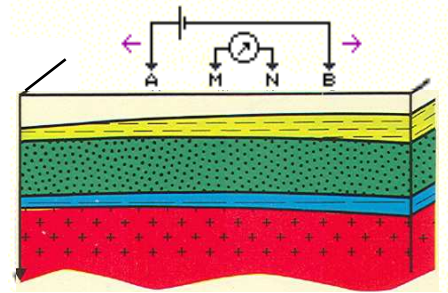


RESISTIVITY SOUNDING:

step-by-step operation of SYSCAL resistivitymeters

Principle of resistivity methods:

- Transmit a current I between two grounded electrodes
- Measure a voltage V between two other ones
- Compute the apparent resistivity $= K \times V / I$
- Move the electrodes to the next station and start a new reading
- Transfer the data to a PC to process them, and run an inversion software to interpret the results and get layer depths
- Correlate the values of the resistivity with the geological layers



THE RESISTIVITY OF ROCKS MAINLY DEPENDS ON:

- the quantity of water (matrix or fracture porosity)
- the resistivity of the water
- the content in clay material
- the content in metallic minerals

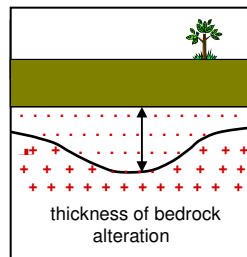
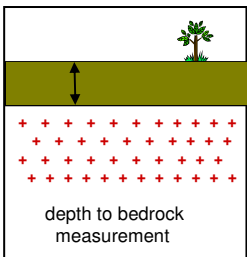
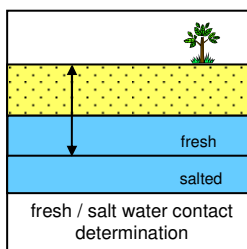
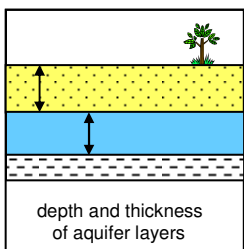
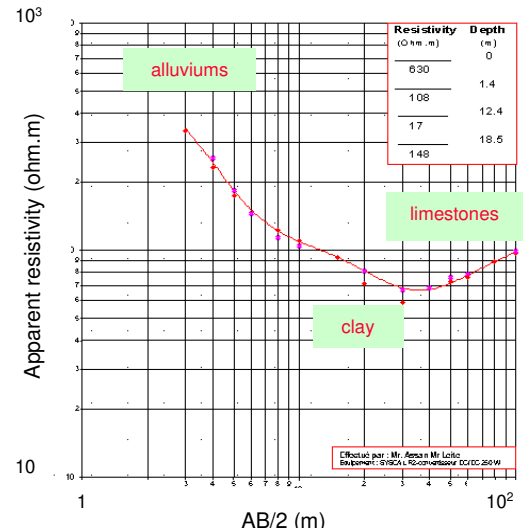
RESISTIVITY SOUNDING

Vertical Electrical Soundings, such as Schlumberger soundings, are carried out by increasing the transmitting line AB step by step for increasing the depth of penetration of the MN reading made in the middle of AB.

The apparent resistivity value obtained at each step is plotted as a function of $AB/2$, the plotting depth increasing from left to right.

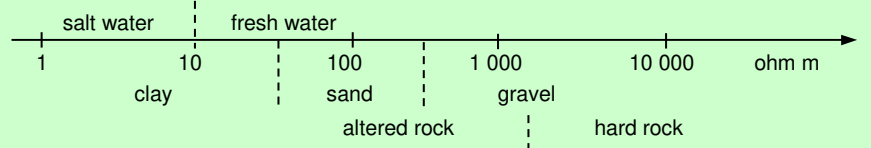
A PC 1D software gives the interpreted resistivities and the depths of each layer detected with the sounding

1D RESISTIVITY SOUNDING



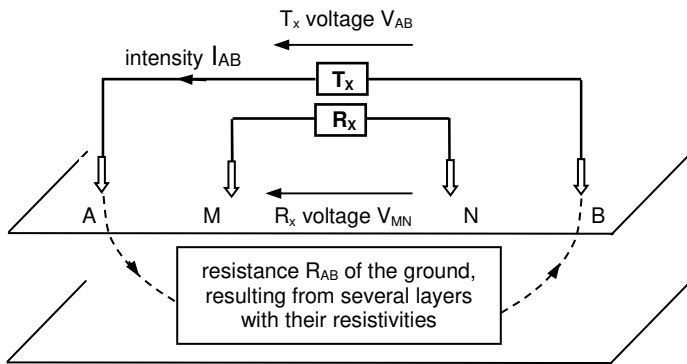
A few applications of vertical electrical soundings

