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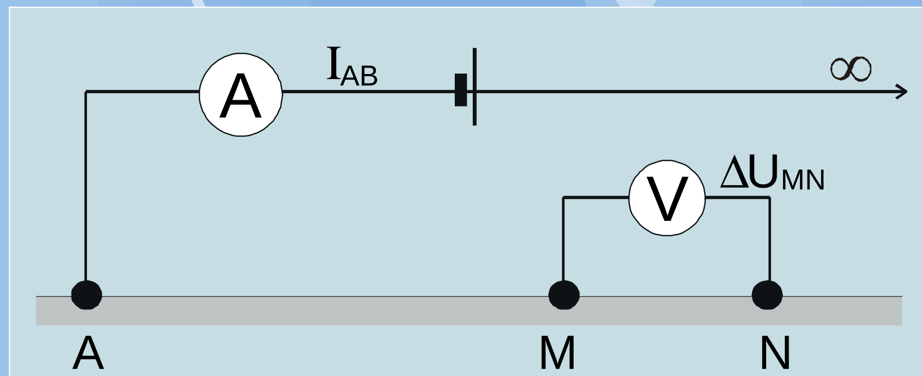
The use Half-Schlumberger array for multi-electrode resistivity survey

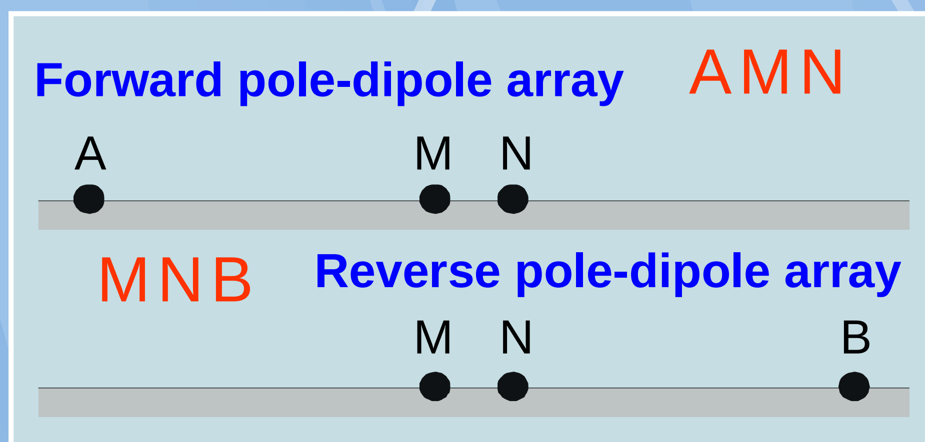
- Introduction to Pole-Dipole array
- Disadvantages
- Advantages
- Difference between AMN and MNB sounding curves as indication of 2D object
- Distortion of VES curves by 2D inhomogeneities
- Field example

WEB: http://geophys.geol.msu.ru E-mail: boba@geophys.geol.msu.ru

Introduction to Pole-Dipole array

Electrode configuration





$$AM \geq MN$$

Pole-Dipole and Schlumberger arrays

Apparent resistivity for pole-dipole and Schlumberger arrays is the same in **1D** case

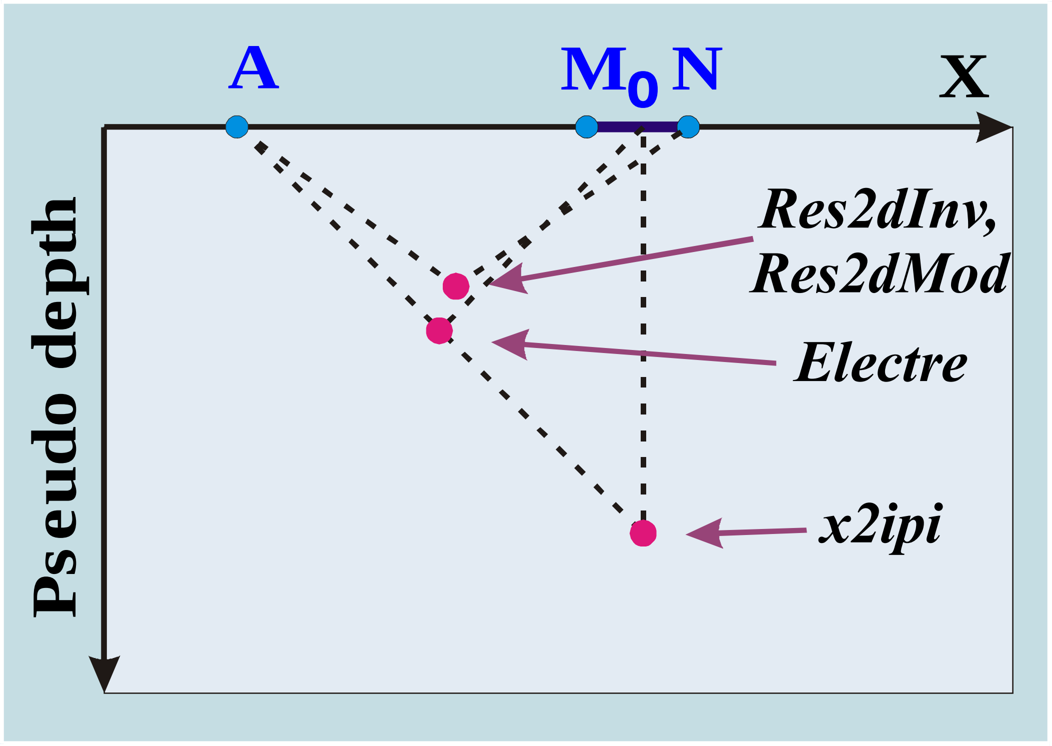
$$\rho_a^{\mathbf{AMN}} = \rho_a^{\mathbf{MNB}} = \rho_a^{\mathbf{AMNB}} \text{(Schlumberger)}$$

General case

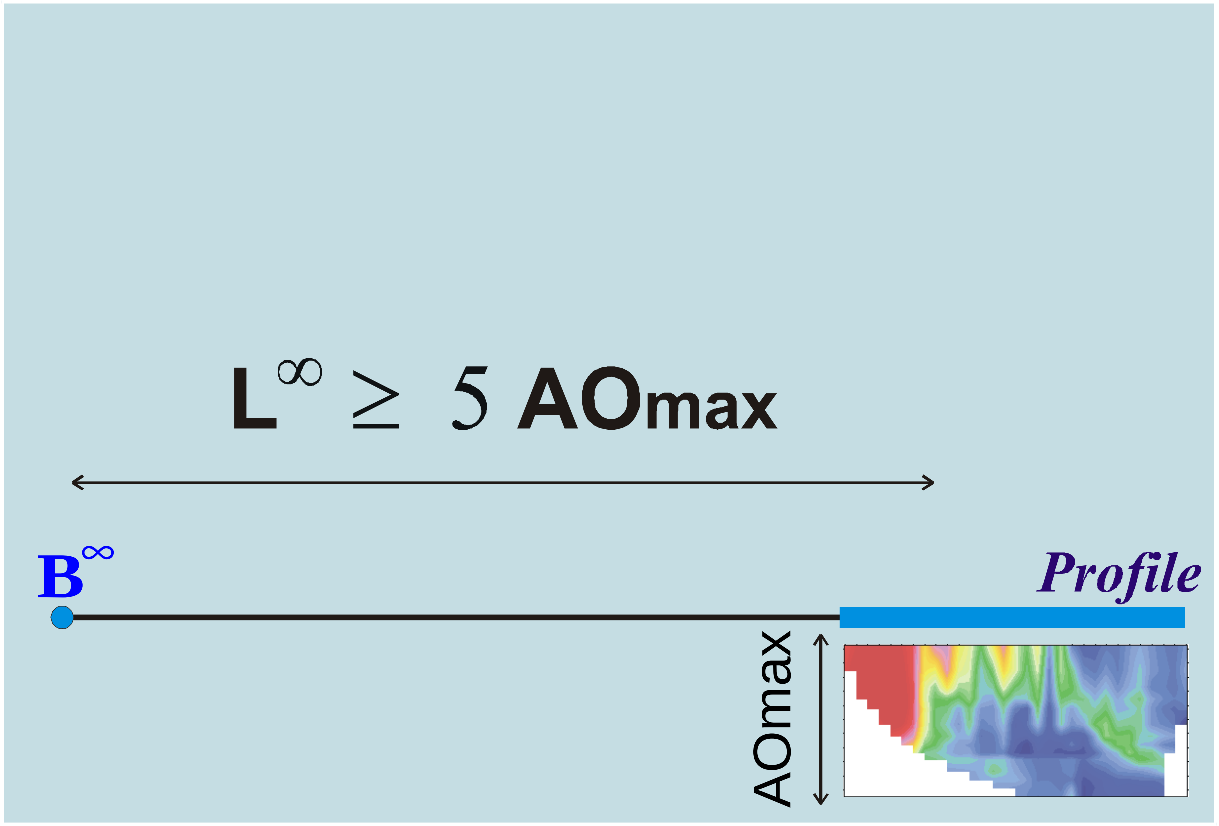
$$\rho_a^{\mathbf{AMNB}} = \frac{\rho_a^{\mathbf{AMN}} + \rho_a^{\mathbf{MNB}}}{2}$$

Reference point for Pole-Dipole array

Pole-Dipole is asymmetrical array



Length of infinity line for Pole-Dipole array



Disadvantages of Pole-Dipole array

- **Unconventional** array for modelling, measurements and presentation of results
- Infinity line
- Small value of measured signal
- Great number of possible measurements
- All measurements are doing twice for forward and reverse array
- High sensitivity to inhomogeneities
- Segmented VES curve

- Common used software does not support Pole-Dipole array
- A lot of problems
- High current
- Special software to make optimal SEQ files
- Long time of measurements
- Complicated app. resistivity pseudo section
- Special data preprocessing

Problems using infinity line

- Additional good wire (300-700m)
- Extra work and space to set up infinity
- Infinity electrode should be with minimal grounding resistance
- Danger of electrical current leakage from wire, especially in wet weather
- Probability of accident break of wire by somebody
- Danger of electrical shock from infinity wire

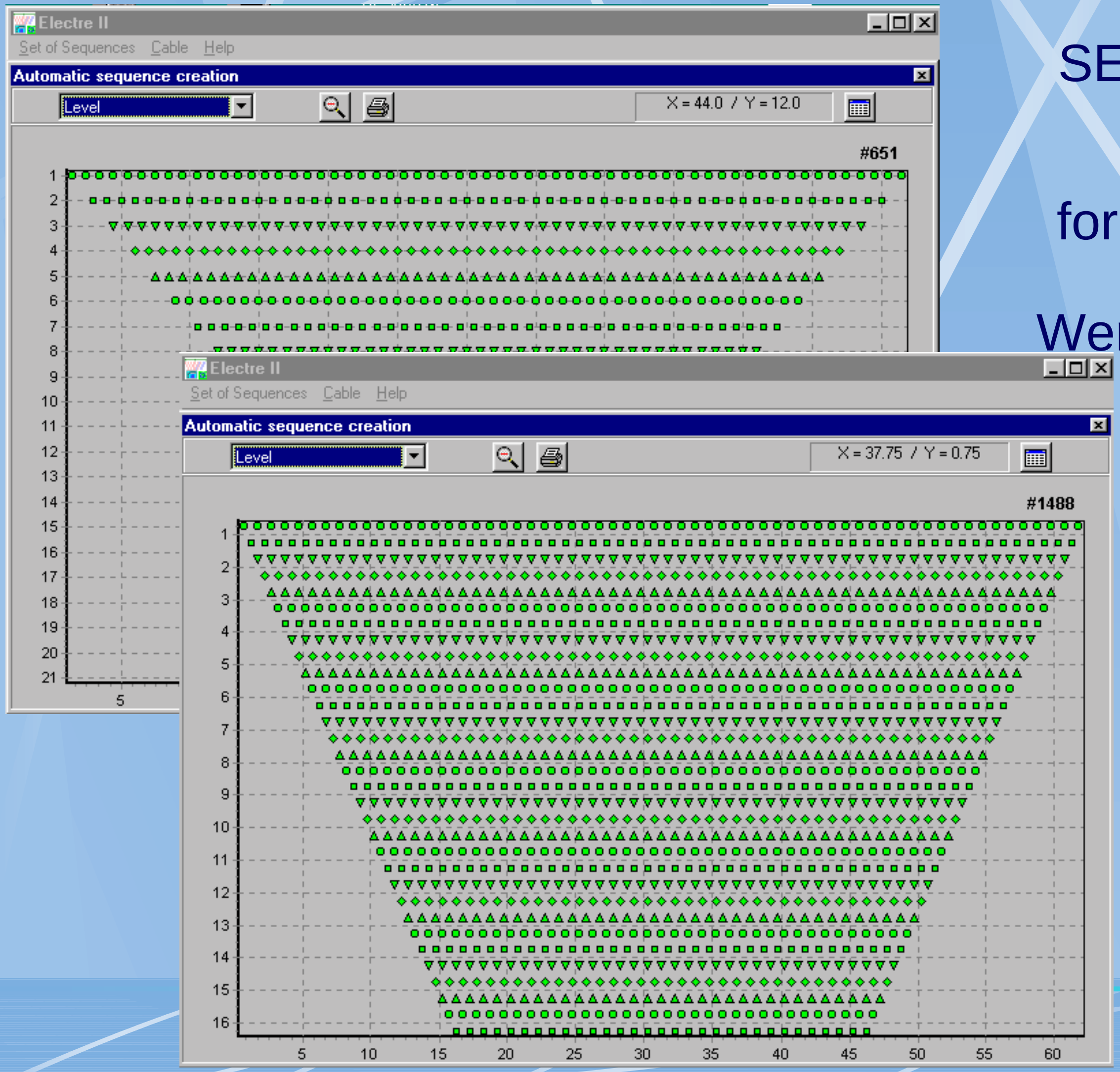
Small value of measured signal

Wenner

AMN

$$\Delta U_{MN} = \frac{\Delta U_{MN}}{4 \,..\, 20}$$

Great number of possible measurements



SEQ files are generated by "Electre II"

