MetaFile it is necessary to set the video adapter "Color palette" High Color (16bit) or True Color (32 bit).**
- 3. The minimum allowable RAM of your PC has to be at least 512 MB.**
- 4. The operation of saving the image to the Windows EMF sometimes requires closing all or part of the active applications**

### **SAVING OF THE DATA IN THE “SECTION” WINDOW**

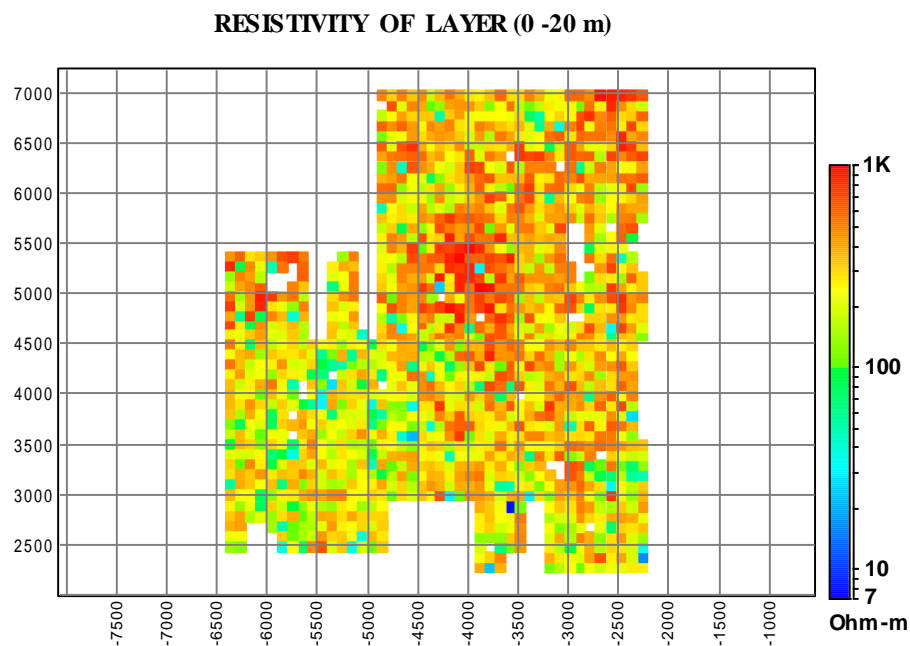


Fig. 46

The data with information on the resistivity section, you can save three different formats (Fig. 47)

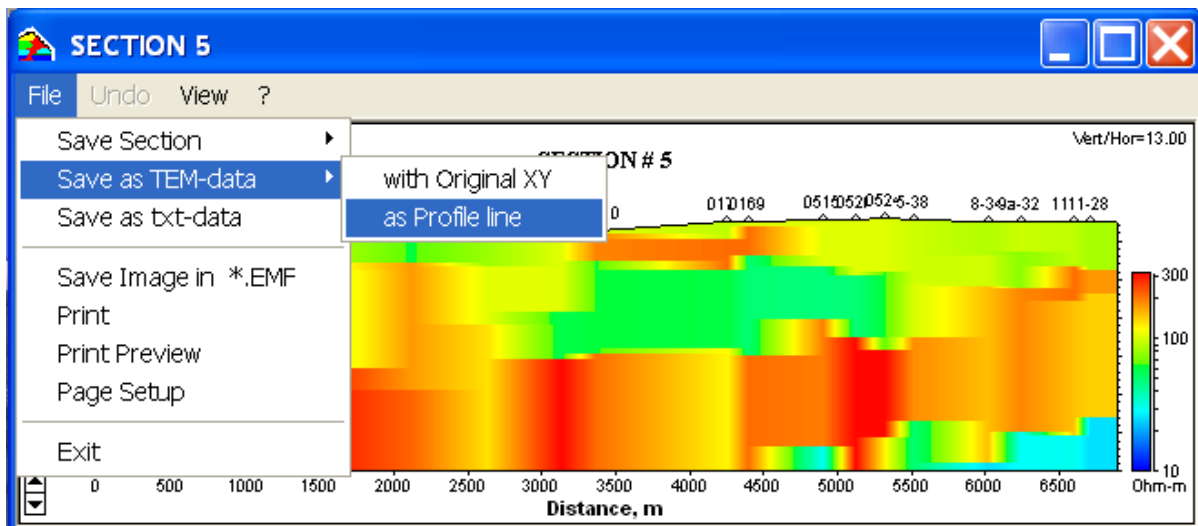


Fig. 47

**Save Section → with Original XY**- saving of the data in INT or PSC / SEC format with the coordinates that were at the measuring points before they were included in the section (e.g. GPS coordinates).

**Save Section → as Profile line** - saving of the data in INT or PSC / SEC format with coordinates corresponding to the profile, which is present on the screen.

**Save as TEM-data → with Original XY**- saving of the data in TEM format with the coordinates which were at the measuring points before they were included in the section (e.g. GPS coordinates). You can again carry out the procedure of smoothing and other activities with these TEM-data. (available if downloaded files are in 2008 format)

**Save as TEM-data → with Original XY**- saving of the data in TEM format with coordinates corresponding to the profile, which is present on the screen. (available if downloaded files are in 2008 format)

**Save as txt**- saving of the data in a special text format suitable for the construction of laterally-uniform layered model in an electronic tables:

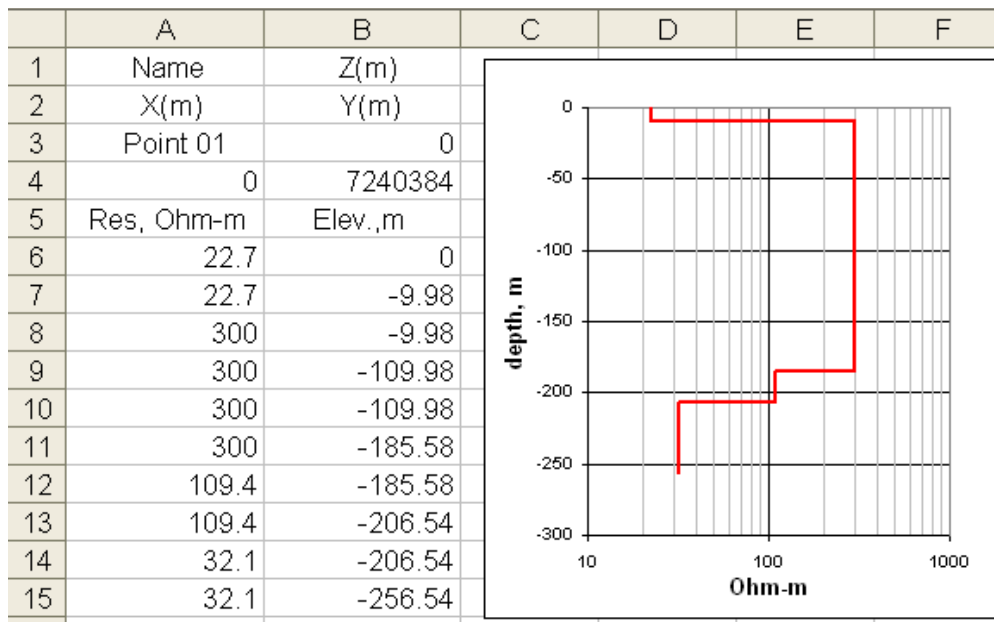


Fig. 48

Text data can be used to compare the results of TEM inversions and well logs (Figure 49):

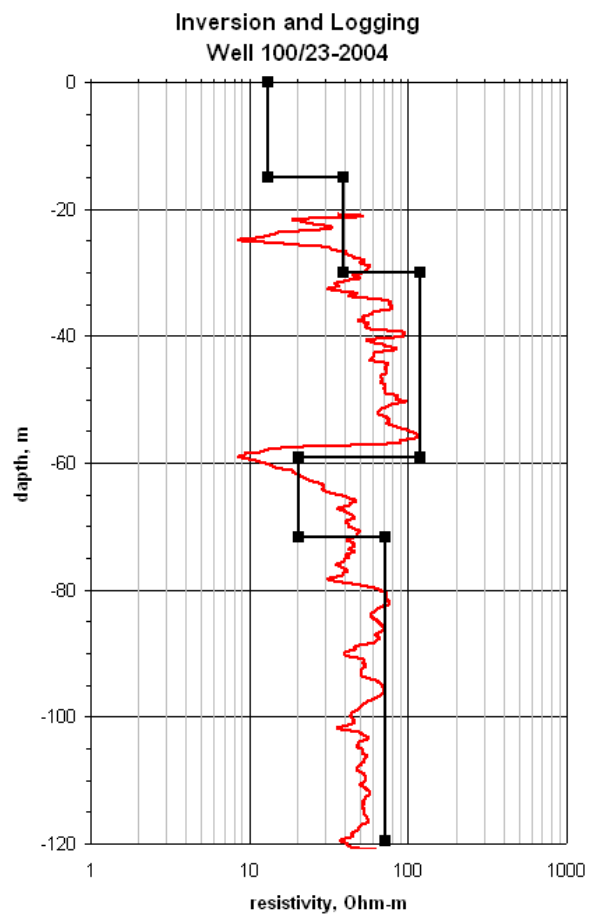


Fig. 49

## SAVING THE RESISTIVITY MAPS IN ENHANCED METAFILE (EMF)

Maps of the resistivity (Fig. 45) and sections (Fig. 42) can be saved as images in Enhanced MetaFiles of WINDOWS system (EMF-Enhanced MetaFile). When you invoke **File-> Save Image in \* EMF** the menu appears (Fig. 50a (Box Section) and Fig. 50b (Box Map))

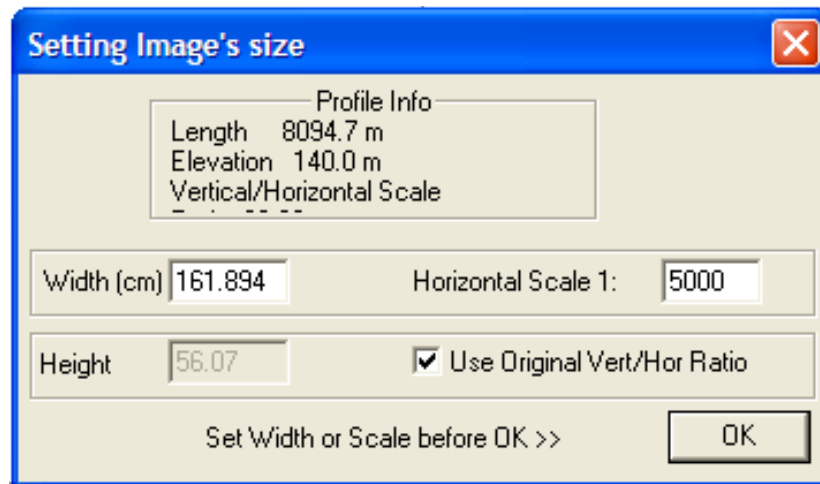


Fig. 50a

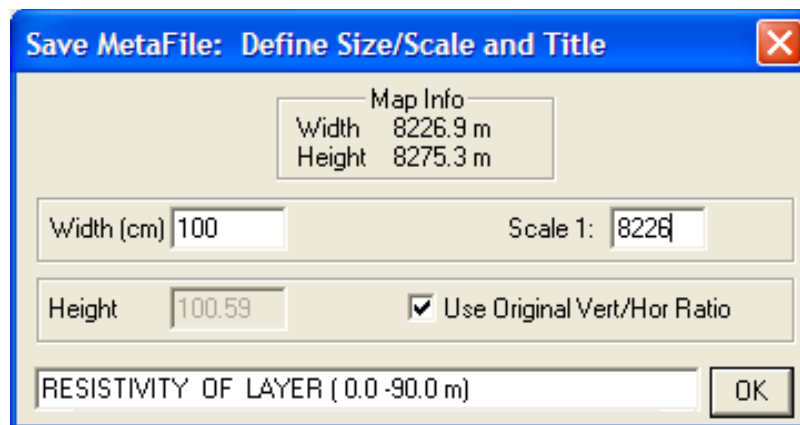


Fig. 50b

The user can specify either the size of images, or the scale of the Graphs (Scale) Image size is determined by the frame limiting the section or map without axis labels, etc. (Fig. 51). By setting the needed size, go to the Scale 1, set the scale (1:5000 for example) and go to the Width - the appropriate parameters set automatically.

