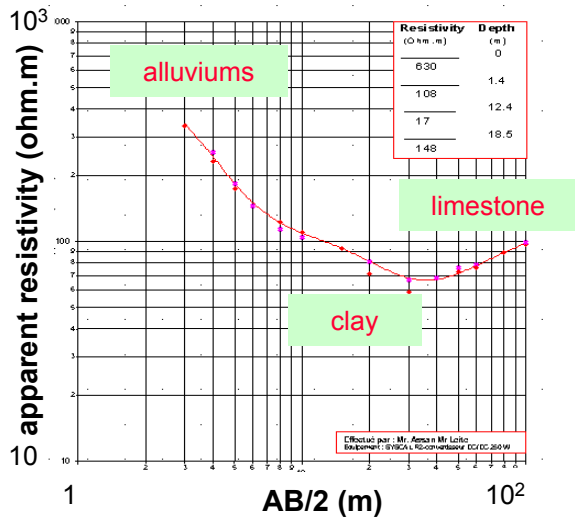# INTRODUCTION GUIDE TO 3D RESISTIVITY IMAGING
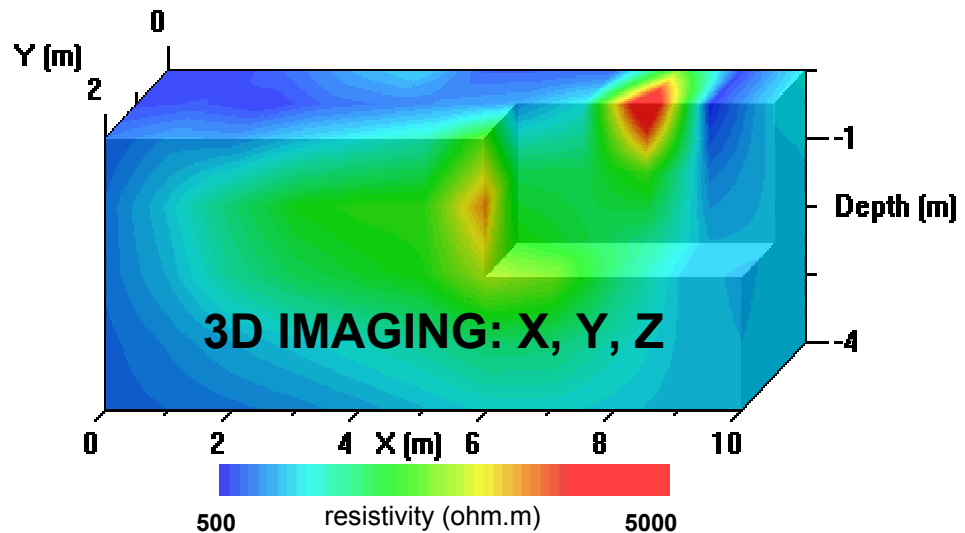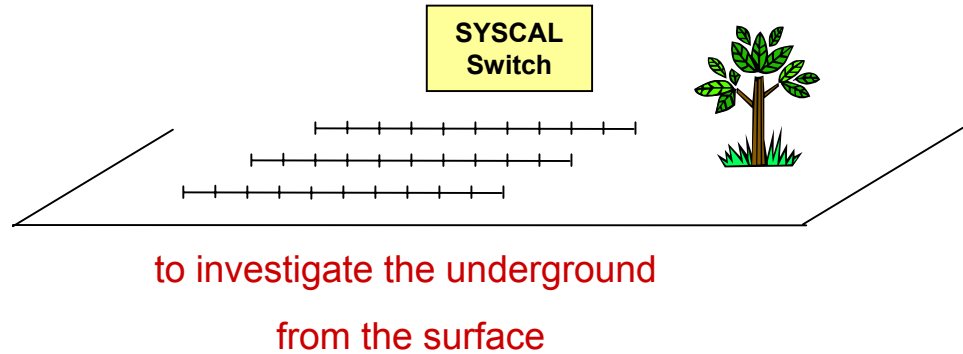

1D SOUNDING: Z

2D SECTION: X, Z
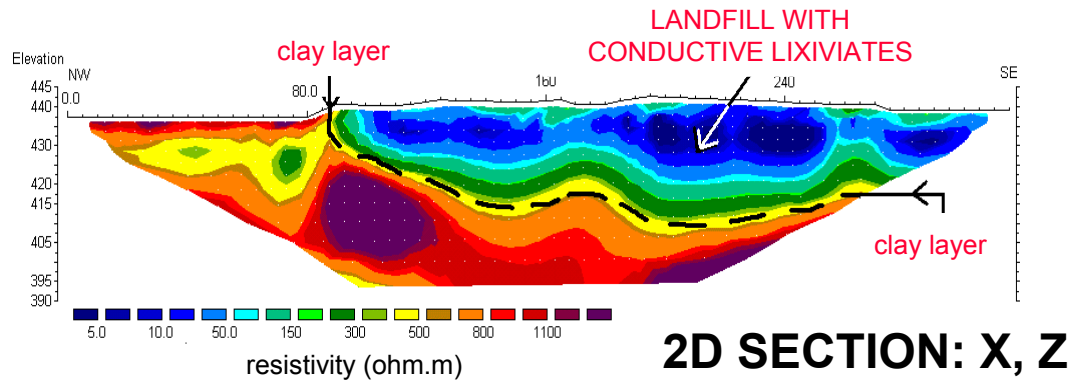
3D IMAGING: X, Y, Z

SURFACE AND HOLE 3D RESISTIVITY IMAGING

3D IMAGING FROM THE SURFACE

(with surface cables)

SYSCAL Switch

to investigate the underground from the surface
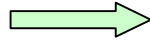
3D IMAGING BETWEEN TWO HOLES

(with borehole cables)