for array with 64 electrodes

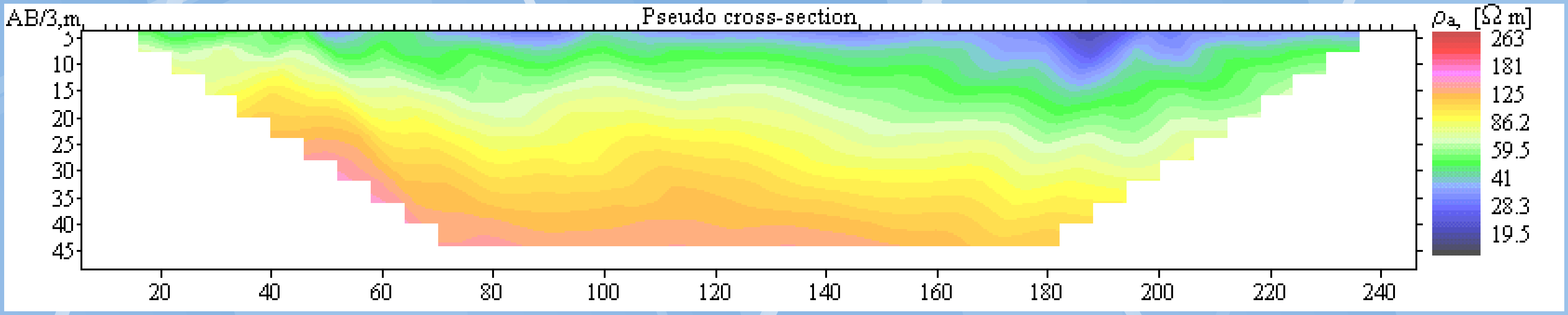
Wenner - N quadripoles = **651**

AMN – N_q = **1488**

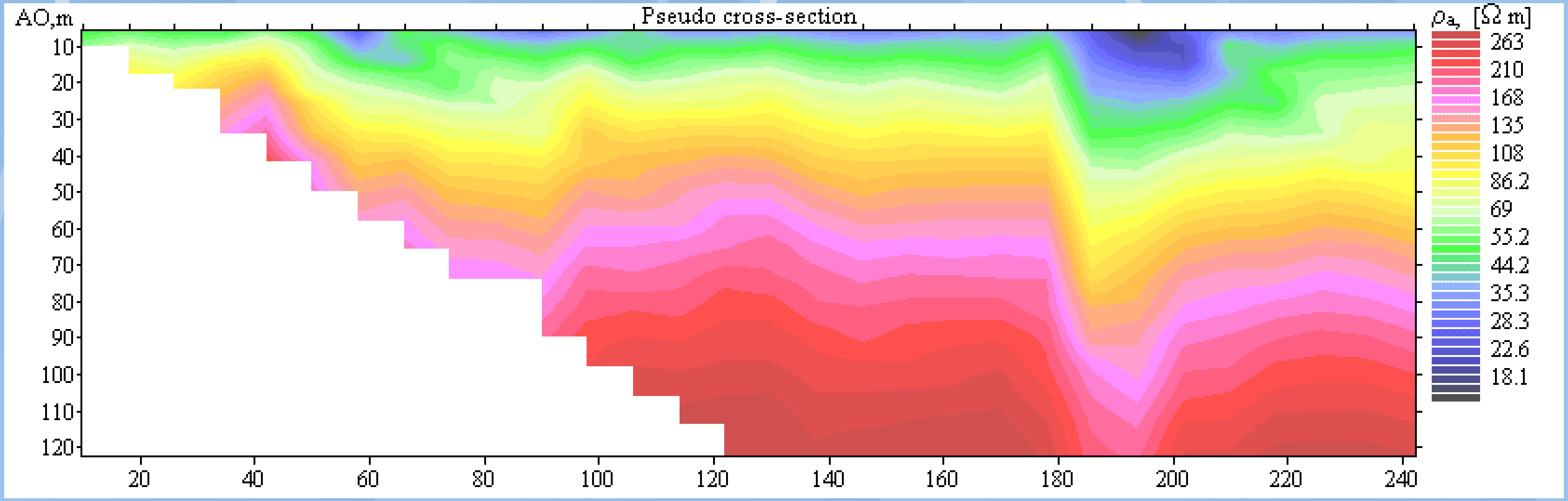
(for 32 lines)

High sensitivity to inhomogeneities

Wenner

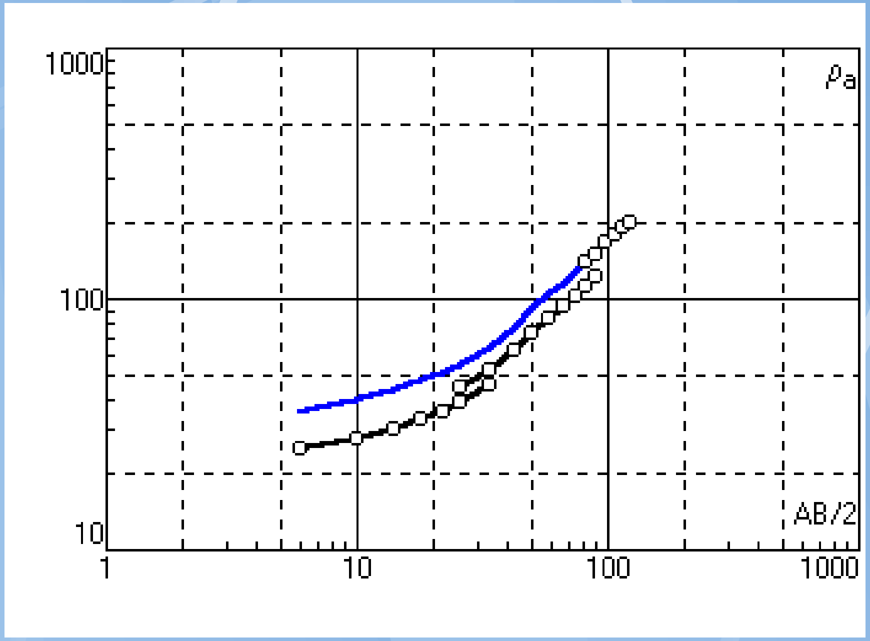


AMN

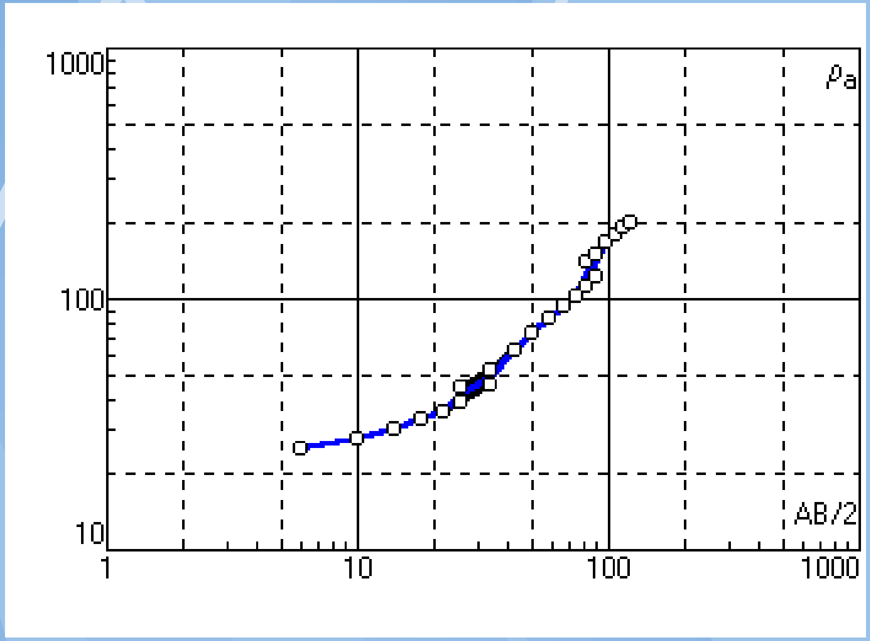


Data by Henri Robain, pseudo section from "IPI2win"

Merger of segmented curve

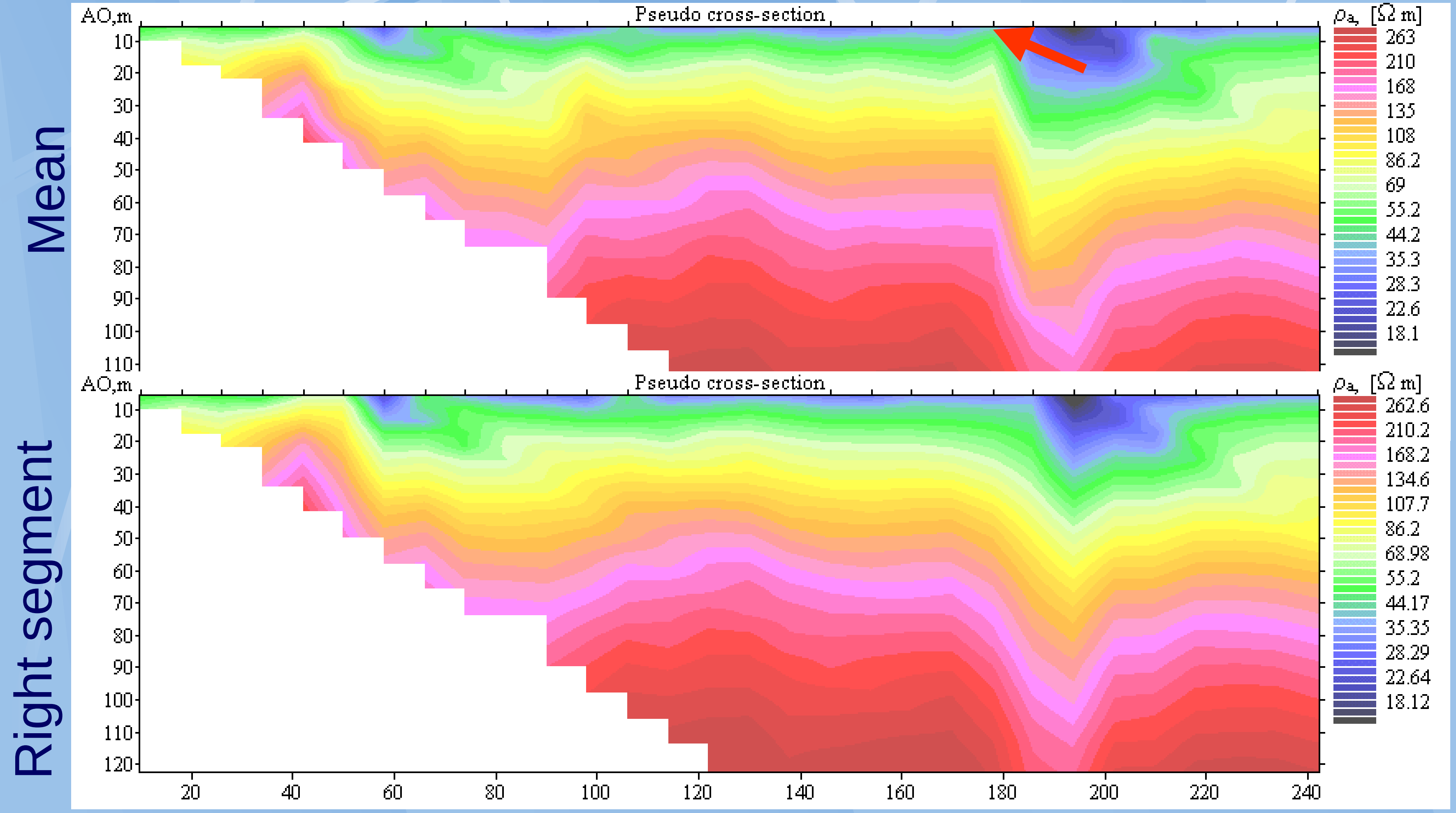


On level of right segment



Mean

Pseudo section after different segments' merger

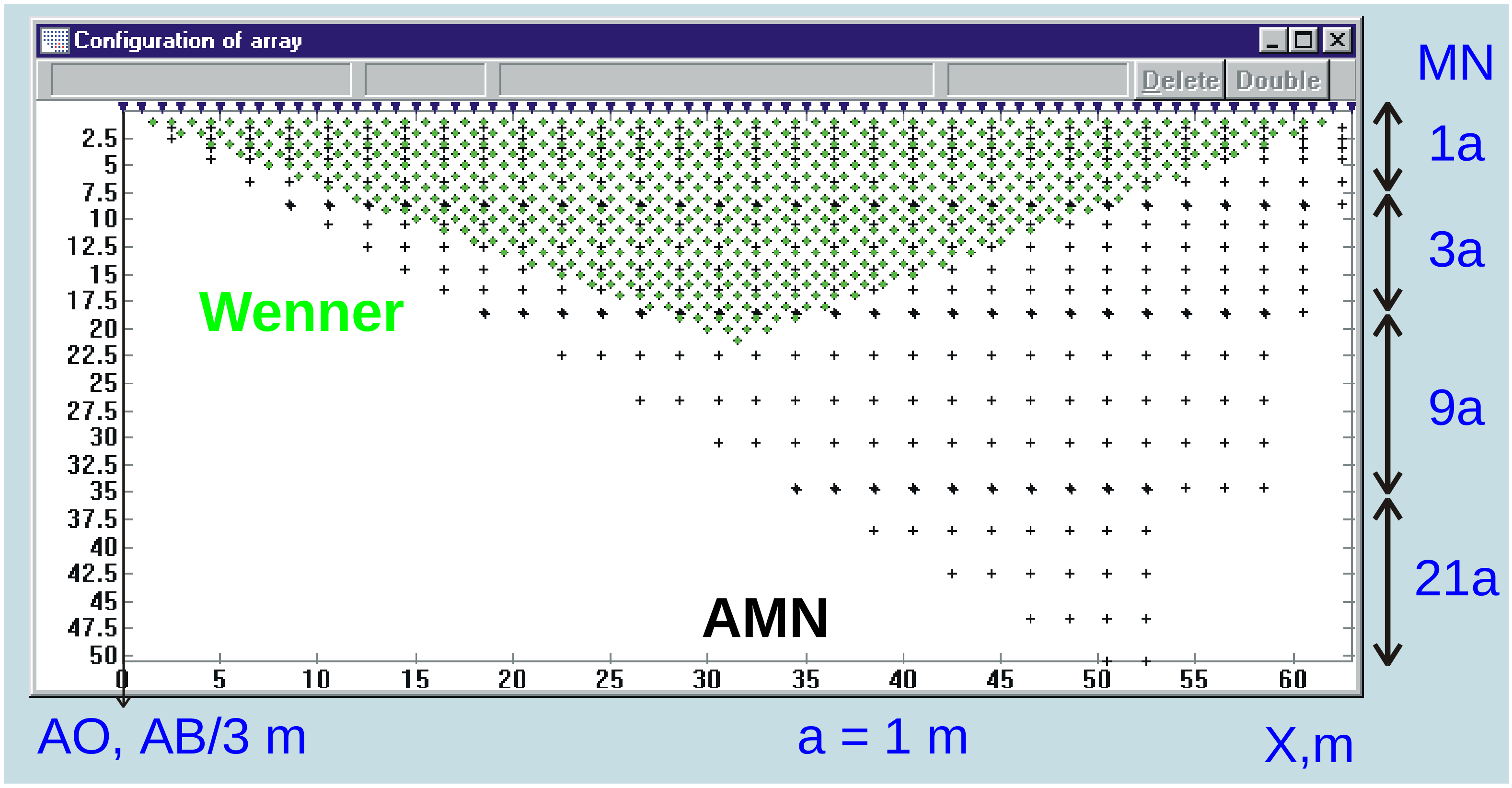


Data by Henri Robain, pseudo section from "IPI2win"

Advantages

- Maximal depth of research
- Optimal using of rolling array along profile
- Two VES curves for each location
- Regularity of geological distortion

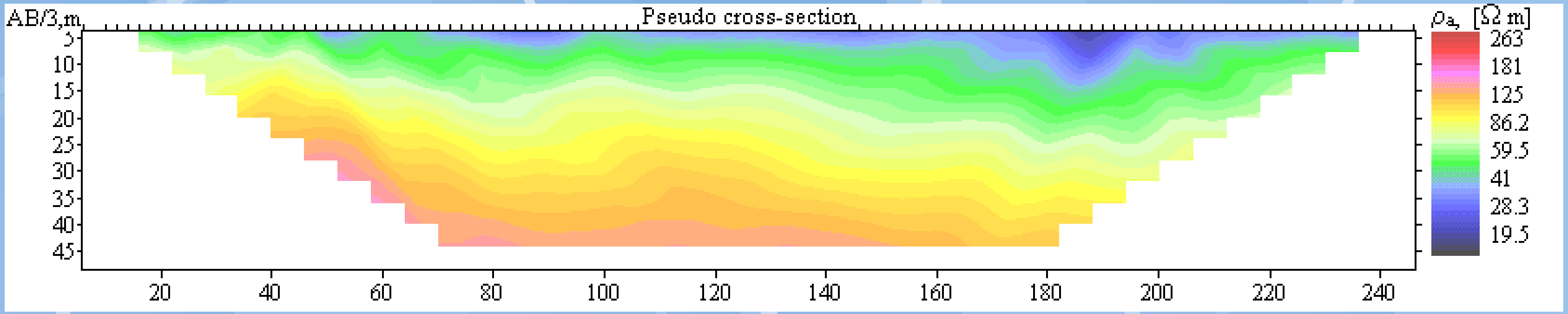
Depth of research for Pole-Dipole and Wenner arrays



