Discussion of correlations between geotechnical and electrical data; case studies at France and India

Ze-Zong Lin

- Philippe Cosenza, Eric Marmet, Faycal Rejiba, Yu Jun Cui, Alain Tabbagh, Yvelle Charlery, 2006. **Corrections between geotechnical and electrical data; A case study at Garchy in France.** Journal of Applied Geophysics 60 165-178.
- Kumari Sudha, M. Israil, S. Mittal, J. Rai, 2009. **Soil characterization using electrical resistivity tomography and geotechnical investigations.** Journal of Applied Geophysics. 67 74-79.

Introduction

- **Geotechnical tests are time-consuming and expensive. On the other hand, geoelectrical method are faster and comparatively cheap. The number of geotechnical tests in a site investigation is commonly limited.**

- **Therefore, it is desirable to extrapolate and/or interpolate consistent 1D geotechnical data from geophysical measurements that are more rapid and non-invasive.**

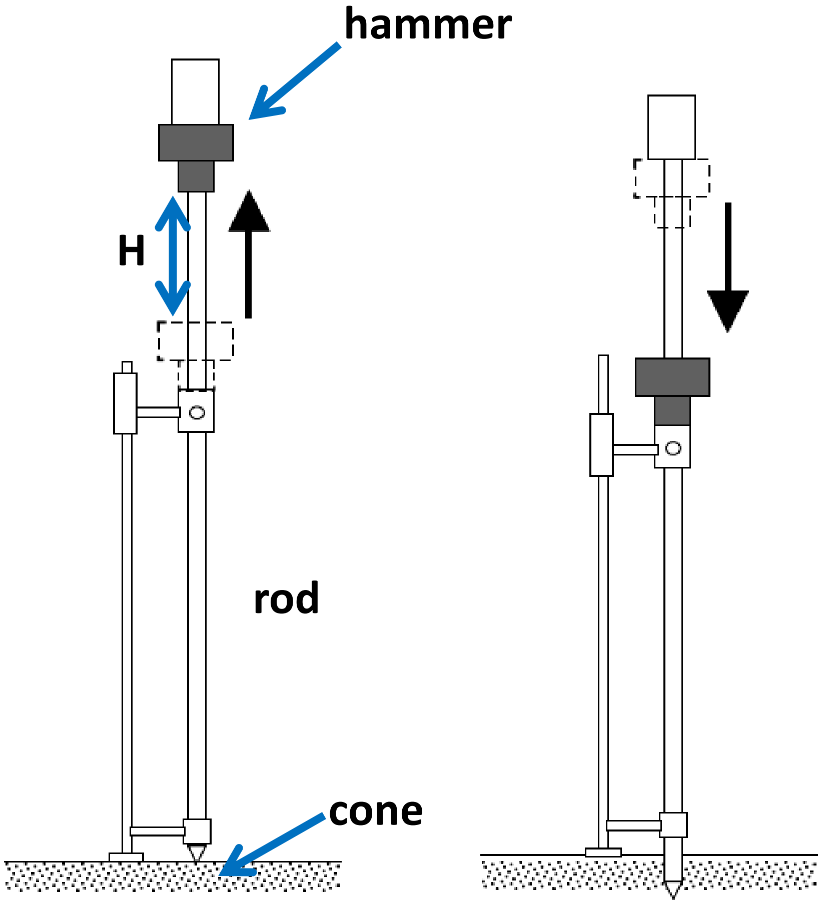
Case I: Garchy , France

- **In this case, the main objective is to provide a significant amount of data collected from the same site to analyse this set in order to establish correlations.**

- **The first part is devoted to the methodology used to collect geotechnical and geophysical data at the site.**

- **The second and the third parts deal with the qualitative and the quantitative analysis of this dataset respectively.**

Geotechnical test in this case



Dynamic cone penetration test

$$q_d = \frac{M}{e(M + M')} \frac{MH}{A}$$

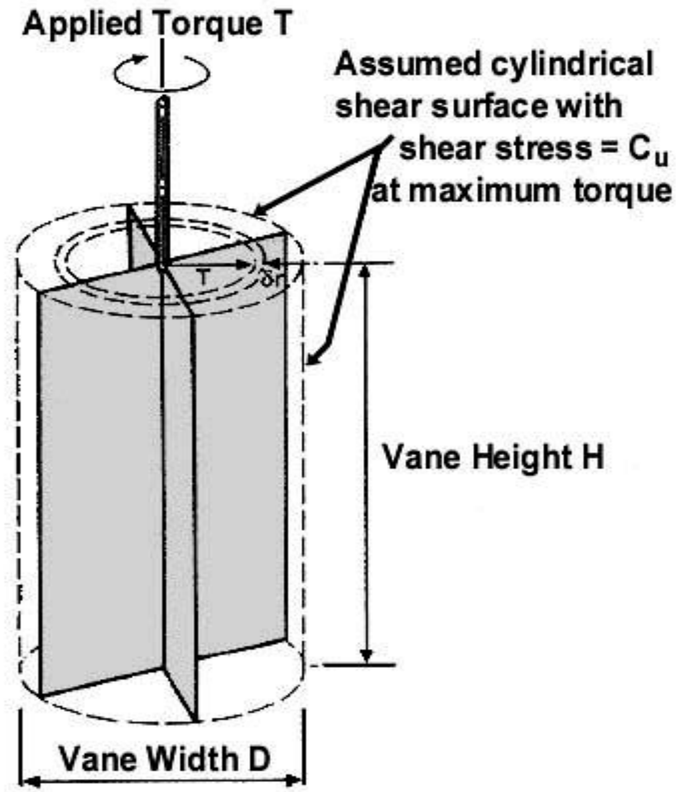
q_d : cone resistance

M : weight of the striking mass (hammer)

M’: weight of the sruck mass (rod+cone)

