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Identification of Sub-Surface Formations in different Geological Environs using ERI (Multi Electrodes) at Kadalangudi and Kottuchurry, Cavery Plain Area

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Abstract

Among all geophysical methods, resistivity methods are most widely used in ground water, mineral and oil exploration. The resistivity methods involve passage of current through two iron stakes into the ground and measuring potential by means of two other electrodes. What we measure in these methods is the resistivity of the ground, which we call as 'apparent resistivity'. Practically a known amount of current (I) is sent into the ground using two metal stakes, called current electrodes, and the potential is measured using other two probes, called potential electrodes. The concept of apparent resistivity arises from the fact that the measured current between the two current (+I, -I) electrodes and voltage between the other two potential (P1 and P2) electrodes which are arranged in different configurations were introduced by various workers over the years in resistivity prospecting. the multi electrodes play a very significant role in the resistivity/IP prospecting, for detecting sub-surface formations and for studying sub-surface geological stratal architecture. In this type of surveys, a number of electrodes are planted on the ground surface maintaining an equal inter-electrode separation. The number of electrodes may be 12,24,48,72 or 96…..depending upon type of the measuring system. For the present survey, IRIS make system called SYSCAL Pro-96 has been used for the field and lab studies. Most of the conventional electrode arrays viz., two-electrode, three-electrode, Wenner; Dipole-Dipole etc have been applied in different geological environs.

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Keywords: Sub Surface formation, multi electodes.

1. General geology of the Cauvery plains

The Cauvery river basin lies between latitude 10^0 7'N to 13^0 28'N and longitude 75^0 28'E and 79^0 52'E. The river basin covers an area about 87,900 Km^2, spread over the states of Karnataka, Kerala, and Tamilnadu (Fig.1). The delta is river dominated and is occupied by several distributaries of Cauvery River. On the western margin of the delta Precambrian gneisses are exposed overlain by cretaceous to recent sediments.

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The Cauvery delta as it seen presently developed a triangular pattern constituting a marginal denudation unit, a central fluvio-marine depositional unit and a coastal marine depositional unit The Cauvery drainage system in the upper reaches flow through Archean granitoid gneisses (amphibolites-facies) and intrusive, Closepet granite, Precambrian granulites (ranging in composition from granite to gabbro) and supracrustal belts. Before KRSD, the Cauvery flows through basic granulites, ultramafic rocks, pelites and carbonate bands, hypersthenes bearing granulites (charnockites) and Peninsular gneissic rocks which are exposed around Kushalnagar Holenarsipur, Krishnarajpet and Nagmangala schist belts surrounded by tonalitic and trondhjoemitic gneisses are exposed in the drainage basin of the river Hemavati. Sargur schist belt, peninsular gneisses and granulites are exposed in the catchment area of Laskhmanthirtham and Kabini River.

River Kaveri cuts across the plexus of felsitic and porphyry ring dykes near Srirangaptinam, Karnataka. Before the confluence point of Kabini, Kaveri flows south of Dodguni, southern tip of Chitradurga schist belt where bands of dolomitic limestone associated with manganese chert, quartzite and phylites are present. Bhavani, a major tributary to Cauvery passes through granulites of the Nilgiri Range which consists of granetiferous enderbites and basic granulites (gabbroic to anorthositic in composition). Two-pyroxene granulites and pyroxinites occur as extended bodies, lenses and pods with increasing abundance towards north in the Nilgiri Range.

The rocks in middle reaches of Cauvery river are predominantly granulitic gneisses, which have been subjected to high grade polyphase deformation, shows banded migmatitic structure and fold patterns and are composed of granulite facies assemblage of plagioclase, quartz, orthopyroxene, garnet and biotite. The delta and mouth of the river consists of recent alluvium deposits.