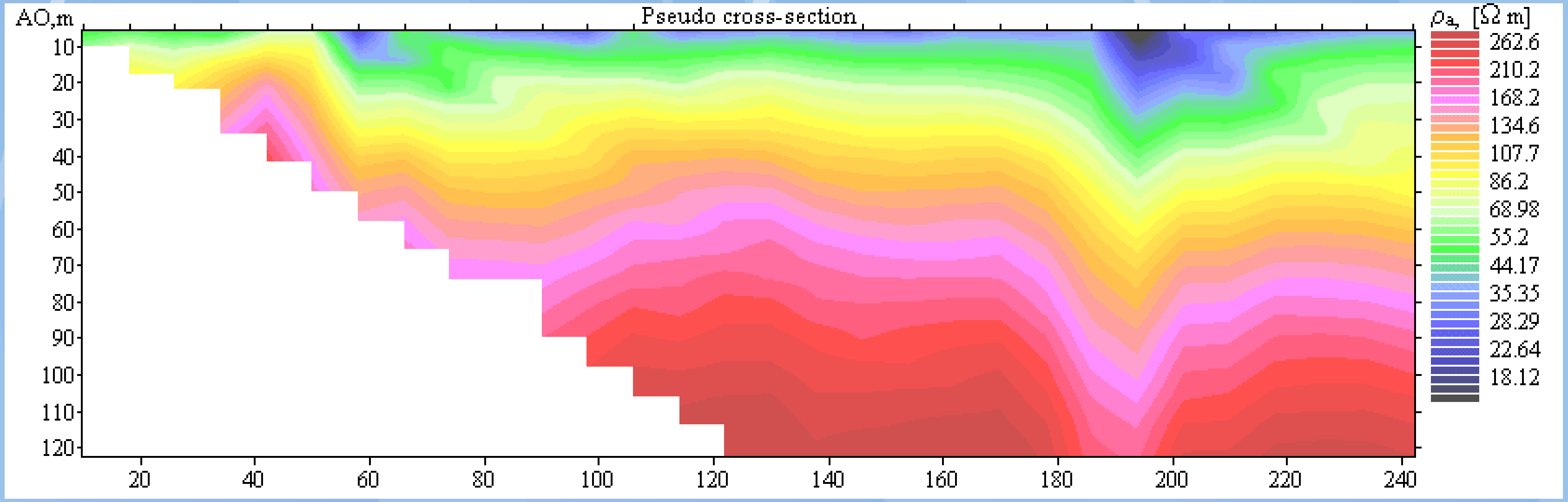
SEQ file for AMN array is generated by “x2ipi” (N_q=441)

Depth of research for Pole-Dipole and Wenner arrays for field example (a=4m, N_{el}=64)

Wenner

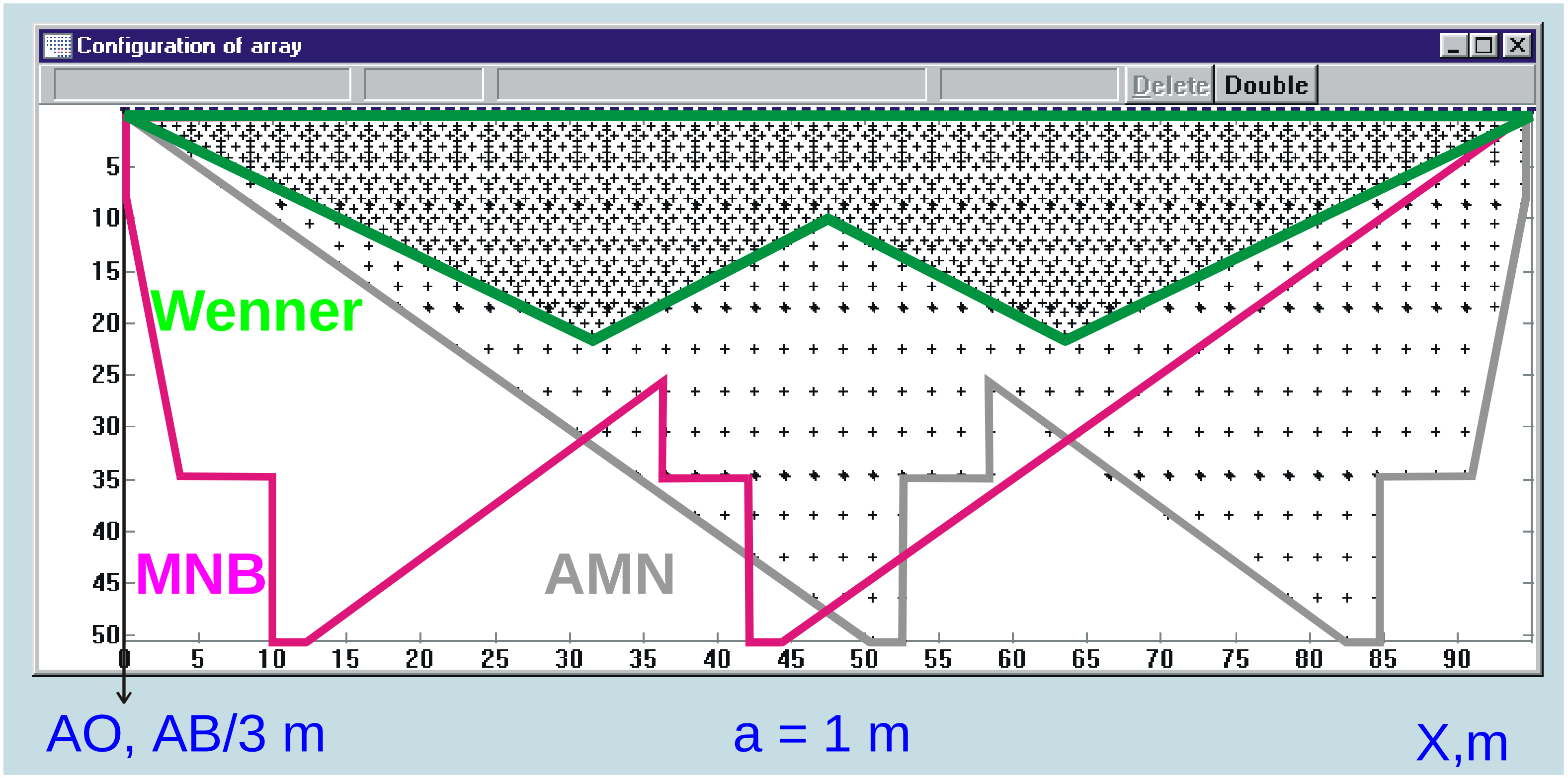


AMN



Data by Henri Robain, pseudo section from "IPI2win"

Rolling array along profile

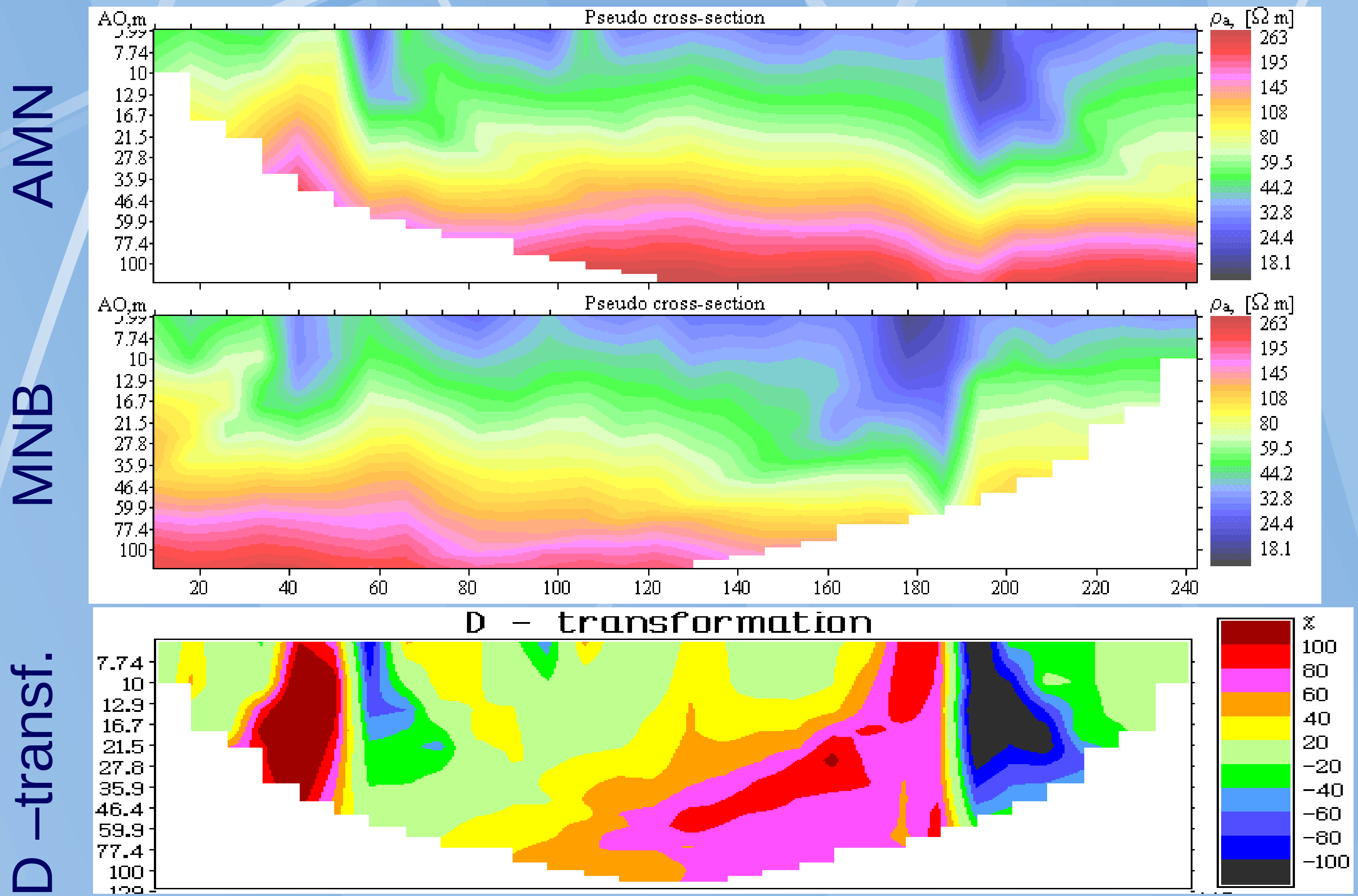


Comparing pseudo sections for AMN and MNB arrays

$$\rho_a^{AMNB} = \frac{\rho_a^{AMN} + \rho_a^{MNB}}{2}$$

$$D = \ln(\rho_a^{AMN}) - \ln(\rho_a^{MNB})$$

Comparing pseudo sections for AMN and MNB arrays (field example)



Data by Henri Robain, pseudo section from "IPI2win" and "IPI_2d"

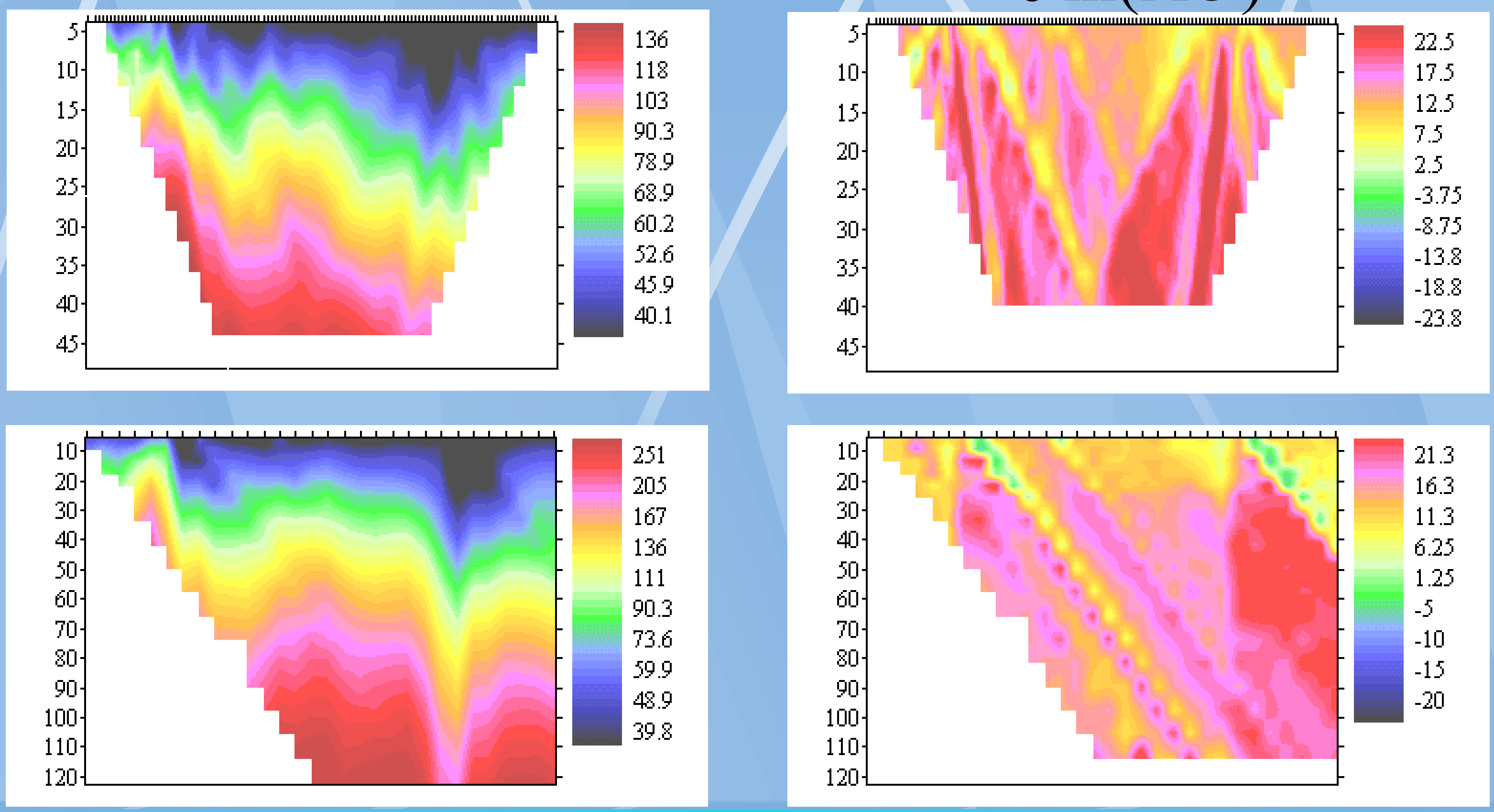
Regularity of geological distortion VES curves