SYSCAL Switch

water level

to investigate the space between two holes

HOLE 1   HOLE 2
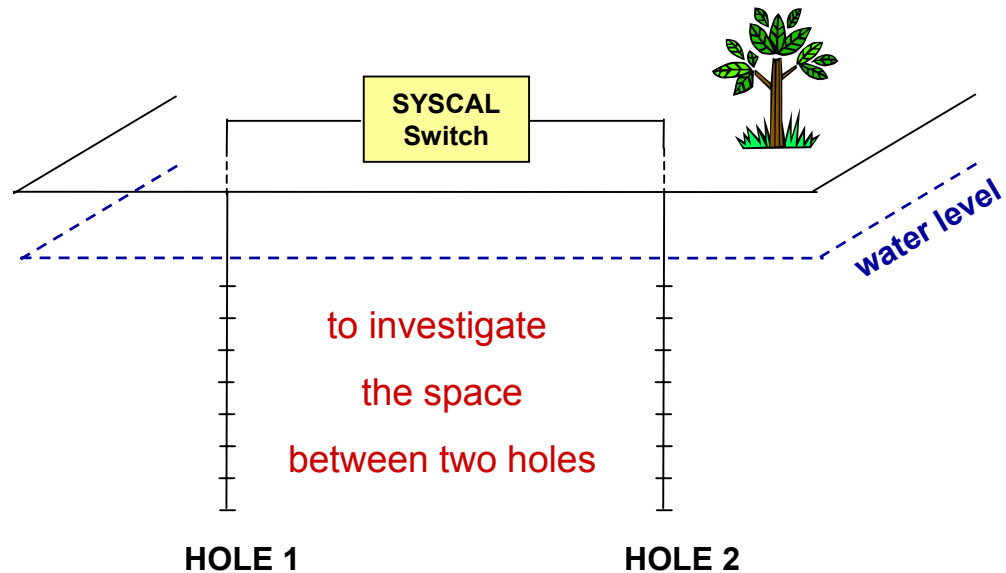
(the electrodes have to be placed under the water level)

Combinations of surface and borehole electrodes can also be used
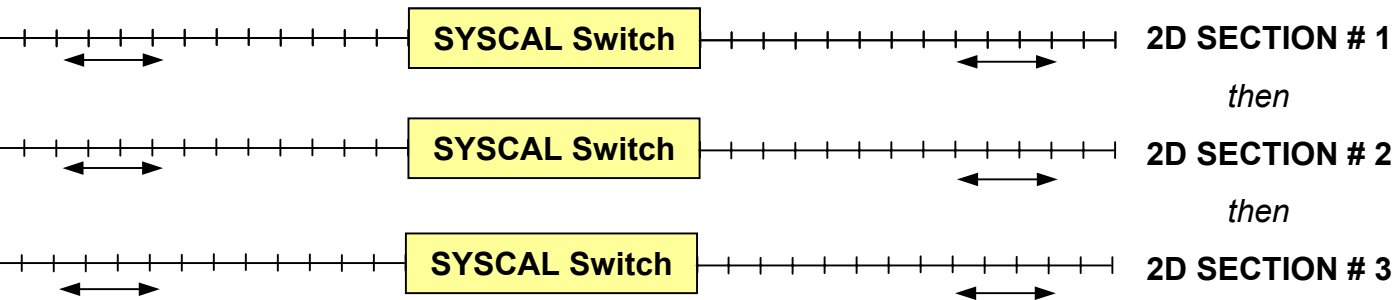
IRIS instruments

SIMPLIFIED AND TRUE 3D RESISTIVITY IMAGING

1) SIMPLIFIED 3D IMAGING: 2D DATA ACQUISITION, 3D INVERSION

SYSCAL Switch — 2D SECTION # 1

then

SYSCAL Switch — 2D SECTION # 2

then

SYSCAL Switch — 2D SECTION # 3

2) TRUE 3D IMAGING: 3D DATA ACQUISITION, 3D INVERSION

SYSCAL Switch

Switch unit

Switch unit

3D ACQUISITION: sections # 1, 2 and 3, **+** readings with current electrodes & potential electrodes located in different lines, for a better investigation of the structures in the perpendicular direction

3D INVERSION SOFTWARE
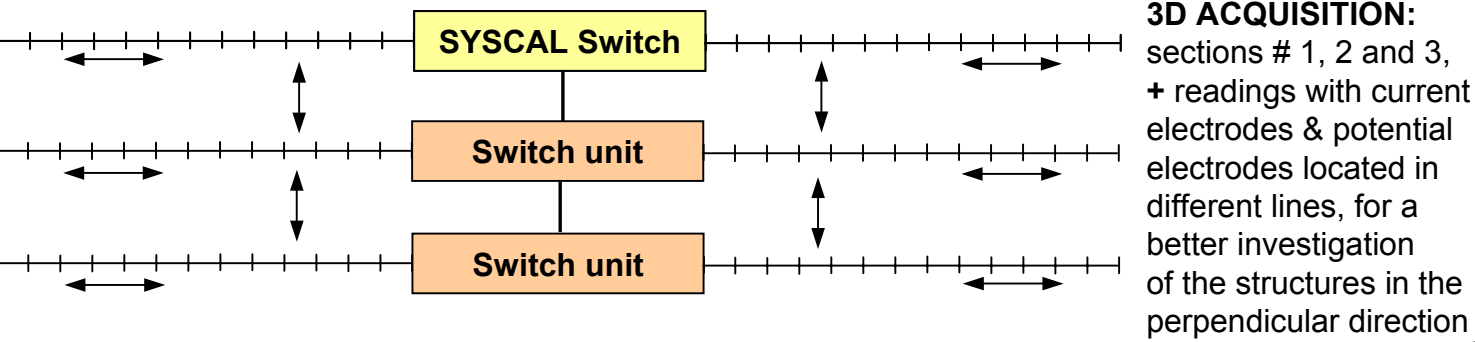
(Res3Dinv)
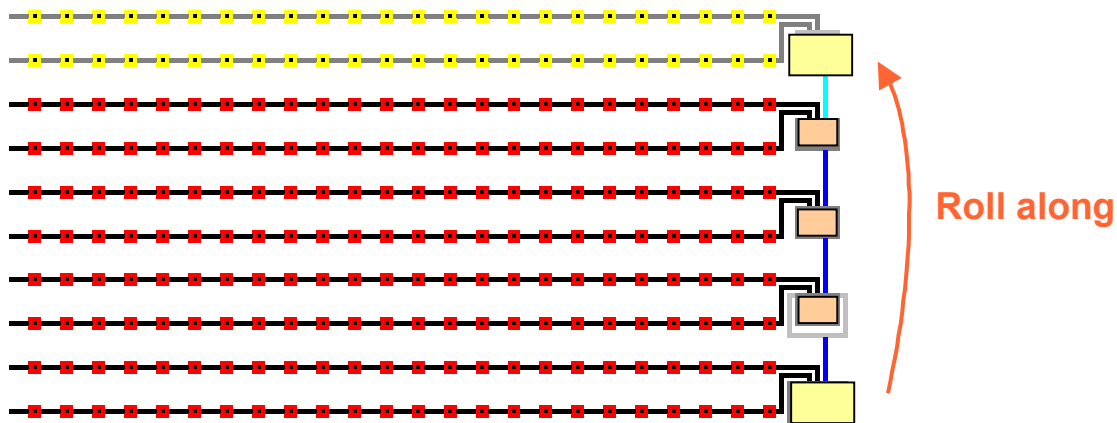
SYSCAL Switch = *Transmitter + Receiver + Switch*