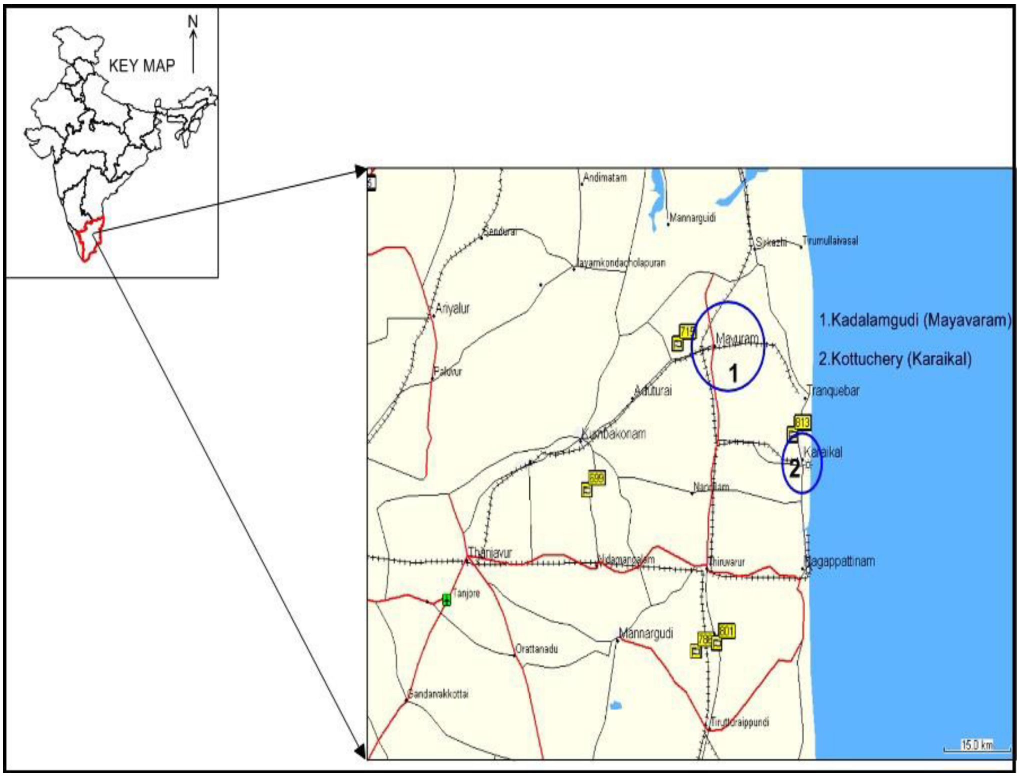


Fig. 1. Location map of the identified zones in Cauvery plains.

2. Methodology and equipment

Vertical Electrical Sounding (VES) technique in Resistivity method cannot measure the signatures from sub-surface in lateral directions. Further, the depth wise resistivity changes are not possible being measured with the resistivity profiling/mapping technique. Both these conventional techniques commonly employ a four-electrode set-up where the signatures from a singular depth level of the sub surface can be measured on the surface. Resistivity variations, both in lateral and vertical directions can be measured concurrently by using multi electrode system (Griffiths et al.1990; Barkar1992) Connected to multi-core cable (Griffiths and Barkar1993). The number of electrodes with the multi electrode systems can be with specified inter-electrode spacing, for example 24, 48, 72 or 96 etc. The inter-electrode spacing can be varied from the specifications as per the available area and topography. In any case, a traverse of length from half a kilometer to one kilometer horizontal distance can be covered in a single-run depending upon the size of the array and number of electrodes. Conventional Electrode Configurations namely, Dipole-dipole, Three- electrode, Two -electrode, Wenner, Schlumberger etc. can be applied for sub- surface data acquisition. To cover horizontal traverses in a phased manner, 'role-along'/or 'move-on' techniques as per the situation are applied in which case the set of electrodes are moved forward in a systematic 'pre-set' manner. The depth down below the traverse can be increased by increasing the array size sequentially depending upon the 'depth of investigation' of the corresponding array. Each array has got its own investigation depth, depending upon the theories like 'maximum contribution concept' (Roy and Apparao,1971) or 'median depth concept' (Edwards,1977). Some are following the data presentation methods which have been proposed by Hallof (1957).

Electrical Resistivity Tomography (ERT)/Electrical Resistivity Imaging (ERI) which is a non-invasive method, is extremely useful for understanding the sub-surface formations and for depth estimations of natural resources.

High-resolution Electrical Resistivity Tomography (HERT) surveys play an important role in data acquisition especially in noisy areas. This is achieved by over lapping data levels with different combinations of Dipole lengths and Dipole's separations, as a whole, when Dipole –dipole array is applied. Similar conditions are possible with Wenner- Schlumberger and Three-Electrode array also. The number of data points produced by such High resolution survey is more than twice that obtained with a conventional array in routine application and hence a better area coverage and resolution can be achieved.