e : average penetration depth

H : height corresponding to the hammer fall



In situ vane shear test

$$C_u = \frac{T}{\pi D^2 \left(\frac{H}{2} + \frac{D}{6}\right)}$$

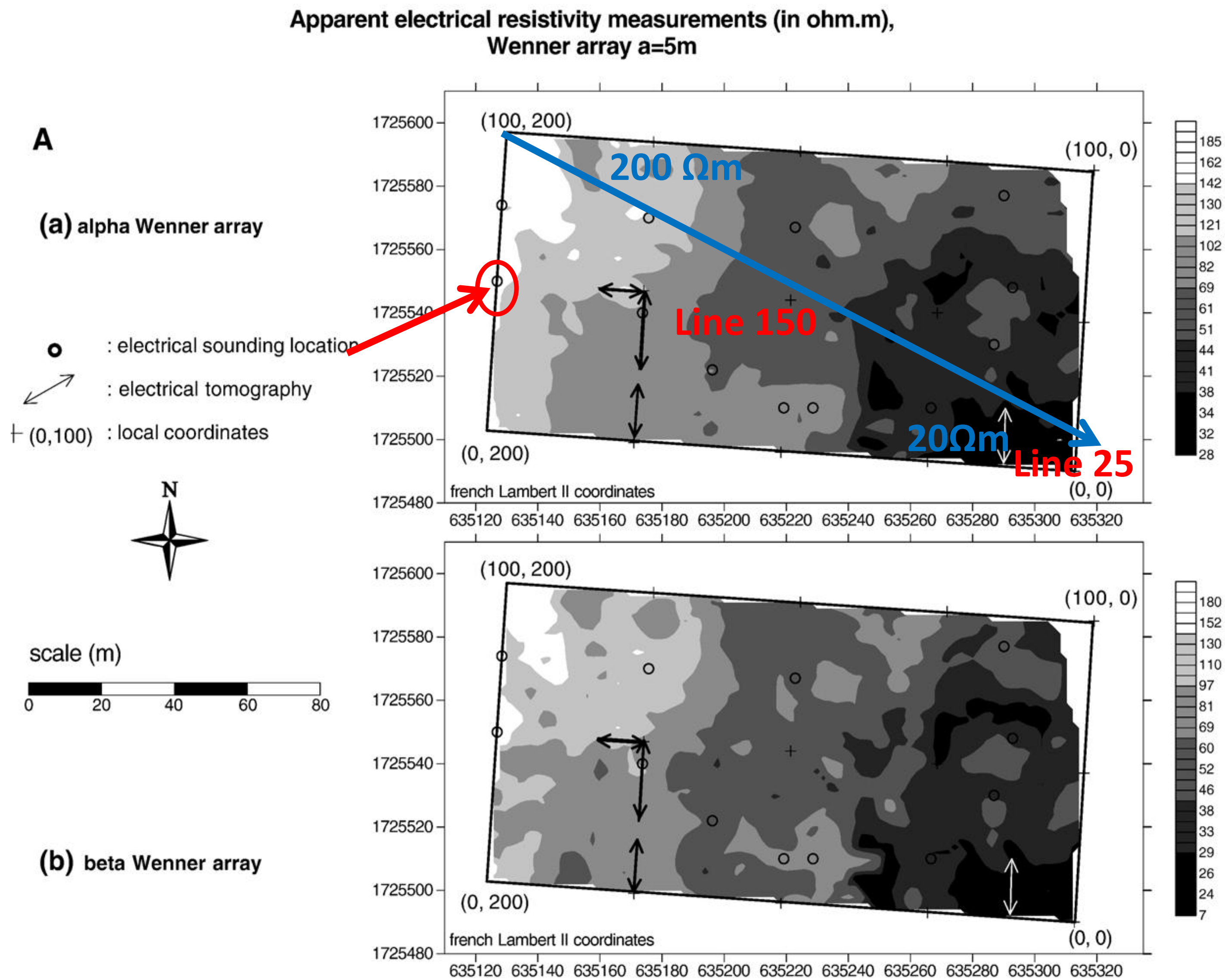
C_u : shear stranth

T : the torque at failure

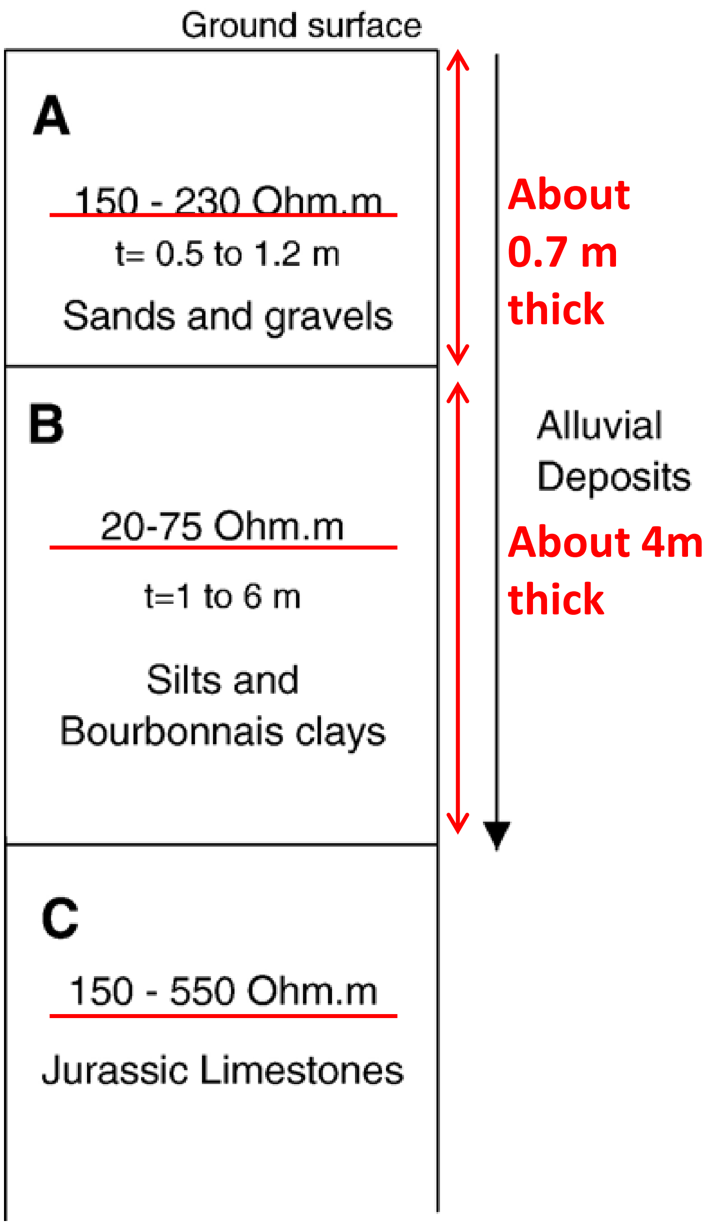
D : overall diameter of the vane

H : height of the vane

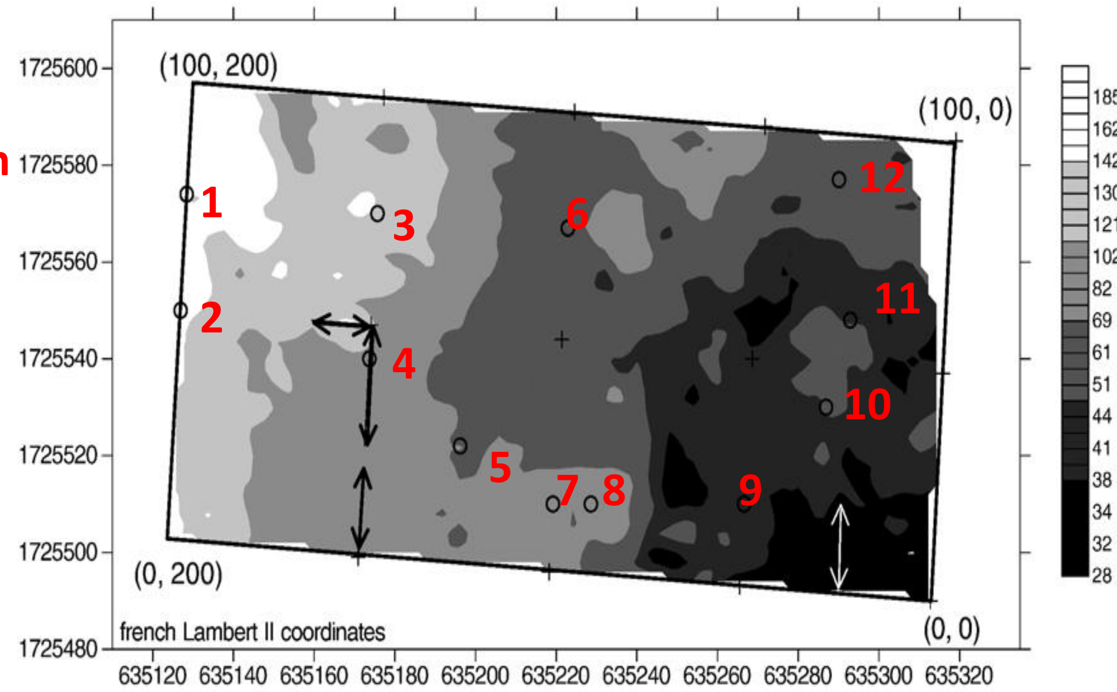
Result of the preliminary electrical survey



Electrical maps following two configurations (alpha Wenner array and beta Wenner array)



- **VES (vertical electrical sounding) curves obtained from 12 soundings with an alpha Wenner array suggested a three-layers organization.**

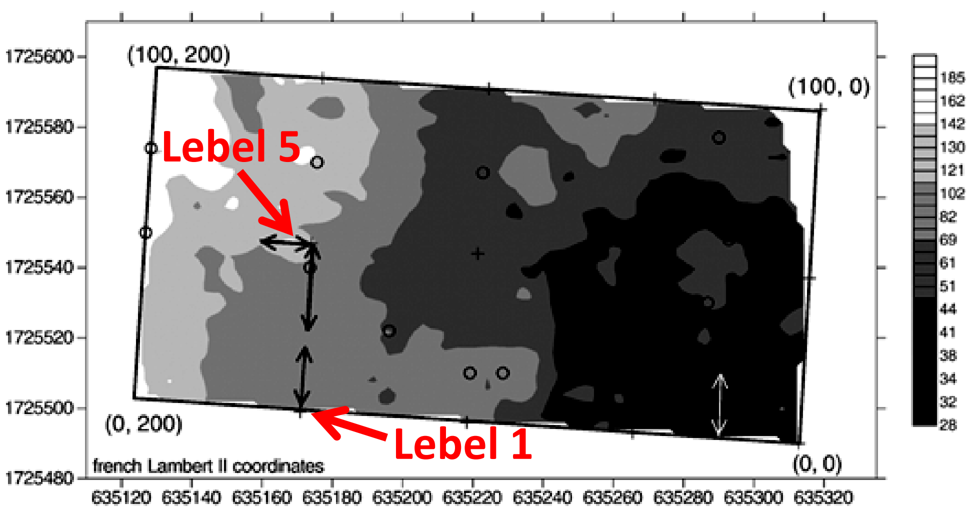


Location and electrode separation of the ERT profiles (see also Fig. 2)

Line	ERT profile	Label	Electrode separation (m)
Line 150	$x0.5–16y150$,	1	0.5
	$x2.5–18y150$,	2	
	$x24–39.5y150$,	3	
	$x34.5–50y150$,	4	
	$x50y150–165.5$ [a]	5	
	$x14–45y150$,	6	1
	$x19–50y150$	7	
Line 25	$x–1–14.5y25$	8	0.5

The 32 electrodes profiles were labelled according to the local coordinates (in the line) of the extreme electrodes. For instance, the ERT profile $x0.5–16y150$ means that both extreme electrodes in the single spread of 32 electrodes were located between the points $x=0.5$m $y=150$ m and $x=6$ m $y=150$ m in the local reference.

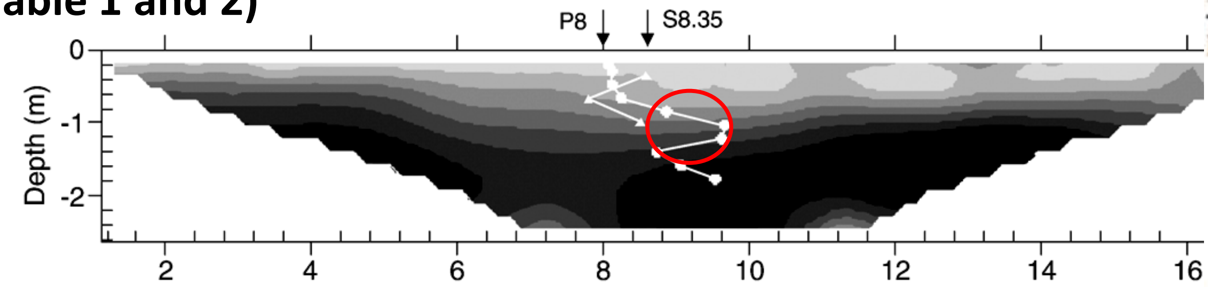
[a] This profile has been carried out perpendicular to the line 150.



- **Concerning the geotechnical data acquisition, in situ vane shear tests and dynamic cone penetration tests were initially designed alternatively every 4 m in line 150.**
- **But, the existence of gravels in the top layer A has limited the number of geotechnical tests: maximum depth of numerous tests was smaller than 50 cm.**

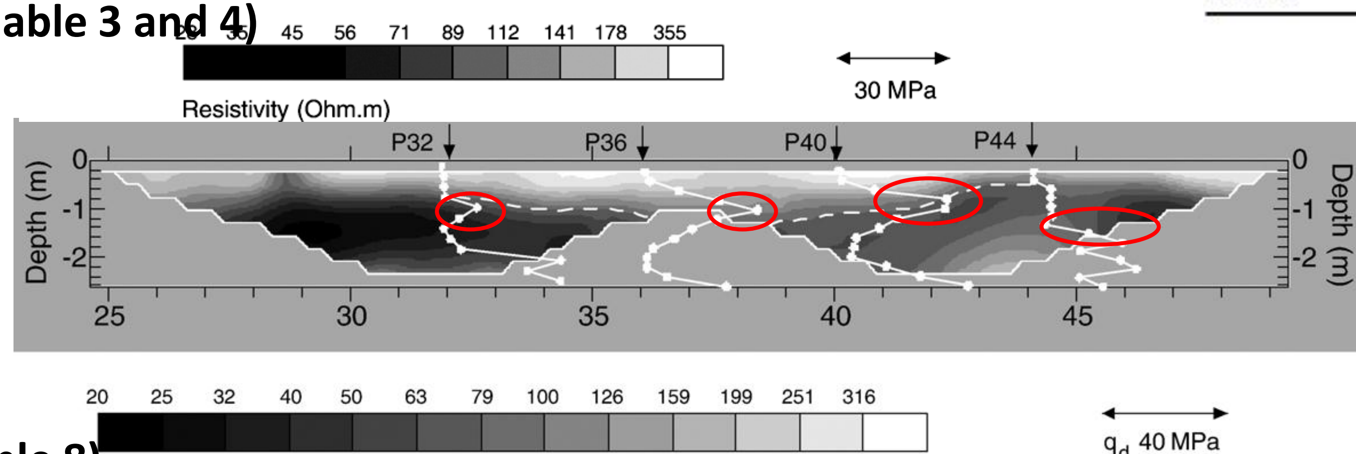
Qualitative correlations between electrical and geotechnical data