RESISTIVITY SCALE FOR WATERS AND ROCKS



IRIS INSTRUMENTS - 1, avenue Buffon - 45100 Orléans - France
 Phone: +33 (0)2 38 63 81 00 - Fax: +33 (0)2 38 63 81 82
 E-mail: sales@iris-instruments.com - Web site: www.iris-instruments.com

RESISTIVITY SOUNDING: FIELD SET-UP



$$INTENSITY = Tx \text{ voltage} / \text{resistance}$$

$$I_{AB} = V_{AB} / R_{AB} \quad (\text{units: mA} = \text{V} / \text{kohm})$$

$$APPARENT \text{ RESISTIVITY} = (\text{coeff}) \times Rx \text{ voltage} / \text{intensity}$$

$$Rho = K \times V_{MN} / I_{AB} \quad (\text{units: ohm.m} = \text{m} \times \text{mV} / \text{mA})$$

$$\text{with } K = 2\pi / (1/AM - 1/AN - 1/BM + 1/BN)$$

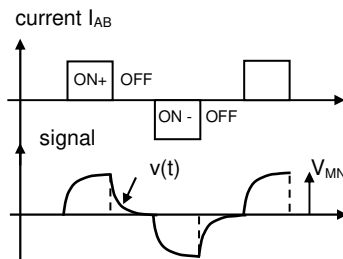
$$APPARENT \text{ CHARGEABILITY} = M = \int v(t) dt / V_{MN} \Delta t$$

(unit of chargeability: mV / V, or per mil)

SCHLUMBERGER SOUNDING DATA SHEET									
area:		site:			VES n°:				
operator:		equipment:			date:				
AB/2 m	MN/2 m	V _{AB} V	I _{AB} mA	V _{MN} mV	RHO ohm.m	Q %	M mV/V	Mem #	
2	0.5								
3	0.5								
4	0.5								
...	1								
5	0.5								
...	1								
6	1								
8	1								
...	2								
10	1								
...	2								
15	2								
...	5								

PRINCIPLE OF IP METHODS

The Induced Polarization (IP) phenomenon occurs with some types of minerals such as sulphide particles: when the pulse of current is switched off a decay curve is observed at the receiving electrodes. The M chargeability is a measurement of this decay



PRACTICAL MATTERS

The **SYSCAL resistivitymeter** is placed in the central part of the sounding.

The **metallic electrodes** have to be plugged into the ground as deeply as possible to decrease the ground resistance, for both the transmitting electrodes A, B, and the receiving electrodes M, N. A resistance of a few kohms is convenient (10 to 20 kohm max). When possible, water can be poured on the electrodes, or two electrodes can be set in parallel at each point to decrease this value.

The **wires** going from the SYSCAL to the A, B electrodes (up to several hundreds volts) have to be placed as far as possible from the wires going to the M, N electrodes (down to a few mV) to prevent insulation troubles.

The **sounding** starts by small values of the AB line (see table here above). For some values of the AB/2, two readings for different values of MN/2 have to be taken to check the lateral variations of the resistivity of the surface. Ideally, both resistivity values are identical.

The **AB/2 values** are logarithmically spaced (about 8 values par decade from 1 to 10, 10 to 100, 100 to 1000m, etc.)

When the measurement becomes noisy (standard deviation Q greater than 5%), it is recommended to decrease the ground resistance of the A, B electrodes to drive more current, to increase the number of stackings, and to repeat several times the same reading.

The **apparent resistivity values** have to be plotted on a bilogarithmic paper sheet, to check how the new reading compares with respect to the previous ones, before moving the A, B electrodes to the next measuring point.

The **data are stored** in the internal memory of the equipment after each reading

The **depth of investigation** is of the order of 20% of the length of the AB line.