Switch unit = *Switch*
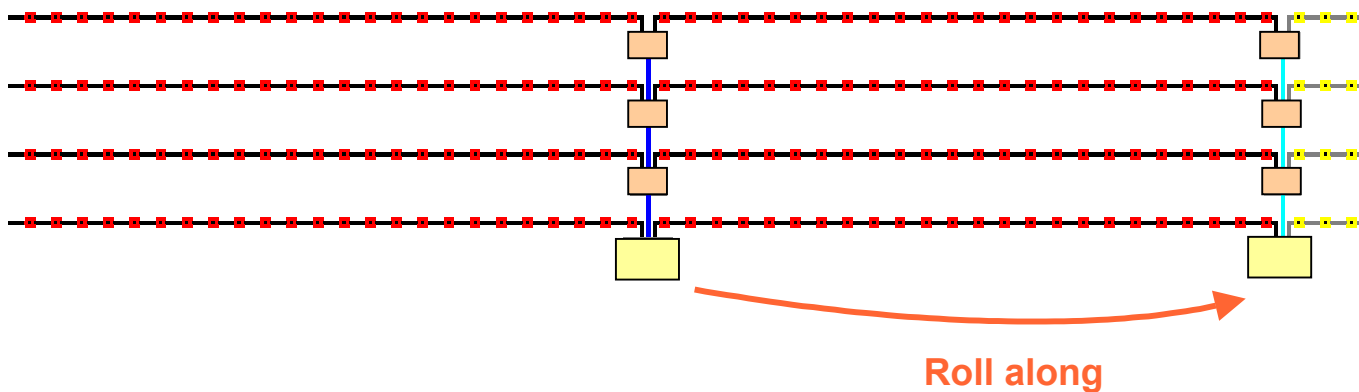
Ω IRIS instruments

SKETCH OF A 3D RESISTIVITY IMAGING SURVEY
with one « SYSCAL Switch » and three « Switch units »

« SQUARE TYPE » CONFIGURATION

SYSCAL Switch

Switch unit

Roll along

« RECTANGLE TYPE » CONFIGURATION

Roll along

IRIS instruments

SKETCH OF A 3D RESISTIVITY IMAGING SURVEY
with a « SYSCAL Switch » and 72 electrodes

2D CONFIGURATION FOR A ONE LINE SURVEY, WITH 72 ELECTRODES

1,2,3,…   (electrode number)   **36, 37,…**   **72**

SYSCAL
Switch
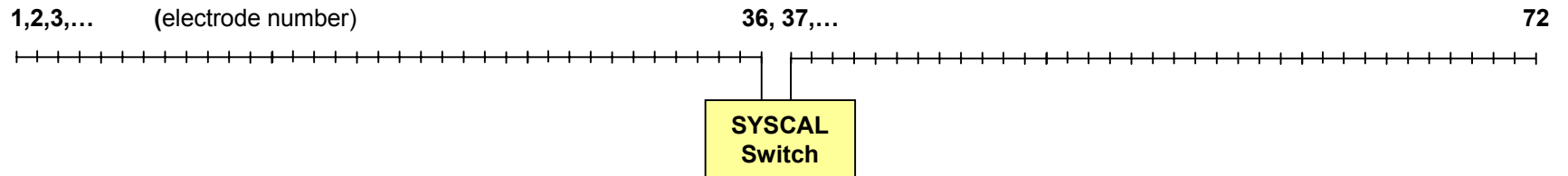
3D CONFIGURATION FOR A 6 LINE SURVEY, WITH 12 ELECTRODES / LINE

12	1	*line 1*
13	24	*line 2*
36	25	*line 3*
37	48	*line 4*
60	49	*line 5*
61	72	*line 6*

SYSCAL
Switch
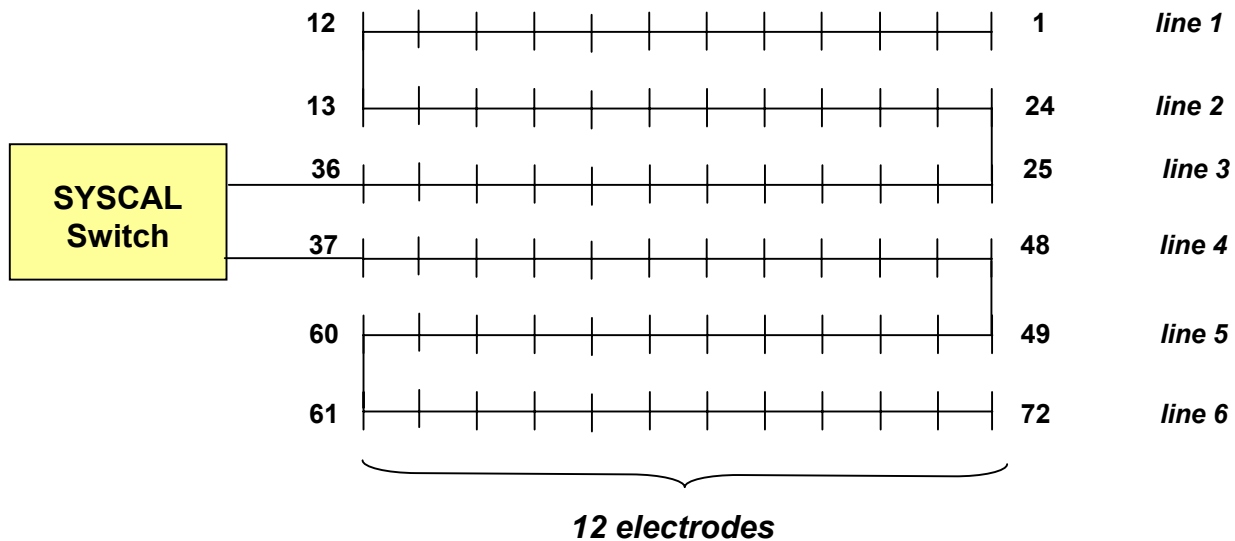
6 lines x 12 electrodes
=
72 ELECTRODES