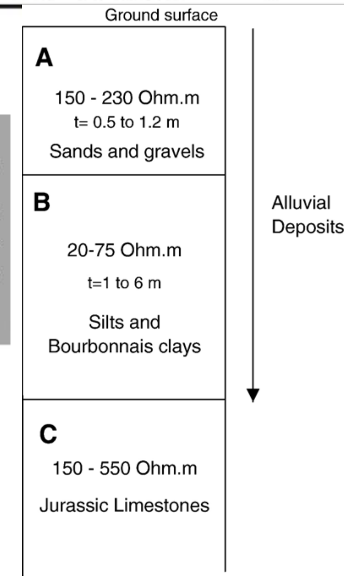
Line 150 (lable 1 and 2)



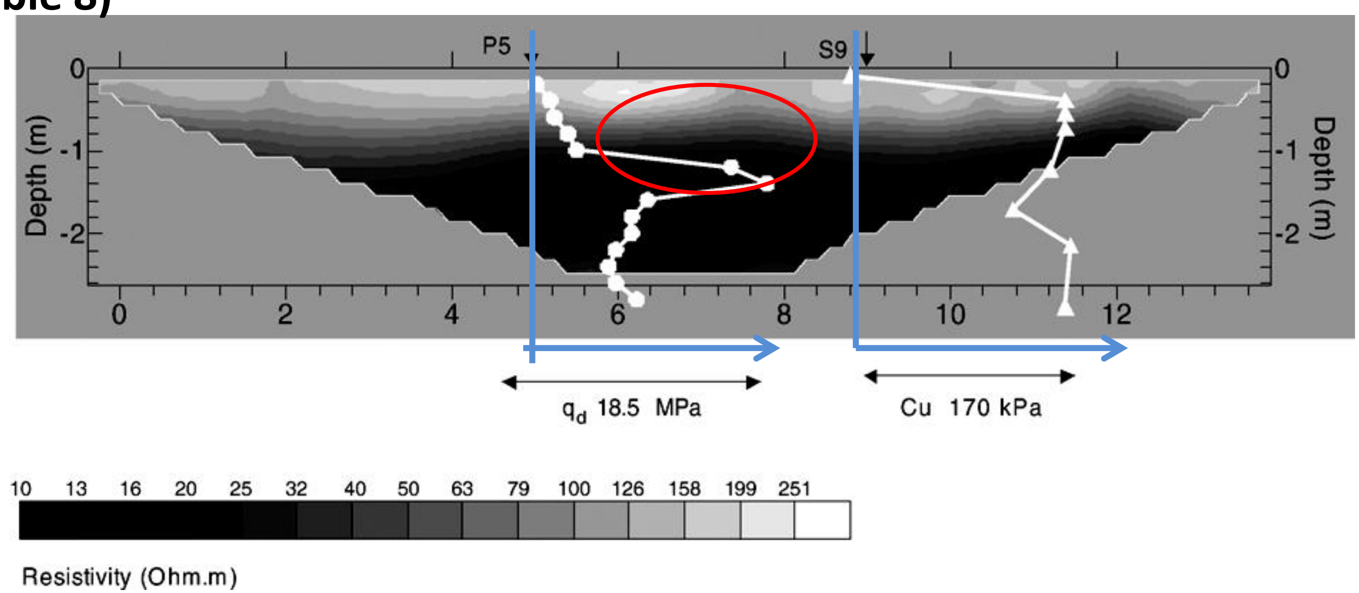
Line	ERT profile	Label
Line 150	*x*0.5–16*y*150,	1
	*x*2.5–18*y*150,	2
	*x*24–39.5*y*150,	3
	*x*34.5–50*y*150,	4
	*x*50*y*150–165.5[a]	5
	*x*14–45*y*150,	6
	*x*19–50*y*150	7
Line 25	*x*–1–14.5*y*25	8

Line 150 (lable 3 and 4)

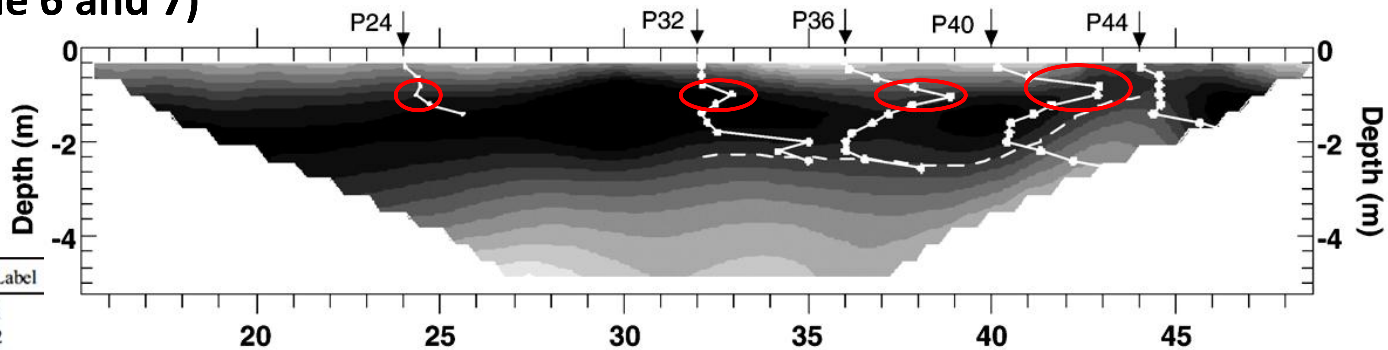


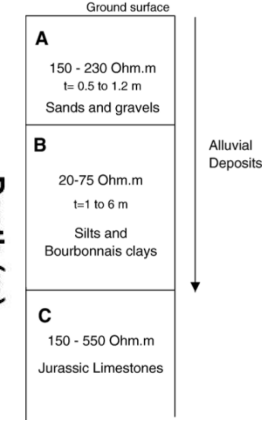


Line25 (lable 8)

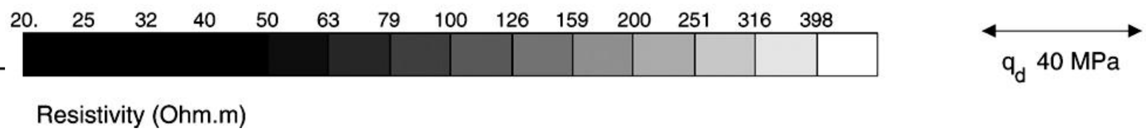


Line 150 (lable 6 and 7)

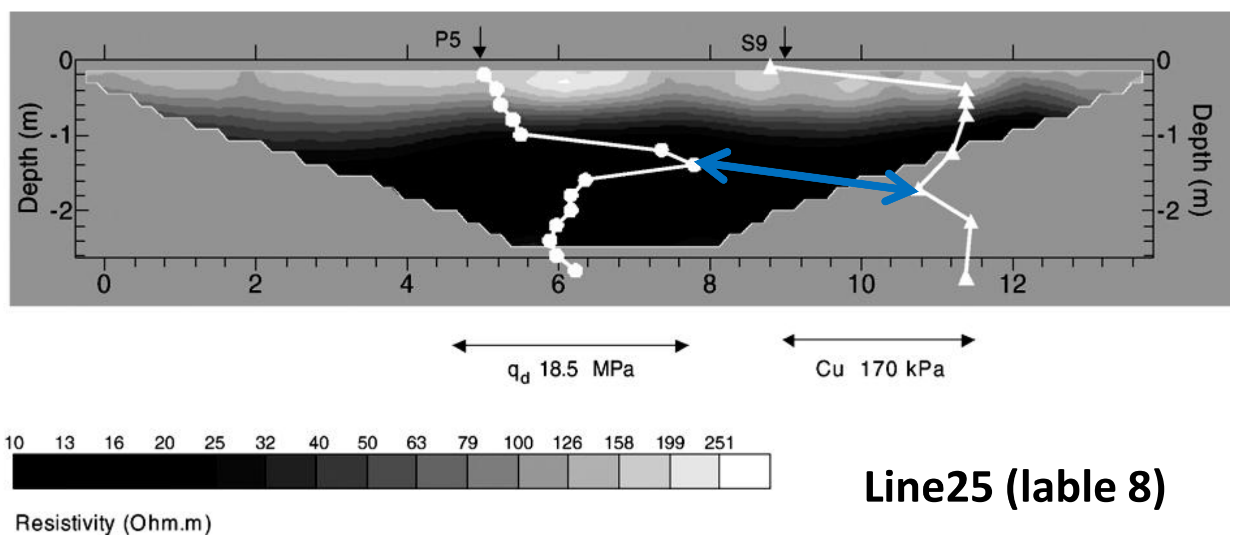




Line	ERT profile	Label
Line 150	$x0.5–16y150$,	1
	$x2.5–18y150$,	2
	$x24–39.5y150$,	3
	$x34.5–50y150$,	4
	$x50y150–165.5$ [a]	5
	$x14–45y150$,	6
	$x19–50y150$	7
Line 25	$x–1–14.5y25$	8



