SURVEY DESIGN

Two categories of field techniques exist for conventional resistivity analysis of the subsurface. These techniques are vertical electric sounding (VES), and Horizontal Electrical Profiling (HEP).

1- Vertical Electrical Sounding (VES) .

The object of VES is to deduce the variation of resistivity with depth below a given point on the ground surface and to correlate it with the available geological information in order to infer the depths and resistivities of the layers present.

In VES, with wenner configuration, the array spacing “a” is increased by steps, keeping the midpoint fixed (a = 2 , 6, 18, 54…….) .

In VES, with schlumberger, The potential electrodes are moved only occasionally, and current electrode are systematically moved outwards in steps

AB $\geq$ 5 MN.

2- Horizontal Electrical profiling (HEP) .

The object of HEP is to detect lateral variations in the resistivity of the ground, such as lithological changes, near- surface faults…… .

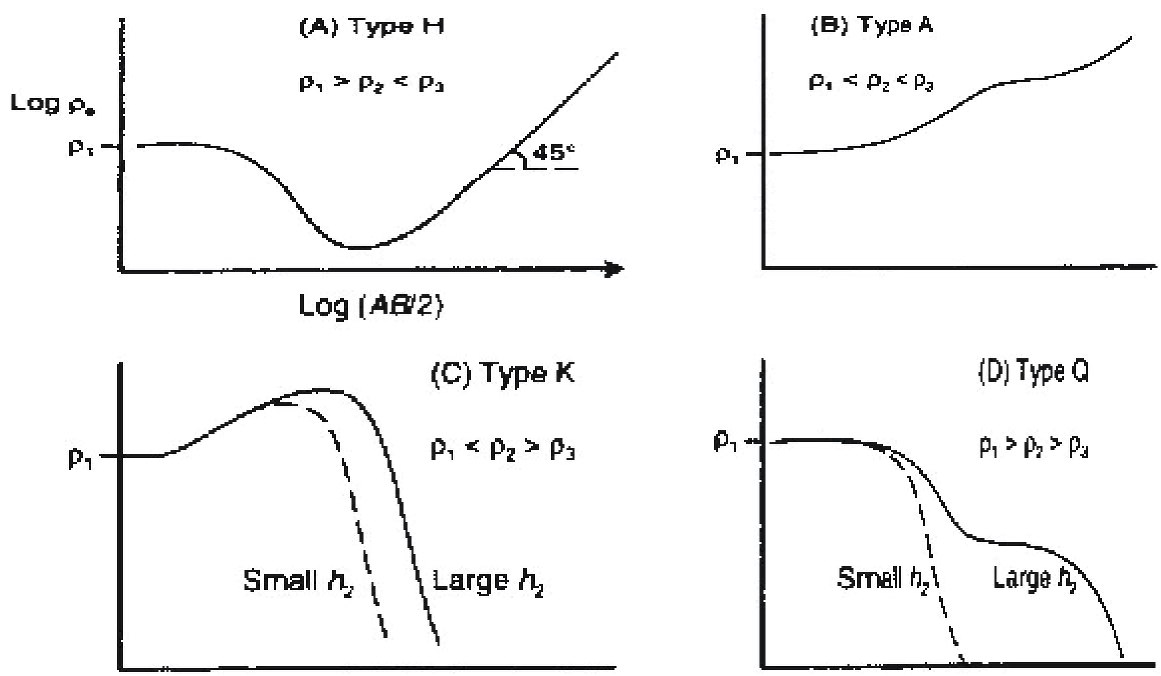
In the wenner procedurec of HEP , the four electrodes with a definite array spacing “a” is moved as a whole in suitable steps, say 10-20 m. four electrodes are moving after each measurement.

In the schlumberger method of HEP, the current electrodes remain fixed at a relatively large distance, for instance, a few hundred meters , and the potential electrode with a small constant separation (MN) are moved between A and B .

Multiple Horizontal Interfaces

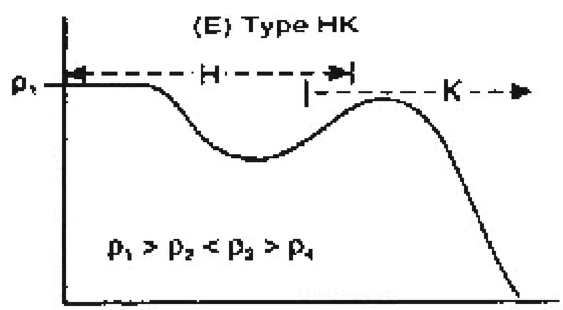
For Three layers resistivities in two interface case , four possible curve types exist.