App. resistivity

$$\frac{\partial \ln(\rho_a)}{\partial \ln(AO)}$$

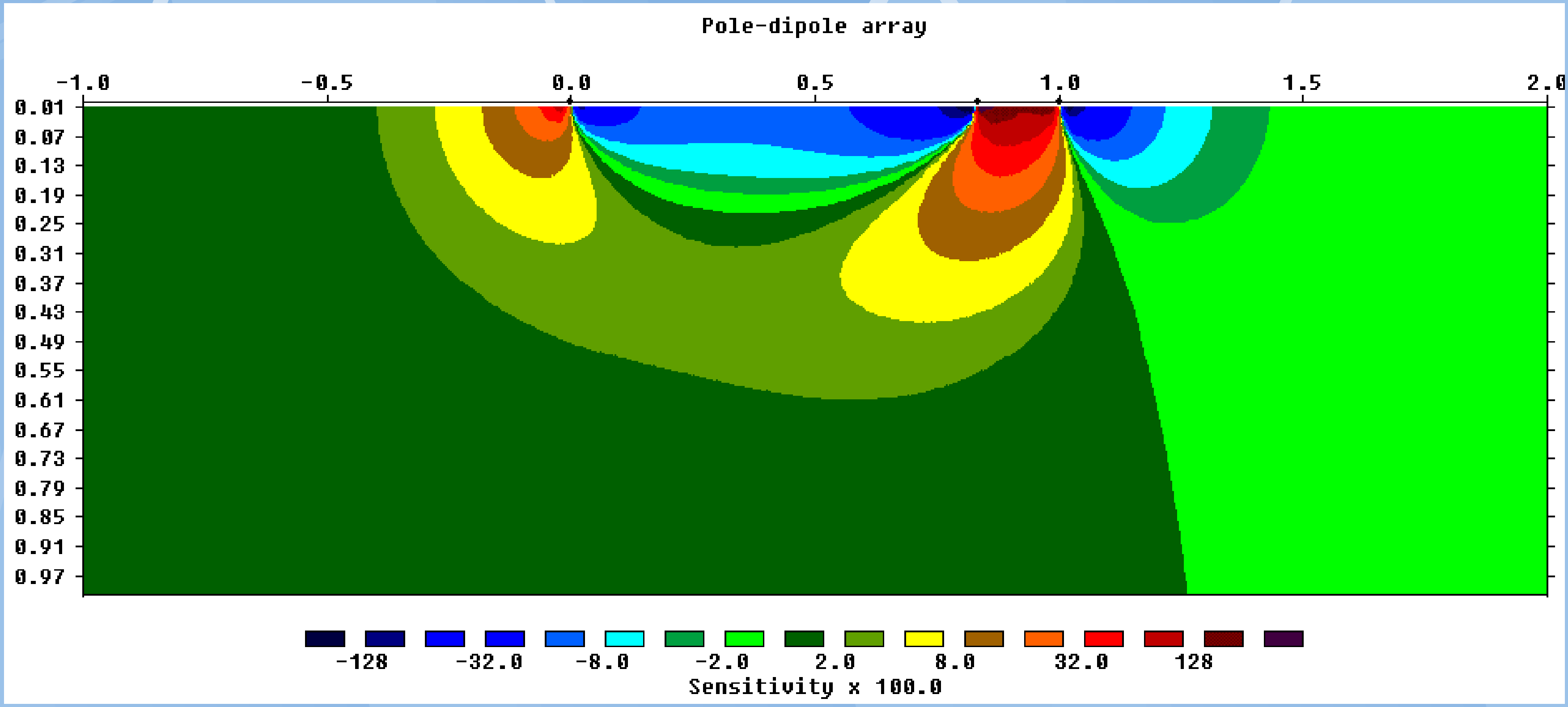
Wenner

AMN



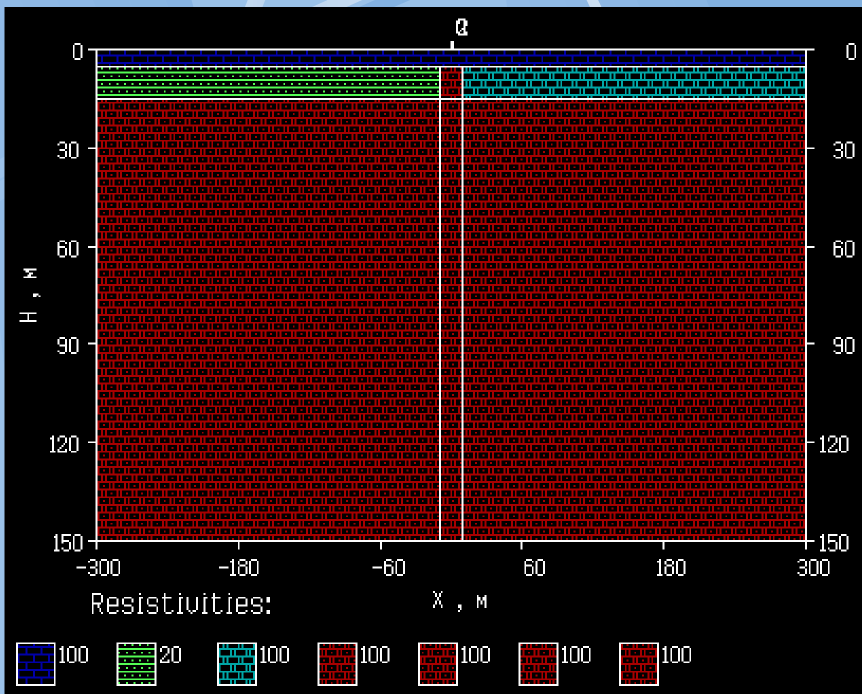
Data by Henri Robain, pseudo section from "IPI2win"

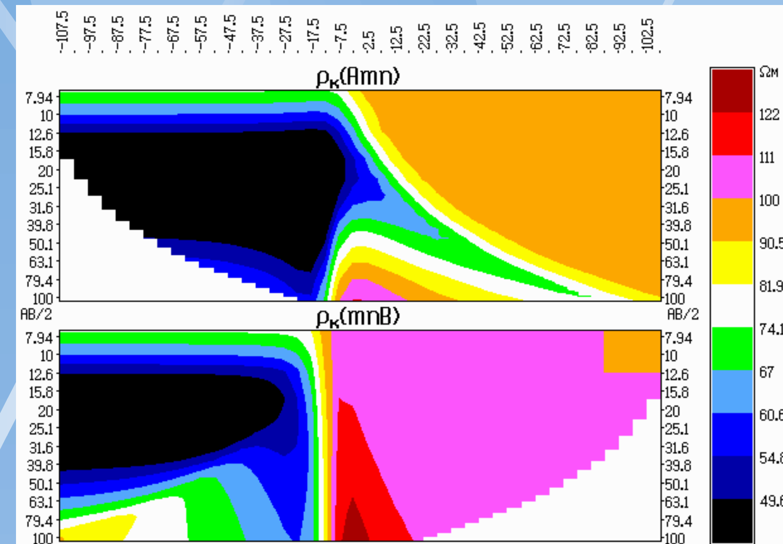
Difference between AMN and MNB sounding curves as indication of 2D object

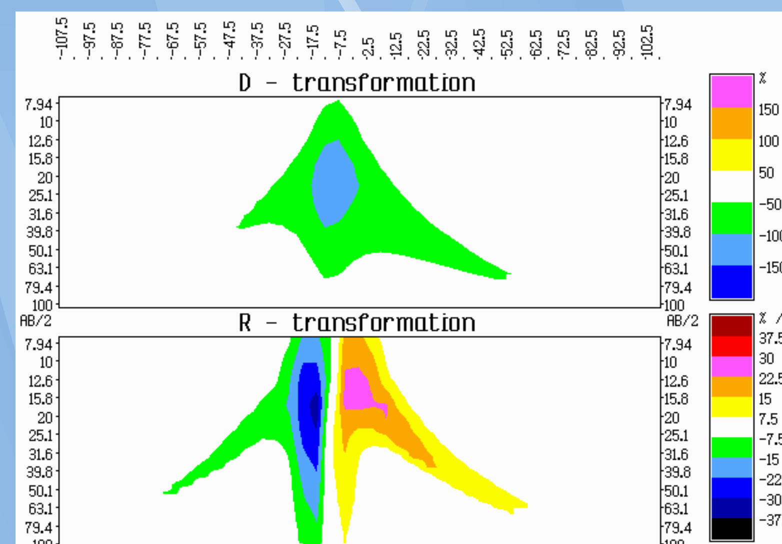


by "Res2dMod"

One vertical boundary





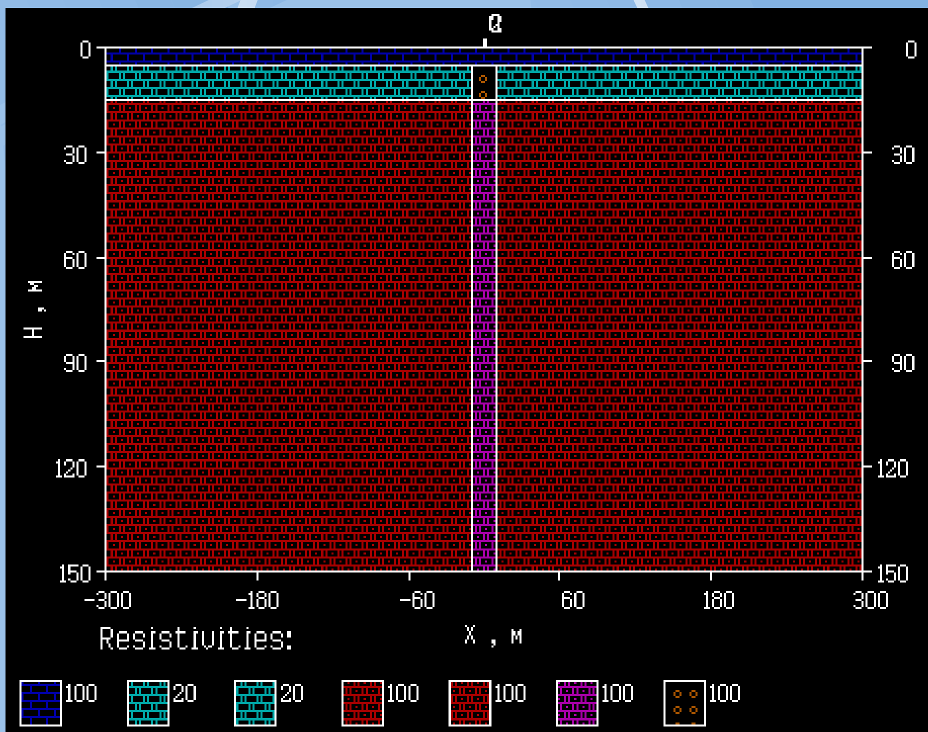


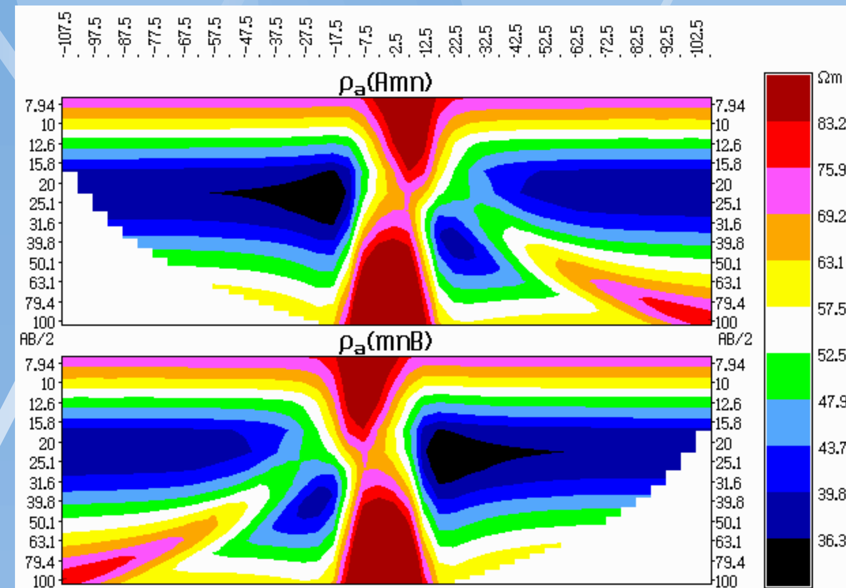
D=Ro_a(AMN)-Ro_a(MNB)

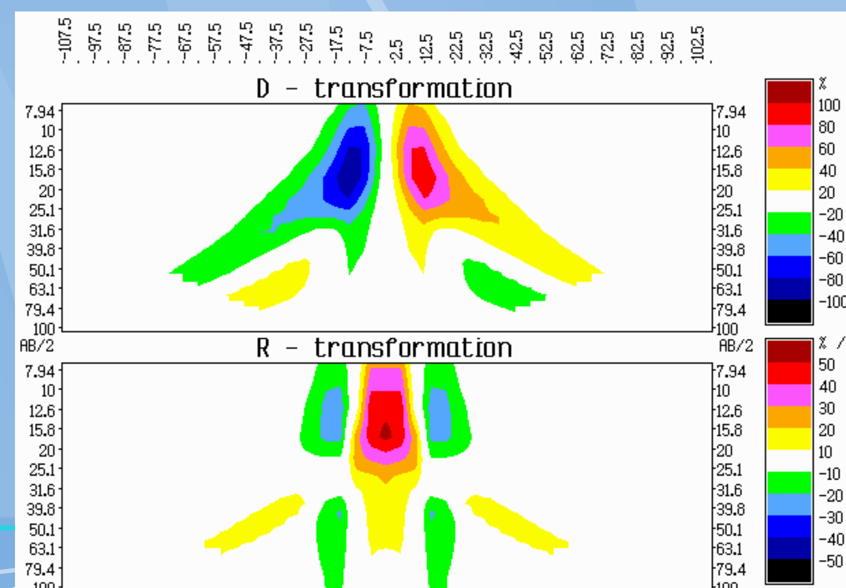
R=d D / d X

Modelling by “Ie2dl”, Modin & Bobatchev, transformation by “Ipi_2d”