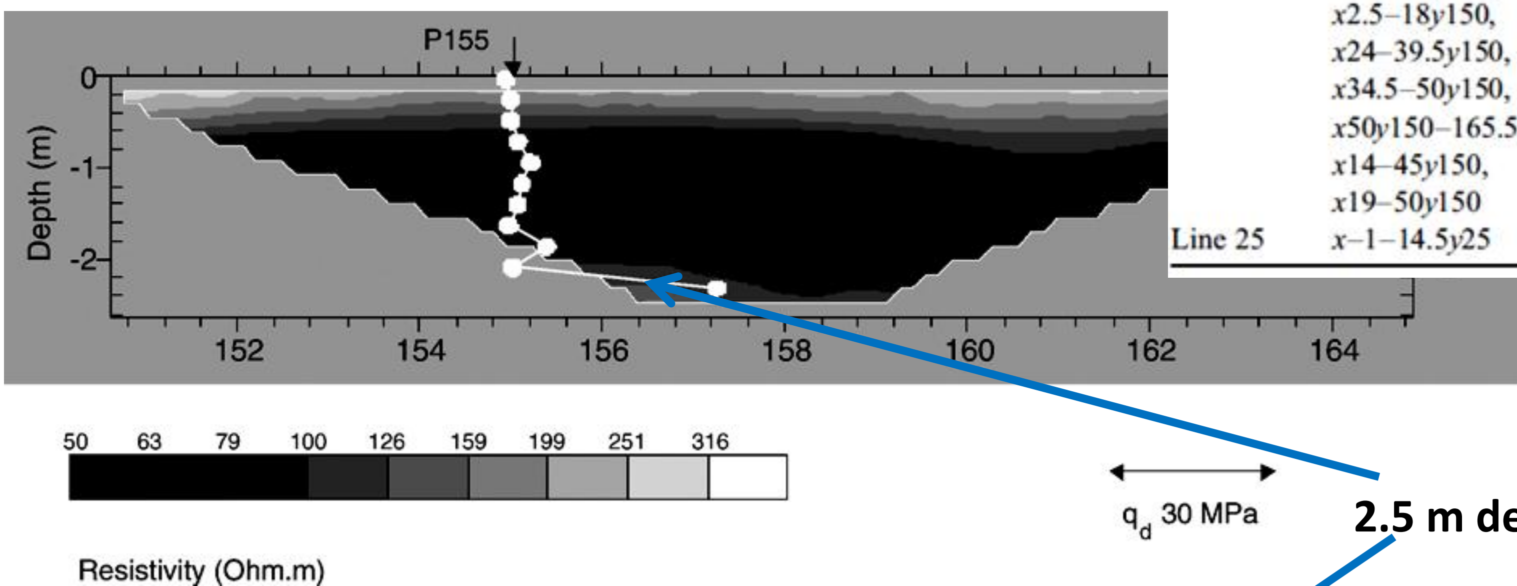
This qd peak seem to be accociated with a decrease of the undrained shear strength and it is qualitatively well correlated with the transition between the shallow high resistivity values and and the low resistivity values associated with clayey soils.



Line25 (lable 8)

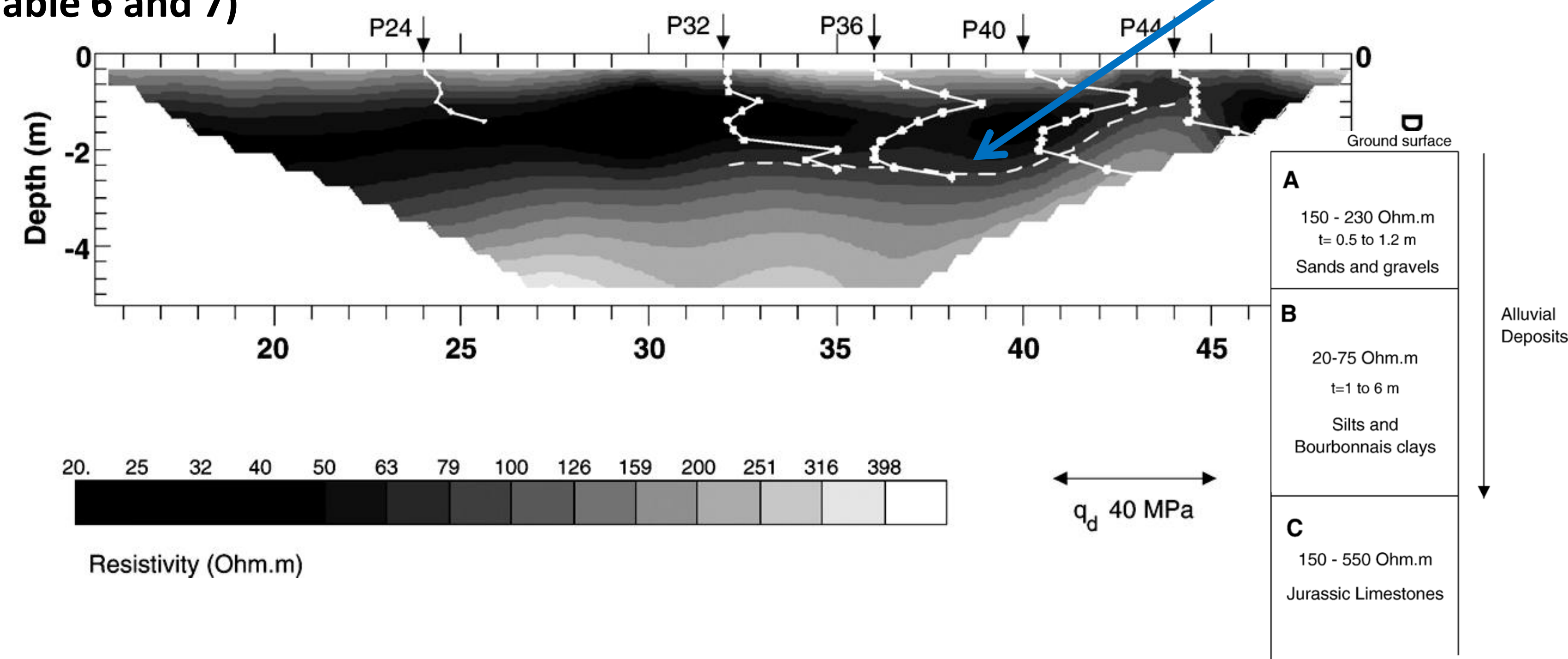
Line 150 (lable 5)

Line	ERT profile	Label
Line 150	$x0.5–16y150$,	1
	$x2.5–18y150$,	2
	$x24–39.5y150$,	3
	$x34.5–50y150$,	4
	$x50y150–165.5$ [a]	5
	$x14–45y150$,	6
	$x19–50y150$	7
Line 25	$x–1–14.5y25$	8



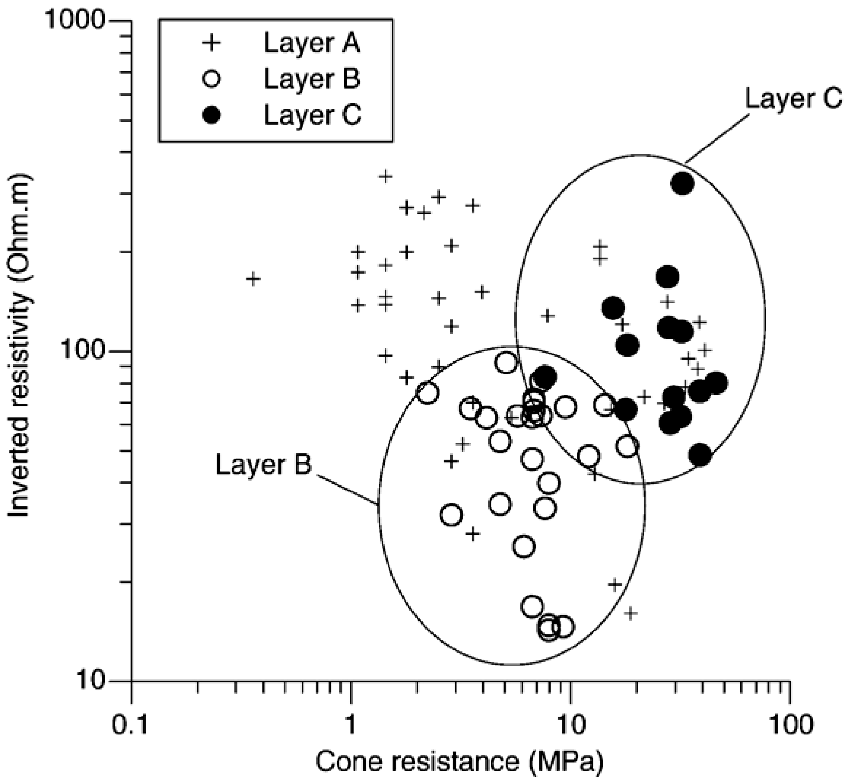
2.5 m depth

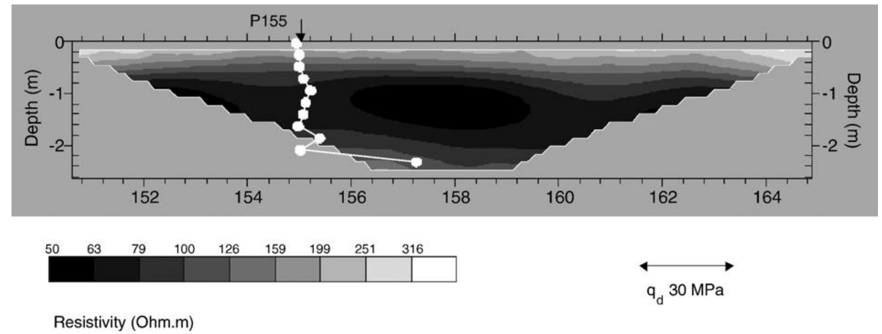
Line 150 (lable 6 and 7)