12 electrodes

IRIS
instruments

CREATION OF 3D SEQUENCES FOR 72 ELECTRODES with ELECTRE III software

INTRODUCE THE ELECTRODE COORDINATES WITH THE AUTOMATIC NUMBERING PROCEDURE
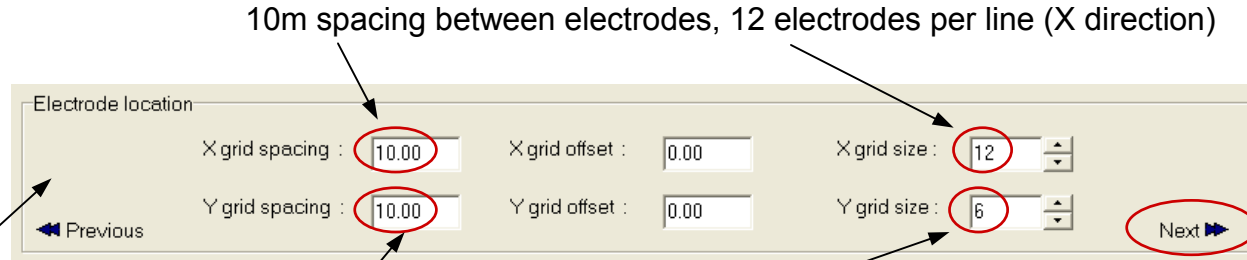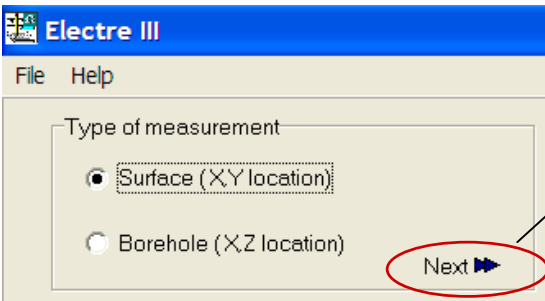
10m spacing between electrodes, 12 electrodes per line (X direction)

Electre III

File   Help

Type of measurement

- (●) Surface (XY location)
- (○) Borehole (XZ location)

Next ►►

Electrode location

| X grid spacing : | 10.00 | X grid offset : | 0.00 | X grid size : | 12 |
| Y grid spacing : | 10.00 | Y grid offset : | 0.00 | Y grid size : | 6 |

◄◄ Previous   Next ►►

10m separation between lines, 6 lines, (Y direction)

Y | X	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00
0.00												1
10.00												
20.00												
30.00												
40.00												
50.00												

click in case 1 and use "click and drag" to select the first line to number

Y | X	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00
0.00	12	11	10	9	8	7	6	5	4	3	2	1
10.00												
20.00												
30.00												
40.00												
50.00												

repeat the operation for all the other lines to number

Grid function

- (●) Increment electrode value
- (○) Delete all selection

Increment in :
- (○) Row
- (○) Column

Step : 1

✔ Apply   ✗ Cancel

Y | X	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00
0.00	12	11	10	9	8	7	6	5	4	3	2	1
10.00	13	14	15	16	17	18	19	20	21	22	23	24
20.00	36	35	34	33	32	31	30	29	28	27	26	25
30.00	37	38	39	40	41	42	43	44	45	46	47	48
40.00	60	59	58	57	56	55	54	53	52	51	50	49
50.00	61	62	63	64	65	66	67	68	69	70	71	72
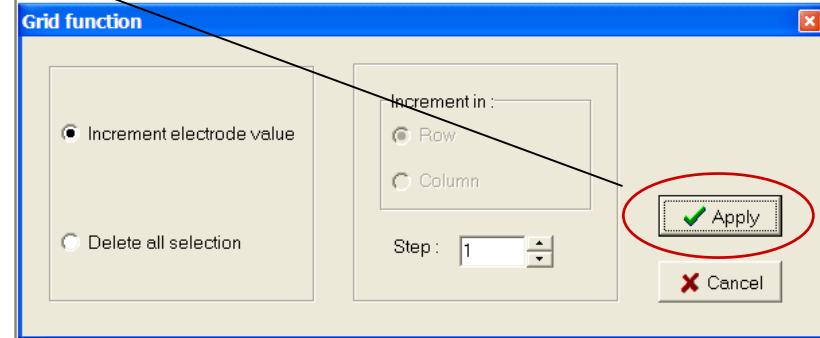
Next ►►

CREATION OF 3D SEQUENCES FOR 72 ELECTRODES

CHOOSE THE ELECTRODE ARRAY(S) FOR THE 3D RESISTIVITY IMAGING

3D = MANY ELECTRODES,
HIGH RESOLUTION REQUIRED

3D = ACQUISITION TIME
USUALLY < FIELD SET UP TIME
(ELECTRODES & CABLES, …)

USE SEVERAL SEQUENCES
CORRESPONDING
TO VARIOUS ELECTRODE ARRAYS, SO AS
TO HELP THE INVERSION SOFTWARE,
IN THE DELINEATION OF THE STRUCTURES

Type of array :

Wenner-Schlumberger

complete pole-pole
cross-diagonal pole-pole
dipole-dipole
dipole-dipole equatorial
pole-dipole forward
pole-dipole reverse
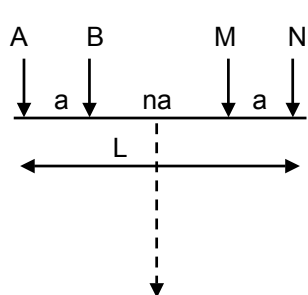Wenner
Wenner-Schlumberger
Schlumberger reciprocal

rank (1 : best)	penetration depth (in % of line length)	lateral resolution	signal amplitude	field set up (# of far electrodes)
1	Pole Pole (90%)	Dipole Dipole	Pole Pole	Wen Schlumb (0)
2	Pole Dipole (35%)	Pole Dipole	Wen Schlumb	Dipole Dipole (0)
3	Wen Schlumb (20%)	Wen Schlumb	Pole DIpole	Pole Dipole (1)
4	Dipole Dipole (20%)	Pole Pole	Dipole Dipole	Pole Pole (2)

with the **SYSCAL Pro SWITCH**
ELECTRE III optimizes the sequences
for enabling the SYSCAL to _simultaneously_ measure
as many readings as possible,
for reducing the acquisition time
(for Wen and Wen Schlum, use the Schlum reciprocal)

ONCE AN ELECTRODE ARRAY HAS
BEEN SELECTED, THE PROGRAM
AUTOMATICALLY GENERATES A
SEQUENCE WHICH INCLUDES ALL
THE POSSIBLE COMBINATIONS OF
THIS ELECTRODE ARRAY,
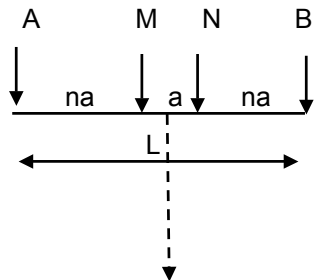**IN THE X AND Y DIRECTIONS**