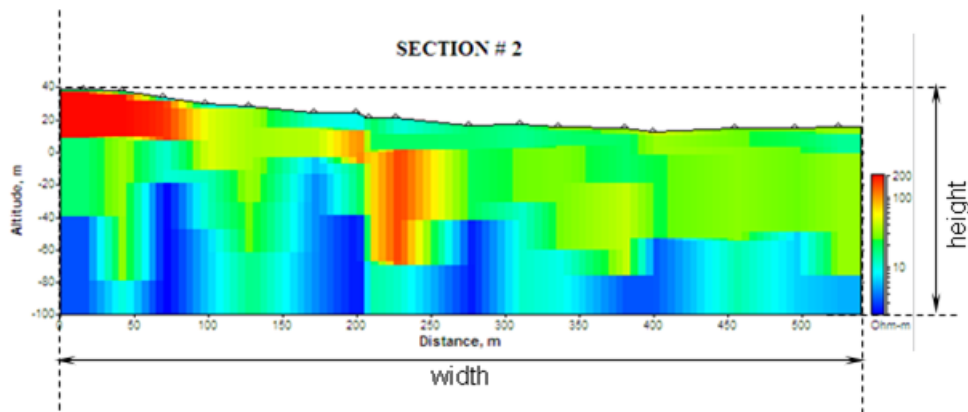


Fig. 51

## DATA CONVERSION

The program TEM-RES provides several types of data conversion. When entering data in the main menu **File-> Input Field Data** you can download the sounding curves from TEM (text or binary) files or from the INT/PSC/SEC files (format 2008). Next, open the Map (Fig. 52 - SEC file is open).

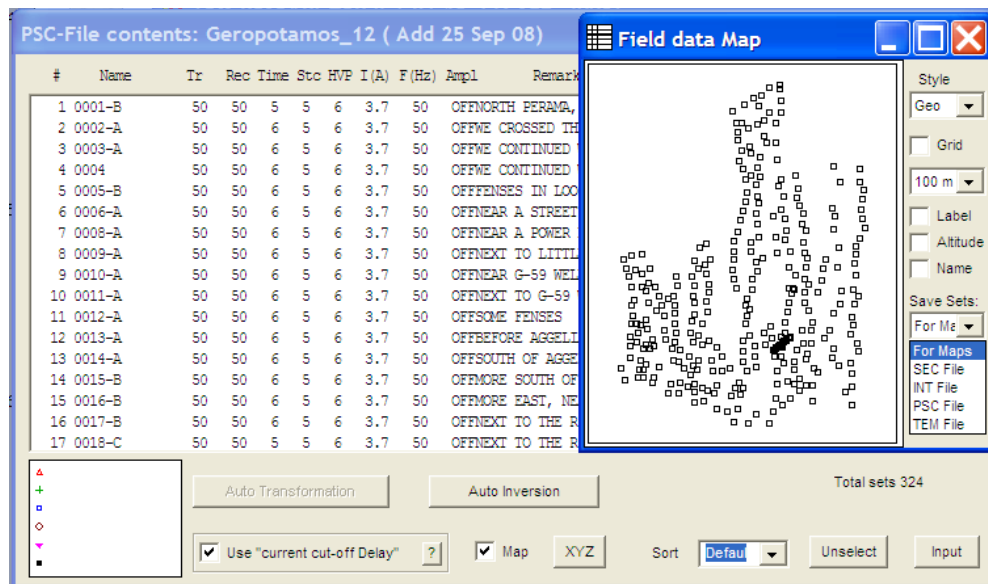


Fig. 52

To edit the test information within the set of soundings - double click with the left mouse button on the right square on the map. If you want to save in a new file (make converting) only part of the sets represented on the map, you need to move unwanted sets in "inactive" state by double click with the, right button on the appropriate box on the map (inactive sets



painted in gray color). If you want to do inactive at once a lot sets in a large area of the map, you must act as described in Fig. 4b.

With the help of **Save Sets** menu one can save into a new file all active sets in the formats:

- TEM (text) with downloaded file of any type (TEM-txt, bin, INT / PSC / SEC);
- INT – with downloaded file of INT or SEC type;
- PSC - PSC with downloaded file or SEC type;
- SEC - SEC file with downloaded SEC type.

The order sets in the file corresponds to the procedure established previously (Fig. 52 - a list of sets)

If the INT / PSC or SEC file opens in the main menu as a **Section-> New**, then after loading, the screen appears as shown in the left side of Fig. 53.