Quantitative correlations between electrical and geotechnical data

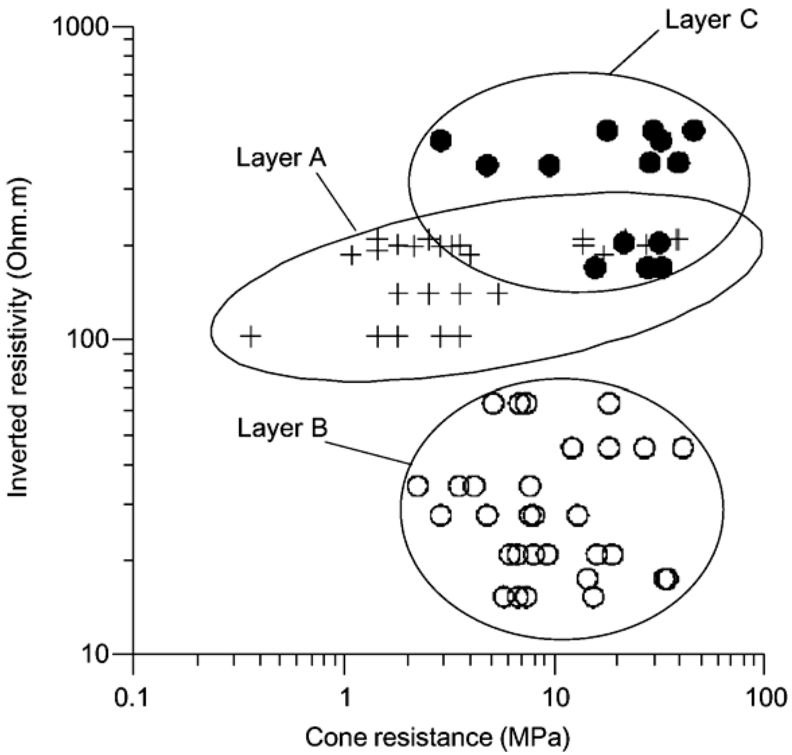
- **In order to compare in a relevant way both parameters, two approaches have been considered.**
- **First approach, the cone resistance values are compared to the inverted resistivity values directly extracted from the grid given by RES2DINV.**
- **Second approach, the cone resistance values are compared to the inverted resistivity values obtained from an inverted of 1D resistivity soundings extracted from the 2D apparent resistivity dateset.**

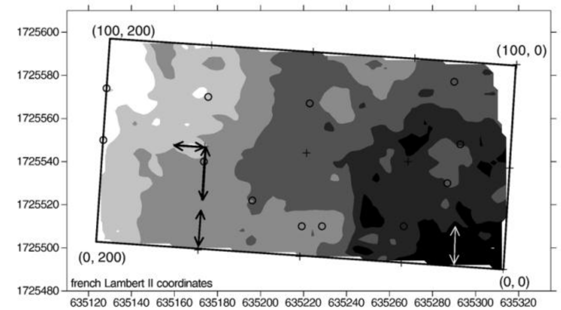


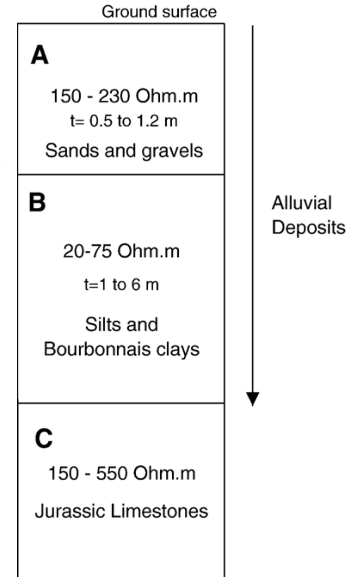


2D inverted resistivity value

- **The resistivity values from the grid were interpolated linearly to the points (x,y,z) corresponding the qd values from geotechnical tests.**





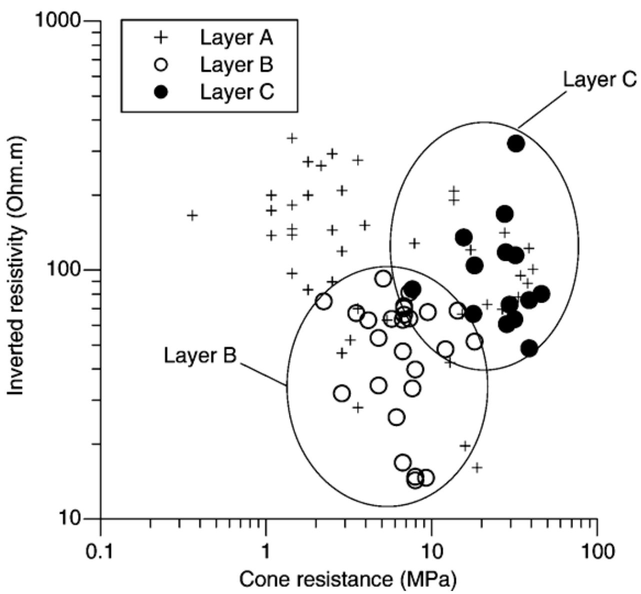


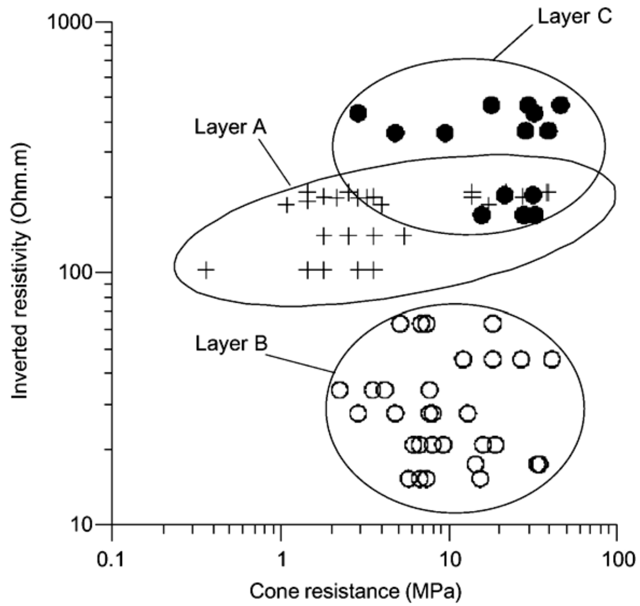
inverted of 1D resistivity soundings extracted from the 2D apparent resistivity dateset.

- **These 1D soundings were inverted 3 or 2 layer model, where the depth of each interface is determined from the geotechnical results.**

- If the whole set of couples (qd, ρ) or the sets related to the three layers separately are considered, no quantitative correlation can be observed.

- But the figures show that couples (qd, ρ) associated with layer B and layer C constitute two distinct populations. This distinction is better when inverted resistivity values from 1D soundings are considered.