IRIS
instruments

DEFINITION OF MOST USUAL ELECTRODE ARRAYS

Dipole Dipole

A   B   M   N

a   na   a

L

depth: **about 0.2** x **L**

Wenner-Schlu

A   M   N   B

na   a   na

L

depth: **about 0.2** x **L**

Schlum reciprocal

M   A   B   N

na   a   na

L

depth: **about 0.2** x **L**

Pole Dipole

B   A   M   N

∞   na   a

L

depth: **about 0.35** x **L**

Pole Pole

B   A   M   N

∞   a   ∞

L

depth: **about 0.9** x **L**

note: the electrode(s) at infinity must be placed at a distance of about 5 to 10 times the maximum line length of the array (L)

Type of array :
Wenner-Schlumberger
complete pole-pole
cross-diagonal pole-pole
dipole-dipole
dipole-dipole equatorial
pole-dipole forward
pole-dipole reverse
Wenner
Wenner-Schlumberger
Schlumberger reciprocal

rank (1 : best)	penetration depth (in % of line length)	lateral resolution	signal amplitude	field set up (# of far electrodes)
1	Pole Pole (90%)	Dipole Dipole	Pole Pole	Wen Schlumb (0)
2	Pole Dipole (35%)	Pole Dipole	Wen Schlumb	Dipole Dipole (0)
3	Wen Schlumb (20%)	Wen Schlumb	Pole DIpole	Pole Dipole (1)
4	Dipole Dipole (20%)	Pole Pole	Dipole Dipole	Pole Pole (2)

Equatorial Dipole DIpole

depth: **about 0.4** x **L**

A   M
a   L = na   a
B   N
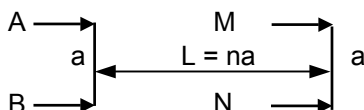
CREATION OF 3D SEQUENCES FOR 72 ELECTRODES

CREATE THE SEQUENCE OF READINGS WITH THE AUTOMATIC GENERATION PROCEDURE

select the electrode array

select the levels for the spacing «a»

select the levels for the spacing «2a»

select the levels for the spacing «3a»

select the number of channels measured simultaneously (1 for SYSCAL Jr, R1+, R2, 10 for SYSCAL Pro)

Type of array :
dipole-dipole

cross-diagonal pole-pole
dipole-dipole
dipole-dipole equatorial
pole-dipole forward
pole-dipole reverse
Wenner
Wenner-Schlumberger
Schlumberger reciprocal

IRIS instruments

First spacing
Level : 1

Edit level
Depth level selection :
- ✔ 1
- ✔ 2
- ✔ 3
- ✔ 4
- ✔ 5
- ✔ 6
- ✔ 7
- ✔ 8
- 9
- 10
- 11
- 12
- 19
- 20
- 21
- 22
- 23
- 24
- 25
- 26
- 27

✔ OK

Second spacing
2 x spacing
Level : 0

Edit level
Depth level selection :
- 1/2
- 1
- 3/2
- 2
- 5/2
- 3
- 7/2
- 4
- 9/2
- 5
- 11/2
- 6
- 13/2
- 7
- 15/2
- ✔ 8
- 17/2
- ✔ 9
- 19/2
- ✔ 10
- ✔ 11
- 23/2
- ✔ 12
- 25/2
- ✔ 13
- 27/2
- ✔ 14
- 29/2
- ✔ 15
- 31/2
- 16

✔ OK

Third spacing
3 x spacing
Level : 0

Edit level
Depth level selection :
- 37/3
- 38/3
- 13
- 40/3
- 41/3
- 14
- 43/3
- 44/3
- ✔ 15
- 46/3
- 47/3
- ✔ 16
- 49/3
- 50/3
- ✔ 17
- 52/3
- 53/3
- ✔ 18
- 55/3
- ✔ 56/3
- 19
- 58/3
- 59/3
- ✔ 20
- 61/3
- 62/3
- ✔ 21
- 64/3

✔ OK

Multi-channel optimization
Nb channel : 1

Multi-channel optimization
Nb channel : 10

Compute

Computed

Original sequence statistics
Quad. number : 336
Number of injection : 90
Number of channel(s) used : 8

computation of the sequence

Optimized sequence statistics
Quad. number : 336
Number of injection : 90
Number of channels finally used : 8
Optimization gain : 1

✔ OK
✖ Cancel

Enregistrer sous
Enregistrer dans : Electre III
- Comment.Txt
- DD.txt
- DDe.txt

give a name to the file which will include the sequence just defined («txt» format)

Nom du fichier : DDee   Enregistrer
Type : Text file (*.txt)   Annuler

Save as
C:\Program Files\IRIS Instruments\Electre III\DDee.txt

Save in file
- ✔ Electode coordinate
- ✔ Quadripole array

Separator
- ○ Comma
- ○ Space
- ● Tabulation

✔ OK
✖ Cancel

then, with ELECTRE II:
- press OPEN button to open the «txt» file
- save it as a «sqx» file (file menu),
- transfer it into the SYSCAL memory

FIELD DATA ACQUISITION WITH SYSCAL Switch

FIELD SET UP:

- dig the electrodes and connect them to the cables; connect the SYSCAL Switch to the cables

- select the **sequence** to apply

- check the batteries

- check the electrode ground resistance

- control **the quality** of the future readings by fixing the "stack min", "stack max", and "quality factor" (standard deviation) parameters

- run the selected sequence

ACQUISITION TIME FOR A SEQUENCE OF **1000 READINGS**	RESISTIVITY (5 stacks, 0.5s ON time)	RESISTIVITY & IP (15 stacks, 2s ON & OFF times)
SYSCAL R1 Plus Switch (1 channel measurement)	**1 hour**	**12 hours**
SYSCAL Pro Switch (10 channel measurement)	**8 minutes**	**1 hour ½**