PACKING LIST FOR A RESISTIVITY SURVEY

MAIN EQUIPMENT

The equipment (resistivitymeter), with charged batteries
The PC computer for data transfer and interpretation

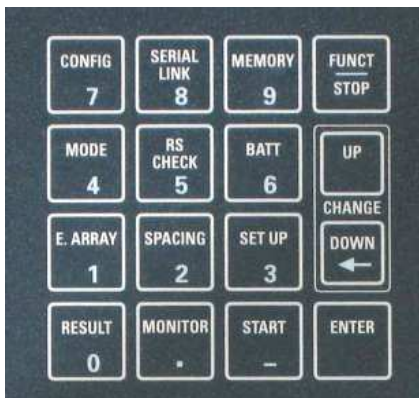
REELS AND ELECTRODES

Reels with electric wires for current transmission (AB line)
Reels with electric wires for voltage measurement (MN line)
Metallic stakes, with hammers
Cables and clips for wire to stake connection

OTHER ACCESSORIES

Measuring tapes (100m)
Tool kit box (pliers, screwdrivers, voltmeter, isolating tape)
Field note book and data sheets
External 12V car battery

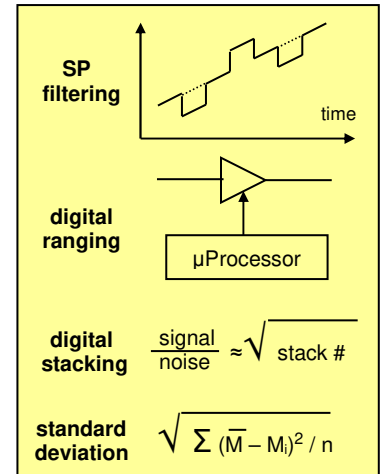
RESISTIVITY SOUNDING: SYSCAL Junior, R1 Plus, and R2 OPERATION



general use of the keyboard (SYSCAL Junior, R1 Plus, R2):

FUNCT: to select a function
UP, DOWN: to move in a menu
ENTER: to validate a value

Main differences in operation between SYSCAL Junior, R1 Plus and SYSCAL R2		
SYSCAL	Junior, R1 Plus	R2
converter	internal	external
battery	Rx: internal Tx: internal or external	Rx: internal Tx: external
electrode checking	between A and B plugs	between A-N, B-N, M-N
voltage fixing	in set up function: save energy, or 50, 100, 500 mV, corresponding to the V_{MN} required level	on the converter, turn the selector on the desired V_{AB} value



SUMMARY OF OPERATION

First reading :

connect wires, check batteries, select mode, times, stack number, quality factor, output voltage, electric array.

All readings:

check electrodes, introduce spacing AB/2, MN/2, press "start", wait for acquisition, read results, store in memory.

Check electrode connection:

Press "Rs CHECK" for Jr or R1 Plus:
 $R_s = 2.8 \text{ kohm } (R_{AB})$

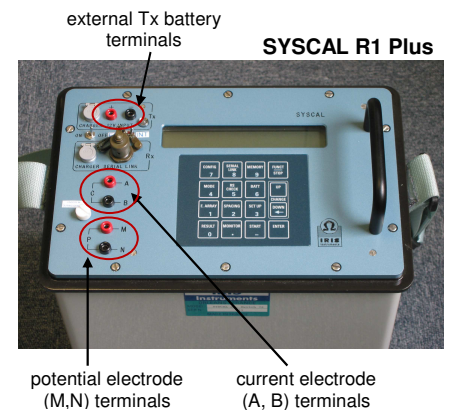
Press "Rs CHECK" for R2:
 hit R_s button A: $R_s = 2.4 \text{ kohm } (R_{AN})$
 hit R_s button B: $R_s = 3.6 \text{ kohm } (R_{BN})$
 hit R_s button M: $R_s = 1.9 \text{ kohm } (R_{CN})$

Check Rx internal battery:

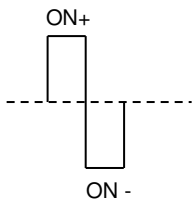
Press "BATT":
 R_x battery = 8.9V (between 5 and 9V)
 Capacity = 99% (between 0 and 100%)

Check Tx battery (Junior or R1 Plus):

- green light: the battery is OK,
 - yellow / red: recharge the battery



FOR SCHLUMBERGER SOUNDINGS (no IP)



1- MODE: RHO mode (no IP)
 (ON+, ON- current)

2- SET UP: Preset times, 500 ms
 Range 1/249, stack min, 3, stack max, 10
 Range 1/100, Q,E %, 3
 for SYSCAL Jr and R1Plus: Set T_x power to "save energy"