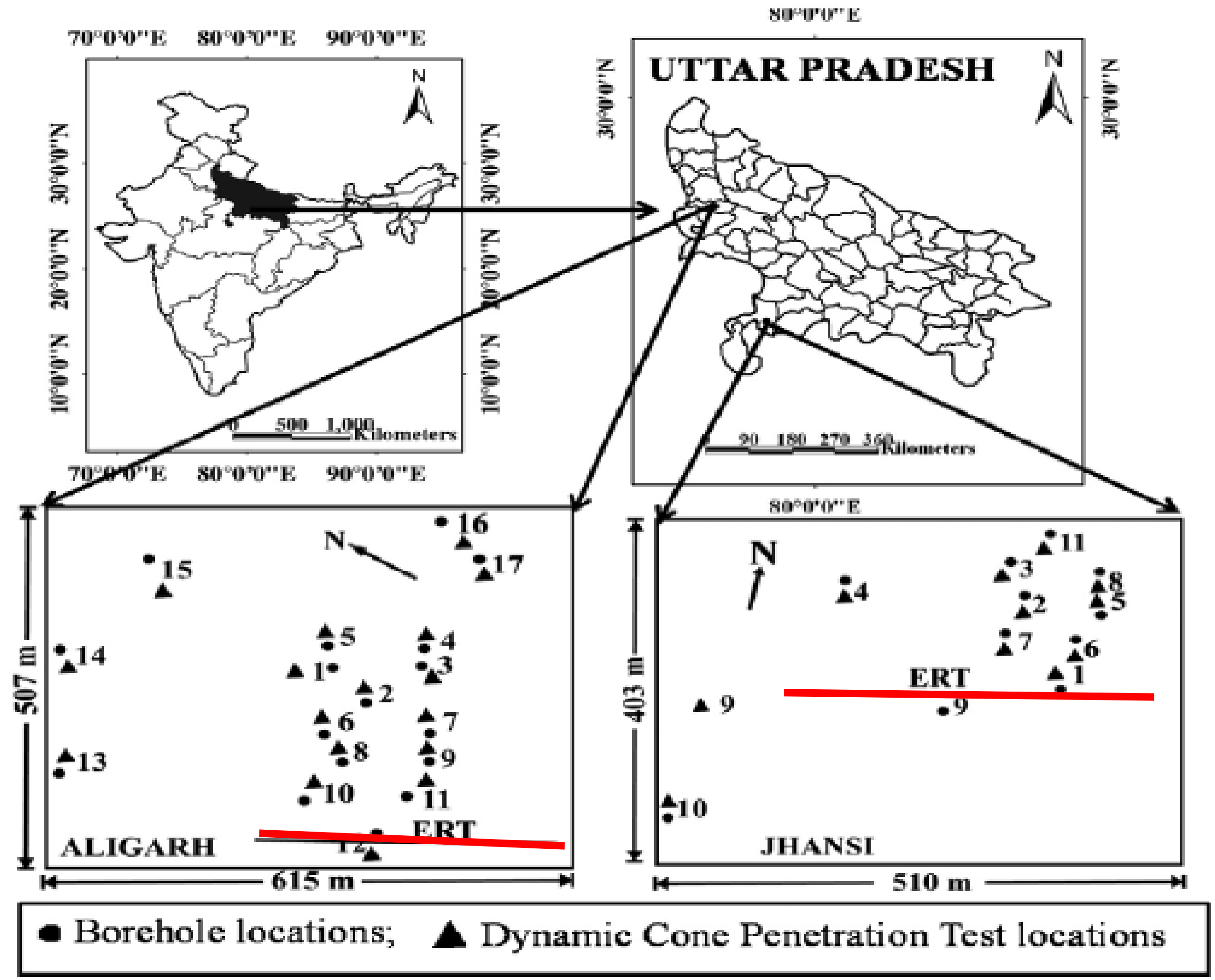


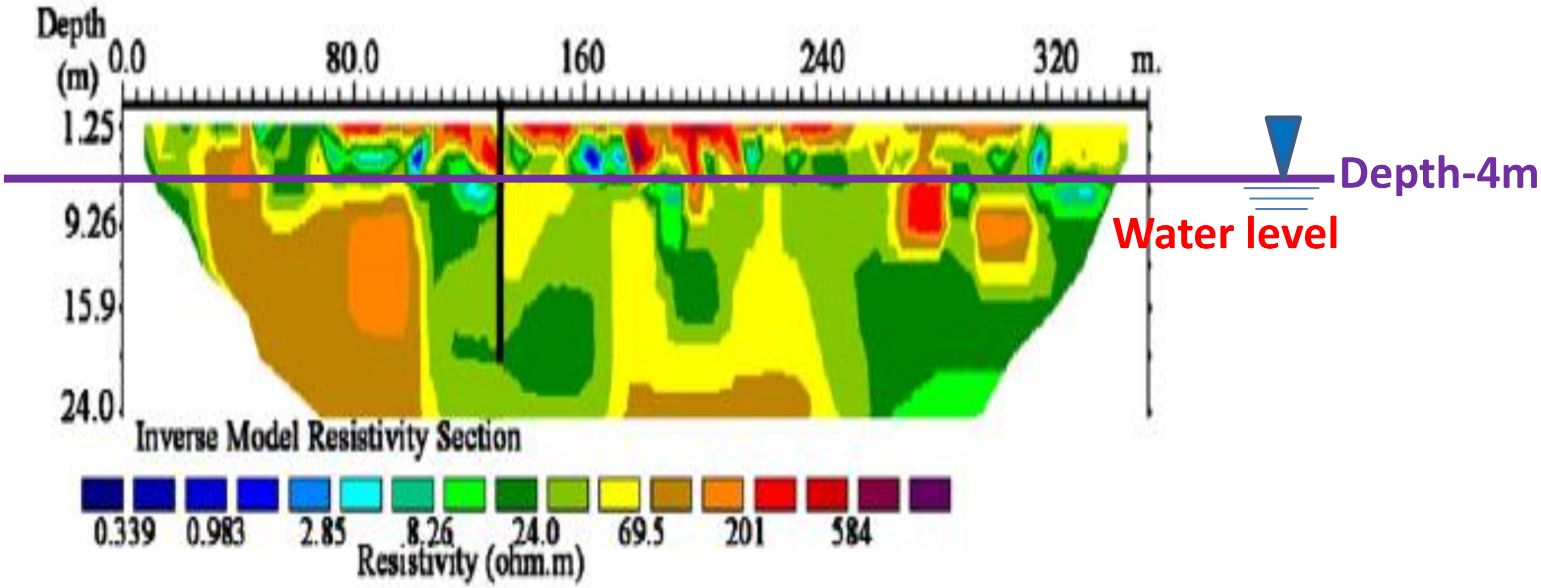


Case II: Uttar Pradesh (UP), India

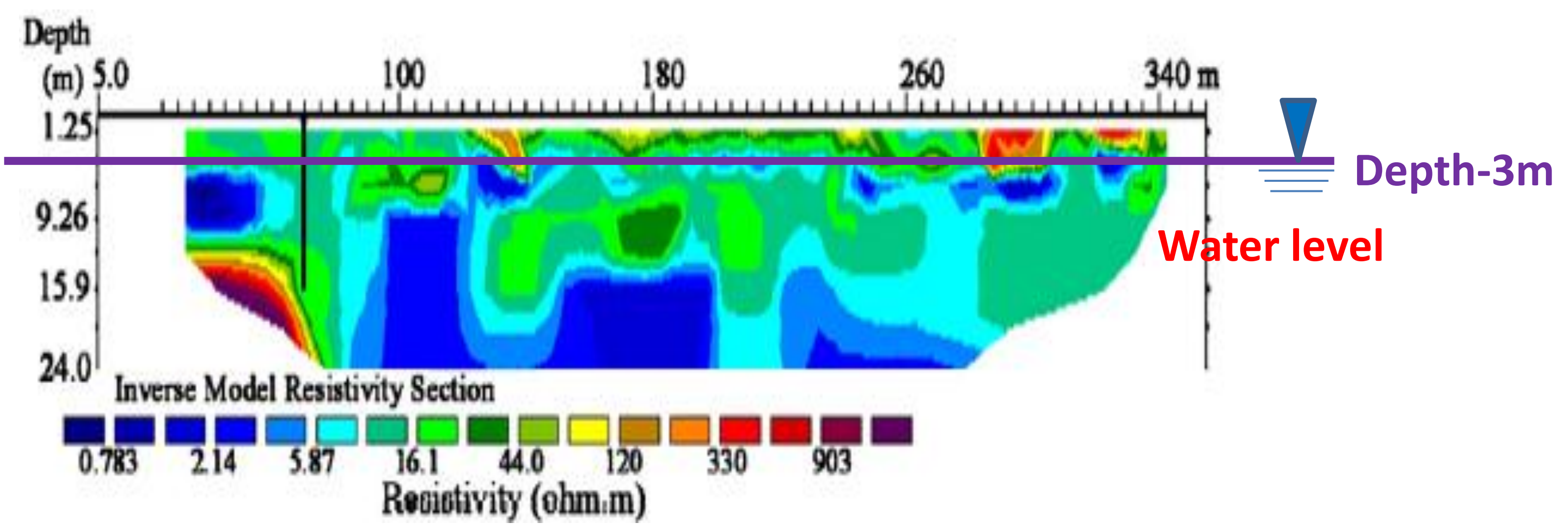
- **In this case, the derived electrical resistivity values are first calibrated with the borehole data of subsurface soil, and subsequently used to compute transverse resistance, which is correlated with the N-values recorded from geotechnical tests at each site.**