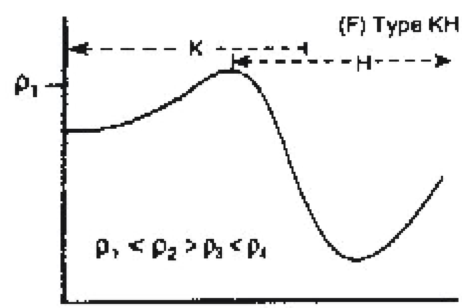
1- **Q – type** $\rho_1 > \rho_2 > \rho_3$
2- **H – Type** $\rho_1 > \rho_2 < \rho_3$
3- **K – Type** $\rho_1 < \rho_2 > \rho_3$
4- **A – Type** $\rho_1 < \rho_2 < \rho_3$



In four- Layer geoelectric sections, There are 8 possible relations :

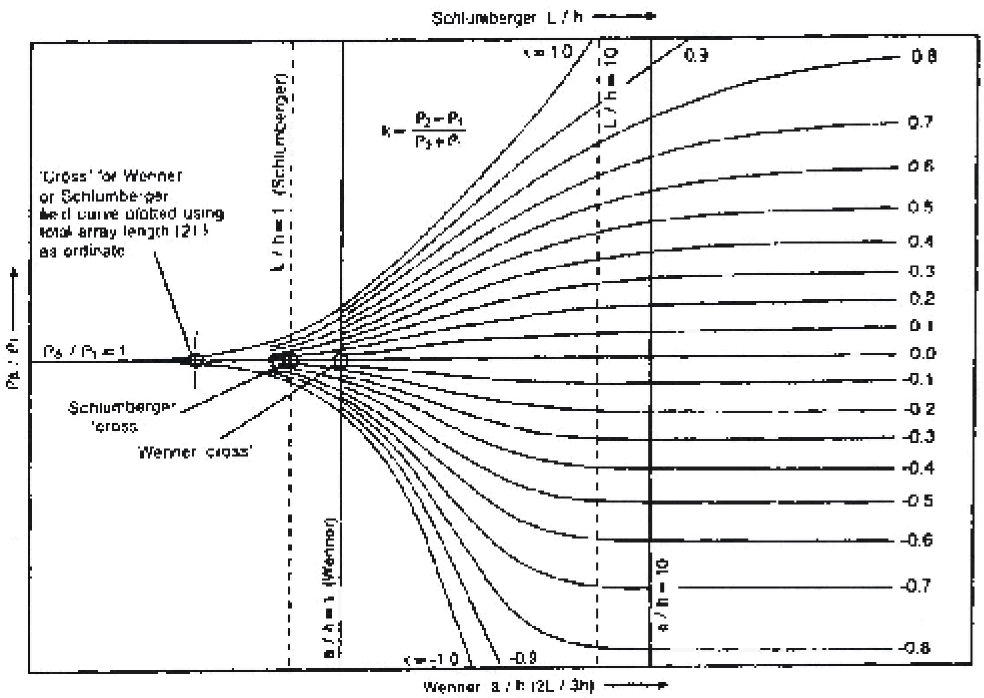
$\rho_1 > \rho_2 < \rho_3 < \rho_4$	**HA**	**Type**
$\rho_1 > \rho_2 < \rho_3 > \rho_4$	**HK**	**Type**
$\rho_1 < \rho_2 < \rho_3 < \rho_4$	**AA**	**Type**
$\rho_1 < \rho_2 < \rho_3 > \rho_4$	**AK**	**Type**
$\rho_1 < \rho_2 > \rho_3 < \rho_4$	**KH**	**Type**
$\rho_1 < \rho_2 > \rho_3 > \rho_4$	**KQ**	**Type**
$\rho_1 > \rho_2 > \rho_3 < \rho_4$	**QH**	**Type**
$\rho_1 > \rho_2 > \rho_3 > \rho_4$	**QQ**	**Type**





Quantitative VES Interpretation: Master Curves

Layer resistivity values can be estimated by matching to a set of master curves calculated assuming a layered Earth, in which layer thickness increases with depth. (seems to work well). For two layers, master curves can be represented on a single plot.



Master curves: log-log plot with ρ_a / ρ_1 on vertical axis and a / h on horizontal (h is depth to interface)

- Plot smoothed field data on log-log graph transparency.
- Overlay transparency on master curves keeping axes parallel.
- Note electrode spacing on transparency at which (a / h=1) to get interface depth.
- Note electrode spacing on transparency at which (ρ_a / ρ_1 =1) to get resistivity of layer 1.
- Read off value of k to calculate resistivity of layer 2 from:

Quantitative VES Interpretation: Inversion

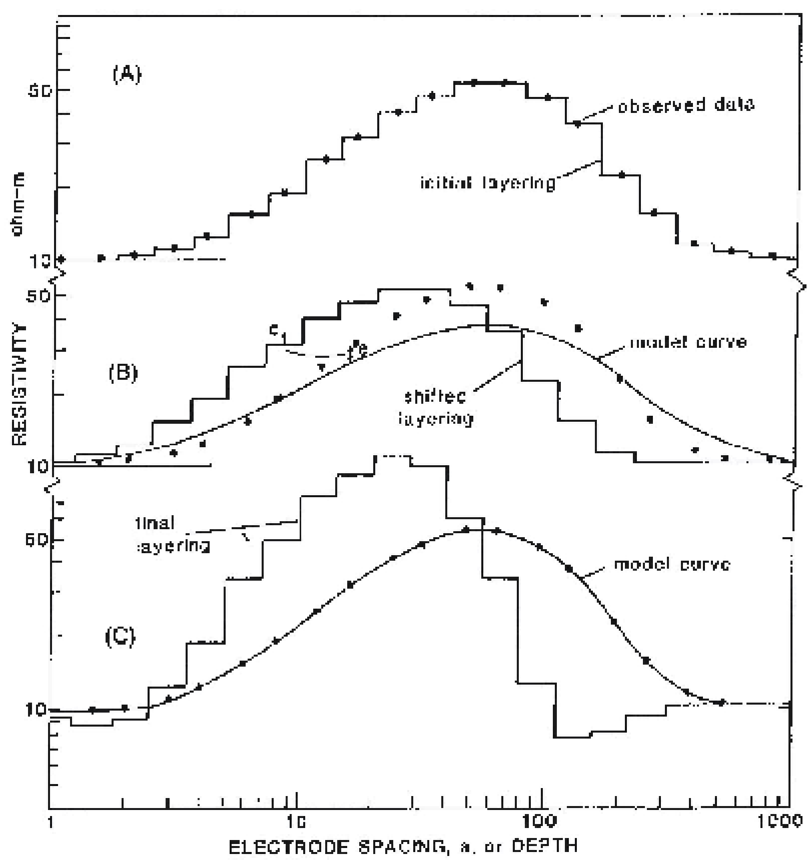
Curve matching is also used for three layer models, but book of many more curves.

Recently, computer-based methods have become common:

- forward modeling with layer thicknesses and resistivities provided by user
- inversion methods where model parameters iteratively estimated from data subject to user supplied constraints

Example (Barker, 1992)

Start with model of as many layers as data points and resistivity equal to measured apparent resistivity value.



Calculated curve does not match data, but can be perturbed to improve fit.

Applications of Resistivity Techniques

1. Bedrock Depth Determination

Both VES and CST are useful in determining bedrock depth. Bedrock usually more resistive than overburden. HEP profiling with Wenner array at 10 m spacing and 10 m station interval used to map bedrock highs.

2. Location of Permafrost

Permafrost represents significant difficulty to construction projects due to excavation problems and thawing after construction.

- Ice has high resistivity of 1-120 ohm-m

3. Landfill Mapping

Resistivity increasingly used to investigate landfills:

- Leachates often conductive due to dissolved salts
- Landfills can be resistive or conductive, depends on contents

Limitations of Resistivity Interpretation

1- **Principle of Equivalence**.

If we consider three-lager curves of K ($\rho_1 < \rho_2 > \rho_3$) or Q type ($\rho_1 > \rho_2 > \rho_3$) we find the possible range of values for the product $T_2 = \rho_2 h_2$ Turns out to be much smaller. This is called T-equivalence. H = thickness, T : Transverse resistance it implies that we can determine T_2 more reliably than ρ_2 and h_2 separately. If we can estimate either ρ_2 or h_2 independently we can narrow the ambiguity. Equivalence: several models produce the same results. Ambiguity in physics of 1D interpretation such that different layered models basically yield the same response.

Different Scenarios: Conductive layers between two resistors, where lateral conductance (σh) is the same. Resistive layer between two conductors with same transverse resistance (ρh).

2- Principle of Suppression.

This states that a thin layer may sometimes not be detectable on the field graph within the errors of field measurements. The thin layer will then be averaged into on overlying or underlying layer in the interpretation. Thin layers of small resistivity contrast with respect to background will be missed. Thin layers of greater resistivity contrast will be detectable, but equivalence limits resolution of boundary depths, etc.

The detectibility of a layer of given resistivity depends on its relative thickness which is defined as the ratio of Thickness/Depth.

Comparison of Wenner and Schlumberger

(1)	In Sch.	MN	≤	1/5	AB
	Wenner	MN	=	1/3	AB

(2) In Sch. Sounding, MN are moved only occasionally.
In Wenner Soundings, MN and AB are moved after each measurement.

(3) The manpower and time required for making Schlumberger soundings are less than that required for Wenner soundings.