SYSCAL R1 Plus Switch, 24, 48, 72

600V, 200W, 2.5A

10 simultaneous channel equipment

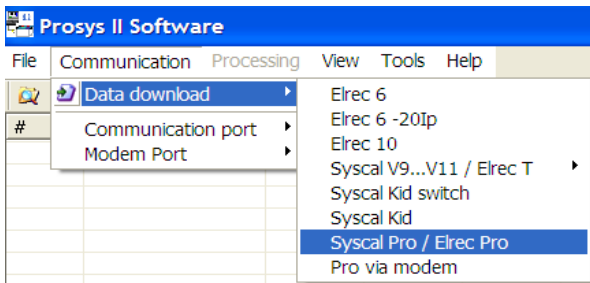**SYSCAL Pro Switch, 48, 72, 96**

800V, 250W, 2.5A

SWITCH Pro unit

(48, 72, 96 extension)
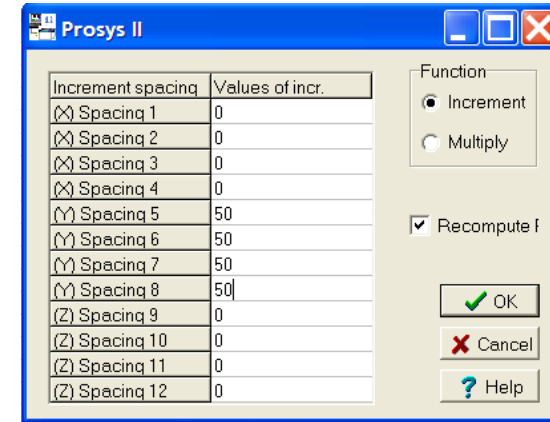
PROCESSING 3D DATA WITH PROSYS II SOFTWARE

DATA TRANSFER TO PC

- **Connect serial or USB link** (SYSCAL to PC)

- **Run PROSYS II** software: communication, data download, SYSCAL type, & follow PC indications

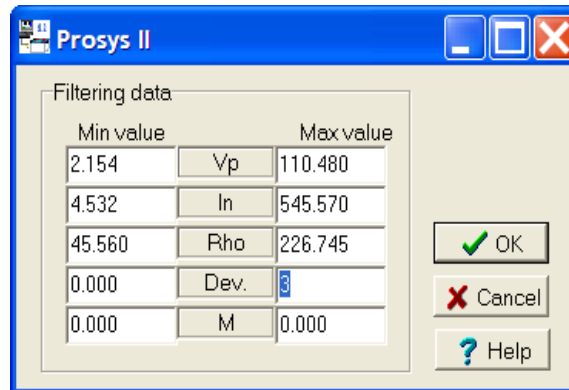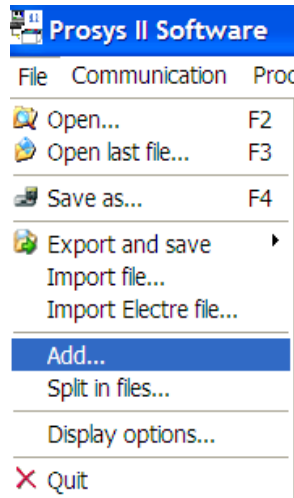- **Give a name** to the new global file data (.bin file)

MODIFY SPACING

If the spacing (like the line number Y of a profile) has to be changed, go to **"file / processing / modify spacing"** and key in the proper value (Y) for the A, B, M, N electrodes (spacings 5, 6, 7, 8) of all the readings of this file

Increment spacing	Values of incr.
(X) Spacing 1	0
(X) Spacing 2	0
(X) Spacing 3	0
(X) Spacing 4	0
(Y) Spacing 5	50
(Y) Spacing 6	50
(Y) Spacing 7	50
(Y) Spacing 8	50
(Z) Spacing 9	0
(Z) Spacing 10	0
(Z) Spacing 11	0
(Z) Spacing 12	0

Function
- ● Increment
- ○ Multiply

☑ Recompute F

✔ OK
✘ Cancel
? Help

Prosys II Software

File | Communication | Processing | View | Tools | Help

Data download →
- Elrec 6
- Elrec 6 -20Ip
- Elrec 10
- Syscal V9...V11 / Elrec T →
- Syscal Kid switch
- Syscal Kid
- Syscal Pro / Elrec Pro
- Pro via modem

Communication port
Modem Port

#

IRIS instruments

MERGING FILES

When various data files successively acquired on the same site and have to be interpreted together, they have first to be merged with the PROSYS II software: **Open** "file 1", **Add** "file 2", **Add** "file 3", **Save as,** and give a name to the file which will include all the data ("file 123")

Prosys II Software

File | Communication | Proc

- Open... F2
- Open last file... F3
- Save as... F4
- Export and save →
- Import file...
- Import Electre file...
- **Add...**
- Split in files...
- Display options...
- ✘ Quit

Filtering data

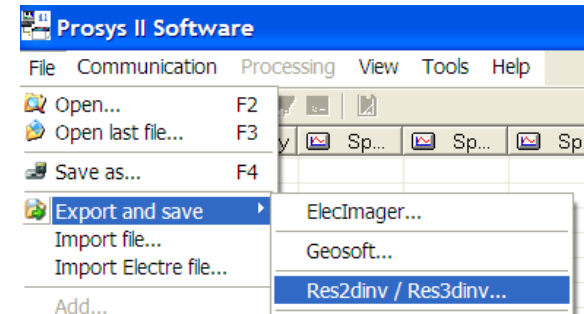| Min value		Max value
2.154	Vp	110.480
4.532	In	545.570
45.560	Rho	226.745
0.000	Dev.	3
0.000	M	0.000

✔ OK
✘ Cancel
? Help

FILTERING THE DATA

By using the **"processing / filtering"** function, it is possible to devalidate the noisy readings for which the standard deviation is greater than a given value (3% for example).
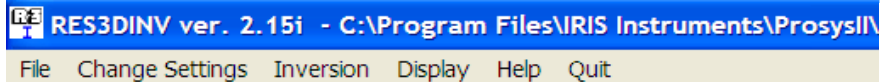
EXPORT TO RES3Dinv

Once the «.bin» data file has been processed with PROSYS II, export them towards RES3dinv, and give a name to this new file («.dat» file)

Prosys II Software

File | Communication | Processing | View | Tools | Help

- Open... F2
- Open last file... F3
- Save as... F4
- **Export and save** →
  - ElecImager...
  - Geosoft...
  - Res2dinv / Res3dinv...
- Import file...
- Import Electre file...
- Add...

FILE 1 + FILE 2 + FILE 3 → **FILE 123**

INTERPRETING 3D DATA WITH RES3Dinv SOFTWARE

BASIC OPERATING PROCEDURE OF THE RES3Dinv SOFTWARE

RES3Dinv MAIN MENU

RES3DINV ver. 2.15i - C:\Program Files\IRIS Instruments\ProsysII\

File   Change Settings   Inversion   Display   Help   Quit

CHANGE THE COLOUR SCALE

- click on "display / show inversion results", then on «display sections / display data and model sections"

- modify the **scale of the colours** (the resistivity limits for the 16 colours, or the colours themselves)

- store the new colour scale with the "file / store colour scale" function

HOW TO INVERT THE DATA ?