3- E. ARRAY: Schlumberger VES

4- SPACING: $AB/2 = 10$, $MN/2 = 2$,
 Line = 1, Opt = 0

5- START: $v = 26.4\text{mV}$ $I = 13.5\text{mA}$
 $q = 0\%$ # 8 stacks

6- RESULT: $U = 26.5\text{mV}$
 $I = 13.3\text{mA}$
(DOWN): $RHO = 304.8 \text{ ohm.m}$ $Q = 0\%$

FOR MEMORY MANAGEMENT

for data storage:
MEMORY. Store. Enter

for data reading:
MEMORY. Read. Enter

for memory clearing:
MEMORY, Clear, 0, 9, -, 7

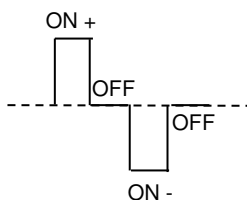
FOR DATA TRANSFER FROM SYSCAL TO PC

1- FROM PROSYS SOFT:
 communication, Data down load,
 SYSCAL version 9, Standard mode,
 First point, Last point, Download

2- FROM SYSCAL:
 Serial link, Baud rate,
 9600, Enter, Down, Dump
 Hexa, Down, Block, Enter

3- FROM PROSYS:
 OK. After the transfer, give a
 name to the file which will
 contain the data (ex.: **test.bin**)

FOR DIPOLE DIPOLE PROFILINGS (with IP)



1- MODE: RHO and IP (with IP)
 ON+, OFF, ON-, OFF current

2- SET UP: Preset times, 2000 ms
 Range 1/249, stack min, 5, stack max 20
 Range 1/100, Q,E %, 3

3- E. ARRAY: Dipole Dipole

4- SPACING: $XC = 10$, $XP = 20$,
 Dipole = 10 Line = 1

5- START: $v = 26.4\text{mV}$ $i = 13.5\text{mA}$
 $m = 14 \text{ mV/V}$ $q = 0\%$ # 8 stacks

6- RESULT: $U = 26.5\text{mV}$
 $I = 13.3 \text{ mA}$

(DOWN): $RHO = 304.8 \text{ ohm.m}$
 $Q = 0\%$ $M = 13.9 \text{ mV/V}$

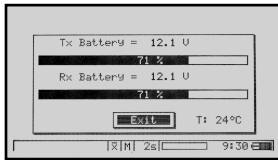
(DOWN): $M1 = 37.1$ $M2 = 25.1$
 $M3 = 14.6$ $M4 = 7.3$

RESISTIVITY SOUNDING: SYSCAL Pro OPERATION

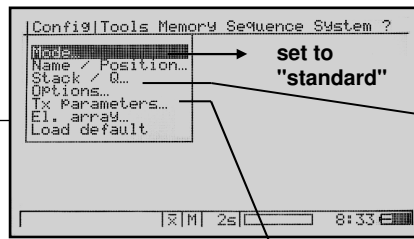


general use of the keyboard SYSCAL Pro):

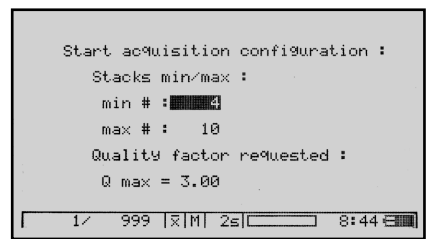
- MENU**: to reach the menu bar
- ▲, ▼, ◀, ▶**: to move in a menu
- ↵**: to validate a value



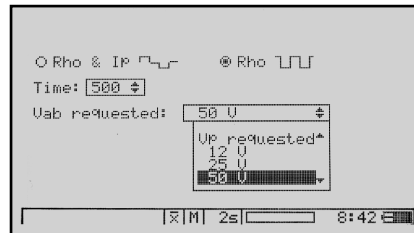
- Press **"Battery"** key to check voltages of:
- internal or external transmitter (Tx) battery
 - internal receiver (Rx) battery



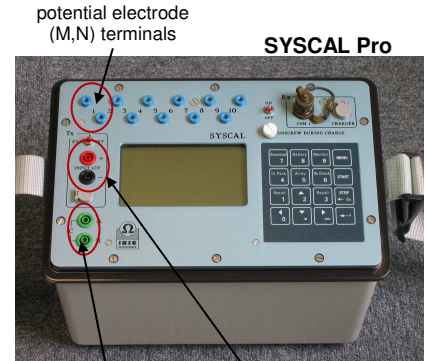
Screen after "switch on"