After analysis and processing of the measured data in the field, pseudo-depth sections are constructed (Apparao and Sarma, 1981, 1983 and 1993) with overlapping data levels. By having such redundant measurements using the over lapping data levels, the effect of more noisy data points will be reduced. Finally High-resolution resistivity (HERT) Surveys play in a significant role especially for scanning the subsurface in noisy area for better data coverage so that the sub-surface architecture can be studied with reasonable precision and faster survey. 2D and 3D subsurface imaging is possible only with multi electrodes. Further to understand the subsurface information to micro level, it is preferable to use 'slicer-dicer' software so that geological strata and sub-strata architecture can be studied with better accuracy, reasonable resolution and optimum precision. The field equipment that is used is an IRIS make SYSCAL Pro-96 system(4.1) This system is multi-channel equipment where Dipole-dipole array can be applied. In the case of single channel equipment, only Wenner, Schlumberger etc can be operated. Figures 4.2 and 4.3show both the systems with electrode array set-up. This system works as a measuring sensor using Multi-electrode system. The ERI survey is carried out using 96 electrodes with facility to have inter-electrode separation upto 5m.

The field parameters like type of the array, size, current intensity, stacking etc will be uploaded to the system .All the data field acquired data is downloaded to the laptop. Then the data is processed, analyzed and then interpreted. For our ERI survey, Dipole-dipole and Wenner-Schlumberger are opted for the reason that dipole array could provide better resolution compared to the other array. Then, Wenner-Schlumberger combination could provide greater depth of investigation.

3. Field observations

Field Observations have carried out the field surveys in some identified zones of Cauvery plains to understand the nature of sub-surface formations. A hybrid combination array called, Wenner-Schlumberger, Dipole-dipole are opted with a special objective; using dipole-dipole array. It is possible to record the signatures even from shallowest depthby Diploe-Dipole array and the studies are extended to deeper level by using Wenner-Schlumberger array.

A number of field surveys carried by the author have been discussed from various and different geological environs where geo-electrical sections have been corroborated with bore-hole lithologs and tomograms.

The locations which are identified for this purpose are Kadalangudi, Pilawadi and Kottucherry. Pilawadi is 30 km from Kumbakonam and Kadalangudi is 73 km from Kumbakonam whereas Kottucherry is 10 km from Karaikal. On the recommendations of locations for drilling based on the ERI tomorgamms, drilling was carried out only in two locations ie., Kadalangudi and Kottucherry whereas the drilling is still going on in Pilawadi. Very interesting observations are made in calibration of the geo-electrical images and lithologs.

4. Tomograms

In each location we obtained three images, namely. The top one indicates the observed image and the middle one indicates the computed one whereas the bottom one indicates the true resistivity image which is obtained after applying the Inversion. As it is not possible to physically measure the true resistivity in the field, the other alternate procedure to get a true resistivity image of the sub-surface is to apply the method of Inversion to the observed apparent resistivity data so that the true resistivity image is obtained. The Inversion procedure is applied by using either least square method or Finite Element method or Finite Difference method. In the present study, least square method is applied and it is incorporated in the software supplied by the Instrument makers. The inversion procedure is applied after obtaining an optimum matching between the observed data and computed data. Care has been taken in eliminating the bad data points before the processing is started. In the process of inversion, the number of iterations are increased in such a way that the RMS error is maintained as minimum as possible. Finally, this processing will pave the way for obtaining the true resistivity picture of the sub-surface formations.After all these things are over, locations for drilling the bore holes are recommended with an objective that the recommended bore hole should pass thro' as many formations as possible so that an in-depth study can be made regarding such individual formations like., geo-chemistry, dating, pollens, etc. All such studies are beyond the scope of the present study.