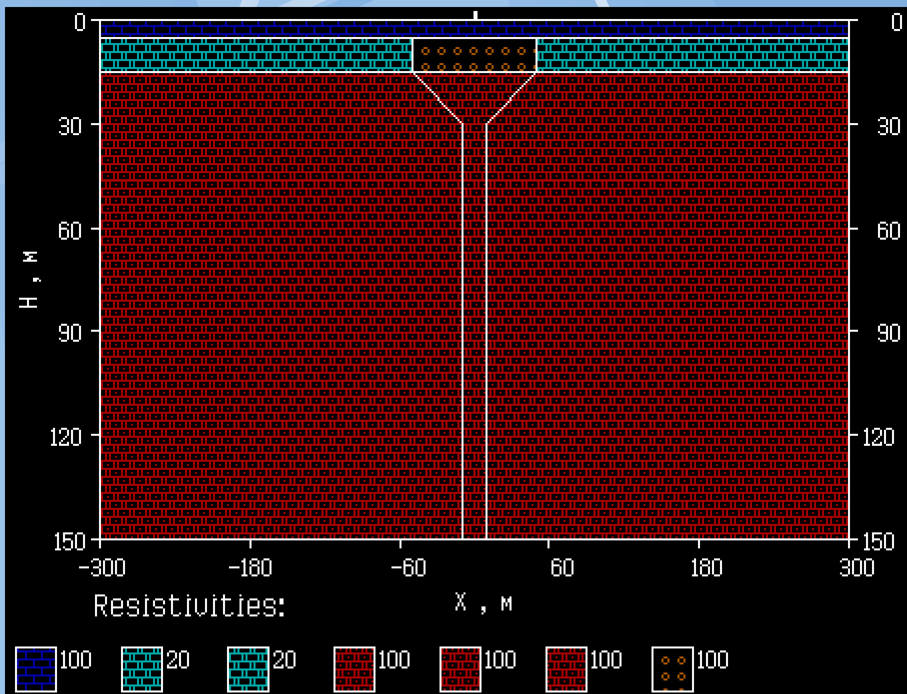
Two vertical boundaries

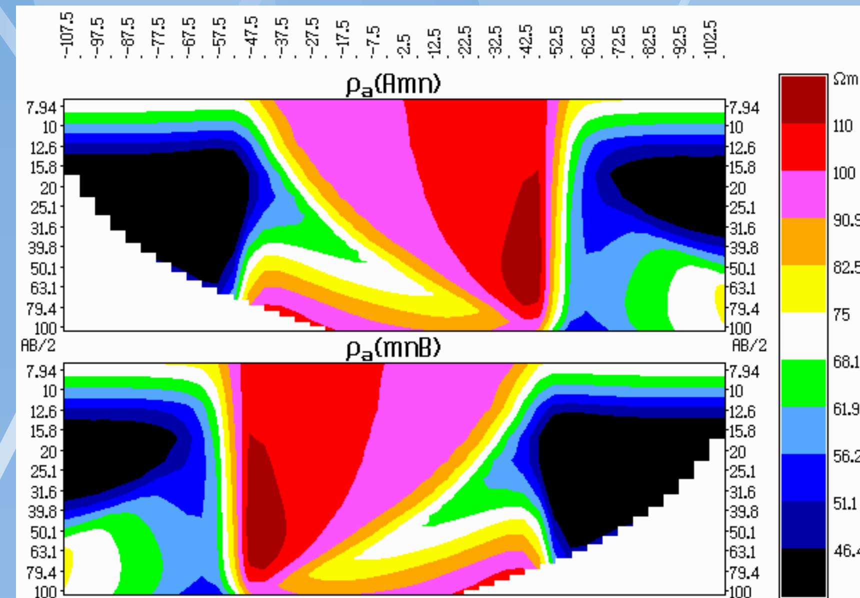


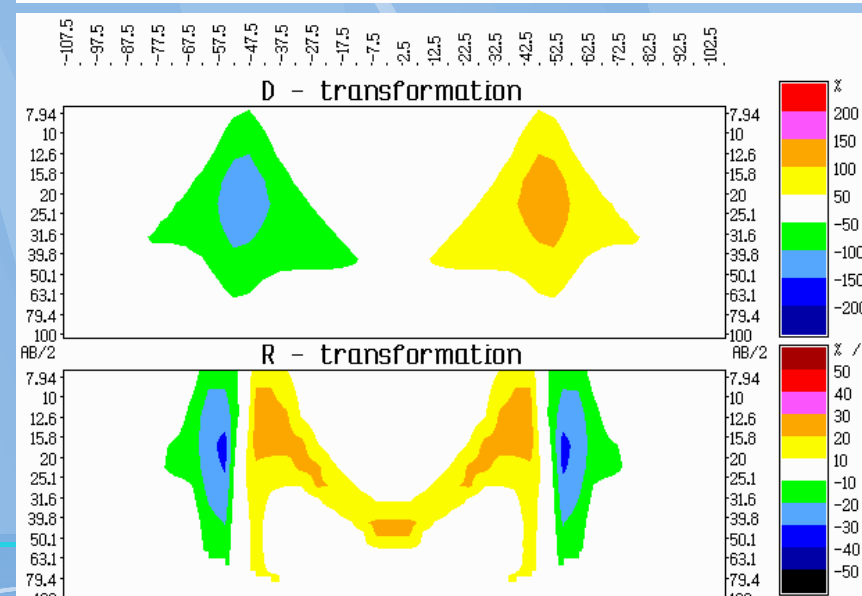




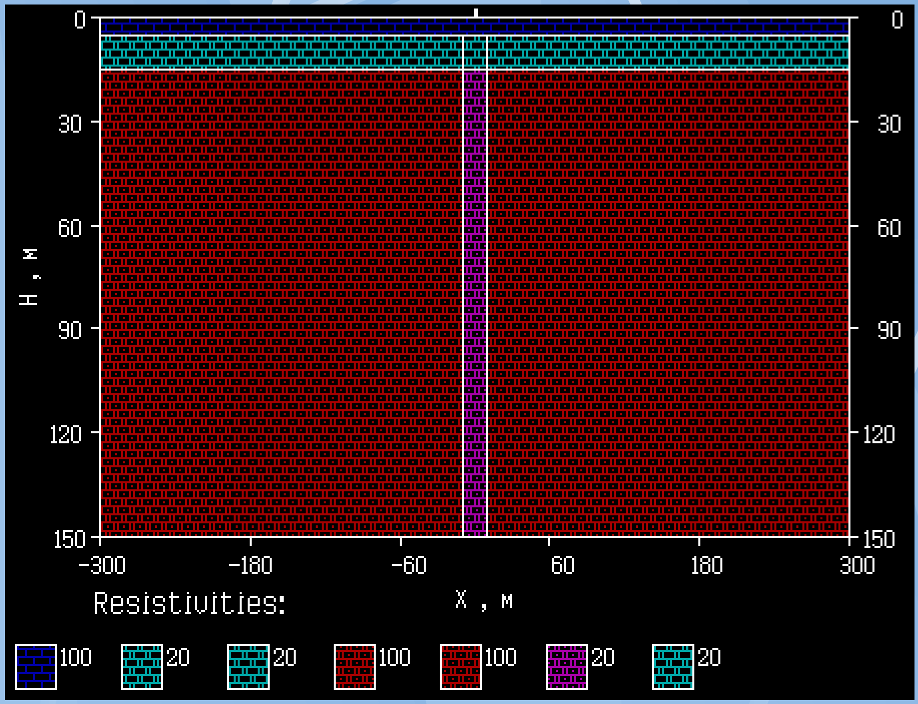
Wide 2D object



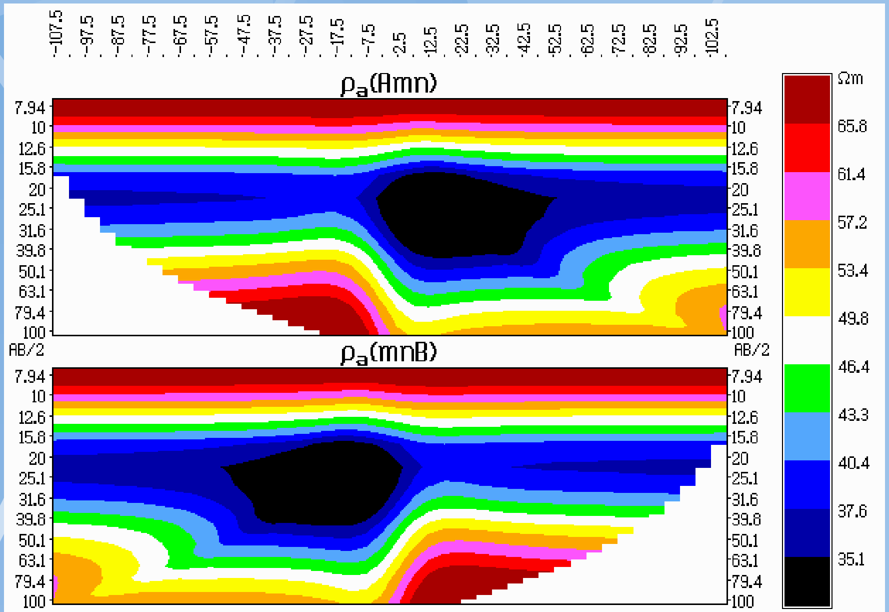




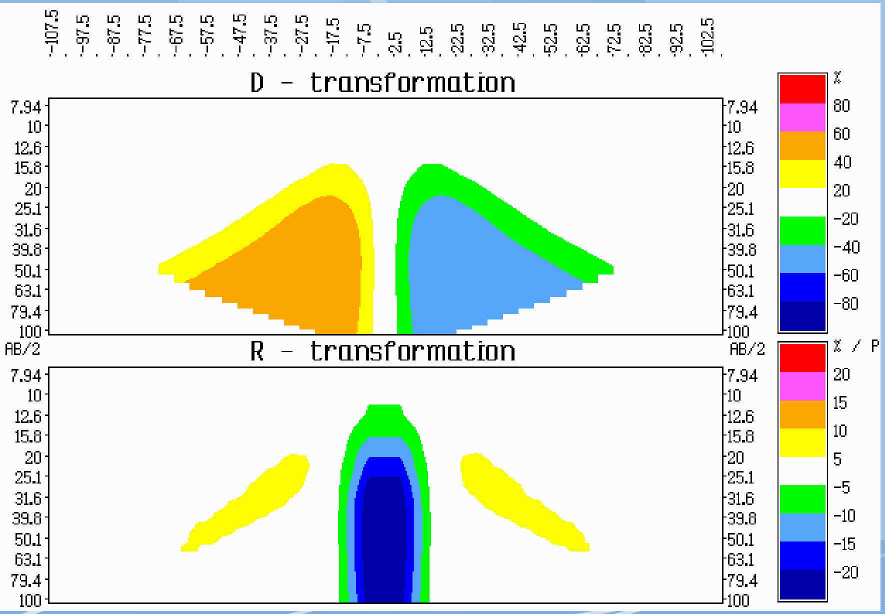
Fault zone



H , м
X , м
Resistivities:
100
20
20
100
100
20
20

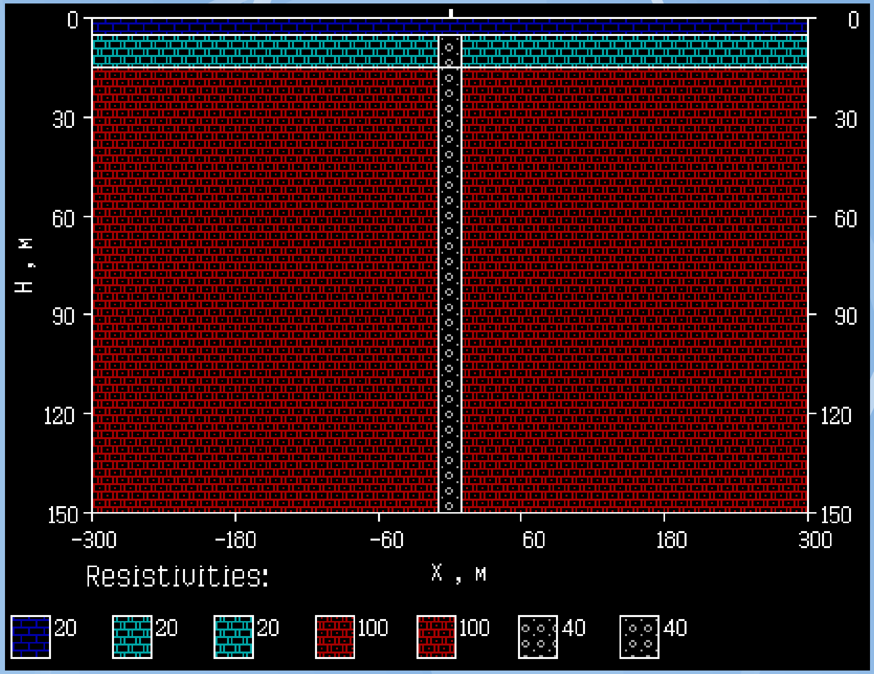


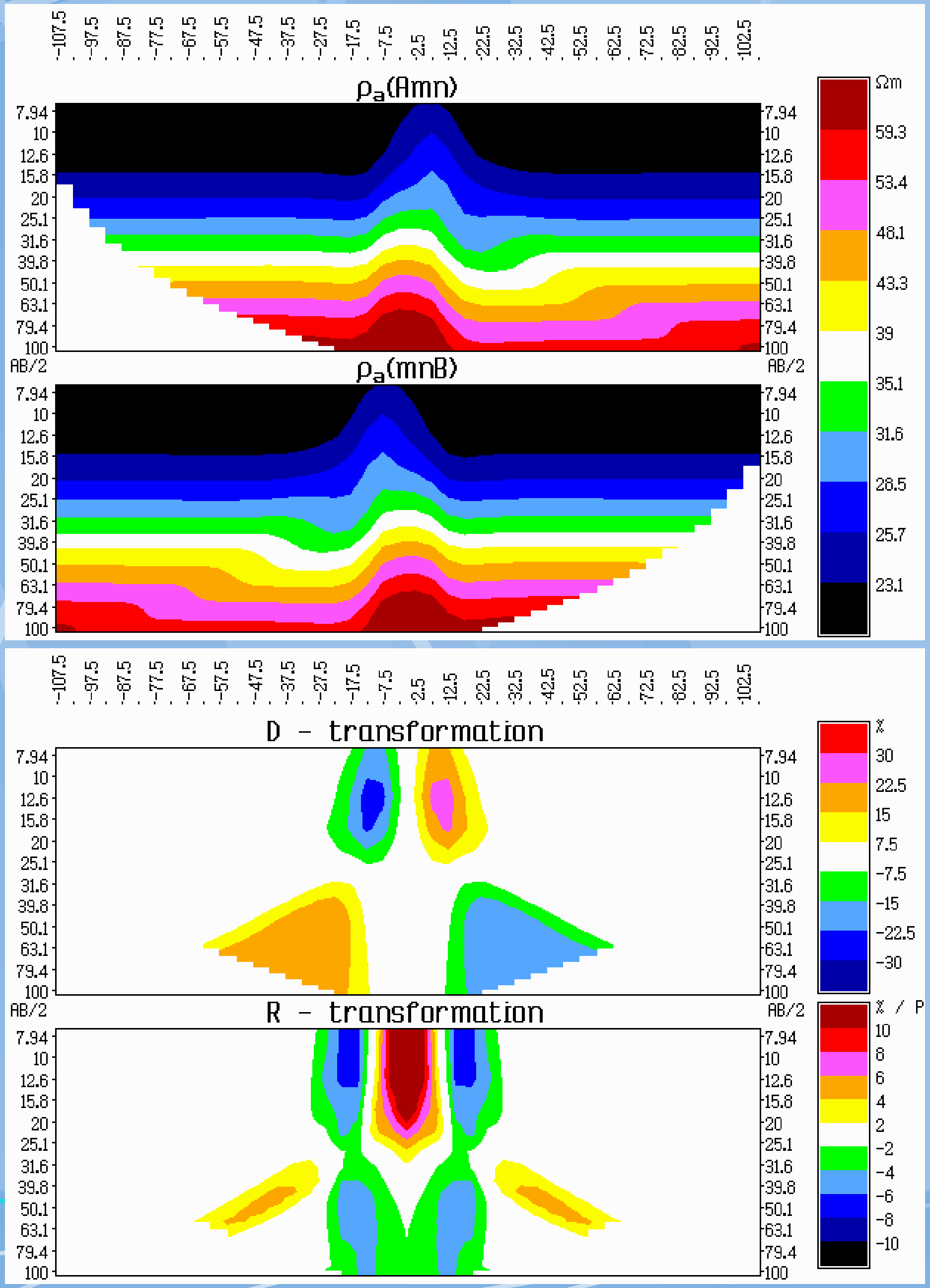
ρa(Amn)
ρa(mnB)
AB/2
Ωm



D - transformation
R - transformation
AB/2

Two 2D objects



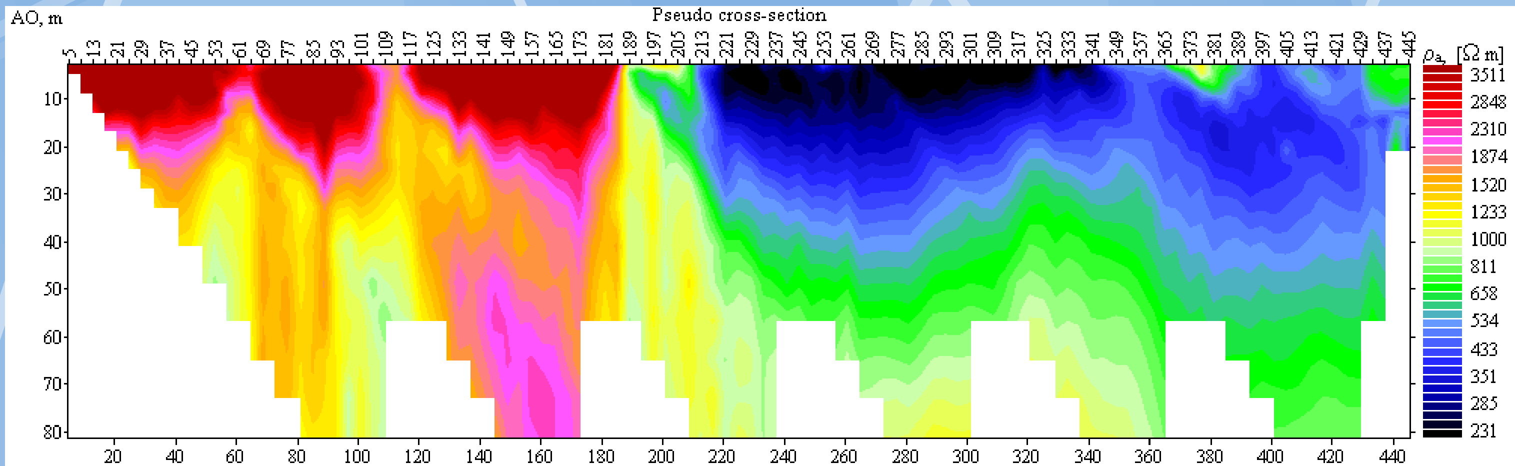


Distortion of VES curves by 2D shallow depth inhomogeneities

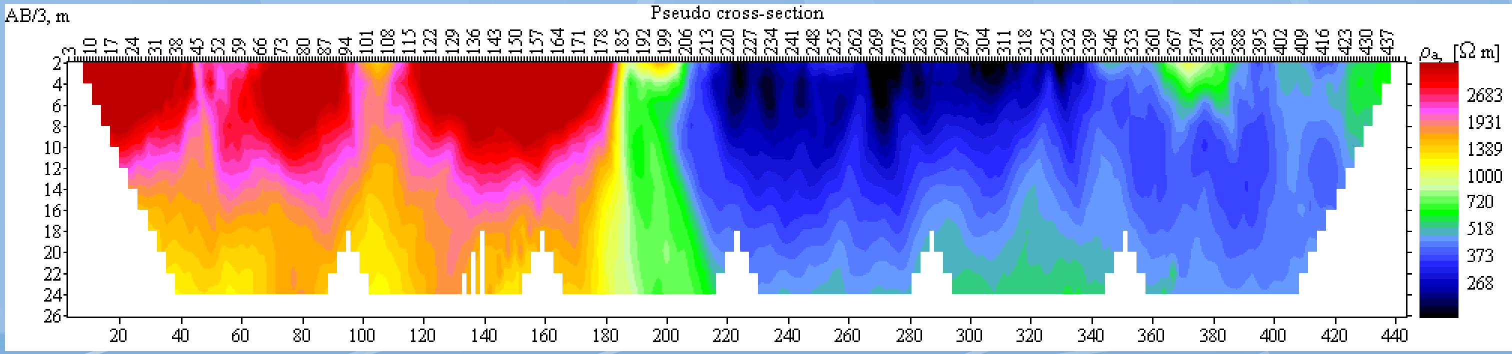
- P&C – effects for pole dipole array VES curves