Location map of the study area

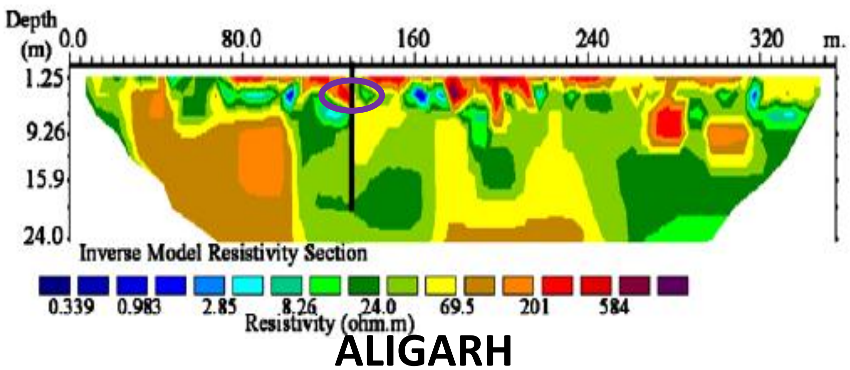


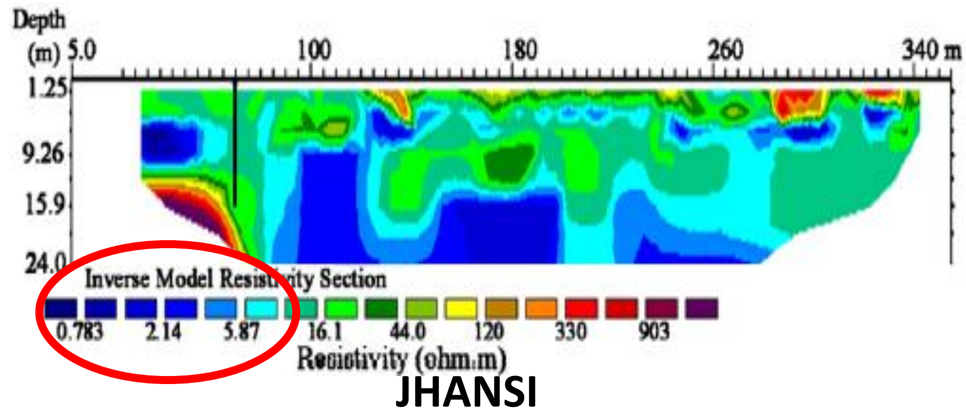


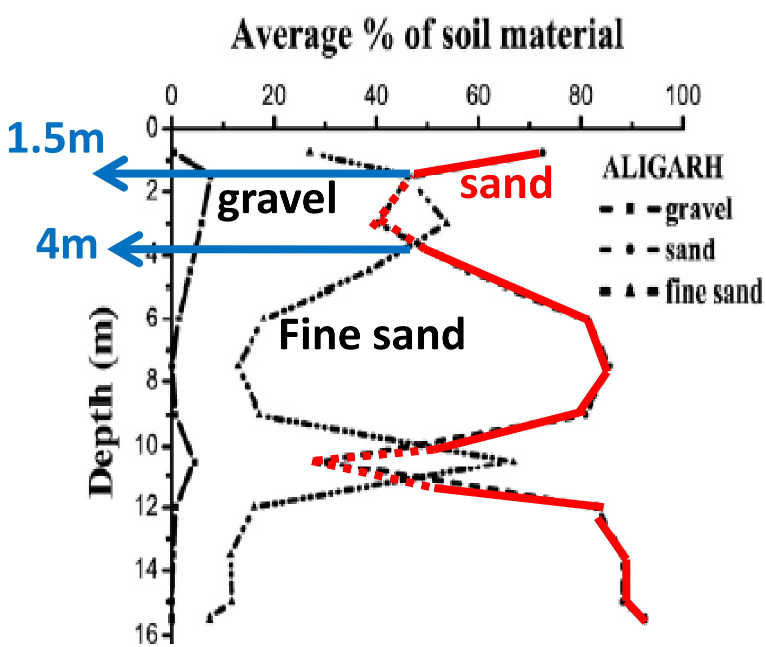
ALIGARH

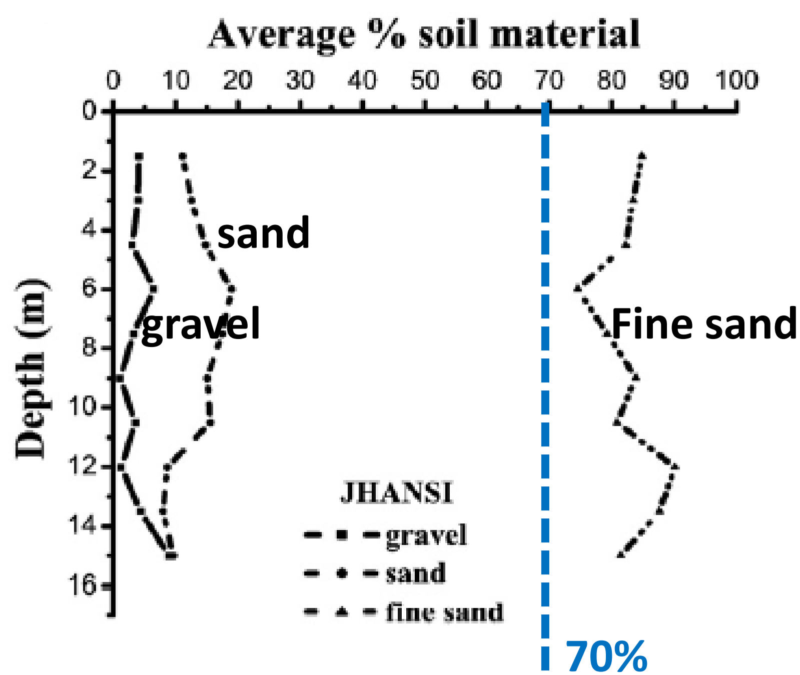


JHANSI

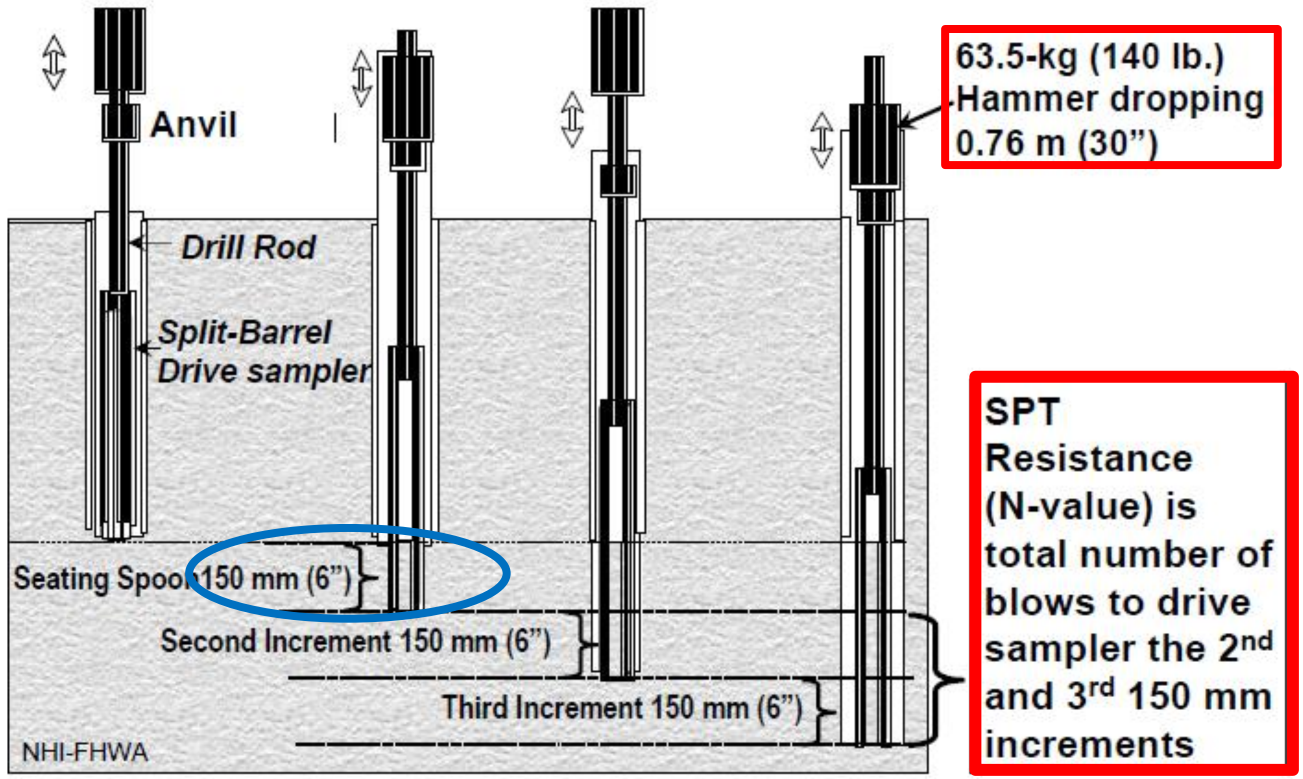

Depth (m)
0.0
80.0
160
240
320
m.
1.25
9.26
15.9
24.0
Inverse Model Resistivity Section
0.339
0.983
2.85
8.26
24.0
69.5
201
584
Resistivity (ohm.m)
ALIGARH


Depth (m)
5.0
100
180
260
340 m
1.25
9.26
15.9
24.0
Inverse Model Resistivity Section
0.783
2.14
5.87
16.1
44.0
120
330
903
Resistivity (ohm.m)
JHANSI


Average % of soil material
0
20
40
60
80
100
Depth (m)
1.5m
4m
gravel
sand
Fine sand
ALIGARH
gravel
sand
fine sand


Average % soil material
0
10
20
30
40
50
60
70
80
90
100
Depth (m)
sand
gravel
Fine sand
JHANSI
gravel
sand
fine sand
70%

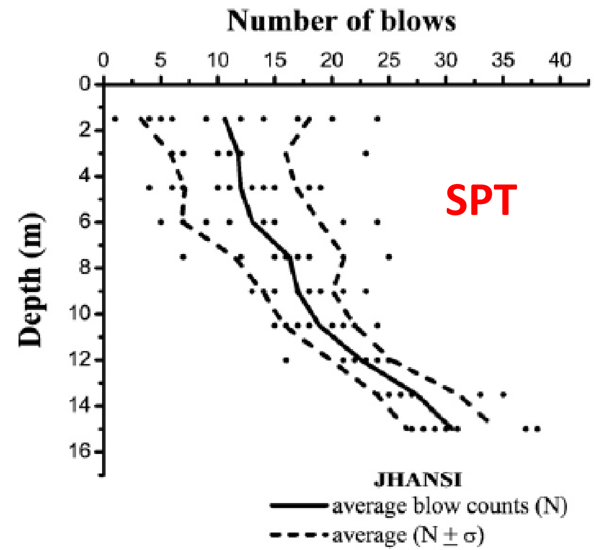
Standard Penetration Test

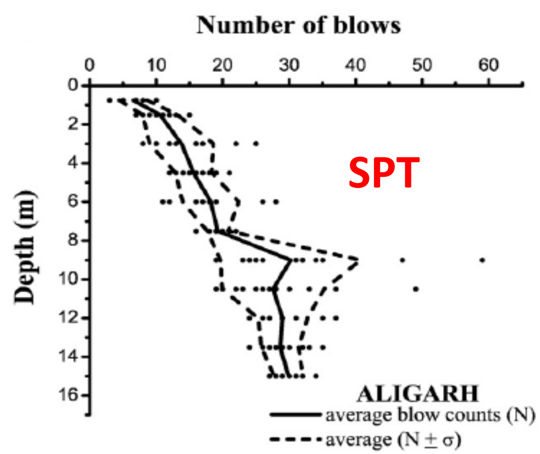


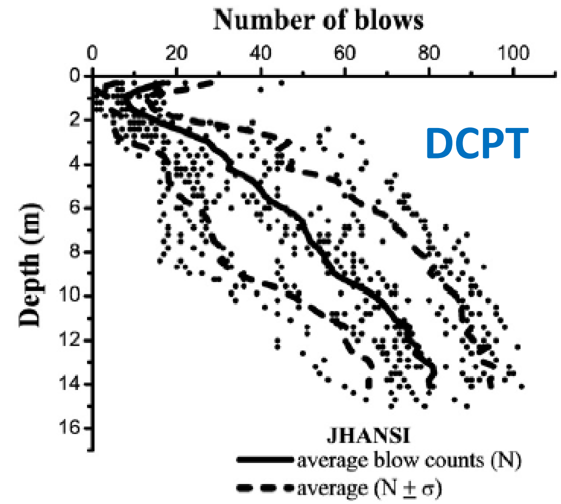
- We can use the data to evaluate the soil strength in terms of number of blows (N-value).

Variation of number of blow counts with depth

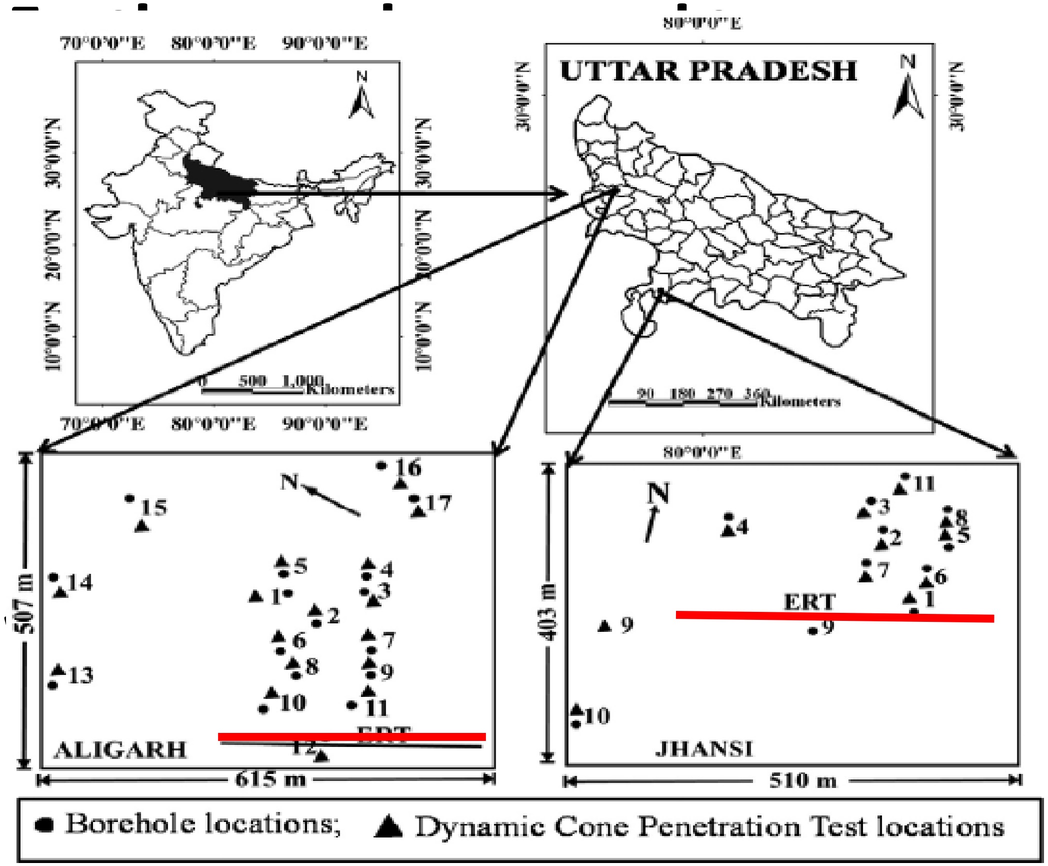
- **The N-value increase with depth and the rate of increase varies with depth, which depends on the soil strength parameters such as grain size distribution, porosity, degree of saturation, and cementation of soil matrix, etc.**