"Stack" function for fixing the min and max stack numbers and the Quality factor (standard deviation) requested



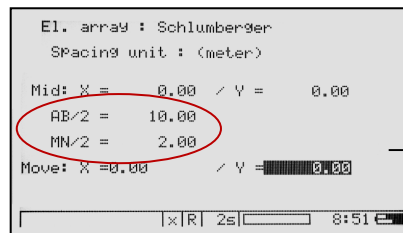
- "Tx parameters" function for:
- waveform (Rho, for ON+, ON- current)
 - pulse duration (500ms)
 - output voltage selection (U_{AB} , from 12 to 1000V), or level of input voltage requested V_P (from 50 to 3 000 mV), or Save Energy option (recommended)



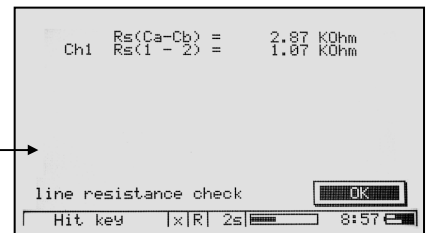
potential electrode (M,N) terminals
current electrode (A, B) terminals
external Tx battery terminals



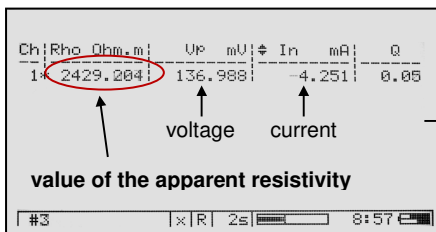
"El array" function for selecting the electrode array (Schlumberger)



Press the **"Start"** key for introducing the various spacing parameters: AB/2, MN/2



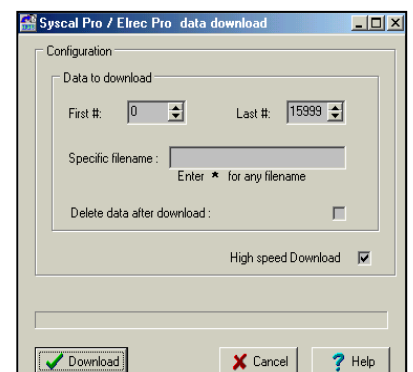
Then, the ground resistances of the electrodes are checked (R_{AB} and R_{MN})



Display of the results, at the end of the measurement, or with the **"Result"** key



Storage of the measurement; confirm the memory location (0 to 21 000)



Menu of PROSYS PC software during data download

FOR DIPOLE DIPOLE PROFILINGS (with IP) :

- in "El array", select dipole dipole, introduce the number of channels (up to 10) to use
- in "Tx parameters", select "Rho and IP" waveform, the number of IP windows, and 2000ms
- in "Start", introduce the coordinates of CA and P1, and the dipole length
- the other functions are identical to the Schlumberger sounding case

FOR MEMORY MANAGEMENT

for data storage:

MEMORY, Store, Enter

for data reading:

MEMORY, Recall, Enter

for memory clearing:

MEMORY, Delete data

FOR DATA TRANSFER FROM SYSCAL TO PC

1- FROM PROSYS SOFT:
Communication, Data download, SYSCAL Pro, Standard mode, First point, Last point, Download

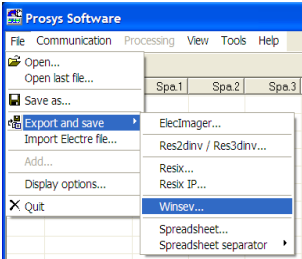
2- FROM SYSCAL:
Connect the serial link cord, then press the **"Download"** key

3- FROM PROSYS:
OK. After the transfer, give a name to the file which will contain the data: **test.bin**

RESISTIVITY SOUNDING: 1D INTERPRETATION

First step: from the PROSYS software, open the file which includes the field data (**test.bin**), with the 'file, open' instructions: each reading corresponds to a line which includes AB/2 (spa1), MN/2 (spa2), Rho and the other parameters (deviation, voltage Vp, intensity In). To discard a line, if the reading appears too much noisy for instance, click on the corresponding line with the right mouse button and select 'discard' the first column icon of the line becomes .