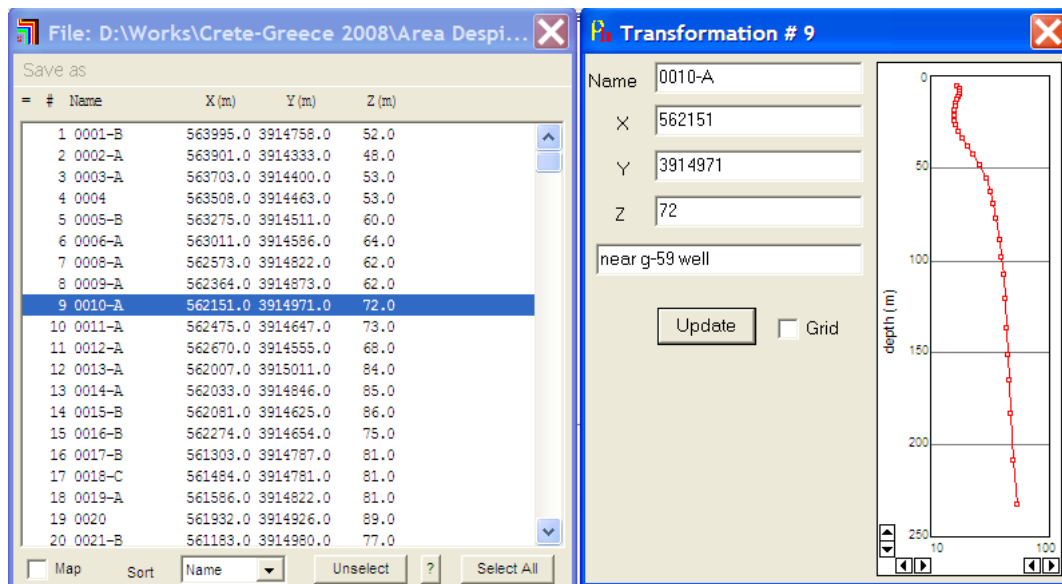


Fig. 53

Double click on Set data allows you to open an editing window shown on the right side of Fig. 53.

After editing the data it is necessary to note the sets to be recorded (converted) into a file and go to the menu **Save as**.

The files can be written in the following formats:

- TEM (text) - for any type of downloaded file: (INT / PSC / SEC);
- INT – for INT or SEC type of downloaded file;
- PSC – for PSC or SEC type of downloaded file ;
- SEC – only for SEC type of downloaded file.

## FORMATS OF THE FILES

### TEM-file (text)

```

TEM-FAST 48 HPC/S2   Date:      Wed May 07 10:58:59 2001
Place: SEVASTOPOL-01 H-way SEV-YALTA
#Set      FF-01-SEV-JA
Time-Range      5      Stacks  15      deff= 2µs      I=1.0 A      FILTR=50 Hz
T-LOOP (m)      25.000 R-LOOP (m)  25.000 TURN=      1
Comments:      landslide 18km S-YALTA
Location:x=      +16622.000      y=      +36536.000      z=      +93.00
Channel Time[µs] E/I[V/A]      Err[V/A]      Res[Ohm-m]
  1      4.06      8.291e-001      7.965e-003      43.64
32      956.53      2.737e-005      2.091e-006      4.01

```

### INT-file (format 2008)

```

#GEOSEC: 001A /50/50/1./490245.000/ 3930191.000/2.0/36/3/0/21030 SPM=0 K=0 H=0 DH= 0/rms=2.29
S [V/A]: +5.004e-002 +4.589e-002 +1.582e+000 +1.702e+000 +1.223e+000 +9.911e-001 +8.311e-001
Err[V/A]: -3.808e-005 -2.374e-005 -2.447e-004 -3.664e-004 +1.000e-010 +1.113e-004 +1.869e-004
300.0000      2.88
4.2435      22.78
0.7164 100000.00
<Date: Wed May 28 07:06:56 2008
<Time Range=6 Currrent= 3.70 Stack= 5 Filter=50 Deff=      6 Ampl=OFF
<Remark: NEXT TO NATIONA
<Place: LIDL PLATANIA
<*****

```

### PSC-file (format 2008)

```

#TRANSFORMSEC: 001A / 50.0/ 50.0/ 1.0/ 490245.000/ 3930191.000/ 2.0/36/4/ 773
TrueRes [Ohm-m]: +69.976 +48.626 +37.719 +31.011 Derivative [log]:
0.500 -0.500 -0.499 -0.498 -<Date: Wed May 28 07:06:56 2008
<Time Range=6 Currrent= 3.70 Stack= 5 Filter=50 Deff=      6 Ampl=OFF
<Remark: NEXT TO NATIONA
<Place: LIDL PLATANIA
S [V/A]: +5.004e-002 +4.589e-002 +1.582e+000 +1.702e+000 +1.223e+000
Err[V/A]: -3.808e-005 -2.374e-005 -2.447e-004 -3.664e-004 +1.000e-010
<***** AUTO TRANSFORMATION *****

```

### SEC-file (format 2008)

```

#TRANSFORMSEC: 001A / 50.0/ 50.0/ 1.0/ 490245.000/ 3930191.000/ 2.0/36/4/ 773
TrueRes [Ohm-m]: +69.976 +48.626 +37.719 +31.011 +24.946 +19.723
Derivative [log]: -0.500 -0.500 -0.499 -0.498 -0.497 -0.495
<Date: Wed May 28 07:06:56 2008
<Time Range=6 Currrent= 3.70 Stack= 5 Filter=50 Deff=      6 Ampl=OFF
<Remark: NEXT TO NATIONA
<Place: LIDL PLATANIA
S [V/A]: +5.004e-002 +4.589e-002 +1.582e+000 +1.702e+000 +1.223e+000 +9.911e-001 +8.311e-001
Err[V/A]: +3.808e-005 +2.374e-005 +2.447e-004 +3.664e-004 +2.000e-010 +1.113e-004 +1.869e-004
<1D INVERSION: N_Layer=3 IP=0 IP_Codes=22222 rms= 2.29
300.0000      2.88      4.2435      22.78      0.7164 100000000.00
<***** AUTO TRANSFORMATION OF 1D INVERSION *****

```

**MAP-file (format 2008)** (Roof and Floor of the layer are included in the file's name automatically)

#	Name	X (m)	Y (m)	Z (m)	$\rho$ Ohm-m	S (1/Ohm)	$\log_{10}$ (Ohm-m)		
Log10 ( (S/m) rms%									
1	sj-01	16622.0	36536.0	93.2	9.390	5.32481	0.3	1.2	3.4

### MAP\_E- file

#	NAME	X	Y	Z	t=4.06 $\mu$ s	t=5.07 $\mu$ s
		(m)	(m)	(m)	V/A	V/A ..... .
1	sj-02	16599.0	36542.0	97.0	+6.76e-001	+4.15e-001 ...
2	sj-03	16589.0	36552.0	99.0	+6.86e-001	+4.35e-001 ...
3	sj-04	16549.0	36557.0	92.0	+6.26e-001	+3.35e-001 ...