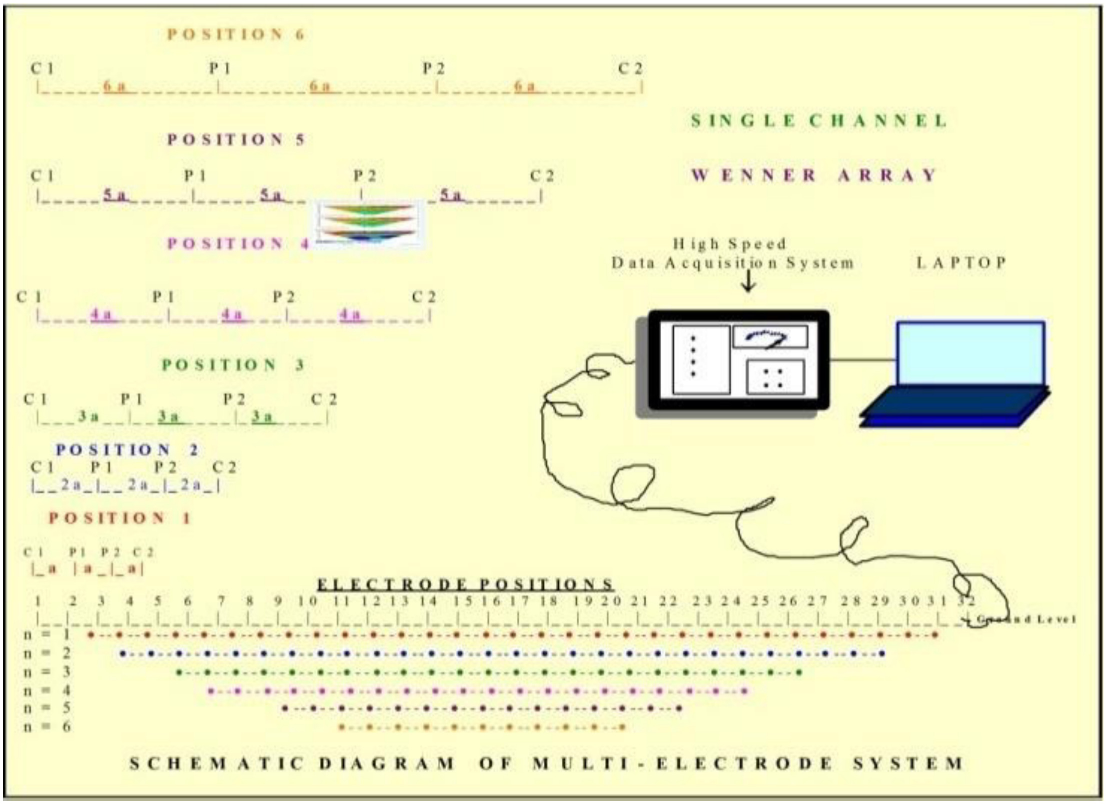


Fig. 2. ERI- Electrode set up with single channel system.