#	Earray	Spa.1	Spa.2	Spa.3	Spa.4	Rho	Dev.	M	Sp	Vp	In
111	Schlum. VES	3.00	1.00	6.00	2.00	96.44	0.0	0.00	-31.0	105.578	13.76
112	Schlum. VES	5.00	1.00	6.00	2.00	77.43	0.0	0.00	-3.0	30.378	14.79
113	Schlum. VES	7.00	1.00	6.00	2.00	72.96	0.0	0.00	-7.0	11.730	12.12
114	Schlum. VES	10.00	1.00	6.00	2.00	68.40	0.0	0.00	-6.0	9.588	21.80
115	Schlum. VES	10.00	2.50	6.00	2.00	64.90	0.0	0.00	-16.0	23.607	21.43
116	Schlum. VES	15.00	1.00	6.00	2.00	61.30	0.0	0.00	-3.0	3.637	20.88
117	Schlum. VES	15.00	2.50	6.00	2.00	57.90	0.0	0.00	-20.0	8.691	20.63
118	Schlum. VES	20.00	2.50	6.00	2.00	51.36	0.0	0.00	-20.0	4.730	22.79
119	Schlum. VES	30.00	2.50	6.00	2.00	40.99	0.0	0.00	-20.0	3.573	48.95
120	Schlum. VES	40.00	2.50	6.00	2.00	36.06	0.0	0.00	-20.0	1.208	33.55
121	Schlum. VES	50.00	2.50	6.00	2.00	39.34	0.0	0.00	-20.0	2.028	80.78



Second step: Always with the PROSYS software, create a file at the format of the WINSEV inversion software, using 'file, export and save, Winsev' instructions and give a name to this new file: **test.ws3**

New File/Nouveau fichier
Read/Lecture
Save/EnRegistre

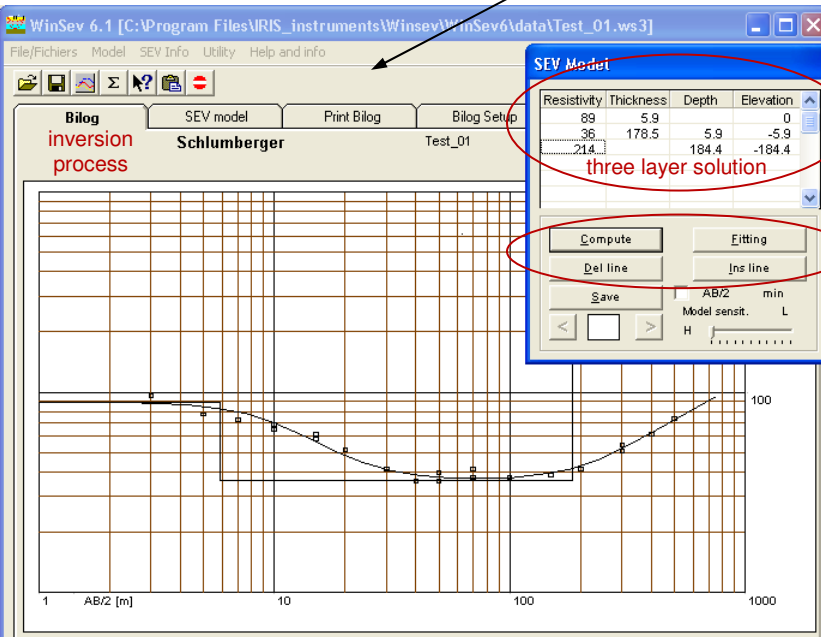
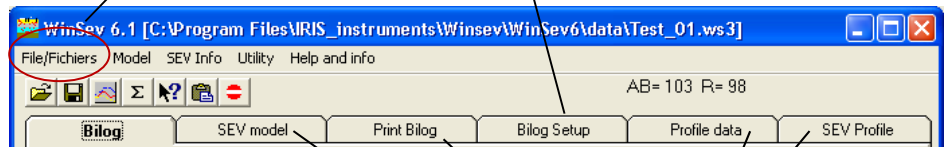
Bilog range