## AUTOMATIC INVERSION OF LARGE DATA SETS

This option is available only in the extended version of TEM-RESEARCHER v8, available on request. **CONTENT FILE** window is of the form -Fig. 54

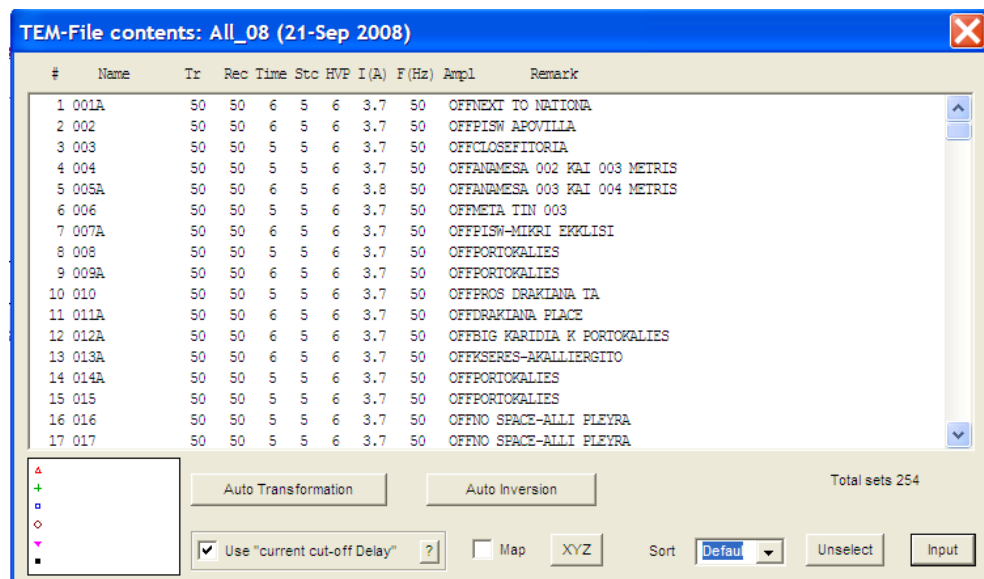


Fig. 54

Click **Auto Inversion** and a display map with the points of soundings available from the public TEM - file (Fig. 55) will arrived.

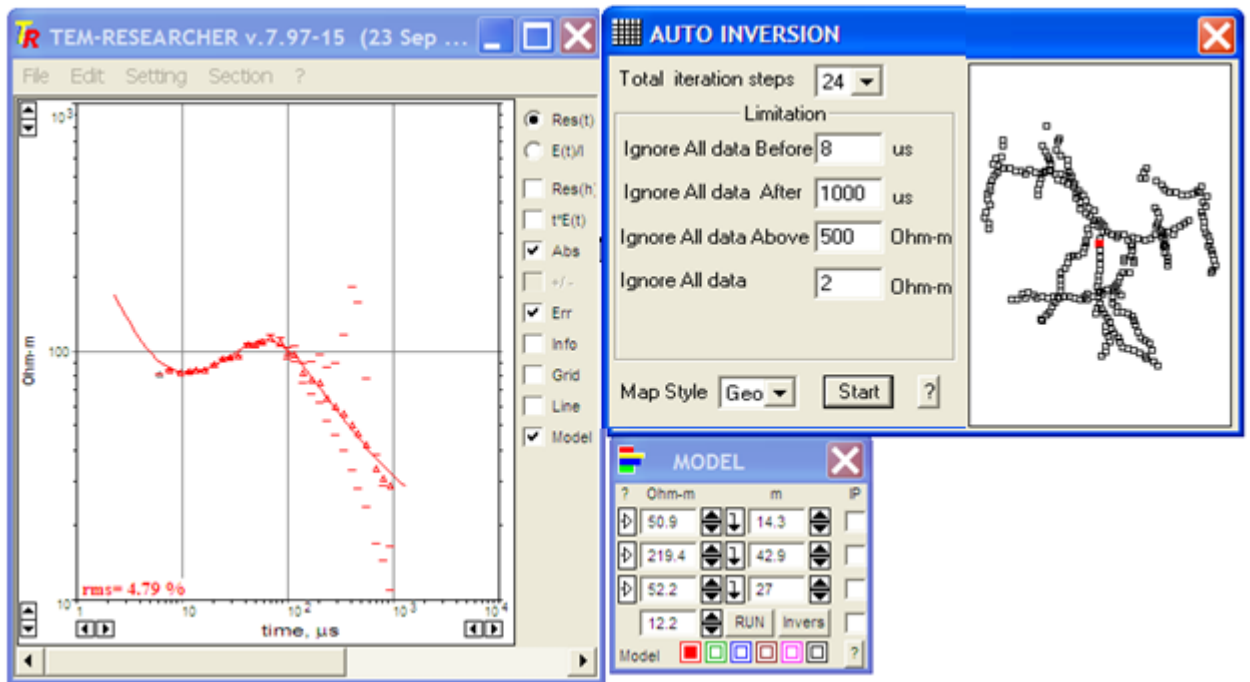


Fig. 55

The red color denotes the set of soundings from which by default the process of inversion will begin. The curve  $\rho(t)$ , corresponding to this point is highlighted in the main panel. The user can change the initial (starting) point of the process by clicking the left mouse button on any set (square) on the map. Next, he must set the "horizontal" and "vertical" limits within which inversion of the data will be carried out (Fig. 56).