(4) Stray currents that are measured with long spreads effect measurements with Wenner more easily than Sch.

(5) The effect of lateral variations in resistivity are recognized and corrected more easily on Schlumberger than Wenner.

(6) Sch. Sounding is discontinuous resulting from enlarging MN.

Disadvantages of Wenner Array

1. All electrodes must be moved for each reading
2. Required more field time
3. More sensitive to local and near surface lateral variations
4. Interpretations are limited to simple, horizontally layered structures

Advantages of Schlumberger Array

1. Less sensitive to lateral variations in resistivity
2. Slightly faster in field operation
3. Small corrections to the field data

Disadvantages of Schlumberger Array

1. Interpretations are limited to simple, horizontally layered structures
2. For large current electrodes spacing, very sensitive voltmeters are required.

Advantages of Resistivity Methods

1. Flexible
2. Relatively rapid. Field time increases with depth
3. Minimal field expenses other than personnel
4. Equipment is light and portable
5. Qualitative interpretation is straightforward
6. Respond to different material properties than do seismic and other methods, specifically to the water content and water salinity

Disadvantages of Resistivity Methods

1- Interpretations are ambiguous, consequently, independent geophysical and geological controls are necessary to discriminate between valid alternative interpretation of the resistivity data (Principles of Suppression & Equivalence)

2- Interpretation is limited to simple structural configurations.

3- Topography and the effects of near surface resistivity variations can mask the effects of deeper variations.

4- The depth of penetration of the method is limited by the maximum electrical power that can be introduced into the ground and by the practical difficulties of laying out long length of cable. The practical depth limit of most surveys is about 1 Km.

5. Accuracy of depth determination is substantially lower than with seismic methods or with drilling.

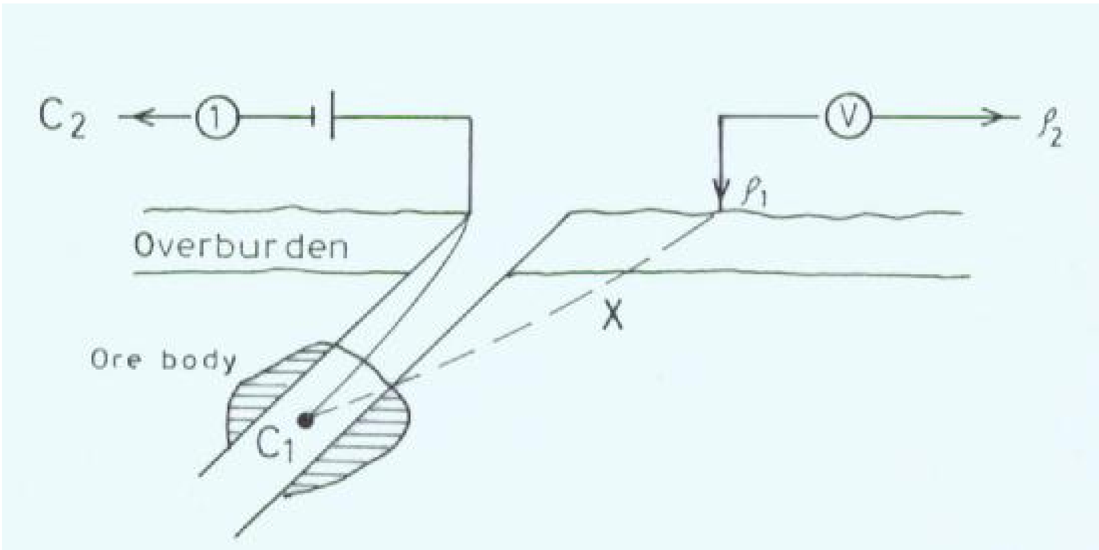
Lateral inhomogeneities in the ground affect resistivity measurements in different ways: The effect depends on

The size of inhomogeneity with respect to its depth

2. The size of inhomogeneities with respect to the size of electrode array
3. The resistivity contrast between the inhomogeneity and the surrounding media
4. The type of electrode array used
5. The geometric form of the inhomogeneity
6. The orientation of the electrode array with respect to the strike of the inhomogeneity

Mise-A-LA-Masse Method

This is a charged-body potential method is a development of HEP technique but involves placing one current electrode within a conducting body and the other current electrode at a semi- infinite distance away on the surface .



This method is useful in checking whether a particular conductive mineral- show forms an isolated mass or is part of a larger electrically connected ore body.

There are two approaches in interpretation

1- One uses the potential only and uses the maximum values a being indicative of the conductive body.

2- The other converts the potential data to apparent resistivity and thus a high surface voltage manifests itself in a high apparent resistivity

$\rho_a = 4\pi X V/I$:

Where X is the distance between C1 and P1.