- Distortion of Wenner-Alpha and Wenner-Beta array
- Median polish of data

Distortion of VES data

Pole-dipole

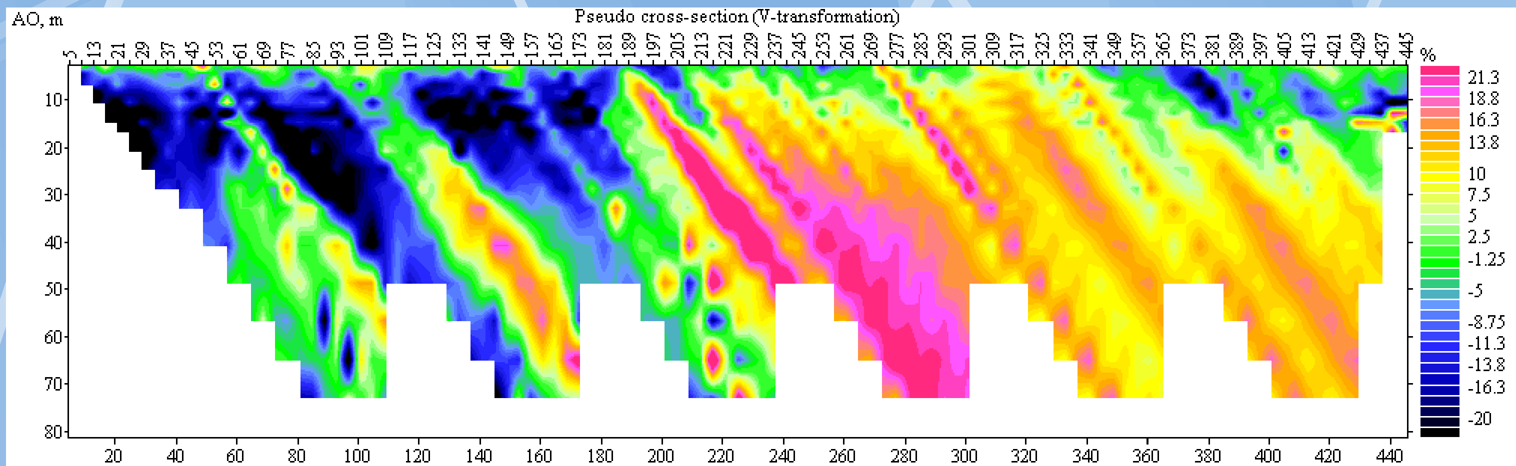


Wenner-alpha

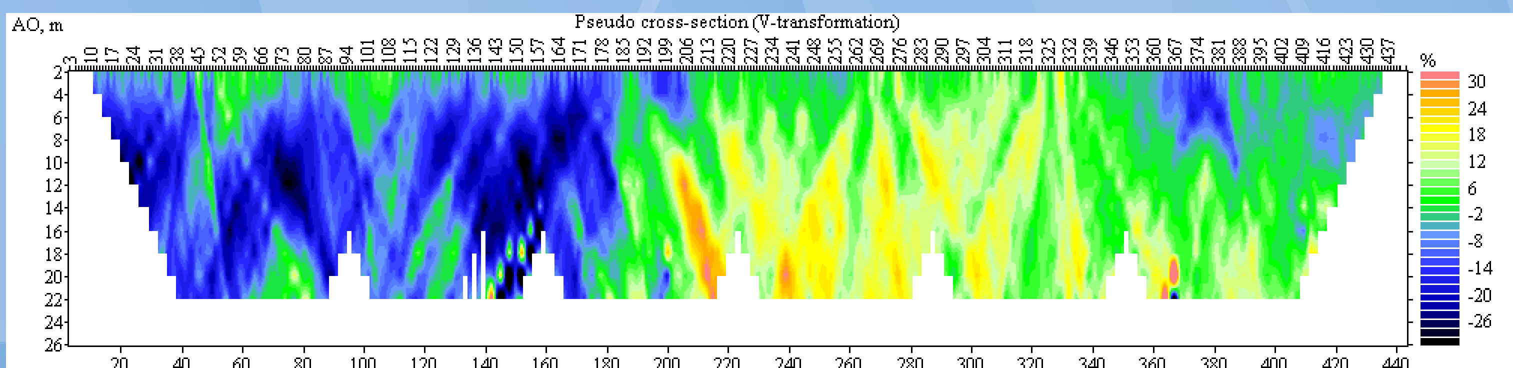


Distortion of VES data

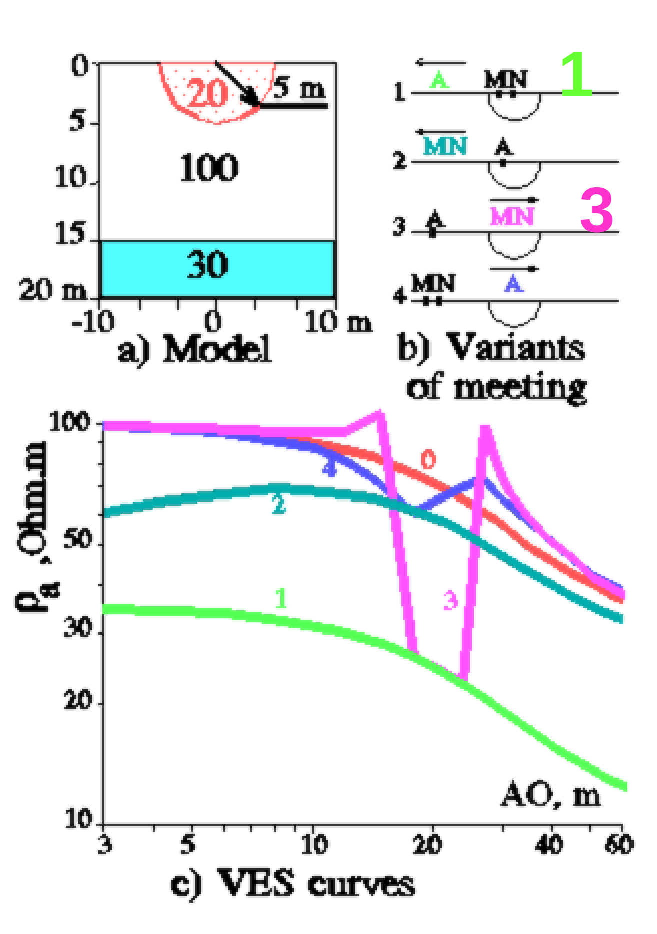
Pole-dipole



Wenner-alpha

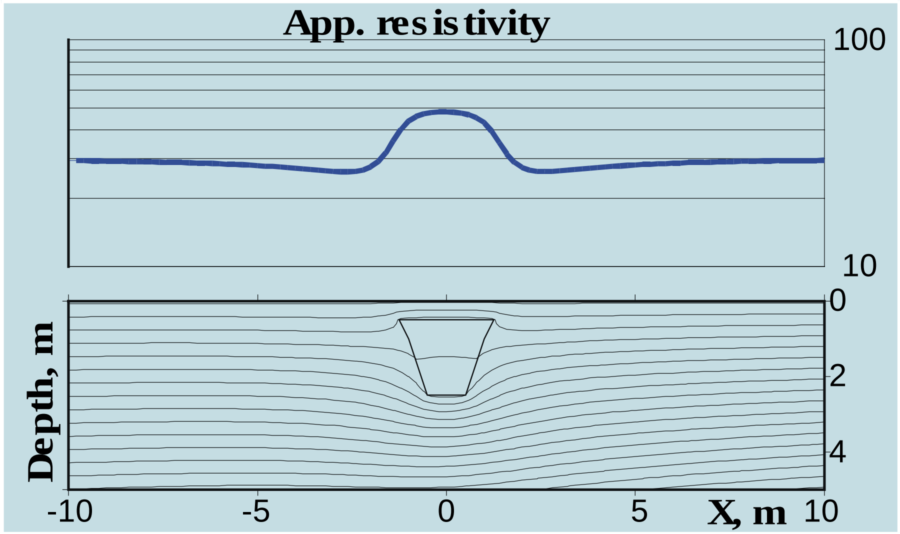


P-effect – distortion of VES curve by anomalous object near DIPOLE-element of array



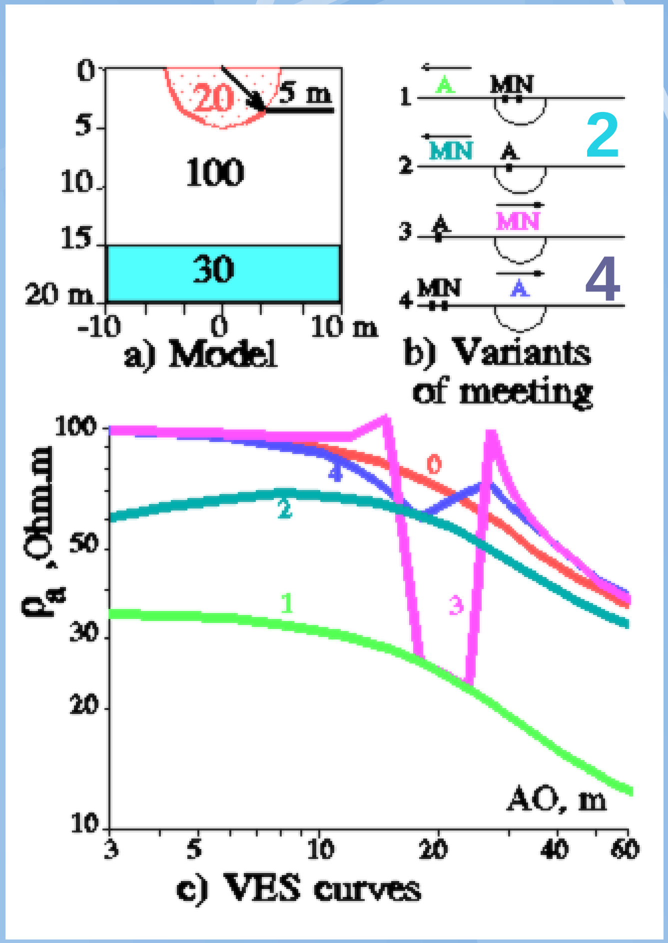
$$\Delta U_{MN} \underset{MN\to 0}{\approx} MN \cdot E = MN\,\rho_{MN}\, j_{MN}$$

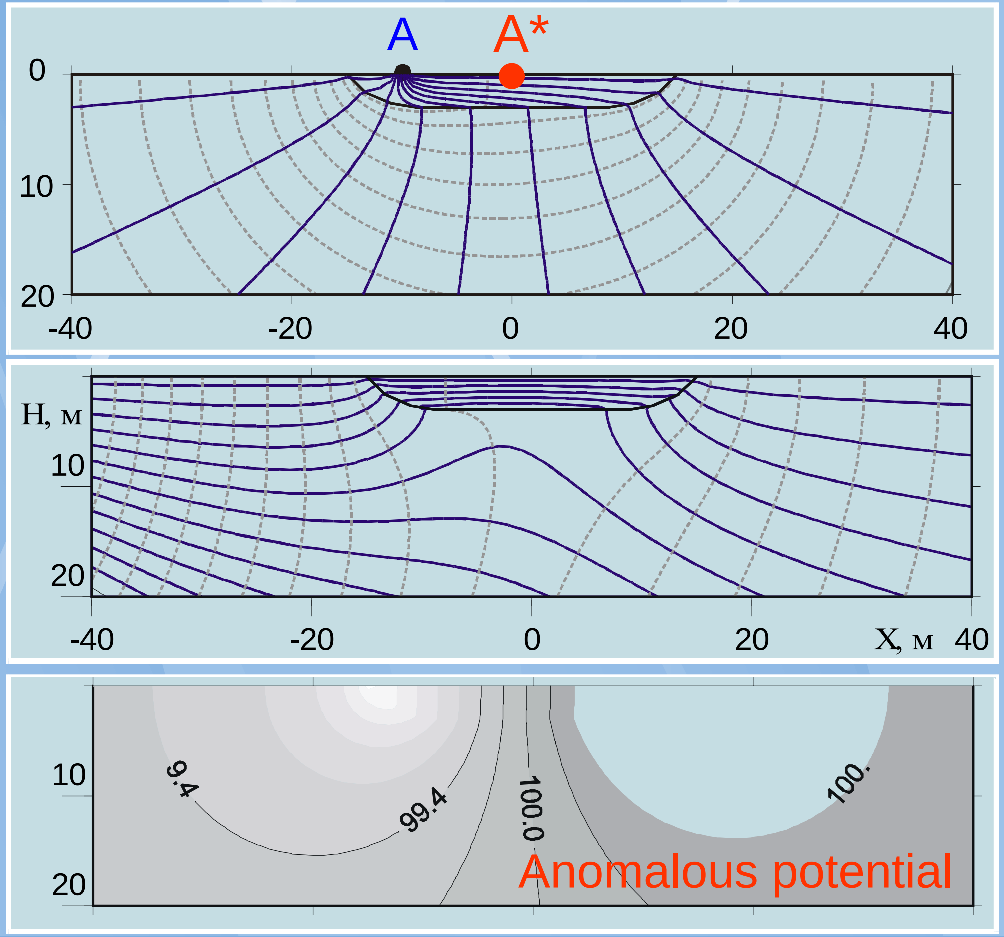
$$\rho_\alpha = K\frac{\Delta U_{MN}}{I_{AB}} \approx \frac{\rho_{MN}\, j_{MN}}{j_0}$$