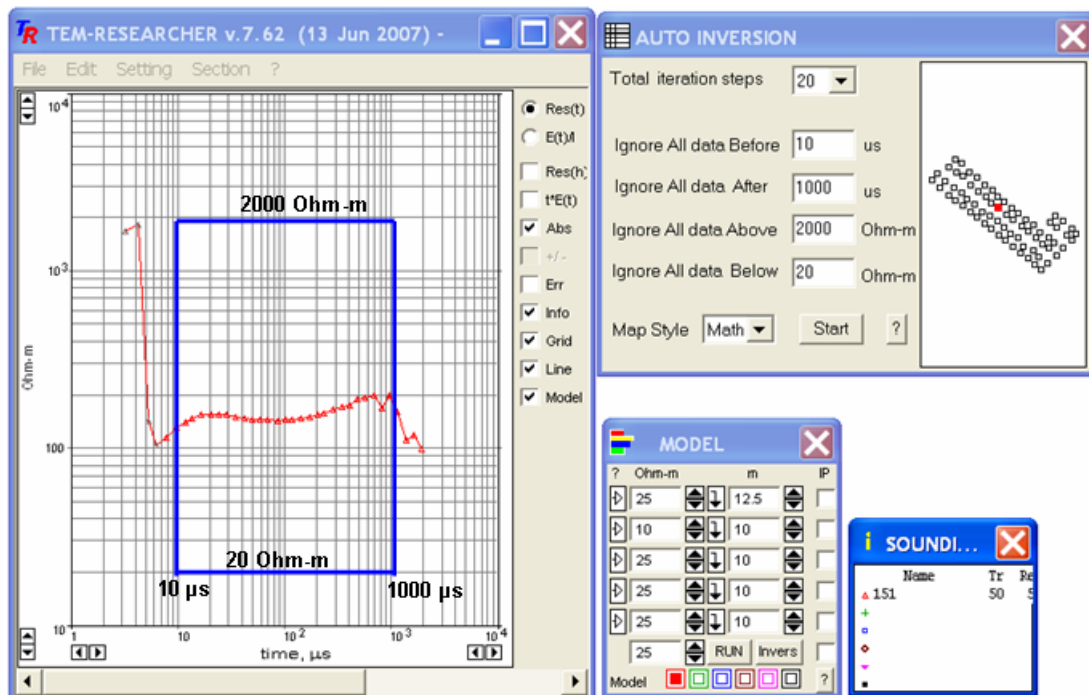


Fig. 56

Now, the points of the curves beyond the blue rectangle of Fig. 56 will be ignored in the inversion process.

Another mandatory procedure before the start of the automatic inversion sets the limits for resistivity and thickness of the sections' layers (Fig. 57).

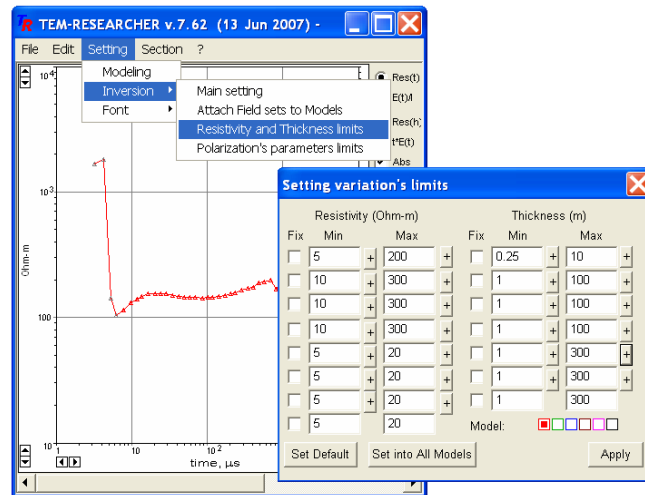


Fig. 57

Next, you need to choose a starting model of a layered medium and determine the number of layers, whose parameters are calculated in the inversion process. This procedure has been described above: **Smoothing-> Res (h) -> Design-> definition of the number of layers-> Set in Model-> Invers.**

Note that such large number of set parameters is absolutely necessary for the automatic inversion procedure. If these settings are too arbitrarily, then most likely that the procedure will go into a dead end and you get nothing useful. For professional work with this option of the TEM-RESEARCHER program, one has to have experience and good knowledge on the geoelectrical structure of the area under investigation.

So, if you-created a set of constraints of  $\rho(t)$ ;

- imposed restrictions on the resistivity and thickness of the layers;
- determined the number of iterations required for high-quality selection of the section's model, then the automatic inversion procedure is ready to work.

The main idea behind the base of this procedure is that the *starting* model for inversion at the sounding point "A" is identical to the *final* model point "B" if the point "A" is at the minimum distance from point "B". Thus, starting from the initial point, the inversion procedure is "looking for" the nearest point and starts sounding the inversion process with a starting model taken from the result of the inversion point of the previous soundings.

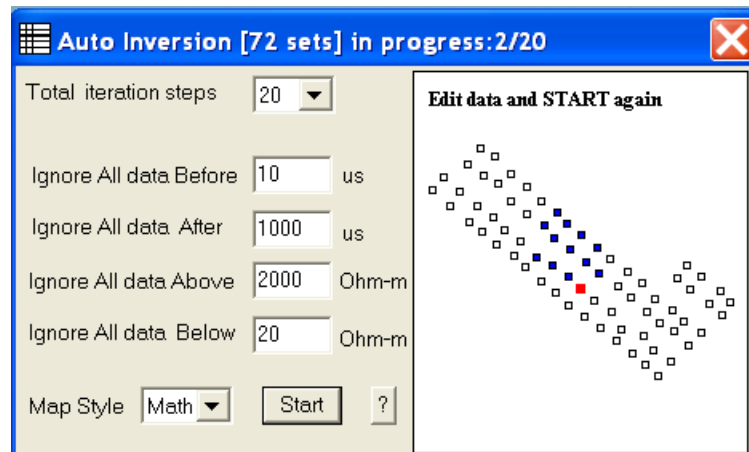


Fig. 58

In the current pause the user can change all the parameters set prior to the automatic procedure of inversion: the number of layers in the model, resistivity and thickness of the layers, all restrictions on the magnitude of the resistivity, the time range and etc. The user can open the **Edit Field Data** and make "correction" of the field data, removing the clearly erroneous point on the curve  $\rho(t)$ . Some parameters of the section can be fixed (or "free"), (*to activate fixation and correction of these parameters, click Run!*)

After all the changes, click again the **Start** button and continue the inversion of the sounding point at which the procedure was interrupted.