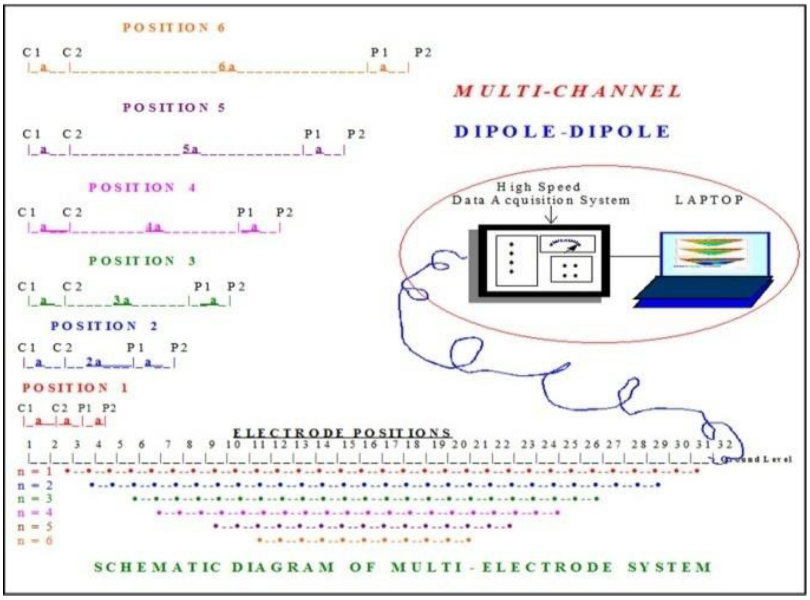
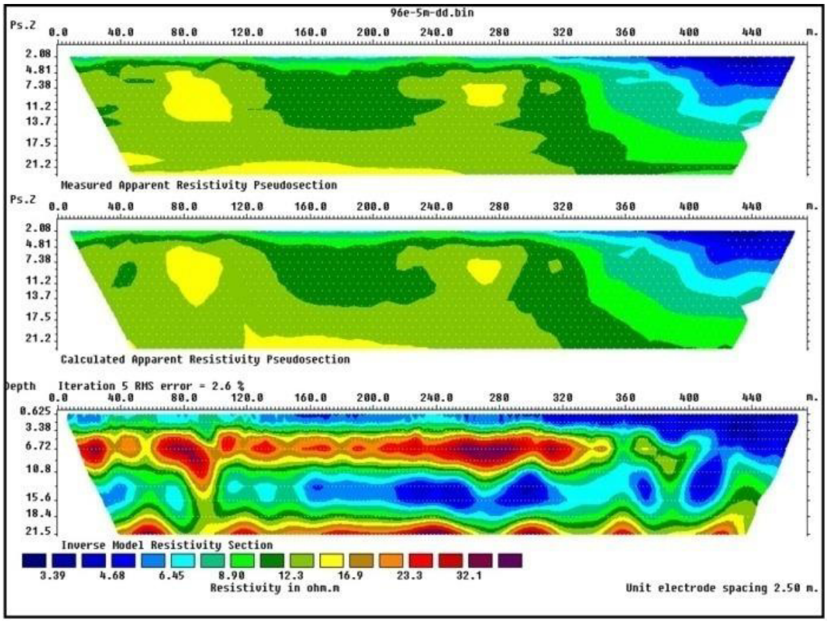