Current lines distribution by "DC_Flow"

C-effect – distortion of VES curve by anomalous object near POLE-element of array



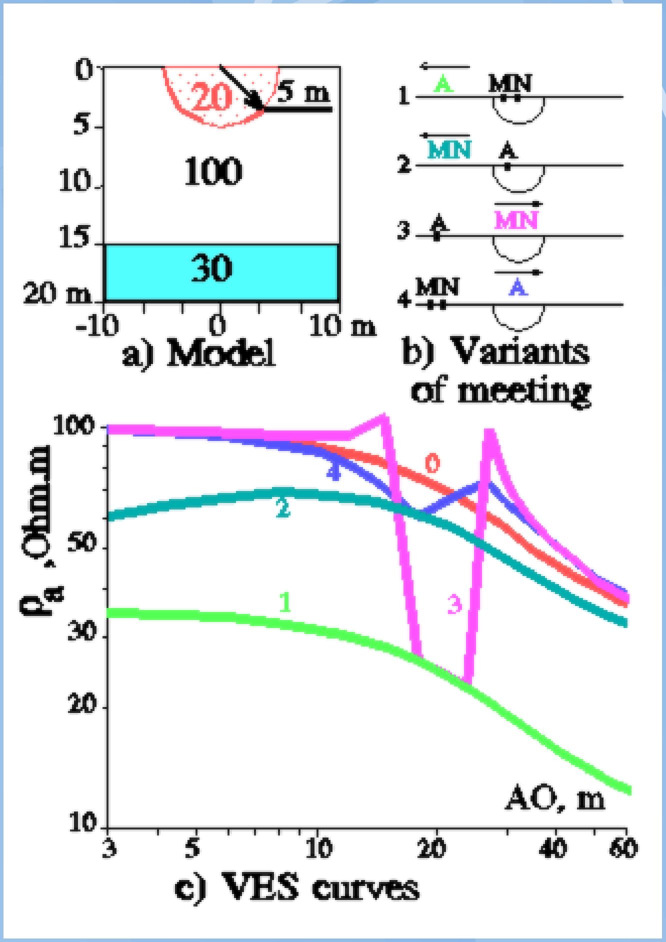


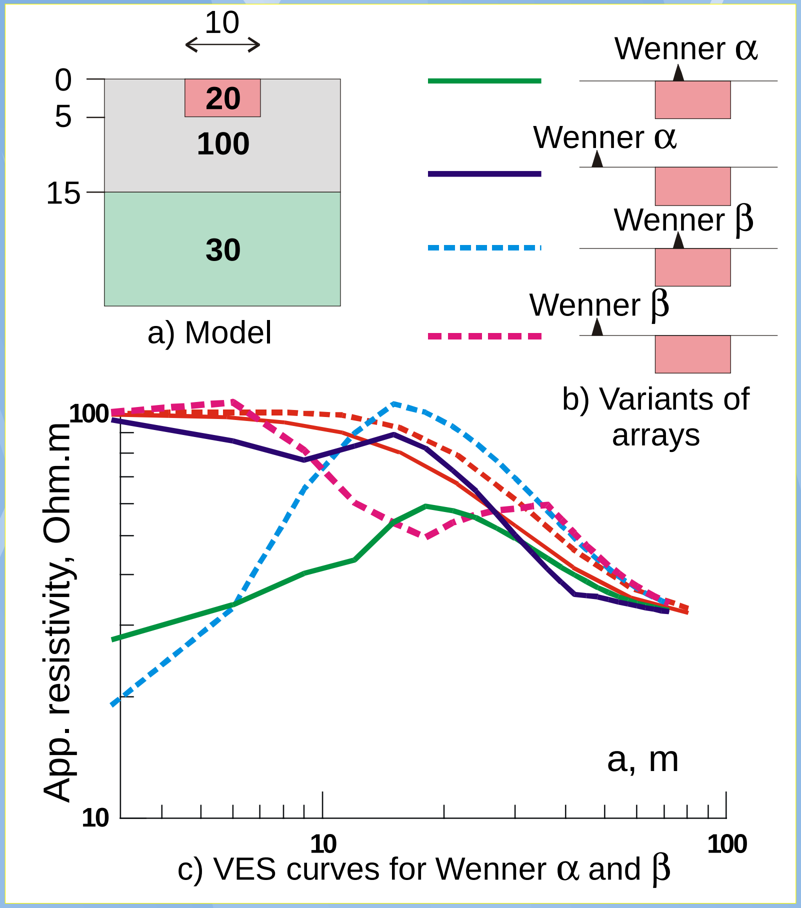
Current lines and potential distribution by "DC_Flow"

Comparing P and C effects

P - effect	C - effect
Great amplitude	Small amplitude
Does not depend on spacing	Decreases slowly with spacing
Depends on MN length	
Usually the same for both AMN and MNB array	Different sign and usually different amplitude for AMN and MNB array
Does not change VES curve form (reference point – MN center)	Changes VES curve form (reference point – MN center)

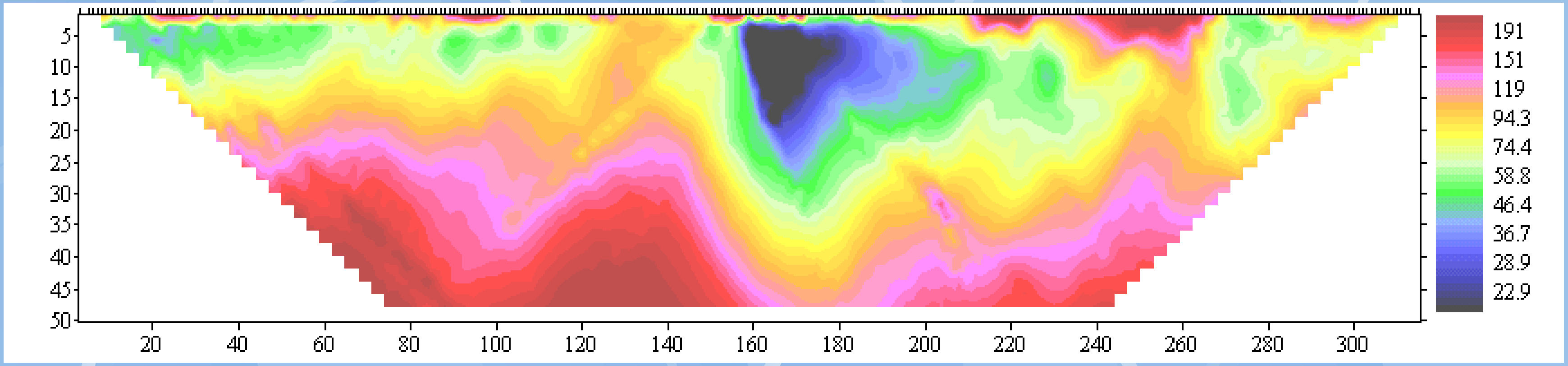
Distortion of Wenner-Alpha and Wenner-Beta array

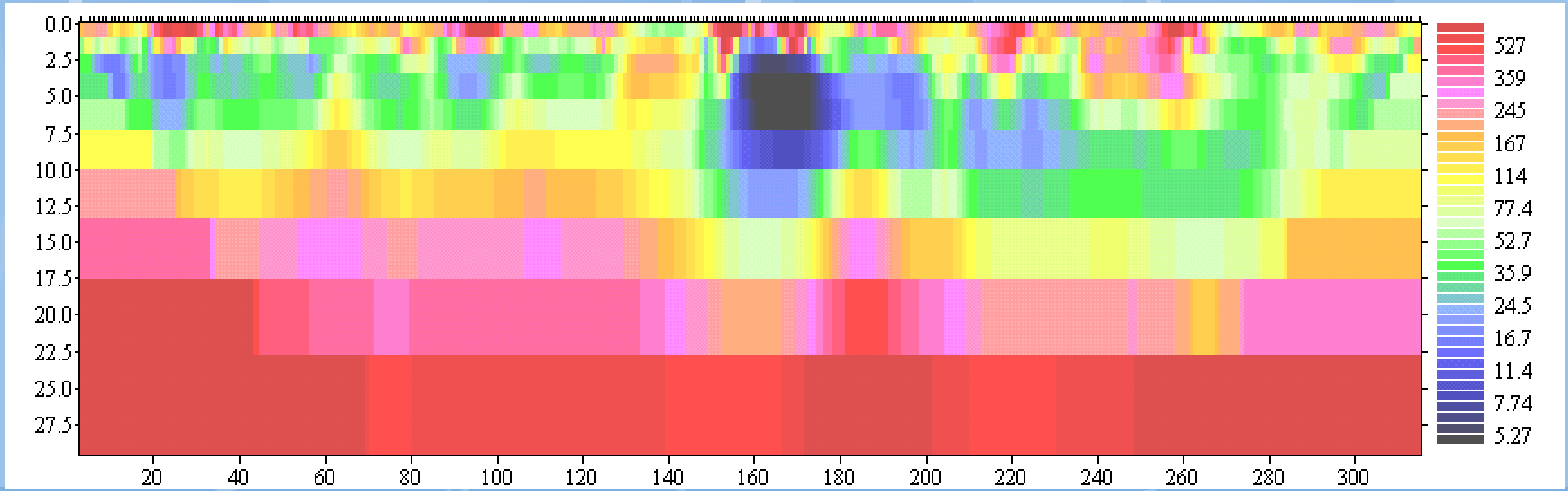




Modeling by "Res2Dmod"

Field example for Wenner-Alpha (N_{el}=160)





2D inversion by "Res2Dinv"

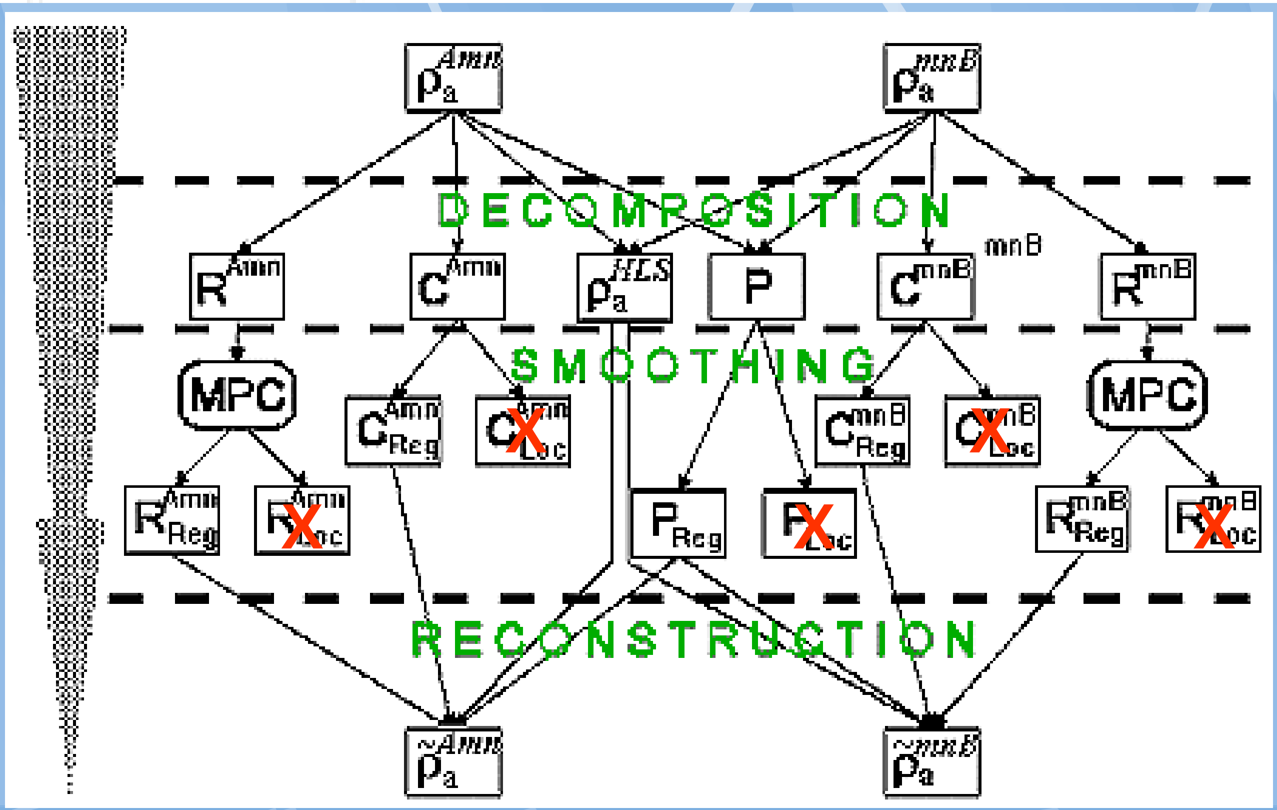
Data by Henri Robain, pseudo section from "IPI2win"

P and C effects for different arrays

Array	Current electrodes	Potential electrodes
Schlumberger, Pole-Dipole	C-effect	P-effect
Pole-Pole	C-effect	C-effect
Dipole-Dipole	P-effect	P-effect
Wenner	Mainly C-effect	

Median polish to decrease P and C effect

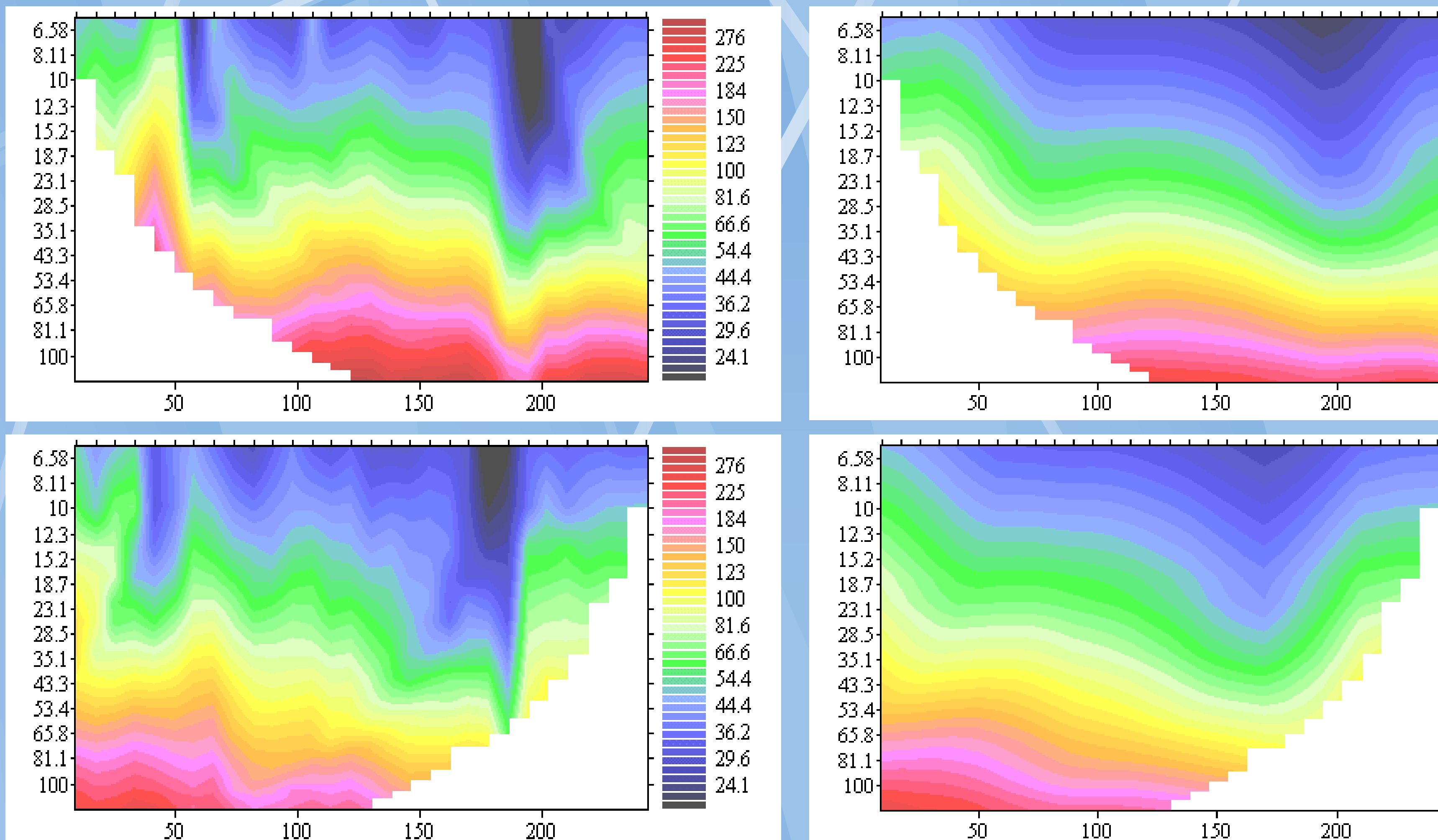
$$\begin{cases} \rho_a^{Amn}(x,r) = \rho_a^{HLS}(r)\cdot P(x)\cdot C^{Amn}(x-r)\cdot R^{Amn}(x,r) \\ \rho_a^{mnB}(x,r) = \rho_a^{HLS}(r)\cdot P(x)\cdot C^{mnB}(x+r)\cdot R^{mnB}(x,r) \end{cases}$$