The effectiveness of the automatic inversion depends primarily on the quality of the field data, uniformity (or variability) of electrical parameters of the medium and how optimally chosen the restrictions on the parameters of the layers.

In some cases it is possible to produce the correct inversion in the automatic mode on an area of more than 5,000 points of soundings with less than 5% unusable. For manual operation of the inversion of such amount of data would require at least 100-120 hours of work, while, as an automatic procedure fulfilled this work without operator intervention for 8 hours.

With a relatively small data set (up to 100-200 sounding points) appropriate to use the above procedure in a *semiautomatic* mode, i.e. with pauses and correction of the inversion parameters and editing the original data. In semiautomatic mode, it is advisable to open multiple windows at the screen, as shown in Fig. 59.

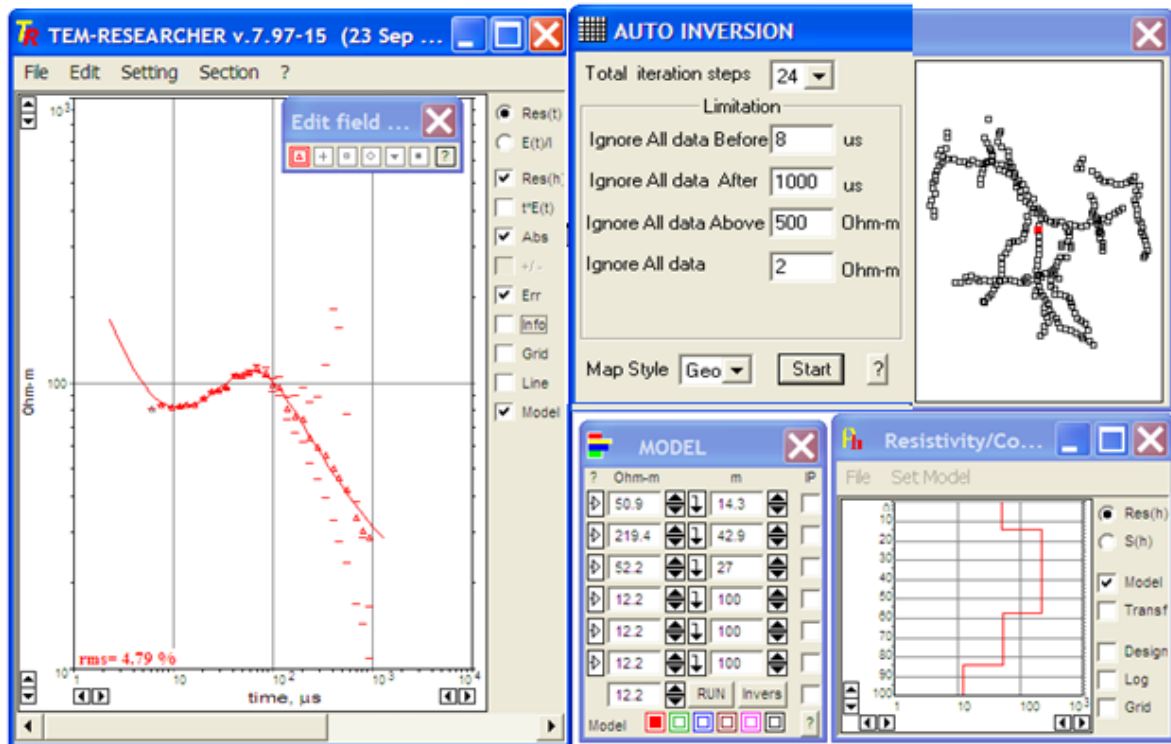


Fig. 59

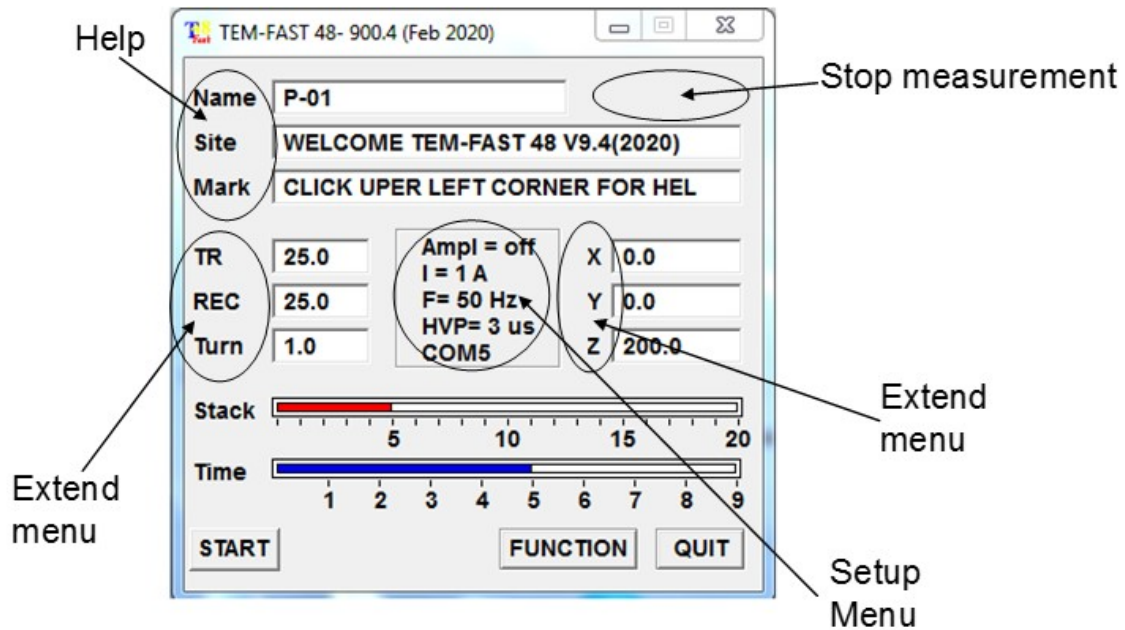
It should be noted that even if in an automatic or semiautomatic inversion you are not able to obtain a *acceptable* result in some points in the profile or research area (due to errors in input data, for example), it can be corrected. After the inversion it is recommended to load INT-file and draw geoelectric section (or set of sections in case of area measurements) and reinterpret the data, as previously described in the relevant chapter.