Fig.3. ERI – Electrode setup with multi-channel system

Fig. 4. Multi-electrode winch set-up



. Fig. 5. ERI – Tomograph with dipole-dipole array in Kadalangudi area.

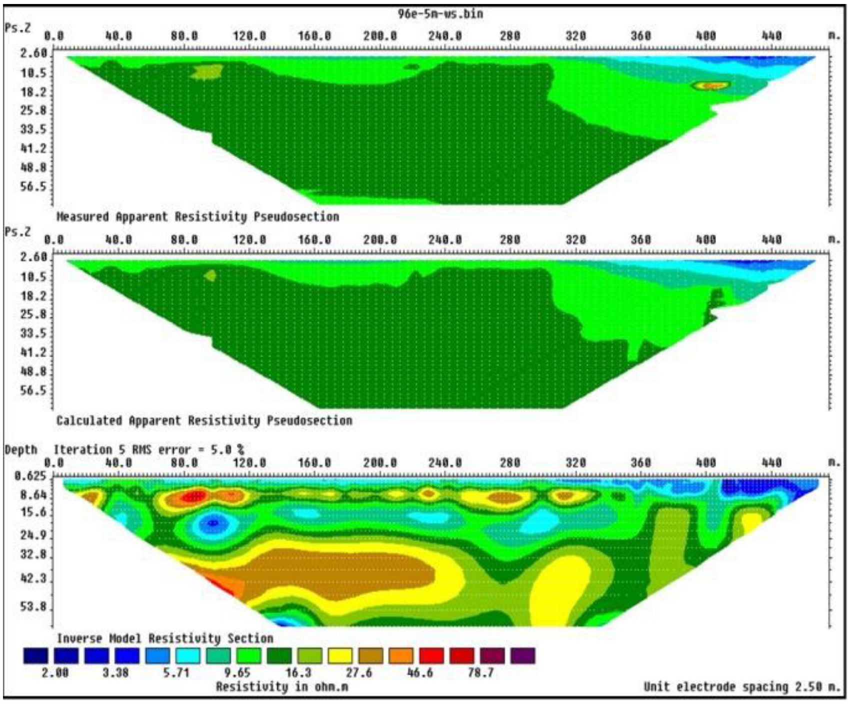


Fig. 6. ERI – Tomograph with Wenner-Schlumberger array in Kadalangudi area,

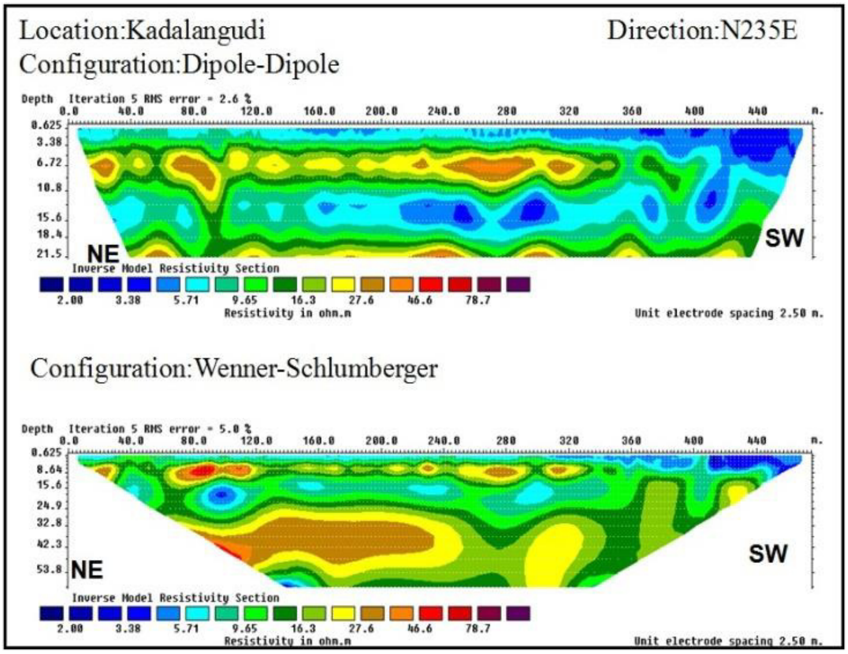


Fig. 7. Inverted images with dipole-dipole and Wenner-schlumberger in Kadalangudi area

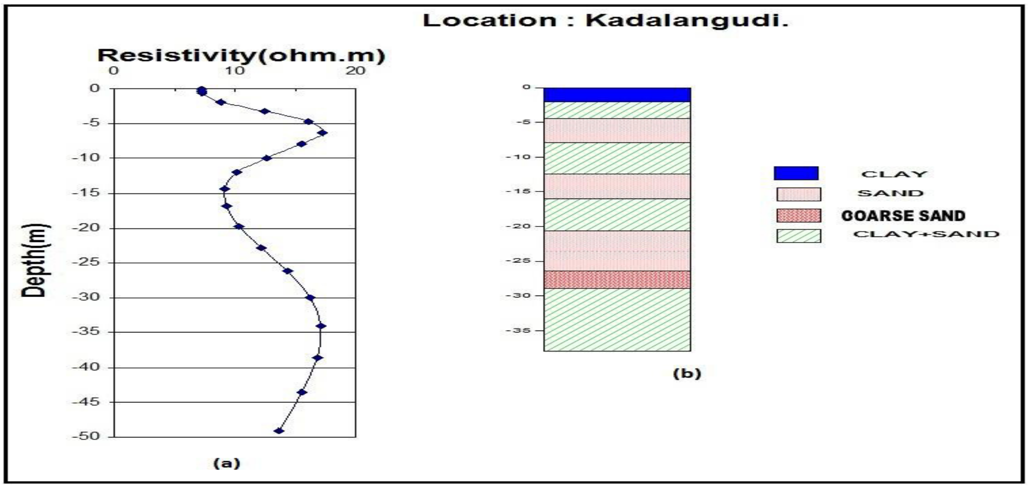


Fig. 8 (a). Depth wise resistivity curve and (b) Litholog of the Kadalangudi area