Introduce the data file (.dat) : "file / read data file", OK

Run the inversion: "inversion / least square inversion"

Display the results: "display / display results / display inversion model"

Select the type of display: "*sections*" (horizontal sections, at various depths) or "*slices*" (vertical slices, along various lines): *see examples on the next two slides*

EXPORT TO 3D VISUALIZATION PROGRAMS

Use the function **"file / export"** to make the RES3Dinv inversion result file compatible with the following 3D visualization software programs:
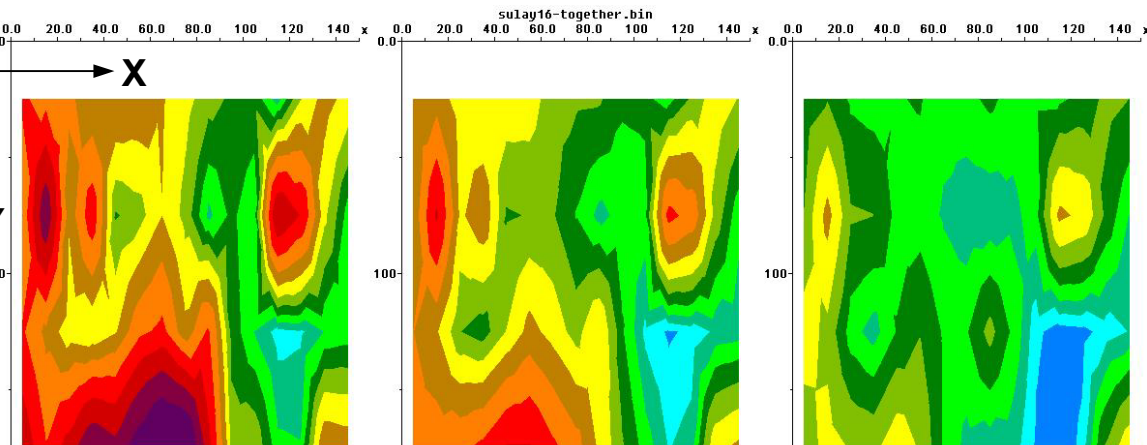
-**Slicer Dicer**

- **Rockware**

These programs visualize the inversion model in 3D, for a better understanding of the volumes of the various structures detected

see an example on third next slide

IRIS instruments

INTERPRETING 3D DATA WITH RES3Dinv SOFTWARE

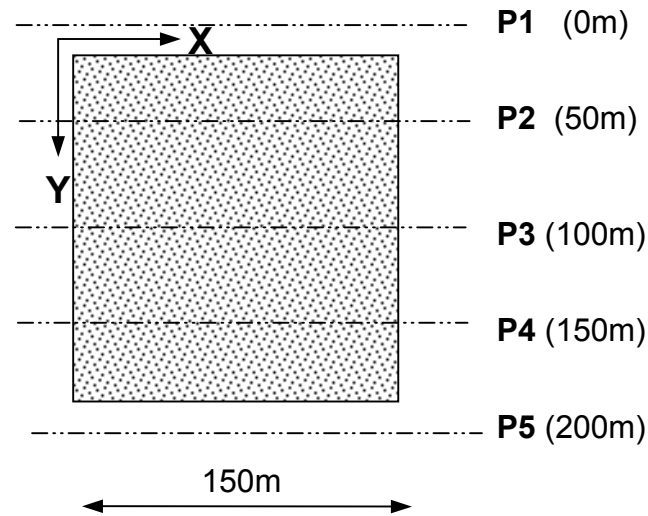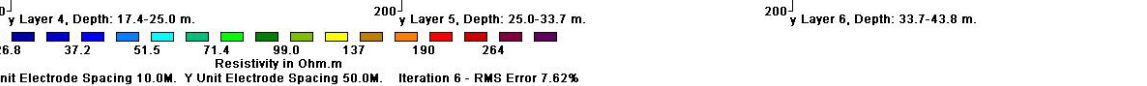## REPRESENTATION OF THE RESULTS IN HORIZONTAL SECTIONS AT VARIOUS DEPTHS
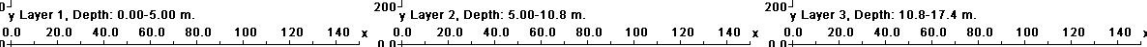
sulay16-together.bin

0-5m depth

y Layer 1, Depth: 0.00-5.00 m.

5-10m depth

y Layer 2, Depth: 5.00-10.8 m.

10-17m depth

y Layer 3, Depth: 10.8-17.4 m.

17-25m depth

y Layer 4, Depth: 17.4-25.0 m.

25-34m depth

y Layer 5, Depth: 25.0-33.7 m.

34-43m depth

y Layer 6, Depth: 33.7-43.8 m.

P1 (0m)
P2 (50m)
P3 (100m)
P4 (150m)
P5 (200m)

150m

5 PROFILES (P1 to P5)
with 16 electrodes at 10m spacing,
Wenner Schlumberger array

26.8   37.2   51.5   71.4   99.0   137   190   264
Resistivity in Ohm.m
nit Electrode Spacing 10.0M.   Y Unit Electrode Spacing 50.0M.   Iteration 6 - RMS Error 7.62%