## APPENDIX

When using the TEM-48-900 program to work with the device on tablets without a mouse or pen (stylus), on which the control buttons are small in relation to the finger and it is difficult to press them correctly, it is proposed to call the Big Buttons and hide them after use. This trick greatly facilitates the work with the program.

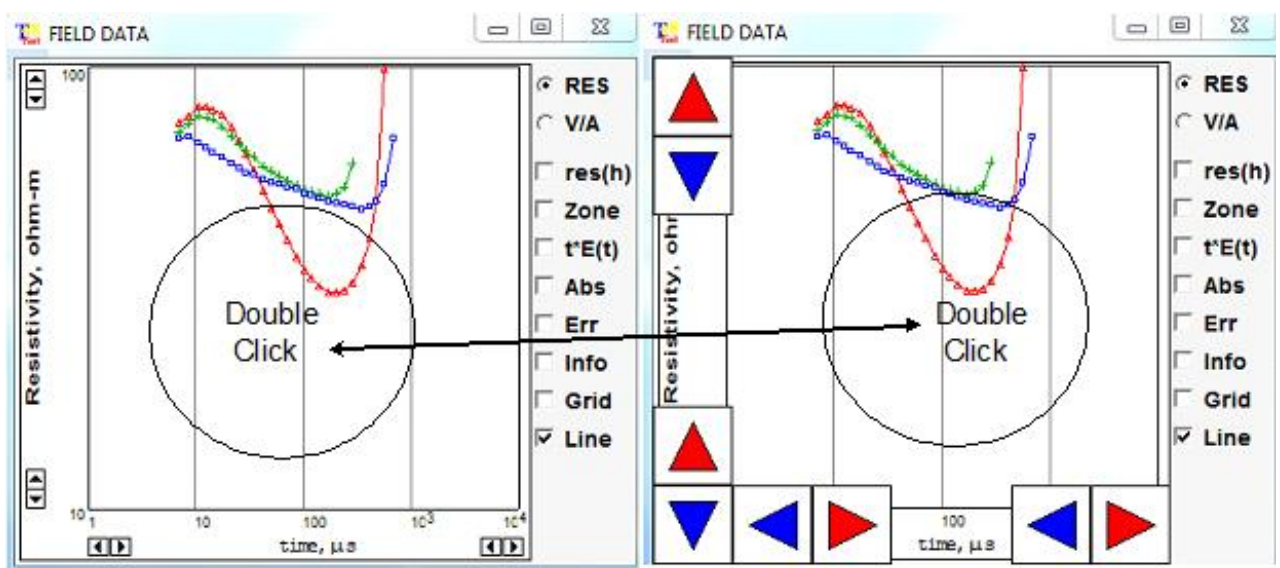
Work with the WIN 32/64 TEM-48-900 program without a mouse and stylus

Main Window



One click on the specified area

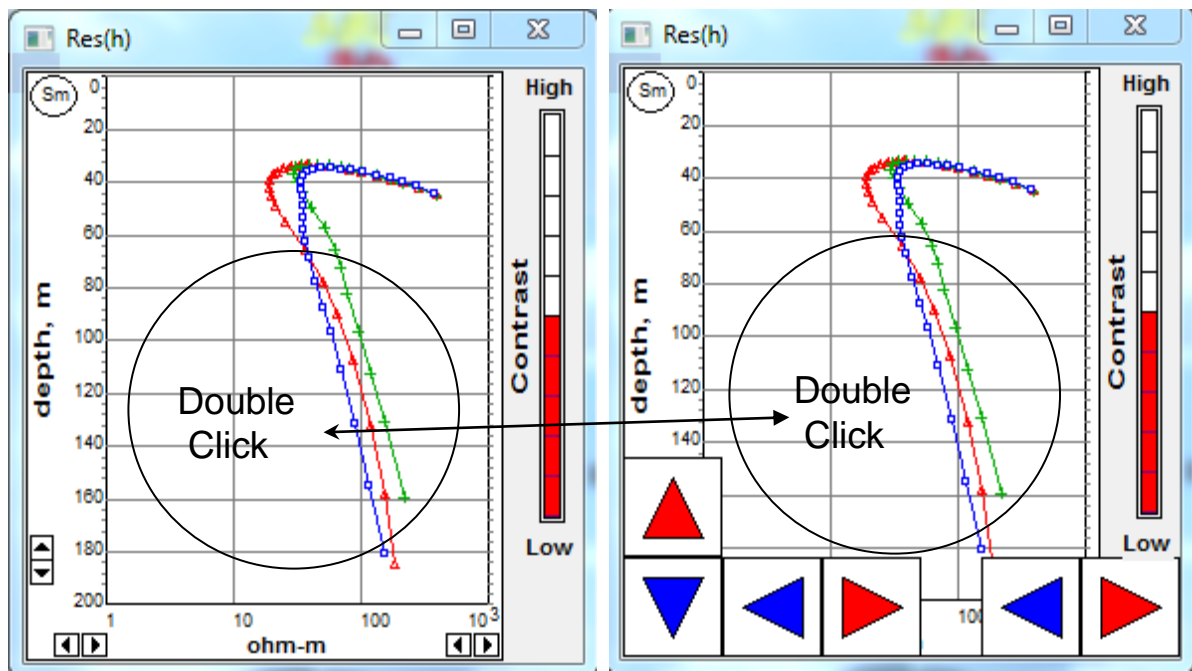
Window view



Double click on the center of the screen to increase/decrease the control buttons



## Transformation Window - Res(h)



Double click on the center of the screen to increase/decrease the control buttons

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