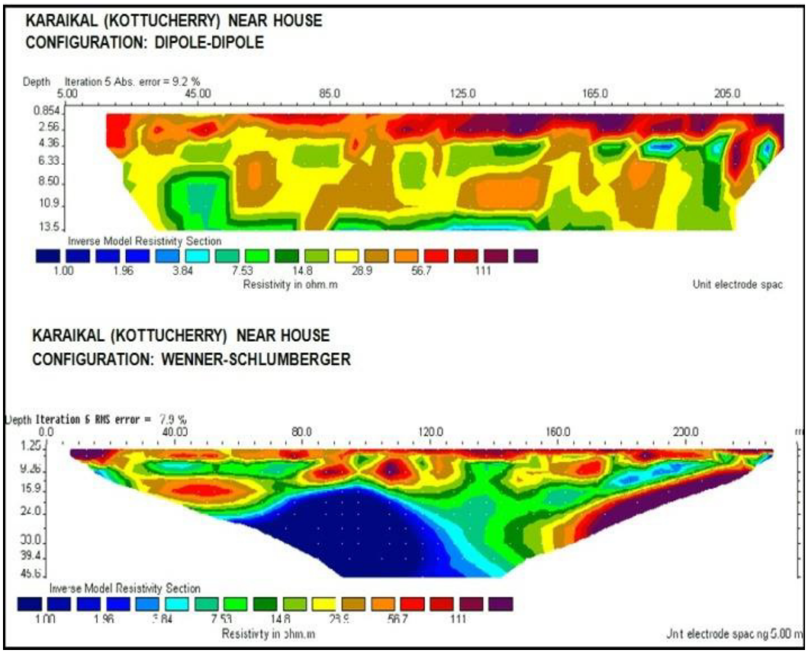


Fig. 9. ERI – Tomographs in Kottucherry area with dipole-dipole array (top) and Wenner-Schlumberger array (bottom)

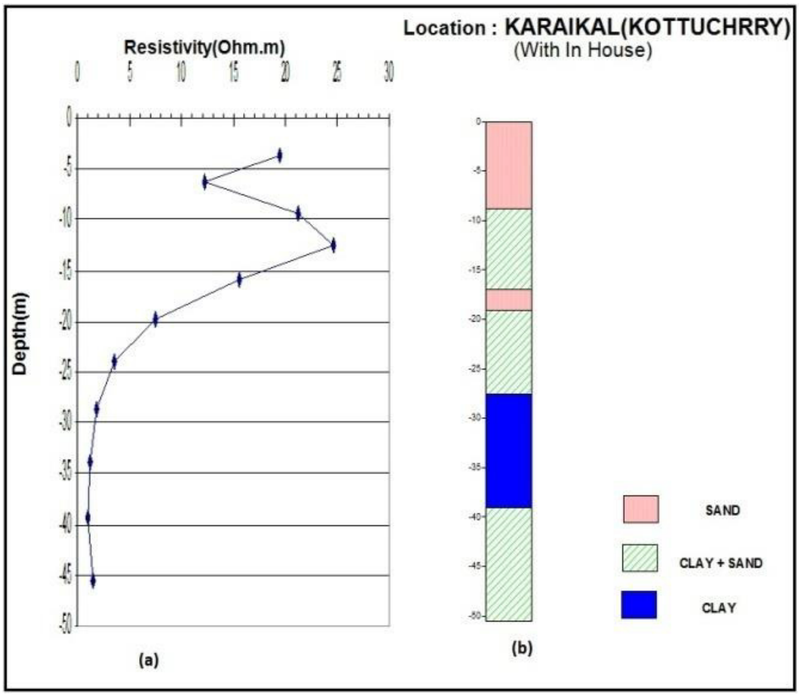


Fig. 10 (a) Depth wise resistivity section and (b) Litholog in Kottucherry area.

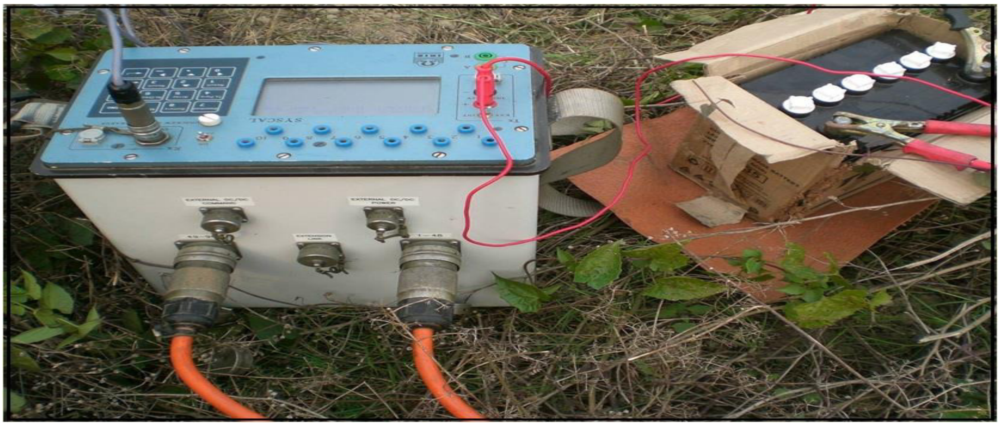


Fig. 11. IRIS make SYSCAL Pro – 96 Field equipment used for the survey.