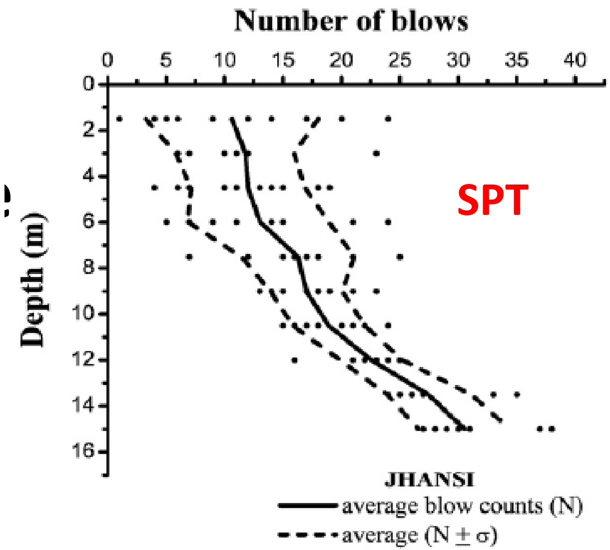


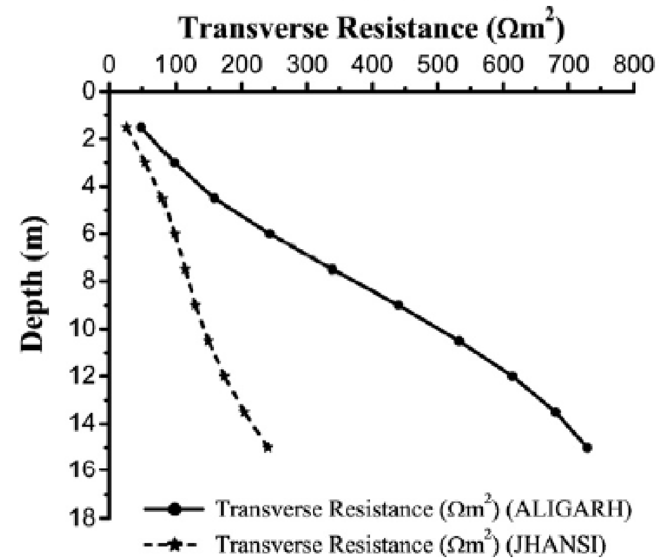




Geoelectrical correlation with geotechnical data

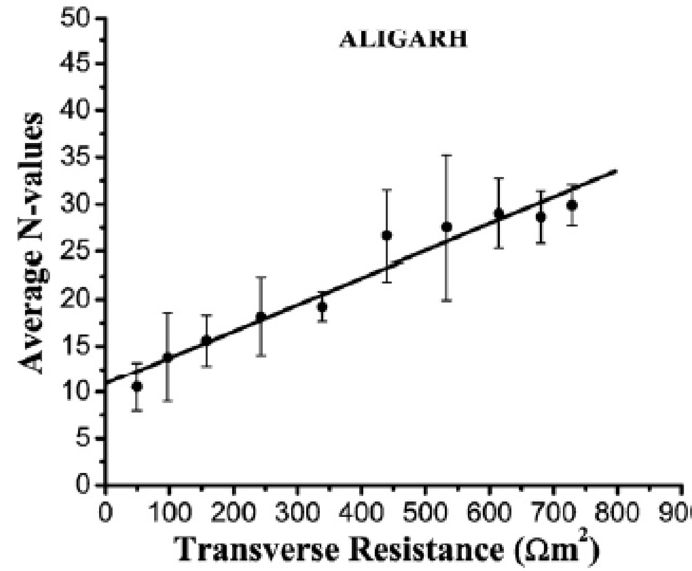




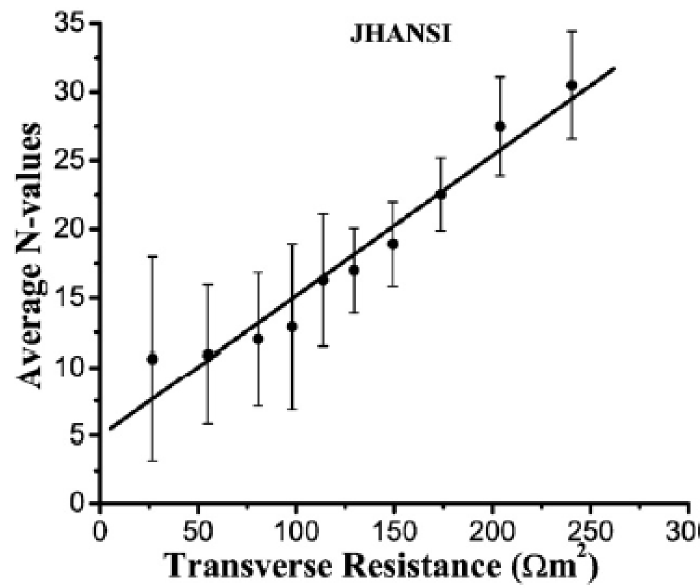


y=0.028x+10.909 Aligarh

y=0.102x+4.922 Jhansi



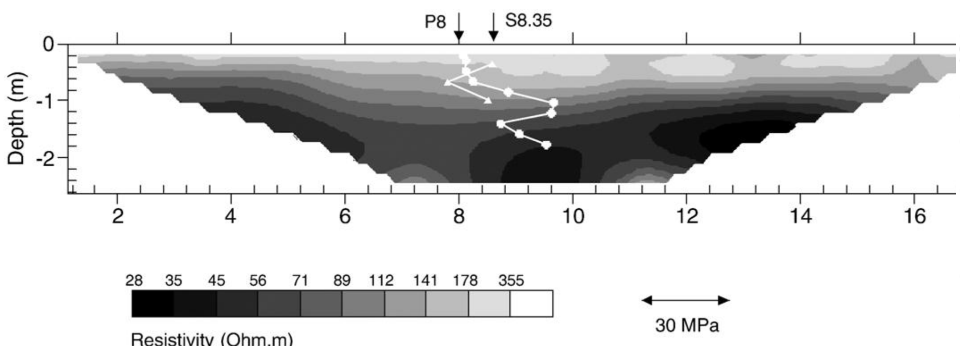
- **Positive correlation between the transverse resistance and N-value is the main outcome of the present investigation.**

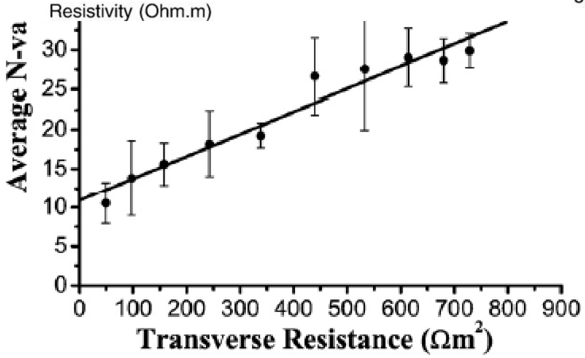


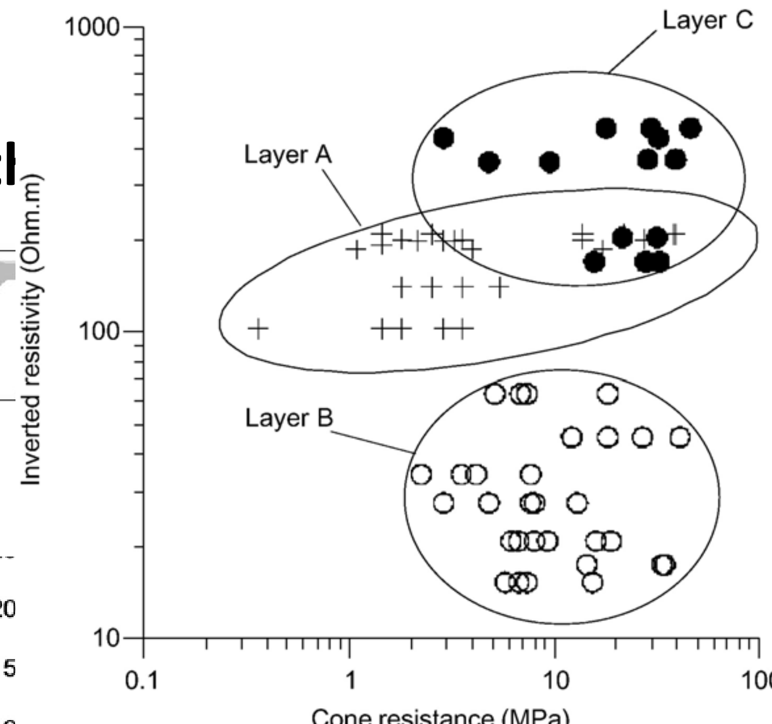
Conclusion

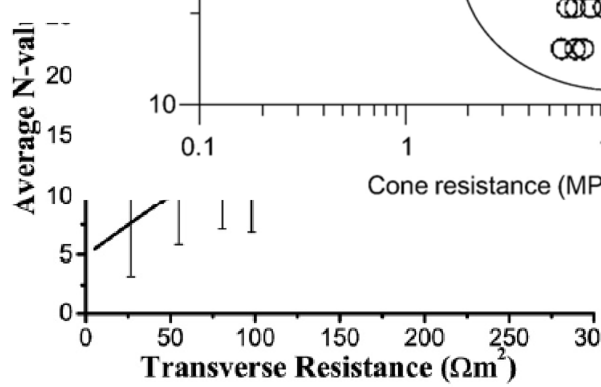
- **In first case (France), they use cone resistance compare with inverted resistivity. No clear relationship between geotechnical and electrical data.**

- **In second case (India), they use th**









Thank you for your attention!