AB/2 min max

Rho app. min max

scale of diagram

Third step: run the WINSEV software, load the **test.ws3** file with the 'file, read' instructions. Click on 'SEV model' to see the data points, then on 'Bilog' to carry out the inversion



printing options for experimental data points and theoretical model

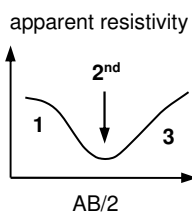
these functions are used to interpret several soundings carried out along a profile, for detecting lateral variations of resistivity with depth

	MN/2	AB/2	DeltaV	I	K	Resist.
1	.3	3				96.44
2	.3	5				77.43
3	.3	7				72.95
4	.3	10				68.39
5	.3	10				64.9
6	.3	15				61.29
7	.3	15				57.9
8	1	20				51.35
9	1	30				40.99
10	1	40				36.06
11	1	50				39.33
12	1	50				35.8
13	1	70				41.48
14	4	70				37.25
15	4	100				37.65
16	4	150				38.57
17	4	200				41.37
18	4	200				41.44
19	4	300				54.07
20	10	300				51.02
21	10	400				62.03
22	10	500				74

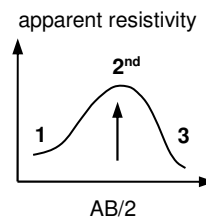
list of experimental data points of the sounding

Press 'fitting' and 'auto' to get the first inversion after the loading of the file.
Click on a line of the SEV model and on 'del line' to delete a layer of the interpretation section
Click on a line of the SEV model and on 'ins line' to insert a layer in the interpretation section
Click on a resistivity or a thickness or a depth case to modify the value, and key in the new value to introduce
Press 'compute' to display the theoretical curve corresponding to the new value, and 'fitting' to adjust the solution

EQUIVALENCE
From a theoretical point of view, several sets of layers with given thickness - resistivities can give the same apparent resistivity curves. This is known as the equivalence principle



In case of a 3 layer ground, if a thin 2nd layer is less resistive than the two other ones, only the ratio thickness / resistivity (known as the longitudinal conductance) characterizes this second layer: a 30m thick 20 ohm.m second layer gives the same apparent resistivity curve as a 15m thick 10 ohm.m layer (conductance 1.5 S)



If a thin 2nd layer is more resistive than the two other ones, it is the product thickness x resistivity (known as the transverse resistance) which is invariant: a 30m thick 20 ohm.m second layer gives the same apparent resistivity curve as a 15m thick 40 ohm.m layer (resistance 600 ohm.m²).

SYSCAL: A RANGE OF RESISTIVITY METERS FOR ELECTRICAL SOUNDINGS

SYSCAL Kid

200V, 25W, 0.5A



SYSCAL Junior

400V, 100W, 2.5A

SYSCAL R1 Plus

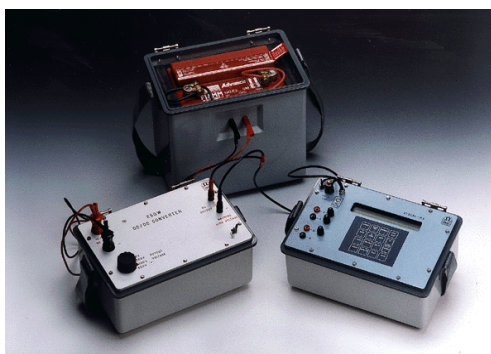
600V, 200W, 2.5A



SYSCAL R2

800V, 250W, 2.5A

800V, 1200W, 2.5A



SYSCAL Pro

1000V, 250W, 2.5A



PRODUCT name	power W	voltage V	current A	power converter	IP windows	receiving dipoles	display
SYSCAL Kid	25	200	0.5	internal	1	1	alpha num
SYSCAL Junior	100	400	1.2	internal	4	1	alpha num
SYSCAL R1 Plus	200	600	2.5	internal	4	1	alpha num
SYSCAL R2	250	800	2.5	DC/DC ext	4	1	alpha num
»	1200	»	»	AC/DC ext	»	»	»
SYSCAL Pro	250	1000	2.5	internal	20	10	graphical
»	500	1500	»	DC/DC ext	»	»	»

other electrical systems available for very deep resistivity and for IP surveys:
VIP transmitters (up to 3000V, 10 kW, 10A) with motor generators, and ELREC receivers

Specifications subject to change without notice NT_SYN_SON_GB_V1



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 E-mail: sales@iris-instruments.com - Web site: www.iris-instruments.com