Median polish on field data (N_{el}=64, 2 x shift)

AMN

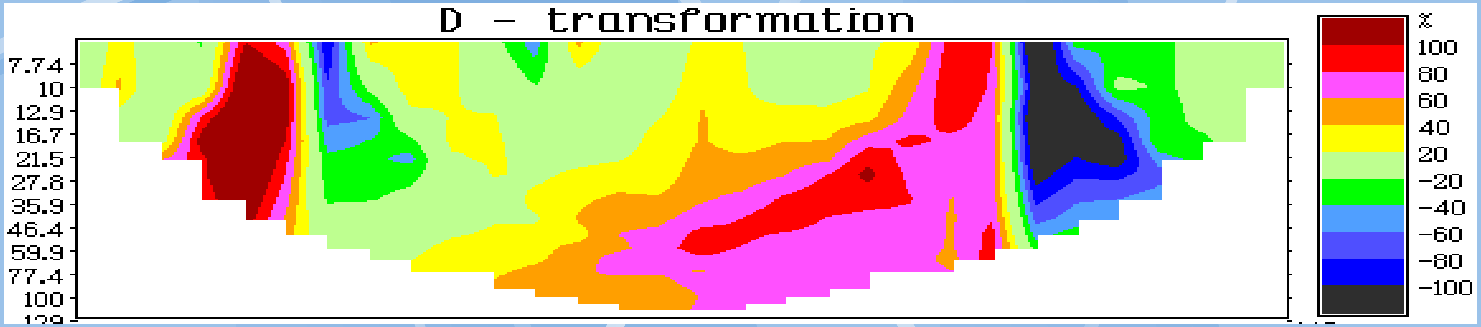
MNB



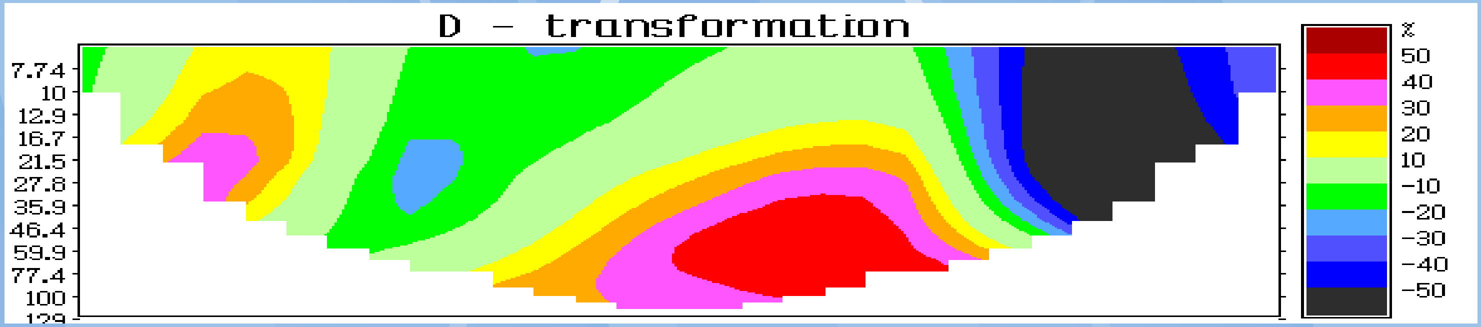
Data by Henri Robain, pseudo section from "IPI2win", data processing by "Median"

D-transformation before and after Median polish

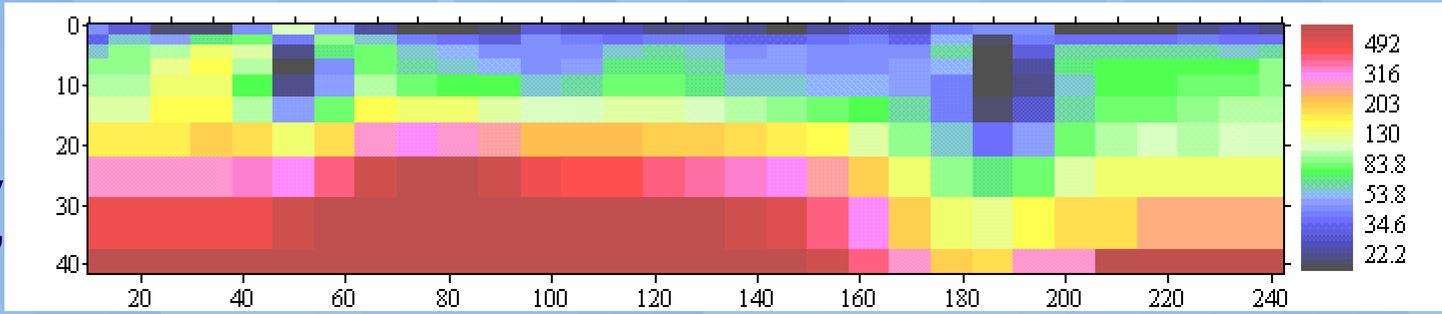
Field data



After polish by "Median"



Inversion field data for MNB array by "Res2dInv"



Data by Henri Robain, pseudo section from "IPI_2d", 2D inversion by "Res2dInv"

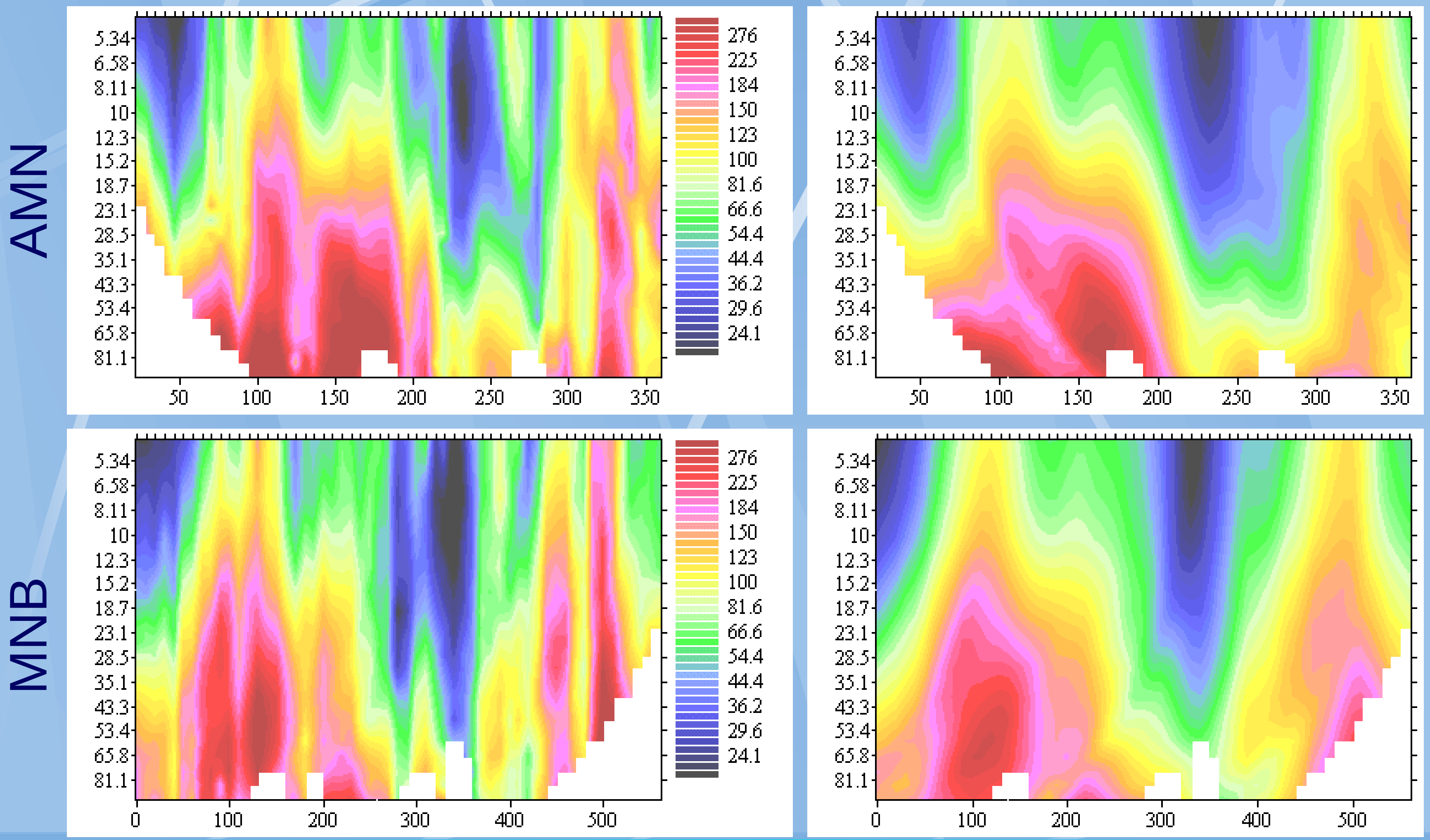
Field example

- Date: Mai, 1999
- Place: South of Madagascar, semi-arid area
- Goals: Hydrogeological research.

  Problems of water resource: rarity and high mineralization
- Geological section:
  - Basement –vertical-layered, weathered, metamorphic precambrian rocks (saprolite), depth (0-12 m)
  - Upper part – laterite and sand
- Equipment: Syscal R2, 64-electrodes array
- Array: Pole-Dipole, distance between electrodes – 3 m,

  MN – 3 and 9 m, AO_{max}=94.5 m

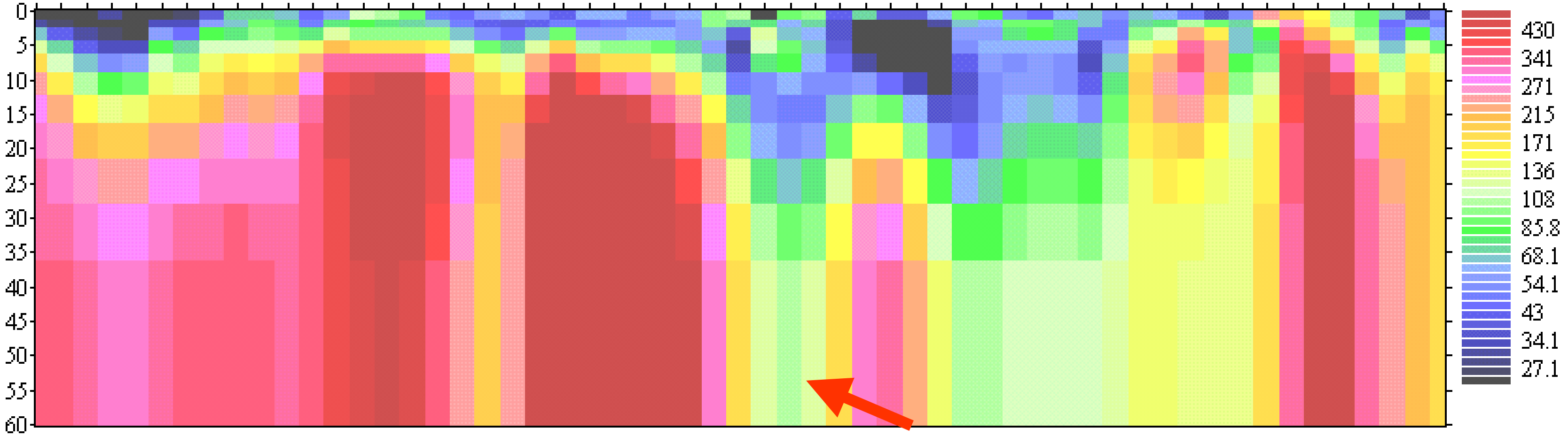
Median polish on field data (N_{el}=64, 2 x shift)



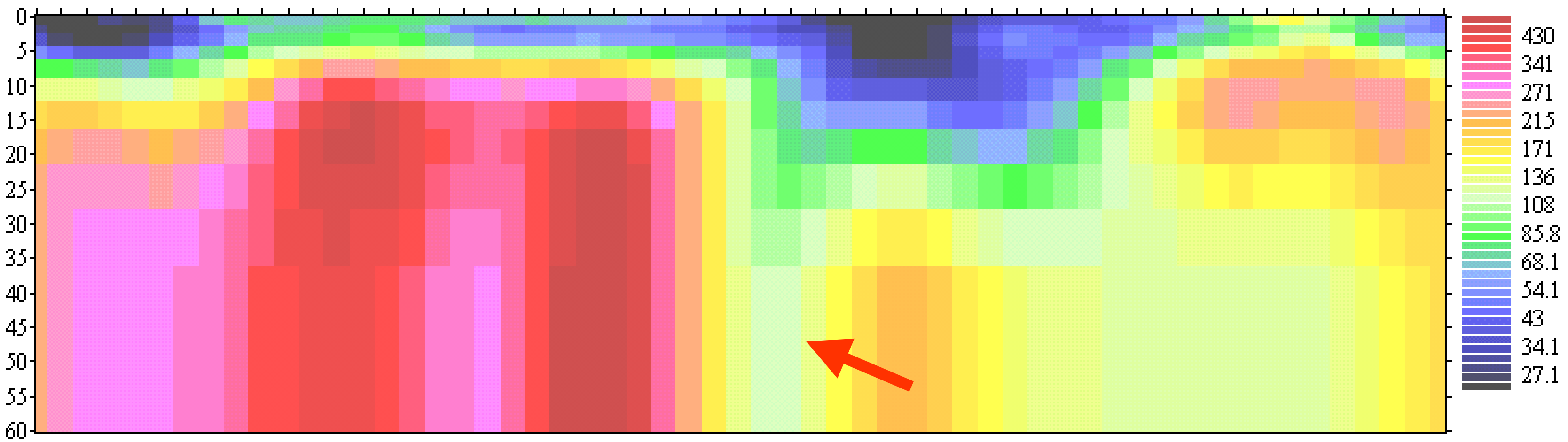
Data by Vero Rabemanana, pseudo section from "IPI2win", data processing "Median"

2D inversion AMN+MNB array

Without polish



After polish



Data by Vero Rabemanana, pseudo section from "IPI2win", 2D inversion by "Res2dInv"

Conclusion

The practical use of Half-Schlumberger array for multi-electrode resistivity measurement is more complicate in comparing with Wenner (α,β) array for field measurement, data processing and inversion.

On the other hand, Half-Schlumberger array allows to receive maximum geophysical information by multi-electrode resistivity survey and to improve quality of interpretation, especially for deepest part of geological section.