Fig. 12.. Some reminiscences, the author is seen in (3).

5. Results and discussion

Figure 1 represents the location map of the identified locations of the Cauvery plains. These zones have been identified taking into account the local geology, geomorphology etc. Figures 5 illustrates the Resistivity Images with dipole-dipole at the location Kadalangudi As explained above, it can be seen that the top image indicates the measured apparent resistivity field data and the middle image illustrates the computed data . After achieving an optimum match between the computed and observed, the process of inversion is applied to get an inverted image which is shown as the bottom one. It can be seen that the RMS error is only 2.6% for 5 number iterations. Figure 6 indicates the resistivity image with Wenner –

Schlumberger array where greater depth of investigation is achieved. It can be understood that with the dipole array, the system could scan up to 22m depth whereas with Wenner- Schlumberger, the scanned depth is up to around 60m. The length of the traverse in both the cases is 480m. For better comparison, both the arrays are shown in figure 7. A high resistivity layer is almost embedded between two low resistivity layers. Bore hole is recommended and lithologs are drawn. The lithologs and the depth-wise geo-electrical section are shown in fig 8. A good corroboration is achieved between the geo-electrical image and litholog. To confirm this, a depth-wise electrical section is constructed which also supported the observation. Fig. 9 shows the final inverted images constructed at Kottucherry near Karaikal. The top image is done with the Dipole array and the bottom image is with the Wenner-Schlumberger array. The traverse length is 250 m in both the cases. It can be observed that the dipole array could scan the sub-surface up-to a depth of 13.5m where as the Wenner-Schlumberger combination could investigate upto a depth of 47m.The RMS error is maintained at a minimum of 7.9% for 6 iterations for Wenner-Schlumberger array and it is 9.2 % for 5 iterations. The slight increment of RMS error is because of local geological noise. The bore holes are recommended and the lithologs are shown in the figure 10 and the constructed depth-wise section is also shown in the same figure. A satisfactory matching is achieved among the electrical images, depth-wise section and litholog. The field equipment which has been used by the author for the surveys is shown in figure 11. Hence, the Electrical Resistivity Imaging (ERI) is a successful geophysical tool for finding out the subsurface geological formations with precision, accuracy and reasonable resolution.

6. Conclusions

Electrical Resistivity Imaging (ERI) survey is carried out in some identified locations of Cauvery plains. The zone selection is done on the basis of local geology, geomorphology etc. The Resistivity Images with dipole-dipole at the location Kadalangudi has been analysed and it can be seen that the top image indicates the measured apparent resistivity field data and the middle image illustrates the computed data. After achieving an optimum match between the computed and observed, the process of inversion is applied to get an inverted image which is shown as the bottom one. It can be seen that the RMS error is only 2.6% for 5 number iterations. The resistivity image with Wenner –Schlumberger array has shown greater depth of investigation. It can be understood that with the dipole array, the system could scan upto 22m depth whereas with wenner-schlumberger, the scanned depth is upto around 60m. The length of the traverse in both the cases is 480m. It is observed that high resistivity layer is almost embedded between two low resistivity formations. Bore hole is recommended and lithologs are drawn. A good corroboration is achieved between the geo-electrical image and litholog. To confirm this, a depth-wise electrical section is constructed which also supported the observation.

Further, the final inverted images constructed at Kottucherry near Karaikal indicated a good corroboration between the top image with the Dipole array and the bottom image with the Wenner-Schlumberger array. It can be observed that the dipole array could scan the sub-surface up to a depth of 13.5m where as the Wenner-Schlumberger combination could investigate up to a depth of 47m.The RMS error is maintained at a minimum of 7.9% for 6 iterations for Wenner-Schlumberger array and it is 9.2 % for 5 iterations. The slight increment of RMS error is because of local geological noise. A satisfactory matching is achieved among the electrical images, depth-wise section and litholog. Hence, the Electrical Resistivity Imaging (ERI) being a non-invasive method is a significant tool in investigating sub-surface formations with precision, accuracy and reasonable resolution. This is the only tool for finding out sub-surface geological stratal architecture.

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