IRIS
instruments

INTERPRETING 3D DATA WITH RES3Dinv SOFTWARE

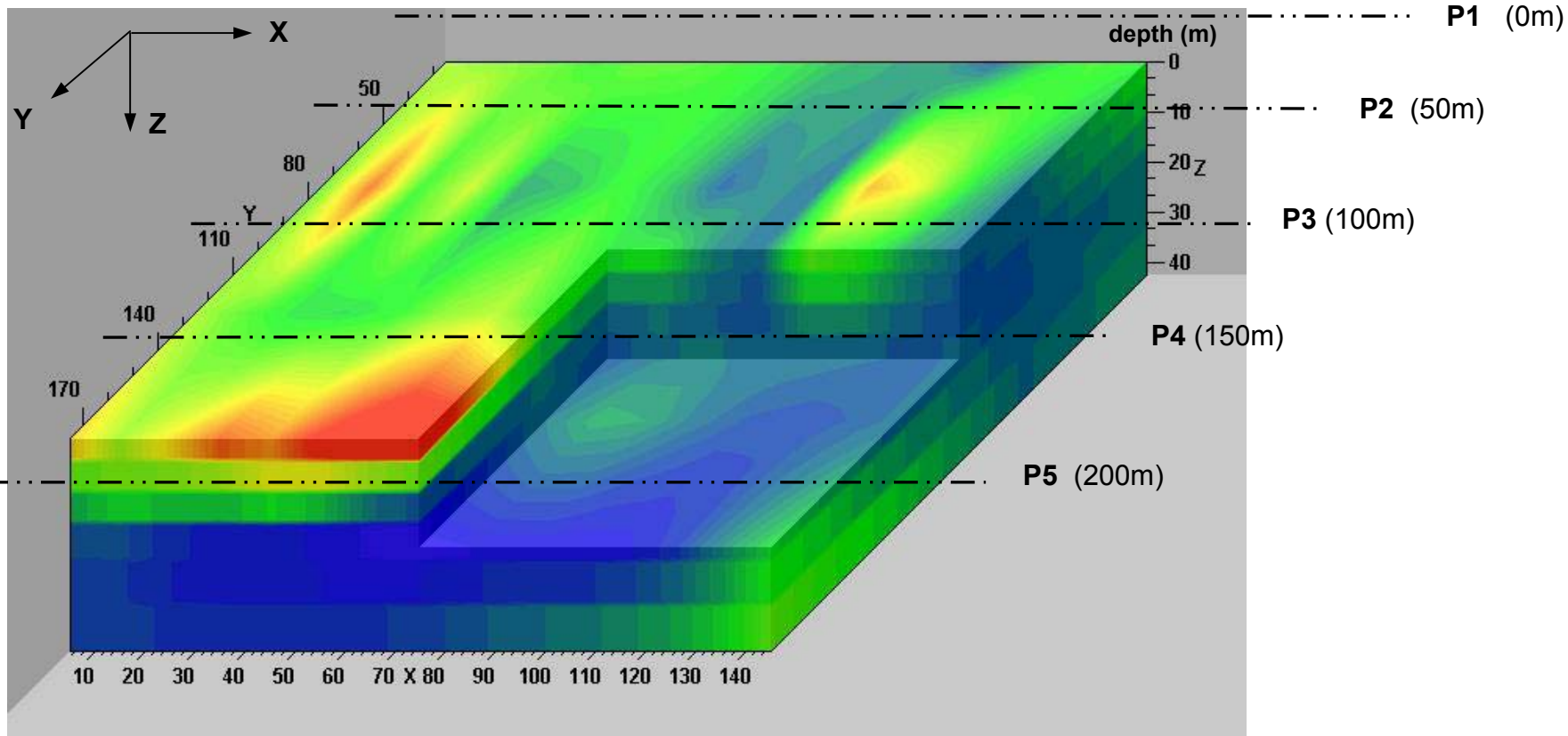## REPRESENTATION OF THE RESULTS IN VERTICAL SLICES, ALONG VARIOUS LINES
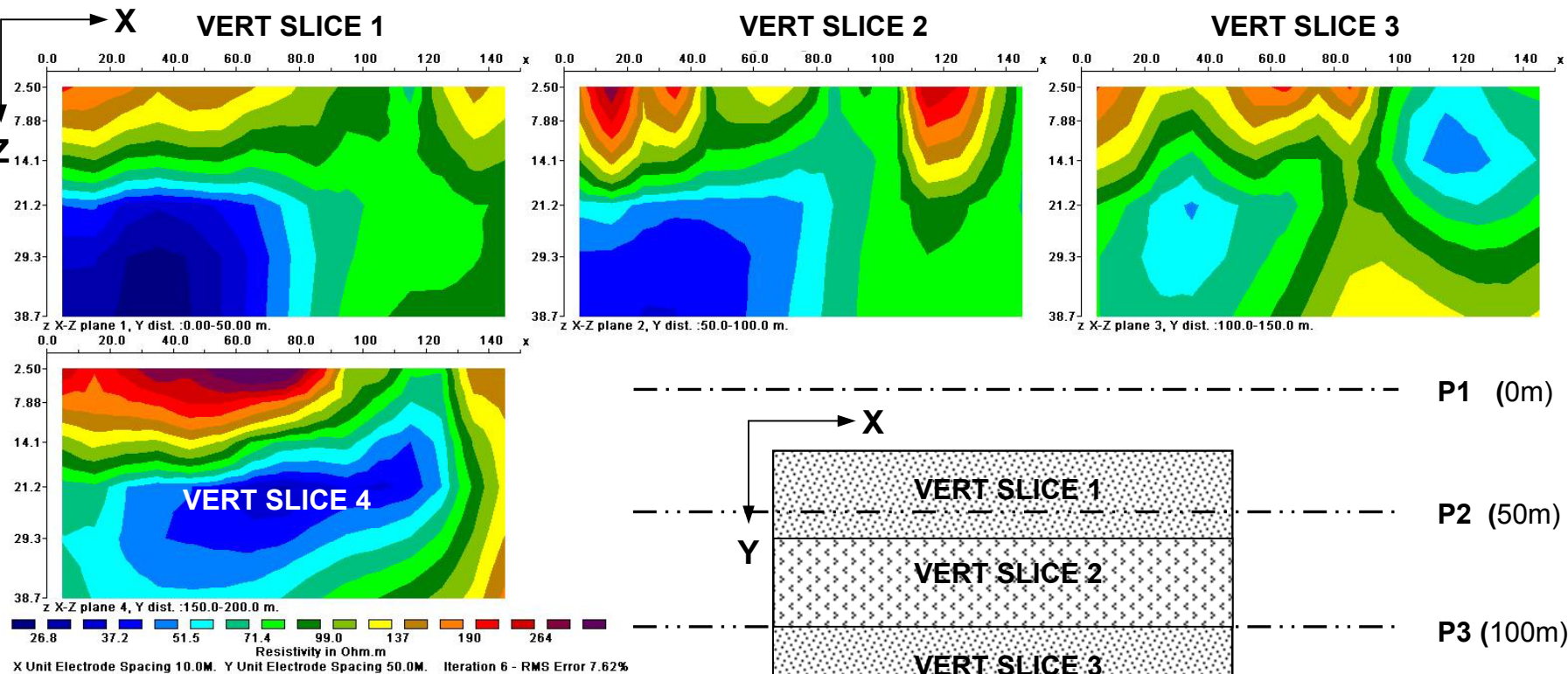
5 PROFILES (P1 to P5)
with 16 electrodes at 10m spacing,
Wenner Schlumberger array

PLOTTING 3D VOLUMES WITH SLICER / DICER PROGRAM

REPRESENTATION OF THE INVERSION RESULTS IN VOLUMES

RESISTIVITY values, in ohm.m

26.8 37.2 51.5 71.4 99.0 137 190 264

5 PROFILES (P1 to P5)
with 16 electrodes at 10m spacing,
Wenner Schlumberger array